

# **Developing a multi-faceted approach to improving and uplifting trauma care in the periphery**

**Thesis**

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## **Dedication**

Hilda Clarke  
14 May 1935 - 4 April 2012

## Acknowledgements

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The incomparable Leonard Cohen has provided the soundtrack to Elizabeth's and my life together and to this thesis. For that I am exceedingly grateful.

“Dance me to the end of Love.”

## Declaration

I..., Damian Luiz Clarke, declare that:

(i) The research reported in this dissertation, except where otherwise indicated, is my original work.

(ii) This dissertation has not been submitted for any degree or examination at any other university.

(iii) This dissertation does not contain data, pictures, graphs or other information belonging to other persons, unless specifically acknowledged as being sourced from other persons.

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a) their words have been re-written but the general information attributed to them has been referenced; and,

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Signed: \_\_\_\_\_

Date: \_\_\_\_\_

As the candidate's supervisor I have approved this thesis for submission.

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Dr Colleen Aldous

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Date: 30 October 2013



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Professor Sandie Thomson

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Date: 30 October 2013

## Abbreviations

ATLS	Advanced Trauma Life Support
BLS	Basic Life Support
CDSS	Clinical decision support system
CTK	Christ the King District Hospital, Ixopo
DSTC	Definitive Surgical Trauma Care
EDH	Edendale Hospital, Regional Hospital, Pietermaritzburg
EGUM	East Griqualand and Usher Memorial District Hospital, Kokstad
GCS	Glasgow Coma Scale
HR	Heart Rate
ICU	Intensive care unit
JDM	Judgment and Decision Making
M and M	Morbidity and Mortality Meeting
MEWS	Modified Early Warning Score
PAT	Penetrating abdominal trauma
PMTS	Pietermaritzburg Metropolitan Trauma Service
PMB	Pietermaritzburg City, Capital of KwaZulu-Natal Province
RR	Respiratory Rate
RV	Rietvlei District Hospital, Umzimkhulu
SAH	St. Apollinaris District Hospital, Centocow
SHD	Sisonke Health District
SWOT	Strengths Weaknesses Opportunities Threats
TBI	Traumatic Brain Injury

## Declaration of Publications

### First-author publications

- **Clarke DL.** Ensuring equitable access to high quality care: the task of uplifting trauma care in rural and district hospitals. *SAMJ* 2012 **103** (9): 588-588.
- **Clarke DL.** Developing a comprehensive structure to facilitate quality improvement programs in health care systems *SAMJ* (In press)
- **Clarke DL, Kong VY, Handley J, Aldous C** A concept paper: using the outcomes of common surgical conditions as quality metrics to benchmark district surgical services in South Africa as part of a systemic quality improvement programme. *S Afr J Surg* 2013; **51** (3):84-6. DOI: 10.7196/sajs.1476.
- **Clarke DL, Gouveia J, Thomson SR, Muckart DJ.** Applying modern error theory to the problem of missed injuries in trauma. *World J Surg.* 2008; **32** (6): 1176-82.
- **Clarke DL, Aldous C.** Surgical outreach in rural South Africa: are we managing to impart surgical skills? *SAMJ* 2013; **104** (1): 57-60. DOI: 10.7196/samj.7252.
- **Clarke DL, Aldous C, Thomson SR.** The implications of the patterns of error associated with acute trauma care in rural hospitals in South Africa for quality improvement programs and trauma education. *Injury* 2014; **45** (1):285-8. DOI: 10.1016/j.injury.2013.04.011. Epub 2013 May 28.
- **Clarke DL, Aldous C, Thomson SR.** Assessing the gap between the burden of trauma in Sisonke District and the surgical capacity of the district hospitals: What are the implications for planning? *Europ J Trauma Emergency Surg* 2014, **40** (3): 303-308 DOI: 10.1007/s00068-013-0369-0)
- **Clarke DL, Furlong H, Laing GL, Aldous C, Thomson** Using a structured morbidity and mortality meeting to understand the contribution of human error to adverse surgical events in a South African regional hospital. SR. *S Afr J Surg* 2013; **51** (4): 122-6. DOI: 10.7196/sajs.1537.
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## Non-first author publications

- Alexander T, Fuller G, Hargovan P, **Clarke DL**, Muckart DJ, Thomson SR. An audit of the quality of care of traumatic brain injury at a busy regional hospital in South Africa. *S Afr J Surg* 2009; **47** (4): 120-2, 124-6.
- Stewart WW, Farina Z, **Clarke DL**, Thomson SR. Variations in levels of care within a hospital provided to acute trauma patients. *S Afr J Surg* 2011; **49** (4):194-8.
- Keene CM, Kong VY, Brysiewicz P, **Clarke DL**. Establishing the feasibility of a nursing driven modified early warning system (MEWS) in a South African regional hospital. *SAJS* (Submitted).
- Allorto NL, Oosthuizen GV, **Clarke DL**, Muckart DJ. The spectrum and outcome of burns in a regional hospital in South Africa. *Burns* 2009; **35** (7): 1004-8.
- Aldous C, Searle R, **Clarke DL**. An educational programme for error awareness in acute trauma for junior doctors. *African J Health Education* (In press).
- Laing GL, Bruce JL, **Clarke DL**. Tick box admission forms improve the quality of documentation of surgical emergencies, but have limited impact on clinical behavior. *SAMJ* 2013; **104** (6): 435-438.
- Laing GL, Skinner DL, Bruce JL, Bekker W, Oosthuizen GV, **DL Clarke**. A multi-faceted quality improvement programme results in improved outcomes for the selective non-operative management of penetrating abdominal trauma in a developing world trauma centre. *Injury* 2014; **45** (1): 327-32. DOI: 10.1016/j.injury.2013.08.021. Epub 2013 Sep 4.



## Ancillary publications emanating from this thesis

- Kong VY, Bulajic B, Allorto NL, Handley J, **Clarke DL**. Acute appendicitis in a developing country Kong VY, Bulajic B, Allorto NL, Handley J, **Clarke DL**. *World J Surg* 2012; **36** (9): 2068-73.
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- Laing GL, Bruce JL, Aldous C, **Clarke DL**. The design, construction and implementation of a computerized trauma registry in a developing South African metropolitan trauma service. *Injury* 2014; **45** (1): 3-8. DOI: 10.1016/j.injury.2013.05.013.
- Laing GL, Bruce JL, Skinner DL, Allorto NL, **Clarke DL**, Aldous C. Development, implementation and evaluation of a hybrid electronic medical record system specifically designed for a developing world surgical service. *World J Surg* 2014; **38** (6): 1388-97. DOI: 10.1007/s00268-013-2438-2.
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- Wall SL, Figueiredo F, Laing GL, **Clarke DL**. The spectrum and outcome of pregnant trauma patients in a metropolitan trauma service in South Africa. *Injury* 2014. pii: S0020-1383(14)00219-8. DOI: 10.1016/j.injury.2014.04.045. [Epub ahead of print]

- Allorto NL, Clarke DL. Merits and challenges in the development of a dedicated burn service at a regional hospital in South Africa. *Burns* 2014. pii: S0305-4179(14)00249-6. DOI: 10.1016/j.burns.2014.07.021. [Epub ahead of print]
- Laing GL, Bruce JL, Skinner DL, Allorto NL, Aldous C, Thomson SR, **Clarke DL**. Using a Hybrid Electronic Medical Record system for the surveillance of adverse surgical events and human error in a developing world surgical service. *World J Surgery* (In press).
- Kong VY, **Clarke DL**. The spectrum of visceral injuries secondary to misplaced intercostal chest drains: Experience from a high volume trauma service in South Africa. *Injury* 2014; **45** (9): 1435-9. DOI: 10.1016/j.injury.2014.05.013. Epub 2014 May 21.
- Kong VY, Oosthuizen GV, **Clarke DL**. What is the yield of routine chest radiography following tube thoracostomy for trauma? *Injury* 2014; **23**. pii: S0020-1383(14)00308-8. DOI: 10.1016/j.injury.2014.06.015.
- Kong VY, Sartorius B, **Clarke DL**. Selective conservatism for penetrating thoracic trauma is still appropriate in the current era. *Injury* 2014; **19**. pii: S0020-1383(14)00339-8. DOI: 10.1016/j.injury.2014.07.011.

The candidate contributed to all the above publications at all phases of their gestation. He helped conceptualise the research questions and design the methodology. He provided advice and assistance with data collection, helped analyse and interpret the data and was involved extensively in drafting and rewriting all the papers, and in managing the submission process.

## Contents

Dedication .....	i
Acknowledgements.....	ii
Declaration.....	iii
Abbreviations .....	v
Declaration of Publications .....	vi
First Author Publications.....	vi
Non-first author publications.....	vii
Ancillary publications emanating from this thesis .....	viii
Foreword.....	1
Summary .....	3
Introduction .....	3
Methodology.....	3
Results.....	3
Conclusion.....	4
Structure of the thesis.....	5
Chapter One: Conceptual framework, research setting, aims and objectives.....	7
Background .....	7
Strategic planning .....	7
The health system model.....	7
Quality metrics.....	7
Error theory.....	8
Setting .....	8
Research question.....	11
Aims .....	11
Objectives.....	11
References .....	12
Chapter Two: Theoretical constructs .....	13
Chapter overview .....	13
Publication 1: The Pietermaritzburg Metropolitan Trauma Service experience with the development of a comprehensive structure to facilitate and contextualise quality improvement programmes and basic research in rural trauma and acute care .....	14
Publication 2: A concept paper – using the outcomes of common surgical conditions as quality metrics to benchmark district surgical services in South Africa as part of a systematic quality improvement programme.....	23

Publication 3: Applying modern error theory to the problem of missed injuries in trauma .....	26
Summary .....	33
Chapter Three: Situational Analysis .....	34
Overview .....	34
Publication 4: Assessing the gap between acute trauma workload and the capacity of a single rural health district in South Africa: What are the implications for systems planning.....	35
Publication 5: An audit of the quality of care in traumatic brain injury at a busy regional hospital in South Africa .....	41
Publication 6: Variations in levels of care within a hospital provided to acute trauma patients .....	47
Publication 7: Establishing the feasibility of a nursing driven modified early warning score (MEWS) in a regional hospital in South Africa .....	52
Publication 8: The implications of patterns of error associated with acute trauma care in hospitals in South Africa for quality improvement programs and trauma education .....	59
Publication 9: The spectrum and outcome of burns at a rural hospital in South Africa .....	63
Summary .....	68
Chapter Four: Synthesis and implementation .....	71
Overview .....	71
Inputs .....	71
Processes of care.....	71
Publication 10: Surgical outreach in South Africa: Are we managing to impart surgical skills? .....	73
Publication 11: Using a structured morbidity and mortality meeting to understand the contribution of human error to adverse surgical events in a South African regional hospital.....	77
Publication 12: An educational programme for error awareness in acute trauma for junior doctors .....	82
Publication 13: Tick box admission forms improve the quality of documentation of surgical emergencies, but have limited impact on clinical behaviour .....	86
Publication 14: The introduction of an acute psychological support service for surgical patients is an effective error reduction strategy.....	92
Publication 15: A multi-faceted quality improvement programme results in improved outcomes for the selective non-operative management of penetrating abdominal trauma in a developing work trauma centre .....	96
Summary .....	102

Chapter Five: Discussion and Implications ..... 105

Appendix A: Ethics approval..... 111

## Foreword

This project was undertaken over an eight-year period following my appointment as the Head of the Clinical Unit for Trauma in Pietermaritzburg in July 2006. My thoughts have evolved over this time and this evolution is reflected in the thesis. Some of my proposed quality improvement programmes, such as telemedicine and rural retrieval teams, were not implemented and others were implemented in slightly different forms to what I envisaged when I drew up my concept sheets in 2009/2010. As such, this thesis reflects a pragmatic response to an environment, which is complex and challenging. As my thinking evolved, I began to realise that, without a systematic approach, individual quality improvement initiatives risk becoming unco-ordinated and *ad hoc*. In response to this, I began to formalise my thought process around the idea of an overarching structure which would allow me to integrate a strategic planning model with a health system model and to situate a number of different tools and constructs which are useful in quality improvement initiatives. Out of this I developed an overarching structure to facilitate systematic analysis and thinking about the quality of the trauma care. I then proceeded to use this structure to measure the quality of rural trauma care and to develop and implement a diverse group of targeted quality improvement interventions for rural trauma in Sisonke Health District. I began to realise that this is a key contribution of my thesis to the body of knowledge. Paradoxically the publication which discusses this grid structure and which subsequently comprises the first publication of the thesis, was one of the last to be submitted for peer review. It has formed the basis for the accompanying guest editorial in the *South African Medical Journal* on the topic of improving trauma care in rural and district hospitals. It has also since been accepted for publication in the forum section of the *SAMJ*. It continues to be used in the Pietermaritzburg Metropolitan Trauma Service (PMTS) to help contextualise the many different quality improvement programmes and research projects we are engaged in. This dissertation provides an overarching structure to the many diverse programmes and/or research projects that constitute the thesis and situates them appropriately so that they complement each other.

The publications that form the body of this thesis are presented as first-author publications, and non-first author publications. Included also, are a number of ancillary publications, which follow the broad theme of improving the quality of rural trauma and acute surgical care. I have played an integral role in developing each of these publications. Some of the ancillary publications have formed the basis of a number of other higher degrees, which I have supervised. The thesis concludes with the broad overarching grid structure I developed at the beginning and situates all the publications within this grid structure. It is intended that this structure be used in the future to contextualise ongoing quality improvement programmes and research projects within the PMTS.



## Ensuring equitable access to high quality care: The task of uplifting trauma care in rural and district hospitals



Although there are well-established Trauma Centres of Excellence in South Africa (SA), the reality is that many acutely injured patients will be taken to busy rural, district and regional hospitals where the quality of care varies from facility to facility.

Available evidence suggests that there is a high burden of trauma in SA and that resources to deal with it are inadequate.<sup>[1-4]</sup> Improving the quality of trauma care in rural and district hospitals will be a massive task.

Any healthcare system is tightly interlinked and complex – altering one component may have significant effects on the others. For example, employing an additional surgeon without expanding the capacity of the operating suite or the intensive care unit to cater for increased operative throughput may result in increased levels of frustration rather than improved service.

Poor outcomes tend to reflect systematic failures rather than individual failures. Without an overarching framework to provide a structure, strategic planning aimed at quality improvement risks becoming haphazard, ineffectual and even counter-productive. Improving a healthcare system requires multiple coordinated rather than isolated uncoordinated interventions.

Systems redesign encompasses three components, all of which need to be integrated: (i) the strategic planning process; (ii) design of a health system model; and (iii) appropriate quality metrics. A good strategic plan aims to develop a sustainable advantage and must answer these questions: ‘What future do we want for our organisation/system?’ – the vision; ‘Where is our organisation/system now?’ – the analysis; ‘How is the vision to be achieved?’ – synthesis; and ‘How are plans to be put into action?’ – implementation.

There exists a well-established model that breaks healthcare systems into three components namely, inputs, processes and outcomes, the latter being a direct product of the interaction between inputs and processes. Inputs include capital, physical infrastructure, consumables, fixed equipment, human resources and educational initiatives. Process refers to how care will be delivered. The relationship between inputs and process is not linear – increasing inputs without altering process will not necessarily result in improved outputs, and the converse holds true.

Being able to quantify how well an organisation performs requires appropriate metrics and multiple indicators that provide a platform from which to begin to improve processes and, ultimately, outcomes.

Improving the quality of rural trauma and acute surgical care in SA demands a situational analysis to assess the burden of disease, as well as the resources available. Planners can measure the infrastructure in terms of the number of operating theatres, the availability of equipment and adequacy of radiology facilities. They can measure

the quality of the human resources available and the quality of the process of care and the outcomes. They can assess the process by auditing the delays that patients experience and assessing whether his/her visit to the district hospital added value to an individual patient's care. Once this situational analysis has been performed, the phase of synthesis can begin to decide strategies and interventions. For example, should more district hospitals be built or should the role of district hospitals in trauma care be reconsidered with decisions to bypass them by taking specific categories of trauma patients directly to the regional hospital? Based on the deficits identified, could staff training be improved? Which staff should be trained? Should new, targeted courses be developed or will pre-existing courses suffice? Should management fund emergency care staff to attend established courses such as those developed by the American College of Surgeons (e.g Advanced Trauma Life Support for doctors, Advanced Trauma Care for Nurses for nurses and Pre-hospital Trauma Life Support for paramedics)<sup>[5]</sup> and hosted in SA academic centres, or should educational programmes be developed that would offer training to staff within the rural and district hospitals in which they work? Can the development of new infrastructure such as telemedicine or surgical outreach programmes improve care?

There are many interventions to be considered. Without a structured systematic approach to improving the quality of rural trauma and emergency care these interventions risk being isolated and *ad hoc* and may well be ineffective.

### Damian Clarke

Guest Editor  
damianclar@gmail.com



1. Clarke DL, Gouveia J, Thomson SR, Muckart DJ. Applying modern error theory to the problem of missed injuries in trauma. *World J Surg* 2008;32(6):1176-1182. [<http://dx.doi.org/10.1007/s00268-008-9543-7>]
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3. Stewart WW, Farina Z, Clarke DL, Thomson SR. Variations in levels of care within a hospital provided to acute trauma patients. *S Afr J Surg* 2011;30(4):194-198.
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# Summary

## Introduction

Rural trauma care in South Africa is under resourced and the quality of rural trauma care appears to be uneven. This project aimed to assess the quality of rural trauma care in Sisonke Health District and to develop targeted quality improvement programmes to improve it.

## Methodology

A strategic planning methodology consisting of a situational analysis, planning synthesis and implementation was used in the project and was integrated with a health system's model of inputs, process and outcome to provide a structured overview of the whole process. A number of academic constructs from fields outside of health care were used to analyse the quality of care and to develop targeted quality improvement programmes.

## Results

The table below summarises the results of this project by placing each of the published papers in this thesis into the integrated grid. The various tools that were adopted to assist with the project included error theory and quality metrics for trauma and acute surgery. These are also situated within the grid.

*Analysis* of the inputs of rural trauma care revealed that there were major deficits in terms of the human resources available to manage the large burden of trauma seen in rural hospitals. Analysis of the process revealed deficits in the transfer process and the quality of documentation and observation of trauma patients in our system. Analysis of the outcomes revealed a high incidence of error associated with rural trauma care and poor outcomes for a number of conditions such as burns.

*Synthesis and Implementation* involved the development of a number of strategies and a review of their efficacy. These included a surgical outreach programme, restructured morbidity and mortality meetings, error-awareness training and the use of tick-box clerking sheets. The impact of these various programmes was mixed. The surgical outreach programme was successful at delivering surgical care in the districts but less successful at transferring surgical skills to rural staff. The morbidity and mortality meetings, and the error-awareness training changed the culture of the institution and increased the understanding of the danger of error. The tick-box initiative revealed how difficult it is to change human behaviour. A number of audits have suggested that there is a general improvement in the



quality of care. This has resulted in improved outcomes for the management of penetrating abdominal trauma and burns care.

## Conclusion

Rural trauma care has many deficits and these translate into poor outcomes. Addressing these deficits is difficult and requires a multi-faceted approach. Undertaking quality improvement programmes in an *ad hoc* manner may be counter-productive and using a structured systematic approach may allow planners to contextualise their interventions. Currently trying to increase the inputs and resources available for rural trauma care is difficult and most of the intervention should aim at refining and improving the process of care. A number of projects have emerged from this thesis.

<b>Vision</b>	Quality metric	Quality metric	Quality metric	
<b>Mission</b>	<b>Inputs</b>	<b>Processes</b>	<b>Outcomes</b>	
<p><b>Analysis</b> Tools A concept paper: using the outcomes of common surgical conditions as quality metrics to benchmark district surgical services in South Africa as part of a systemic quality improvement programme</p> <p>Applying modern error theory to the problem of missed injuries in trauma.</p>	<p>Assessing the gap between the acute trauma workload and the capacity of a single rural health district in South Africa. What are the implications for systems planning?</p>	<p>An audit of the quality of care of traumatic brain injury at a busy regional hospital in South Africa.</p> <p>Variations in levels of care within a hospital provided to acute trauma patients</p>	<p>The implications of the patterns of error associated with acute trauma care in rural hospitals in South Africa for quality improvement programs and trauma education.</p> <p>The spectrum and outcome of burns in a regional hospital in South Africa.</p> <p>Quantifying the disparity in outcome between urban and rural patients with acute appendicitis in South Africa.</p>	<p><i>Metrics Analysis</i></p>
<p><b>Synthesis and Implementation</b> Generic quality improvement strategies. Increase resources Improve process</p>	<p>An educational programme for error awareness in acute trauma for junior doctors</p> <p>Using a structured morbidity and mortality meeting to understand the contribution of human error to adverse surgical events in a South African regional hospital.</p> <p>Surgical outreach in rural South Africa: are we managing to impart surgical skills?</p>	<p>Tick-box admission forms improve the quality of documentation of surgical emergencies, but have limited impact on clinical behaviour.</p> <p>The introduction of an acute physiological support service for surgical patients is an effective error reduction strategy.</p>	<p>A multi-faceted quality improvement programme results in improved outcomes for the selective non-operative management of penetrating abdominal trauma in a developing world trauma centre</p>	<p>Develop targeted Quality Improvement Programme Metrics</p>
<b>Vision</b>	Quality metric	Quality metric	Quality metric	Metrics

Please refer to Table 5.1 on p. 108 for the full references.

## Structure of the thesis

This is a thesis by publication and comprises five chapters. The middle chapters consist of 15 peer-reviewed publications, of which all but one are currently in press. A number of other publications stemming from this research theme are also quoted. Each chapter begins with an overview which is intended to lead into the publications and ends with a brief summary which reviews each publication and highlights its strengths and weaknesses and identifies possible future research themes and topics.

**Chapter One: Conceptual framework, research setting, aims and objectives** is the introduction to the thesis and does not comprise any publications. It provides an overview of the thesis, describes the setting, elucidates the research question and lists the aims and objectives of this work.

**Chapter Two: Theoretical constructs**, provides a theoretical framework for the thesis and integrates diverse theoretical constructs in an attempt to develop a systematic approach to assessing quality of care and of developing interventions to improve it. The chapter introduces an overarching grid structure, which integrates a strategic planning process with a health systems model and provides a theoretical framework to understand how quality improvement programmes must be integrated into a strategic planning process that complements a systematic understanding of the health system. A number of different theoretical constructs are introduced in this chapter. These include methods of quantifying the quality of care and using quality markers to benchmark current standards and to drive ongoing quality improvement programmes. The chapter also introduces the major theme of modern error theory, which provides tools to both analyse quality of care, and to develop and conceptualise targeted quality improvement initiatives.

**Chapter Three: Situational analysis**, reviews the current state of rural trauma care in KwaZulu-Natal. It uses multiple quality markers to provide an overview of the inputs into the system, which include the burden of disease, the capacity to deal with this load, the quality of the process of care and the outcomes of this care.

**Chapter Four: Synthesis and Implementation**, combines the synthesis and implementation phase of a strategic planning process. It documents several quality improvement programmes, which have been developed and assesses their impact. These programmes are classified according to the component of the system they are designed to change. Some programmes are aimed at improving inputs and others at improving the process of care.

**Chapter Five: Discussion and implications**, provides an overview of the entire thesis, highlights its contribution to the body of knowledge, and points the way forward to several ongoing initiatives, which form part of a multi-faceted quality improvement programme. These

various initiatives have a theme of quality improvement running through them and some of these initiatives form part of ongoing higher degree projects. Chapter Five concludes with Table I, which uses the overarching grid structure to situate and contextualise all the research emanating from this thesis. The candidate is senior author on all these publications

# Chapter One: Conceptual framework, research setting, aims and objectives

## Background

There is a growing interest in the issue of rural trauma and acute care.<sup>1,2</sup> Rural areas are generally under resourced and their remoteness means that there are often long delays associated with trauma and acute surgical conditions in these areas. The net result is care of an extremely uneven quality. The challenge is to improve outcomes of care within the existing resource constraints. Quality improvement is a complex task, and it is unlikely that any single intervention will be effective in isolation. Improving outcomes will require many different interventions and any improvement programme will have to be multi-faceted.<sup>3</sup> There are a number of theoretical constructs, which may be useful adjuncts in developing a systematic quality improvement programme. This thesis attempts to integrate these theoretical constructs into an overarching structure to assist with the development of a systematic quality improvement programme. The disciplines and theoretical constructs, which this thesis attempts to integrate, are Strategic Planning, Donabedin's Health System Model, quality metrics and Error Theory.<sup>4-11</sup>

## Strategic planning

The discipline of strategic planning arose in the military and has been adopted by organisational theorists who wish to assist large organisations plan for the future. There are a number of schools of strategic planning which make use of different perspectives and models to develop their approaches.<sup>4-6</sup>

## The health system model

Donabedin was a public health specialist who first popularised a model to help understand how a complex health system functions. He broke the system down into Inputs, Processes and Outcomes. This simple, but durable, model greatly helps planners and managers who are trying to improve a complex system by facilitating their thought processes.<sup>7</sup>

## Quality metrics

Quality is a nebulous term, which needs to be defined to be meaningful. A metric helps define quality of care by specifying what we regard as an appropriate level of care and an acceptable outcome within the constraints of the system and the available resources. There

are many different quality metrics, which provide insight into the quality of a process of care. Choosing the appropriate metric allows managers and planners to benchmark the current level of care and to provide a quantifiable goal for the improvement programme.<sup>7-10</sup>

## **Error theory**

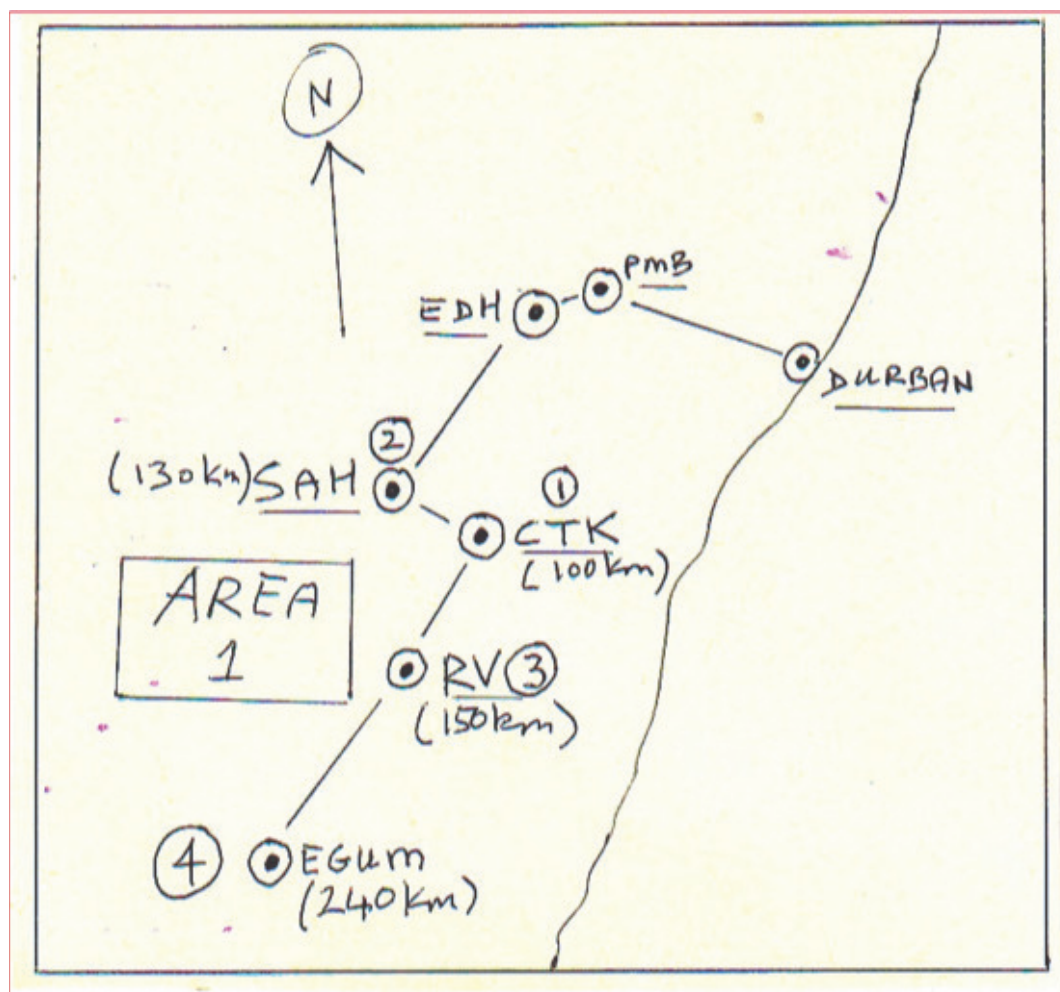
The study of human error is a field of psychology, which arose in the aviation industry and has been extended to other high-risk environments such as the nuclear power industry, the military and, more recently, to health care. The central understanding of this field of study is that human error contributes significantly to adverse events but is not totally random. Human error often follows patterns and by analysing the patterns of error, researchers can develop strategies to reduce the impact of these errors. Human error can never be eliminated but it can be detected and its impact reduced.<sup>11</sup>

## **Setting**

The city of Pietermaritzburg is the capital of KwaZulu-Natal and the largest city in the western part of the province. It has a population of one million people and is served by a tertiary hospital (Greys), a regional hospital (Edendale) and a district hospital (Northdale). Western KwaZulu-Natal is a predominantly rural province and is made up of four health districts with a population of two million people. There are two other regional hospitals in western KwaZulu-Natal and 19 district hospitals. Sisonke District is a rural area in south western KwaZulu-Natal with a population of half a million people and four district hospitals. These are Usher Memorial Hospital in Kokstad, Christ the King Hospital in Ixopo, Saint Apollinaris Hospital near Creighton and Rietvlei Hospital halfway between Kokstad and Harding. Tayler Bequest Hospital in Matatiele has now been incorporated into the Eastern Cape Province and is no longer part of the official drainage area, however, it still refers many patients through to the regional hospital. Edendale Hospital is an 800-bed regional hospital based just outside the city of Pietermaritzburg. It is the referral hospital for Sisonke District and hence Sisonke and Edendale Hospital form a health system. The hand-drawn map created by Dr Jonathan Handley, my anaesthetic companion on many of the visits to these district hospitals over the last five years, shows the four hospitals in geographical relationship to Edendale Hospital in Pietermaritzburg and to Durban.

**Figure 1: Schematic map of Sisonke District and the four district hospitals**  
 Courtesy of Dr Jonathan Handley

Edendale Regional Hospital (EDH)	Distance from Edendale
Christ the King Hospital (CTK)	100 km
Saint Apollinaris Hospital (SAH)	130 km
Rietvlei Hospital (RV)	150 km
East Griqualand and Usher Memorial District Hospital (EGUM)	240 km



### **The Pietermaritzburg Metropolitan Trauma Service**

The Pietermaritzburg Metropolitan Trauma Service (PMTS) was established in 2006 with the intention of providing comprehensive trauma care for all patients in the Pietermaritzburg metropolitan area and of providing leadership in trauma care to the western third of KwaZulu-Natal Province. Prior to this, individual general surgical firms cared for trauma and burns patients. The mission statement of the PMTS is "Taking Care of Pietermaritzburg" and this has been made manifest by the implementation of dedicated trauma teams during the day at both institutions in the complex. Furthermore, a dedicated burns team has been established at the regional hospital, which now comprises a burns consultant, a senior medical officer and two junior medical officers. Over the last five years this nascent trauma service has grown to the point where it comprises five specialist surgeons of whom three are registered sub-specialist trauma surgeons and two are general surgeons. Currently the PMTS has two sub-specialist trauma surgeons in training. All trainees and junior staff work under the supervision of the specialist staff. At an operational level, the trauma staff are sub-divided into three teams, one of which is based at Greys Hospital, and two at Edendale Hospital. This is still insufficient to cover the entire metropolitan complex and the after-hours specialist call roster, is supplemented by the general surgery department. All quality improvement interventions have been integrated into the overarching development of the PMTS. The quality improvement programme is divided into programmes intended to improve the inputs and programmes to improve the processes of care. Ongoing clinical audit is used to measure the outputs of these interventions and to establish their efficacy. The PMTS is different from other South African trauma units in that it provides cover for a whole city and, hence, it is referred to as a service, not a centre or unit. There is no designated centre and trauma patients are taken to one of the two hospitals within the city of Pietermaritzburg depending on geographical location and availability of resources. This makes the implementation and enforcement of safe and pragmatic management algorithms challenging.

## **Research question**

Is it possible to assess the quality of rural trauma and acute surgical care in Sisonke Health District and to use these data to develop a multi-faceted programme to improve this care within the current resource constraints?

## **Aims**

The aims of this project are to:

- Develop a comprehensive structure to integrate a number of diverse theoretical constructs into an overarching structure to facilitate systematic quality improvement programmes.
- To define and develop appropriate metrics to benchmark the quality of surgical care and to drive quality improvement programmes.
- To use modern error theory to analyse quality of care and develop strategies to reduce the impact of human error.

## **Objectives**

The objectives of this project are to:

- Describe and analyse the burden of disease faced by the rural hospitals in Sisonke District.
- Analyse the capacity in terms of human resources and logistics to deal with this load.
- Develop multiple, targeted, evidence-based interventions based on the initial analysis to address these various deficits.
- Assess the impact of these targeted interventions.
- Identify ongoing research projects.



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## Chapter Two: Theoretical constructs

### Chapter overview

This chapter introduces several diverse academic disciplines and concepts, which have found roles in fields outside of health care. These concepts can be applied to health systems research and include strategic planning, models of the health care system, quality metrics and human error theory. The concept of strategic planning arose in the military and has since been widely applied in organisational theory and business. The strategic planning process provides a structured method to assess the internal milieu of an organisation and then to review the external environment in which it operates. Once this has been done, the strategic planning model facilitates the development of targeted initiatives based on the results of the strategic planning exercise. These initiatives must then be implemented and their effect measured in an ongoing review process. However, a health system is a complex organisation and, as such, is difficult to analyse. There is a well-established model of a health system, which is often used to facilitate thinking and strategising around health systems. Integrating the two models allows for the development of a grid structure, which allows planning practitioners to integrate their thinking about the strategic-planning process with the many diverse components of the health system. Leading on from this grid structure is a discussion on the development of quality metrics to assess and measure the quality of care in a surgical system.

Publication 1 discusses the development of this comprehensive structure and the issue of developing metrics to assess the quality of surgical care in a health district.

Publication 2 discusses in more detail the need to collect data about common surgical conditions, which can be used as metrics to assess the quality of surgical care in a health district.

Publication 3 introduces the concept of the study of human error and how this new field of research may be applied to trauma and emergency care.

## Publication 1

### **The Pietermaritzburg Metropolitan Trauma Service experience with the development of a comprehensive structure to facilitate and contextualise quality improvement programmes and basic research in rural trauma and acute care**

Clarke DL

#### **Introduction**

Improving the delivery of efficient and effective surgical care in rural South Africa is a mammoth task, which may well overwhelm anyone who attempts to do so in an isolated and *ad hoc* manner. The field is also beset by a great deal of conflict between various stakeholders, which include rural doctors, surgeons, ancillary staff, researchers, educators, and administrators. Part of the problem is that management training is not part of most medical school curricula yet, as they progress in their careers, many clinicians will find themselves being required to manage a health system and will find the shift from caring about individual patients to managing a complex system difficult. Conflict arises when management-type interventions are imposed in a top-down manner on surgical staff who are suspicious of an unfamiliar field of study. Another area of conflict is over the place of surgical research. Often researchers are accused of not being concerned about the important tasks of service delivery. This publication attempts to help with this by providing an overview of management theory and by developing a comprehensive management structure, which integrates a model for health systems with a strategic-planning process, strategic-planning tools and appropriate quality-metrics. We then proceed to show how the Pietermaritzburg Metropolitan Trauma Service (PMTS) successfully used this grid structure to facilitate and contextualise a diverse number of quality improvement programmes and research initiatives around the problem of rural acute surgery and trauma. We have found this structure to be useful and it is hoped that this structure may be applied to other acute health care systems.

#### **The strategic planning process and health systems**

Strategic planning is a systematic process designed to assist organisational decision making by taking into account the micro-environments within the organisation, as well as the macro-environment in which the organisation exists.<sup>1-5</sup> Health care systems are complex, tightly coupled systems and strategic planning in such a system without an overarching framework to provide a structure, for quality improvement programmes risks becoming *ad hoc*, haphazard, ineffectual and, possibly, even counter-productive. The strategic planning process must identify the organisation's vision and mission or the systems aims and objectives. The mission statement explains the reasons for the health system's existence. The vision statement identifies a potential 'ideal future state' which the system aspires to achieve. The situational analysis follows this and looks at the external environment to identify threats and opportunities and then looks inwards to assess the organisation's resources and

capabilities.<sup>1-6</sup> The stage of synthesis follows where the strategic plan is crafted. The plan must then be implemented and, after that, outcomes must be audited. There are a number of generic strategic planning tools, which are of relevance to developing a structured systemic approach to quality improvement programmes. These include the SWOT analysis, the balanced scorecard and strategic drift and gap analysis.

### **SWOT**

This acronym stands for Strengths, Weaknesses, Opportunities and Threats (SWOT) and identifies both internal strengths and weaknesses, and threats and opportunities in the external environment that may affect the organisation.

### **The balanced scorecard**

The balanced scorecard is a forward-looking management system that views the organisation from four perspectives, namely learning and growth, process, the customer point of view, and results.

### **Strategic drift and gap analysis**

The final outcome of a strategic plan is a result of the interaction of the external environment and three internal factors namely: the plan, the leadership and the culture of the organisation. A gap analysis model helps identify reasons for the strategic gap.

### **A health care system model**

There is a well-established model for thinking about health systems (Table 1), which breaks a health care system down into inputs, process and outcome.<sup>4,5</sup> Table 1 attempts to give examples of the various constituents of a health system and to categorise them according to which component they reflect. The system comprises two variables and a product of those two variables. Health care outcomes are a direct product of the interaction between inputs and processes. The only components of the health system, which planners can directly influence are the inputs and the processes. The relationship between inputs and process is not linear and increasing inputs without altering process will not necessarily improve outputs. Conversely, improving the process of care without increasing the resources available may result in a dramatic improvement in outcomes.

### **Metrics to measure outcomes of a health care system**

A good quality indicator provides a platform to improve processes and outcomes and can be classified according to type or according to which component of a health care system they measure. Tables 2 attempts to contextualise the type of quality markers against the component of the health system being analysed.<sup>5,6</sup>

### **A comprehensive strategic planning structure for health systems**

We have developed an overarching structure or grid (Table 3), which allows planners to contextualise the strategic-planning process against the various components of the health care system, to plan accordingly and to evaluate improvements over time. It integrates the planning process, the components of the health system and quality metrics. The structure comprises a composite grid with an x - and a y - axis. Along the y-axis are the components of the strategic planning process (analysis, synthesis and implementation) and along the x-axis are the three components of a health system (inputs, processes, outcomes). Within each cell of the grid there is room for the appropriate strategic-planning tool as well as the specific quality improvement intervention, and for the appropriate metric. The model allows a planner to identify each metric according to its role in the strategic-planning process and according to the component of the health system it is measuring. Above and below the grid are columns for the mission and vision of the organisation. These should inform each grid. Table 3 attempts to show how the grid could be used to situate each tool, intervention or metric according to the stage of the strategic planning process and the component of the health system it is addressing. The planners can situate each planning tool in its appropriate grid. Each proposed intervention can also be placed in a grid according to whichever component of the system it is intended to address. Table 4 and Table 5 illustrate how such a structure may be used in practice to contextualise data from a number of sources in rural trauma and acute care.

### **Applying the grid to the PMTS**

Since its inception in 2006, the PMTS has run a research and a quality improvement programme aimed at uplifting trauma care in Edendale Hospital and rural Sisonke Health District. This programme is a multi-faceted one as it is obvious that no single intervention will address all the deficits in trauma and acute surgical care in our system. The grid structure has helped us contextualise all programmes within an overarching structure. This is represented in Table 4, which places a number of research projects into context. We commenced by measuring the resources available to deal with trauma and the burden of disease.<sup>7</sup> We then adopted a number of theoretical constructs, which we took from fields outside of surgery and used them to both measure quality of care and to inform potential interventions. These theoretical constructs included error theory and the idea of developing a suitable quality marker for surgery.<sup>8,9</sup> We used these systems to assess the quality of care in the area.<sup>10-15</sup> Once this situational analysis was performed, we moved on to the stage of synthesis of strategies and interventions. We developed educational programmes and refined our morbidity and mortality meetings with the intention of driving quality improvement.<sup>1,17</sup> We introduced a number of innovative registries, which allowed us to capture data for research and to quantify the burden of disease and the outcome more accurately.<sup>18,19,20</sup> We used the data from these registries to further inform morbidity and mortality meetings and educational initiatives. We have run a surgical outreach programme for over a decade designed to uplift

surgical care in the rural hospitals of western KwaZulu-Natal.<sup>18</sup> The grid structure helped us to understand the role of this programme and to attempt to audit its efficacy in transferring skills to the district hospitals. There are ongoing efforts to refine the process of care by developing burns teams, trauma teams and acute physiological support teams.<sup>21-24</sup> The last concept was an innovative attempt to provide improved care to surgical patients who were deemed to be too sick for the general ward but too well for ICU.<sup>22</sup> Ongoing audit has revealed some successes and some failures.<sup>23,24</sup> The grid helped us to contextualise each piece of research and each intervention within the overarching system and to close the loop between research and strategy.

### Conclusion

We have developed a grid structure, which integrates three concepts, namely the strategic-planning process, the associated strategic-planning tools, a model of the health system and the many quality metrics available to measure components of the health system which relate to acute care. As shown, each step in the strategic planning process and each individual quality metric can be placed within the grid to provide a system-wide overview of the whole process. We believe that this grid will facilitate the development and implementation of successful quality improvement programmes in a variety of settings in the South African health system.

**Table 1: The components of a health system (Donabedian)**

Inputs	Process	Outcome
Macro-educational programs University funding Nursing colleges Ambulance training colleges	Application process Admission process Academic support for disadvantaged students Type of education	Newly qualified staff Doctor/nurse/paramedic to patient ratios
Micro-educational programmes at hospital level	Staff attending Staff completing course	Improvement in patient care Compliance with guidelines
Hospital morbidity and mortality meetings	Staff attending Cases discussed	Decreased rates of adverse events
CT scanner Radiology staffing	Call list Protocols for use Waiting time	Patients scanned Treatment influenced Accuracy of reporting
ICU beds ICU staffing	Triage policy Referral system	Patients treated Mortality rates Length of stay Readmission rate

**Table 2**

Generic and disease-specific indicators	Injury per capita
Rate-based	Case load
Sentinel Indicators:	Wrong site surgery
Input/Structural Indicators	Ambulance to patient ratio
Process indicators	Time to theatre Time till admission
Outcome indicators	Mortality rates Length of stay

**Table 3: A comprehensive structure for a quality improvement programme to improve the quality of care of acute trauma patients in a rural health district in South Africa:**

Vision: To have a single high standard of care for urban and rural trauma patients

Mission: To identify deficits in care and provide pragmatic and sustainable interventions to address these deficits.

Planners may need to develop innovative quality metrics. Using the comprehensive structure will help them think about what they wish to measure and how they should measure it

<b>Vision</b>	Quality metric	Quality metric	Quality metric	
<b>Mission</b>	<b>Inputs</b>	<b>Processes</b>	<b>Outcomes cannot be directly targeted but must be audited</b>	
<b>Analysis</b> SWOT Strategic drift Balanced score card	<i>What is the load of trauma?</i> <i>What is the capacity of the rural hospitals to deal with this load?</i> <i>Can we develop new metrics?</i> <i>Can we use new constructs to help us?</i>	<i>What is the delay from injury to arrival at the district hospital?</i> <i>What is the delay from district hospital to regional hospital?</i> <i>Quality of documentation</i> <i>Quality of care</i>	<i>What is the mortality rate compared to elsewhere?</i> <i>What is the error rate compared to elsewhere?</i> <i>What is the length of stay?</i> <i>What is the cost?</i>	<i>Metrics Analysis</i>
<b>Synthesis and Implementation</b> Generic quality improvement strategies. Increase resources Improve process	Can we decrease the load? (Injury prevention) Can we increase the number of staff available? Can we improve the quality of the staff available with educational programmes? Can we improve monitoring systems? Will better reporting and feedback to staff improve care?	Should we change the referral patterns? Should specific trauma patients bypass the small district hospital? Can we change the way we deliver care? Restructuring morbidity and mortality meetings	<i>Have we improved the mortality rate?</i> <i>Have we reduced the error rate?</i> <i>Have we reduced the length of stay?</i> <i>Have we improved cost?</i>	Develop targeted Quality Improvement Programmes
<b>Vision</b>	Quality metric	Quality metric	Quality metric	Metrics



Table 4

<b>Vision</b>	Quality metric	Quality metric	Quality metric	
<b>Mission</b>	<b>Inputs</b>	<b>Processes</b>	<b>Outcomes</b>	
<b>Analysis</b> SWOT Strategic drift Balanced score card	<p>Assessing the gap between the acute trauma workload and the capacity of a single rural health district in South Africa. What are the implications for systems planning?<sup>7</sup></p> <p>A concept paper: using the outcomes of common surgical conditions as quality metrics to benchmark district surgical services in South Africa as part of a systemic quality improvement programme<sup>8</sup></p> <p>Applying modern error theory to the problem of missed injuries in trauma.<sup>9</sup></p>	<p>An audit of the quality of care of traumatic brain injury at a busy regional hospital in South Africa.<sup>10</sup></p> <p>Variations in levels of care within a hospital provided to acute trauma patients<sup>11</sup></p>	<p>An audit of failed non-operative management of abdominal stab wounds.<sup>12</sup></p> <p>The implications of the patterns of error associated with acute trauma care in rural hospitals in South Africa for quality improvement programmes and trauma education.<sup>13</sup></p> <p>The spectrum and outcome of burns in a regional hospital in South Africa.<sup>14</sup></p> <p>Quantifying the disparity in outcome between urban and rural patients with acute appendicitis in South Africa.<sup>15</sup></p>	<i>Metrics Analysis</i>
<b>Synthesis and Implementation</b> Generic quality improvement strategies. Increase resources Improve process	<p>An educational program for error awareness in acute trauma for junior doctors<sup>16</sup></p> <p>Using a structured morbidity and mortality meeting to understand the contribution of human error to adverse surgical events in a South African regional hospital.<sup>17</sup></p> <p>Surgical outreach in rural South Africa: are we managing to impart surgical skills?<sup>18</sup></p> <p>The design, construction and implementation of a computerized trauma registry in a developing South African metropolitan trauma service.<sup>19</sup></p> <p>Development, implementation and evaluation of a hybrid electronic medical record system specifically designed for a developing world surgical service.<sup>20</sup></p>	<p>Tick box admission forms improve the quality of documentation of surgical emergencies, but have limited impact on clinical behaviour.<sup>21</sup></p> <p>The introduction of an acute physiological support service for surgical patients is an effective error reduction strategy.<sup>22</sup></p>	<p>A multi-faceted quality improvement programme results in improved outcomes for the selective non-operative management of penetrating abdominal trauma in a developing world trauma centre<sup>23</sup></p> <p>Challenges and merits of improving burn care in South Africa<sup>24</sup></p>	Develop targeted Quality Improvement Programmes Metrics
<b>Vision</b>	Quality metric	Quality metric	Quality metric	Metrics

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## GENERAL SURGERY

# A concept paper: Using the outcomes of common surgical conditions as quality metrics to benchmark district surgical services in South Africa as part of a systematic quality improvement programme

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The fourth, fifth and sixth Millennium Development Goals relate directly to improving global healthcare and health outcomes. The focus is to improve global health outcomes by reducing maternal and childhood mortality and the burden of infectious diseases such as HIV/AIDS, tuberculosis and malaria. Specific targets and timeframes have been set for these diseases. There is, however, no specific mention of surgically treated diseases in these goals, reflecting a bias that is slowly changing with emerging consensus that surgical care is an integral part of primary healthcare systems in the developing world. The disparities between the developed and developing world in terms of wealth and social indicators are reflected in disparities in access to surgical care. Health administrators must develop plans and strategies to reduce these disparities. However, any strategic plan that addresses deficits in healthcare must have a system of metrics, which benchmark the current quality of care so that specific improvement targets may be set.

This concept paper outlines the role of surgical services in a primary healthcare system, highlights the ongoing disparities in access to surgical care and outcomes of surgical care, discusses the importance of a systems-based approach to healthcare and quality improvement, and reviews the current state of surgical care at district hospitals in South Africa. Finally, it proposes that the results from a recently published study on acute appendicitis, as well as data from a number of other common surgical conditions, can provide measurable outcomes across a healthcare system and so act as an indicator for judging improvements in surgical care. This would provide a framework for the introduction of collection of these outcomes as a routine epidemiological health policy tool.

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Over the three-and-a-half decades since the Declaration of Alma Ata, healthcare systems have tended to become increasingly inequitable and cost-ineffective, implying that the traditional model of primary healthcare conceptualised at Alma Ata has to a large extent been unsuccessful.<sup>[1-7]</sup> This has necessitated a re-imagining of the model of primary healthcare. The new model views primary healthcare as a central hub, which focuses on strengthening the individual components of the health system beneath the overarching umbrella of primary healthcare. Traditionally the public health approach perceived surgical services as expensive curative services that benefited individuals rather than communities.<sup>[1-3]</sup> Since Nordberg first drew attention to the fact that much morbidity and mortality occurs in remote rural African villages because of common surgical conditions,<sup>[1-3]</sup> there has emerged a consensus that surgical care is an integral component of primary healthcare and that common surgical conditions such as trauma, hernias, appendicitis, obstetric emergencies and congenital anomalies are important public health problems.<sup>[1-7]</sup>

There are major disparities in access to surgical care across the world, and this disproportionately affects rural and marginal groups in low-income countries.<sup>[5-7]</sup> The World Health Organization (WHO) classifies countries as high, middle or low income based on the amount of money annually spent on healthcare per head of population, middle- to high-income countries spending between US\$400 and US\$1 000 per head of population. Only a third of the world's population lives in middle- to high-income countries, yet two-thirds of all surgical procedures are performed there, and the poorest third of the world's population undergoes less than 4% of all surgical procedures. It has been estimated that the global volume of major surgery in 2004 was between 187 million and 281 million cases, which equates to one operation for every 25 human beings.<sup>[7]</sup> Major morbidity complicates 3 - 16% of all surgical procedures, and there is an associated death or permanent disability rate from 0.5% to just under 1% in the developed world. The mortality rate of major surgery in the developing world is significantly higher, however, and has been estimated to be in the range of 5 - 10%. This means that approximately 7 million people

a year experience a major complication, and 1 million people a year die, following surgery.<sup>[7]</sup> In view of the large numbers involved, improving outcomes for surgery is a public health priority, and the provision of adequate surgical services has been shown to be an extremely cost-effective healthcare intervention in the developing world.<sup>[7-10]</sup> Most of the strategies designed to address the disparities in access to surgical care focus on building the surgical capacity of district hospitals.<sup>[7-10]</sup>

### Current resources and initiatives

Effective surgical services tend to bolster the entire health system and impact positively on other non-surgical services.<sup>[7-10]</sup> The WHO has responded to this new understanding of the importance of effective surgical systems by developing a number of resources and programmes. In 2005 the Global Initiative for Emergency and Essential Surgery Care was established to increase the capacity of low- and middle-income countries to provide effective surgical services. The Emergency and Essential Surgical Care Project, the Integrated Management of Emergency and Essential Surgical Care toolkit and the textbook *Surgical Care at the District Hospital* are designed to help resource-constrained institutions establish effective educational and service packages based on the WHO's prescribed minimum standards and technologies for emergency and essential surgical care.<sup>[11]</sup> The WHO has emphasised the importance of a systematic approach to healthcare.<sup>[11,12]</sup>

### Systems thinking

A healthcare system involves inputs, processes and outcomes.<sup>[11,12]</sup> Improving the health of a population must address the inputs of healthcare and the processes of delivery of healthcare. The inputs are the money and resources invested in the system, and the processes the way in which healthcare is delivered. The inputs and the processes interact to produce a health outcome. The term 'health system' covers the entire spectrum of care from the recognition and diagnosis of a pathology, through to transfer of the patient to the appropriate facility, up to operative management and postoperative care. Effective treatment depends on all the steps of the healthcare system working harmoniously. Patients must be able to access healthcare facilities easily and timeously. Primary caregivers must be able to recognise surgical pathology and refer the patient to an appropriate facility. Logistics must be organised to ensure quick and efficient transportation of the patient to the appropriate facility, and the receiving facility must be adequately resourced to deal with the problem. If any links in this chain of care are broken, pathology may complicate, and this translates into poor outcomes.

It is important to understand that poor outcomes reflect systematic failure rather than individual failure. To understand the efficiency of the system, administrators need to develop metrics that measure the quality of the system. Mainz has provided an excellent review of quality metrics for healthcare and has identified the following objective criteria for a good metric:<sup>[13]</sup> It must be relevant, acceptable, feasible, reliable, sensitive to changes, valid, and able to differentiate. In addition, whatever disease is chosen as an indicator needs to be sufficiently common to provide a large enough denominator, and ideally should be curable.

### What is the current state of surgery at district hospital level in South Africa?

In *Surgical Care at the District Hospital*, the WHO states that basic abdominal surgery should be undertaken at district hospitals. The following procedures are described: laparotomy for trauma, laparotomy for the diagnosis and management of intestinal obstruction, peritonitis, complicated peptic ulcer disease, and appendicitis.<sup>[11]</sup> However, there remains a discrepancy between the package of care that a district hospital is expected to deliver and the care that is actually delivered, and it is apparent that very few of the procedures discussed in the WHO text are routinely performed in South African district hospitals.

Voss and Duvenage audited the surgical output of 7 district hospitals in the rural Western Cape.<sup>[14]</sup> The volume of general surgical procedures undertaken was low, and almost no abdominal surgery was undertaken. In their year-long review, only 21 appendicectomies were performed at the 7 district hospitals. Of these, 19 were performed in one hospital and 2 in another. The most commonly performed operations in rural South Africa are obstetric procedures, yet the competency to deliver obstetric anaesthesia safely seems to be deficient in the South African district health system.<sup>[15]</sup>

We recently published our experience with acute appendicitis at Edendale Hospital, Pietermaritzburg, South Africa, which differs markedly from that in the developed world. In our setting, acute appendicitis is a disease that presents late and is associated with diagnostic delay and significant morbidity and even mortality.<sup>[16]</sup> We reviewed 1 000 consecutive patients with acute appendicitis treated at Edendale Hospital between 2008 and 2012. Two-thirds were male, and the median age was 19.5 years. Medical care was sought on average 4 days after the onset of symptoms. Twenty-three per cent required temporary abdominal closure and 40% required repeat operation. The mortality rate was 2%, and just under 10% required intensive care unit (ICU) admission. There were significant complications, which included pneumonia (12.5%), wound dehiscence (7%) and renal failure (3%), and 11% required admission to the ICU. Our cohort had a perforation rate of 54%, and the high incidence of perforation often mandated formal laparotomy rather than a local incision. This is very different to the published experience with acute appendicitis from the developed world, where perforation rates are generally in the order of 20% or less and temporary abdominal closure and the need for ICU admission are almost unheard of.<sup>[17]</sup> Table 1 compares the outcomes of acute appendicitis at our institution with those in the developed world.

These poor outcomes reflect a dysfunctional system of surgical care, and it is apparent that the surgical system in the district hospitals of South Africa is deficient and has been allowed to deteriorate alarmingly. Strategies to turn this situation around are urgently required. Part of such a turnaround strategy must be the development of appropriate metrics to allow us to benchmark current performance, to develop targets, and to assess whether we ultimately reach these objectives.

### Developing quality metrics for surgical care

There is a need to develop tools to measure the quality of our surgical care system in South Africa. Maternal and child health

**Table 1. A comparison between outcomes of acute appendicitis at Edendale Hospital, South Africa, and those in the developed world**

	US Department of Defense <sup>[17]</sup>	Edendale Hospital <sup>[16]</sup>
Year	1997	2008 - 2012
Patients, <i>N</i>	4 950	1 000
Centres, <i>N</i>	197	1
Patients for each centre per year, <i>N</i>	25	250
Mortality, %	0.08	2
ICU admission, %	NA	10 (mean 5 days)
Re-operation, %	0.5	41
Temporary abdominal closure, %	NA	23

ICU = intensive care unit; NA = not applicable.

is very developed in terms of applying routinely collected statistics to assess the quality of a system. Infant mortality rates and maternal mortality rates are crude markers that reflect the overall quality of the service. Developing a marker for the efficiency of a modern surgical service remains a challenge. A number of operations and surgical conditions fit this definition. These include amputation, which generally occurs in the more elderly group and is associated with both morbidity and mortality, elective hernia repair, which is not generally associated with significant mortality, and traumatic brain injury.<sup>[18]</sup>

Acute appendicitis is a disease that may allow for the development of a qualitative measure of output of a surgical system. It is a common disease, which is completely cured by a relatively straightforward surgical intervention. Systems failure in the form of delayed diagnosis and recognition results in significant morbidity. A number of clinical outcomes in the management of acute appendicitis may be useful as markers of quality of care. These potential metrics include delay to definitive treatment, perforation rates, laparotomy rates, re-operation rates, ICU admission rates, open abdomen rates and mortality rates. These criteria meet the listed requirements for an effective indicator of quality of care and should be routinely collected by hospital and surgical administrators.

Ongoing efforts must be directed at developing and validating quality metrics for surgical care and using them to drive a turnaround strategy for district level surgery in South Africa.

### Conclusion

The surgical capacity of district hospitals in South Africa has been allowed to deteriorate at an alarming rate, and a turnaround strategy is urgently needed. Part of this strategy must be the collection of a data set that functions as a quality metric for surgical services. This is analogous to the routine data collected to assess the quality of maternal and child health services. A number of potential pathologies and procedures meet the criteria to be considered markers of the quality of the system. Acute appendicitis in our environment is associated with prolonged delays to definitive treatment as well as significant morbidity, and is a good example of a potential quality metric. We suggest that the routine collection of basic data on acute appendicitis may well provide hospital managers with a tool to measure the output of a surgical system. These data would be relatively easy for managers to collect and collate and would expedite a repeatable and reproducible system of monitoring the effectiveness of a surgical service. Further research is needed to identify and validate a number of other potential quality markers, which include

diabetic foot sepsis, traumatic brain injury and inguinal hernia repair.

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# Applying Modern Error Theory to the Problem of Missed Injuries in Trauma

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## Abstract

**Background** Modern theory of human error has helped reduce the incidence of adverse events in commercial aviation. It remains unclear whether these lessons are applicable to adverse events in trauma surgery. Missed injuries in a large metropolitan surgical service were prospectively audited and analyzed using a modern error taxonomy to define its applicability to trauma.

**Methods** A prospective database of all patients who experienced a missed injury during a 6-month period in a busy surgical service was maintained from July 2006. A missed injury was defined as one that escaped detection from primary assessment to operative exploration. Each missed injury was recorded and categorized. The clinical significance of the error and the level of physician responsible was documented. Errors were divided into planning or execution errors, acts of omission or commission, or violations, slips, and lapses.

**Results** A total of 1,024 trauma patients were treated by the surgical services over the 6-month period from July to December 2006 in Pietermaritzburg. Thirty-four patients (2.5%) with missed injuries were identified during this period. There were 29 men and 5 women with an average age of 29 years (range: 21–67 years). In 14 patients, errors were related to inadequate clinical assessment. In 11 patients errors involved the misinterpretation of, or failure to respond to radiological imaging. There were 9 cases in which an injury was missed during surgical exploration.

Overall mortality was 27% (9 patients). In 5 cases death was directly attributable to the missed injury. The level of the physicians making the error was consultant surgeon (4 cases), resident in training (15 cases), career medical officer (2 cases), referring doctor (6 cases).

**Conclusions** Missed injuries are uncommon and are made by all grades of staff. They are associated with increased morbidity and mortality. Understanding the pattern of these errors may help develop error-reduction strategies. Current taxonomies help in understanding the error process, but efforts must be made to develop innovative mechanisms that reduce the potential for error.

## Introduction

The management of acute trauma is complex and dynamic. Missed injury has a reported incidence of 2%–14%, increases morbidity and mortality, and is usually associated with human error [1–7]. Error is the failure of a planned action to achieve the desired goal. Modern theory of human error has shown that what appears to be a random sequence of events actually follows predictable patterns [8–12]. This report attempts to classify a series of missed injuries according to a modern taxonomy of error, and to identify patterns that may facilitate the development of error-reduction strategies.

## Patients and method

The metropolitan surgical service in Pietermaritzburg is a general surgical service with a heavy trauma load. One surgeon of a full-time complement of eight is a dedicated

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trauma surgeon. The consultant surgeons are not based in the hospital and do their calls from home. The initial management of the injured patient is supervised by the resident staff, made up of a combination of surgical trainees and career medical officers. A prospective database of all patients who experienced a missed injury or a human error was maintained from July through December 2006. A missed injury was defined as an injury that escaped detection during the primary and secondary survey and initial investigation or during operative exploration. Once an error was recognized, the first author performed a root cause analysis of the events surrounding the error. This was done by reviewing the notes and by interviewing all staff involved in the patient's management. A taxonomy of error based on work by Reason and Reason and Lucas was used for the analysis and is summarized in Table 1 [8, 9, 11, 12]. Once a root cause analysis was completed, the involved clinicians were debriefed by the first author. These debriefings were informal and fairly unstructured to begin with. As understanding of the problem increased, we formalized the debriefing session, using Reason's taxonomy as a template to dissect out the error. All cases were discussed publicly at the traditional departmental morbidity and mortality meeting. Each missed injury was recorded and categorized into one of the following groups: injury not detected by appropriate clinical examination, injury missed due to the misinterpretation of radiology, and injury missed at operative exploration. We quantified the clinical significance of the error for each patient and identified the level of physician involved in each error.

## Results

A total of 1,024 patients were treated by the surgical service in Pietermaritzburg over the 6-month period July–December 2006. Thirty-four patients (2.5%) with missed injuries were identified during this period. There were 29 men and 5 women whose median age was 29 years (range: 21–67 years). Errors related to clinical assessment predominantly of blunt trauma occurred in 14 patients (Table 2). Misinterpretation of or failure to respond to radiological imaging accounted for eleven cases of which four false negative radiological reports delayed definitive therapy (Table 3). Table 4 details the nine injuries missed during surgical exploration, all of which were due to penetrating trauma.

In 9 patients documented evidence of deranged physiology was ignored. Table 5 summarizes these incidences. There were 12 errors of execution and 22 errors of planning. Fourteen mistakes were rules based and 7 were knowledge-based mistakes. There were 21 acts of omission. Sixteen protocol violations occurred and cognitive lockout was a

problem in every one. Cannulation of the wrong side of the chest was the only documented slip. In 6 patients, missed injury necessitated operative re-exploration. A missed vascular injury resulted in loss of a limb, and ureteric injury resulted in kidney loss. Overall mortality was 27% (9/34 patients), and in 5 cases death was directly attributable to the missed injury. The level of the physician making the error was as follows: consultant surgeon (4), resident in training (15), career medical officer (2), referring doctor (6).

## Discussion

The reported incidence of missed injury ranges from 2% to 14%, and our incidence of 2.5% is in keeping with this [1–7]. Understanding of human error has developed in organizations such as the aviation industry [8–12]. There has been much interest in applying these principles to the analysis of error in healthcare [10]. Latent system errors such as inadequate staffing, long working hours, and inadequate supervision underlie the errors made by staff who deliver healthcare. These latent errors are often hidden from view yet are extremely potent causes of error. It has been shown that after-hours complex emergency surgery is a risk factor for retained swabs [13]. Although this study focuses on active errors, in a situation of limited health care resources latent error is also a potent source of error.

### Taxonomy of error

A medical error is the failure of a planned action to be completed as intended (error of execution), or the application of an inappropriate plan (error of planning) or an unintended outcome resulting from an act of omission or commission. A situation in which the error does not result in an adverse event is referred to as “a near miss” [14]. Human problem-solving capabilities rely heavily on pattern recognition. Professional training is designed to instill uniformly appropriate responses to particular clinical scenarios. Once the scenario has been identified a ready-made solution can be applied. This is a rules-based approach. The more experienced and trained an individual is, the more likely he/she is to recognize the problem correctly. If the solution is appropriate, then the outcome should be satisfactory. Slips, lapses, violations, and acts of omission or commission may, however, intervene.

If an incorrect solution is applied to a problem, the outcome will be unsatisfactory. If the clinical scenario does not match a recognizable pattern, the clinician is forced to solve the problem from first principles. This is the problem-based approach. The danger here is a natural tendency to revert to a stored and trusted solution even if it is inappropriate. This is a particular problem with junior staff,



**Table 1** Definitions

Term	Definition/explanation	
Latent failures	Poor management at levels remote from the area of operations	Inadequate staffing, poor resources, lack of supervision
Active failures	Failures committed by those in direct contact with the patient	Omitting to perform a rectal exam; not requesting a CT
Cognitive lockout	The tendency to suppress contradictory evidence once a path of action has been decided upon	Discharging a patient who is hypotensive following a stab wound
Slips	Observable stupid actions due to loss of attention	Cannulating the wrong chest cavity
Lapses	Failures of memory	Forgetting to examine the diaphragm at laparotomy
Acts of omission	Failing to perform a known needed step	Not ordering a CT scan of the abdomen following a MVA
Acts of commission	Performing an unnecessary procedure	Doing an angiogram in the setting of active haemorrhage in a patient with a penetrating neck wound
Violations	Deviation from safe operating practice Application of the an inappropriate path of action	Not intubating a patient with a GCS < 9
Mistake rule-based mistake	Choosing the incorrect plan for a well-rehearsed clinical scenario	Sending an unstable patient for an investigation
Knowledge-based mistake	Novel situation outside the stored problem solving routines	This is influenced by seniority. For junior doctors a traumatic diaphragmatic hernia may be out with their level of clinical experience
Errors of execution	The appropriate path of action does not lead to the desired outcome	False negative radiology report

MVA motor vehicle accident; CT computed tomography; GCS glasgow coma scale

although senior staff may also fall prey to this tendency. However, slips, lapses, or violations may combine with cognitive lockout to produce an inappropriate plan from a senior doctor. There are three broad areas in the patient care process where errors occurred: during clinical assessment, during radiological assessment, or during operative exploration.

#### *Errors made during clinical assessment*

Inadequate physical examination and the failure to respond to warning signs of deterioration may result in a missed injury. The failure to check a pulse in a fractured limb, or to perform a rectal examination in a patient with a wound in the perineum are errors of omission. Failing to react to or appreciate the significance of derangements in physiology may delay detection of injuries and definitive therapy (Table 5). Tachycardia, hypotension, and increased respiratory rate are nonspecific predictors of organ failure. In our series they were poorly recorded and, even when recorded, were not acted upon [15–18].

#### *Radiological error*

Misinterpretation of radiology is the second broad error type. We found two variations of this error; namely the failure to act on clear radiological evidence of pathology

and the false negative radiology report. The first group represents errors of planning and the latter errors of execution. The presence of free abdominal fluid on computed tomography (CT) scan without evidence of solid visceral injury implies a mesenteric tear or a hollow visceral perforation and mandates laparotomy [19]. These two cases must be regarded as protocol violations and acts of omission. Radiological assessment of thoraco-abdominal trauma is a highly error-prone area [15, 20]. Hemothorax and pneumothorax are common occurrences, whereas diaphragmatic herniation is not. The inexperienced doctor encounters a relatively infrequent pathology and attempts to solve the problem from first principles. Cognitive lockout makes it more attractive to choose a common pathology and follow that algorithm. False negative radiology allows a third party to introduce error. This results in an error of execution on the part of the trauma surgeon. The trauma surgeon needs to interpret radiology reports in the light of clinical findings and to remain vigilant when the clinical situation and the radiological findings disagree.

#### *Operative error*

Except for one case, all the operative errors in this series were errors of execution. The correct plan had been chosen, but the outcome was unsatisfactory because a step in the process was omitted. Examples of omitted steps include

**Table 2** Assessment failure

Structure/injury	No	Mechanism	Delay (hours)	Outcome	Doctor grade	What went wrong	Error type	Error cause
Liver laceration	1	MVA	48	Uneventful	Resident	Did not get CT	RBM	Violation Omission
Brachial artery	1	MVA	24	Delayed repair	Resident	Did not examine	RBM	Violation Omission
Rectal injury	1	Stab	48	Death	Referring doctor	Did not perform rectal examination	RBM	Violation Omission
Transdiaphragmatic hollow visceral injury Gallbladder (1) Stomach (2)	3	Stab	48	Delayed	laparotomy	Consultant (1) Resident (2)		Misled by minimal signs
RBM		Cognitive lock out		Omission				
Injury to colon with retroperitoneal leakage	3	GSW (2) Stab (1)	72	Delayed	laparotomy	Referring doctor	Did not	respond to the patient's failure to improve
KBM		Omission						
Splenic rupture	2	Kick (1)	72	Died; sepsis	Medical officer	Delayed recognition of deteriorating vital signs	RBM	Violation Omission Cognitive lock out
		MVA (1)	24	Delayed	splenectomy	Medical officer	No CT	
Cardiac injury	1	Stab	12	Survived	AE doctor	Delayed recognition of deteriorating vital signs	RBM	Cognitive lock out Omission
Intraperitoneal bladder	1	Fell from height	144	Death	Resident	Delayed review of the films	RBM	Violation Omission
Mesenteric tear with ischaemic small bowel	1	MVA	36	Survived	Resident	Did not get CT	RBM	Violation Omission

GSW gunshot wound; *RBM* rules based mistake; *KBM* knowledge based mistake

failure to inspect the hemidiaphragm and failure to mobilize and explore retroperitoneal structures in the path of the missile that caused the injury. These structures have been particularly associated with missed injury in the reported literature [21–23]. Omitting these steps is a violation. Latent errors at play here include level of experience of the trainee dealing with the injury. Mobilizing retroperitoneal structures may require skills that a trainee may not readily possess. The failure to open the chest when no obvious source of haemorrhage could be found in the abdomen is a planning problem probably caused by cognitive lockout [15, 24, 25].

### Practical implications

Error in trauma is a problem, and all categories of staff may make an error in the care of the trauma patient. Traditionally errors have been dealt with by the so-called blame-and-train approach. This is based on the morbidity and mortality meeting and is a retrospective tool. If it is done honestly and constructively, then important and instructive

information can be conveyed; however, once such knowledge is imparted, it does not become institutionalized but tends to remain with the individual. Thus there is no guarantee that the next generation of house staff or trainees will not have to relearn the lesson.

We cannot change the human condition, but we can change the system in which human beings work and this is referred to as human factors engineering. The idea is to design a system in which recognized error patterns are prevented from occurring. There are several mechanical approaches to this, such as physical lockout techniques, defense in depth strategy, mandatory early-warning systems, and enforced clinical pathways or algorithms. Addressing the psychological factors behind error is more difficult and requires innovative approaches to change the organizational culture in which error flourishes.

### Mechanical error-reduction strategies

Wrong site surgery, one type of error of which we have an example, can be reduced by implementing a check system

**Table 3** Errors involving radiology

Structure/injury	Mechanism	No	Finding	Outcome	Doctor grade	Type of error	Cause of error
<i>Inappropriate response to radiology</i>							
Intraperitoneal bladder injury Violation	MVA	1	Free fluid on CT with no liver or spleen injury	Died from MODS	Consultant	Rule-based mistake Planning	Cognitive lockout
Perforation of gallbladder Violation	Stab	1	Free fluid on CT	Recovered	Consultant	Rule-based mistake Planning	Cognitive lockout
Stomach perforation	Kick	1	Atypical free air on chest radiograph	Died	Consultant	Rule based mistake Planning	Cognitive lockout
Diaphragmatic hernia	Stab	4	Air fluid level in left chest on chest radiograph	Cannulation of herniated stomach (2) Delayed repair and prolonged ICU (2)	Referring medical officer	Knowledge- based mistake Planning	Cognitive lockout
<i>False negative radiology</i>							
Acute disruption of right hemidiaphragm	MVA	2	Normal CT	Delayed repair and prolonged ICU death	Resident in radiology	Execution	Lapse
Traumatic false aneurysm of the left subclavian artery	Stab	1	CT angiogram normal	Delayed repair Death from sepsis	Resident in radiology	Execution	Lapse
Disrupted duodenum	MVA	1	CT reported as normal	Death from sepsis	Resident in radiology	Execution	Lapse

*MODS* multiple organ dysfunction syndrome; *ICU* intensive care unit

and by marking the site of surgery in advance. Use of such devices would create a lockout system whereby the surgeon would be prevented from proceeding by attending staff. Establishing strict protocols that emphasize the importance of aggressive imaging for blunt trauma is another potential solution. Increased imaging will inevitably produce an increased number of false positive and false negative results. The three false negatives in our series effectively derailed appropriate plans and caused significant delay. A defense in depth strategy may be helpful in this situation. Reviewing emergency radiology and emergency cases at a daily morning meeting is an example of a defense in depth system, which may help detect false negative radiology reports. A system for electronic transfer of x-ray images from poorly staffed peripheral hospitals to consultant radiologists for after-hours reporting is another example of a defense in depth system. This may have allowed for the diaphragmatic hernia to be recognized prior to cannulation. However, the problem of junior staff in unsupervised settings represents latent error, and unless this situation is addressed, then improvement is unlikely. An early-warning scoring system may be of use in this setting. The principle behind early-warning systems is that a documented derangement must trigger a response. This

can be converted to a mechanical lockout system. For example, the nursing staff would not allow a patient with deranged physiology to be discharged from the hospital.

Acts of omission are much more common than acts of commission. Most often, this represents protocol violation. In trauma, the failure to adequately investigate blunt trauma is a violation. In our setting with an increasing volume of blunt trauma, resource restraints, and a history of using clinical assessment successfully to manage penetrating trauma, there is a temptation to rely on clinical assessment [26]. Managing patients by protocol has disadvantages, but it may help reduce errors of omission in the assessment stage. If the default decision is to obtain a CT scan on all patients who have experienced high-velocity blunt torso trauma then the onus is on the managing surgeon to justify diversion from protocol in the management of such a patient.

Operative errors are associated with significant mortality and morbidity. A defence in depth strategy would ensure that senior consultant staff are present at all major trauma cases. In-house consultant staff is a well-established concept in level-one trauma centers in North America. Such a system is expensive and may be difficult to implement in a relatively resource-poor environment.

**Table 4** Operative error

Missed injury	Injury mechanism	No	Outcome	Doctor grade	What went wrong	Type of error	Cause of error
Diaphragm	Stab (1) GSW (1)	2	ICU	Resident	Did not examine diaphragm	Execution Violation Omission	Lapse
Mesenteric border of the splenic flexure	Stab	1	Death	Resident	Did not manually compress bowel	Execution Violation Omission	Lapse
Right ventricle	Stab	1	Survived	Consultant	Opened wrong body cavity	Planning	Slip Lapse Cognitive lockout
Intra-abdominal esophagus	GSW	1	ICU	Medical officer	Did not follow path of bullet	Execution Violation Omission	Lapse
Proximal vascular injury	Broken bottle	1	Ischemic hand	Consultant	Unknown	Execution	Slip Lapse Cognitive lockout
Ureter	GSW	1	Nephrectomy	Resident	Did not explore lateral haematoma	Execution Violation Omission	Lapse Cognitive lockout
Contralateral hole in trachea	Stab	2	Neck re-exploration	Resident	Did not explore opposite side of trachea	Execution Violation Omission	Lapse Cognitive lockout

GSW gunshot wound

**Table 5** Ignored derangements in physiological parameters

Site/injury	Mechanism	Hypotension (n = 2)	Tachycardia (n = 9)	Respiratory distress (n = 4)	Acidosis (n = 2)	Delay to definitive treatment (hours)	Outcome
Gallbladder	Stab	No	Yes	Yes	NA	12	Survived
Gallbladder	Stab	No	Yes	NA	NA	48	Survived
Stomach	Stab	No	Yes	NA	NA	24	Survived
Stomach	Stab	No	Yes	NA	NA	12	Survived
Splenic rupture	Kick	Yes	Yes	NA	Yes	48	Died
Injury to colon with retroperitoneal leakage	GSW	No	Yes	Yes	NA	48	Survived
Injury to colon with retroperitoneal leakage	GSW	No	Yes	Yes	NA	72	Survived
Injury to colon with retroperitoneal leakage	Stab	No	Yes	Yes	NA	48	Survived
Cardiac injury	Stab	Yes	Yes	NA	Yes	12	Survived

### Psychological error-reduction strategies

Addressing mental processes, such as distraction, preoccupation, and forgetfulness, which often accompany error, is difficult. Correction would involve teaching techniques that make trauma staff “error wise” [27]. Reason has proposed a “three-bucket” model to help individuals recognize the degree of potential for error in each situation. The buckets represent (1) the current state of the individual health care worker, (2) the context of the task, and (3) the inherent error potential of the task. The number of “bad things” in each bucket should alert one to the potential for error. For example, a number of negatives would accrue

after a surgical resident has an argument with the anesthesia resident, and is then expected to perform a laparotomy late at night on a patient with a thoracoabdominal gunshot wound, clearly a highly error-prone scenario.

Helping to understand cognitive lockout may facilitate development of an open mindset, allowing the health care professional to continuously recycle information and seeking out potential and actual errors. Perhaps the realization that mistakes and errors are ever-present is the most important defense against them. Trainees must be made to feel that asking for help is not a sign of weakness or defeat. The old line “Don’t hesitate to cope” has no place in

modern trauma care. Error flourishes where there is lack of transparency. Developing a culture of error detection in an organization requires openness and a move away from blame allocation. This is difficult, as the natural legalistic process that accompanies error is often directed at individuals rather than at the organizational system as a whole.

## Conclusions

Although not common, missed injuries confer considerable morbidity and mortality, and no grade of staff is immune. Modern error theory provides us with a working framework to classify and analyze errors. The decision-making process in trauma care is complex and requires integration of diverse pieces of evidence, including history, examination, imaging data, and physiological parameters. It is a subjective process that is influenced by experience and training. However, it is not unique; decision making in commercial aviation is certainly just as complex. The widespread application of error theory and human systems engineering in commercial aviation has allowed an excellent safety record. In trauma, the challenge is to use improved understanding of the mechanisms of errors to design systems that reduce the potential for error.

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## Summary

The three papers in this chapter develop a systematic way of thinking about quality improvement in rural trauma care.

*Publication 1: Developing a comprehensive structure to facilitate quality improvement programmes in health care systems. (SAMJ)*

The first paper in the thesis provides a generic overview of strategic planning or decision-making tools and a description of a generic health care system model and potential quality indicators. It then goes on to develop an integrated grid structure, which can be used to contextualise research projects and quality improvement programmes within both the strategic-planning process and a generic health care systems model.

*Publication 2: A concept paper: using the outcomes of common surgical conditions as quality metrics to benchmark district surgical services in South Africa as part of a systemic quality improvement programme*

The second paper is a discussion paper which suggests a way forward in terms of assessing the quality of the system. It describes a system of data capture for outcomes measurement as part of the audit cycle. It is placed in the 'Analysis/Outcomes' part of the grid structure and has been situated within this grid in the introduction and in the results section.

*Publication 3: Applying modern error theory to the problem of missed injuries in trauma.*

The third paper introduces modern error theory as a tool to help with quality improvement strategies and uses the taxonomy of error to analyse missed injuries in 34 patients over a 6-month period. This sets the scene for further work using error taxonomies to both assess quality of care and to develop a number of quality improvement initiatives. It also identifies a number of generic error-reduction strategies, which the authors attempt to implement in subsequent publications. These include error awareness training, defense in-depth strategies and the use of formalised tick boxes and the development of a culture of transparency and error reporting.

Collectively these three papers provide us with tools to analyse the current quality of rural trauma care in Sisonke District. How these concepts can be applied to the quantified burden of trauma is the focus of Chapter Three.

## Chapter Three: Situational Analysis

### Overview

Chapter Three assesses the burden of disease in Sisonke District, the resources available to deal with this burden, the quality of the process of care, and the outcomes of care. As such it corresponds to the analysis phase of a strategic-planning process and looks at all components of the health system. It uses a number of tools such as error theory and quality markers to facilitate this.

In order to assess how well trauma patients are cared for in Sisonke District and Edendale Hospital, a number of audits were undertaken as part of a situational analysis. These projects assessed the inputs of the system by auditing the capability of the rural hospitals in Sisonke to deal with trauma and by assessing the burden of trauma that these institutions are required to manage.

The quality of the process of care was assessed by reviewing the quality of documentation of Traumatic Brain Injury (TBI) patients in Sisonke District and Edendale Hospital, the quality of the observations received by trauma patients at the tertiary hospital in Pietermaritzburg, and the quality of the observations on patients admitted to the acute surgical ward in Edendale Hospital.

The quality of the outcome of care was assessed by an audit of the spectrum of burns at Edendale Hospital from the years 2006 to 2008 and by an audit of the quality of trauma referrals from the rural hospitals of Sisonke to Edendale Hospital. Modern error theory was used to dissect out these errors.

# Assessing the gap between the acute trauma workload and the capacity of a single rural health district in South Africa. What are the implications for systems planning?

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## Abstract

**Introduction** This study focuses on a single rural health district in South Africa, and attempts to establish the burden of disease and to review the capacity of the district hospitals to deal with this load.

**Methods** Ethical approval to undertake this study was obtained from both the University of Kwa-Zulu Natal and the Department of Health. The audit was performed over a 6-month period in the four district hospitals of rural Sisonke District. There were four components to this audit.

1. Information on the hospital incidence of acute trauma in Sisonke was also sourced from the epidemiology unit of the Department of Health in Pietermaritzburg
2. Each of the district hospitals was visited and the medical manager was interviewed. The medical manager was asked to complete the World Health Organization's Tool for Situational Analysis to Assess Emergency and Essential Surgical Care. (SAT).
3. The operative registers were reviewed to determine the number of index cases for trauma. This information was used to determine the unmet need of acute trauma in the district.

4. Each hospital was classified according to the Trauma Society of South Africa (TSSA) guidelines for levels of trauma care.

**Results** The annual incidence of trauma in the Sisonke District is estimated to be 1,590 per 100,000 population. Although there appeared to be adequate infrastructure in the district hospitals, the SAT revealed significant deficits in terms of capacity of staff to adequately treat and triage acute trauma patients. There is a significant unmet need for trauma care in Sisonke. The four district hospitals can best be classified as Level IV centers of trauma care.

**Conclusion** There is a significant burden of trauma in the Sisonke District, yet the capacity to deal with this burden is inadequate. Although the physical infrastructure is adequate, the deficits relate to human resources. The strategic choices are between enhancing the district hospitals' capacity to deal with acute trauma, or deciding to bypass them completely and deliver all acute trauma patients to large regional trauma centers. If the first option is chosen, urgent intervention is required to build up the human resource capacity of district hospitals.

**Keywords** Acute trauma · District hospitals · Rural health · Global surgery · Burden of disease · Surgical capacity

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## Introduction

Over the last two decades, the importance of the role of curative surgical services in sub-Saharan Africa has been better appreciated [1]. However, there is a dearth of credible and reliable data on the burden of surgical disease and the capacity to deal with this burden. Trauma is a surgical disease with an estimated high incidence in sub-Saharan



Africa [1, 2]. Little is known about the burden of injury in rural South Africa, and there is also a paucity of information about the capacity of the health system in rural South Africa to deal with this burden. This study focuses on a single health district, namely the Sisonke District in south-western Kwa-Zulu Natal, and has several linked objectives. It attempts to establish the burden of injury in the Sisonke District, to quantify the surgical capacity of the district hospitals in the area to deal with this burden and to establish the unmet burden of trauma and injury in the Sisonke Health District, and to classify the four district hospitals in the Sisonke District according to published guidelines for the assessment of trauma centers in South Africa.

Quantifying the gap between the capacity of a health system and the burden of disease it is expected to manage requires appropriate metrics [3]. The World Health Organization has developed a Tool for Situational Analysis to Assess Emergency and Essential Surgical Care (SAT) [4]. This tool analyses structure, and to a lesser extent process of care, and is a six page tick box type questionnaire that captures information about the physical resources, the human resources available to treat surgical conditions, and the type of surgical procedures offered at the institution. Questions that relate to structural issues have a high reliability. However, questions related to process are less reliable, and the quality of a process is difficult to measure [3, 4].

The Trauma Society of South Africa (TSSA) has published guidelines to classify hospitals according to the level of trauma care they can deliver [5]. District hospitals and local health care clinics would generally be classified as level III centers. According to the guidelines, the level III trauma center must provide assessment, resuscitation, basic emergency operations, stabilization, and transfer of acute trauma patients. They must have prompt availability of general surgeons or general practitioners with surgical expertise, and must plan the care of injured patients. This requires appropriate transfer systems and standardized management guidelines. Level IV trauma facilities provide basic trauma life support before patients are transferred to definitive care.

## Setting

The Sisonke District is a rural area in south-western Kwa-Zulu Natal Province and has a population of 450,000–500,000 people. Edendale Hospital is a regional hospital in the city of Pietermaritzburg and is the referral hospital for the four district hospitals in the Sisonke Health District. Each district hospital is visited once a month by a surgical specialist from Edendale Hospital.

## Aims and objectives

This study had four objectives:

- To quantify the burden of trauma in Sisonke by ascertaining the volume of disease and quantifying the severity of the disease.
- To quantify the capacity of the district hospitals in Sisonke to deal with this burden.
- To quantify the unmet need using data from the operative registers of the district hospitals and comparing the incidence of index procedures for trauma against the predicted need for these procedures.
- To classify the four district hospitals in Sisonke according to the published guidelines for the classification of trauma centers.

## Methodology

### Burden of disease

The burden of trauma in the Sisonke District was established by sourcing hospital trauma data from the epidemiology unit of the Department of Health in Pietermaritzburg. Based on the reported hospital incidence and the reported population density, incidence of injury and admission as well as mortality per 100,000 of the population were derived. The severity of the trauma presenting to the district hospitals was estimated by reviewing the standard Emergency Rescue Services classification of patients presenting to the district hospitals, and by determining the number of patients requiring admission and the number requiring transfer to a higher center of care.

- Green Code patients were injured but able to walk.
- Yellow Code patients were injured and required either a stretcher or wheel chair, but had normal physiology.
- Red Code referred to any patient who was transported in a stretcher with one or more documented deranged physiological markers.
- Blue codes referred to patients who died prior to arrival at the hospital.

### Surgical capacity

Each of the district hospitals was visited and the medical manager was interviewed. The medical manager was asked to complete the World Health Organization's SAT to provide an overview of the capacity of each hospital to deal with its burden of trauma. Capacity was classified as infrastructure and human-resource-related capacity. The SAT lists equipment needed for acute care and provides three possible

answers: not available, sometimes available and always available. Similarly, it asks if certain procedures are done at an institution and it offers a yes/no choice. If the answer is negative, the SAT asks if patients are referred for the procedure, and then asks the reason why the particular procedure is not performed. There are three possible reasons: lack of skills, lack of drugs, lack of equipment.

#### Estimating the unmet need

The investigators reviewed the operative registers for the 6-month period of January 2012–June 2012 to document what trauma-related surgery was being performed at each district hospital. Two index cases were used, namely orthopedic reduction and laparotomy. We used published estimates of the need for orthopedic reduction and laparotomy as a basis to establish the unmet need for these procedures. Otieno et al. [1, 6] have suggested that at least half of all patients admitted as a result of blunt trauma need some form of fracture reduction. A survey of households in rural Pakistan estimated the incidence of the annual need for laparotomy to be to be 1,364/100,000 of the population [13]. The researchers derived this figure by interviewing the matriarch of each household about cases of illness that would potentially require surgical intervention, and about mortality from a wider range of surgical emergencies.

The estimated incidence rates were 1,531/100,000 persons per year for injuries; and 1,364/100,000 for acute abdomen. The overall rate for minor and major surgical procedures was 411/100,000 persons per year, and appeared to be low and the mortality rates were correspondingly high: 55/100,000 persons per year for injuries and for acute abdomen [7]. Data from Malawi has reported a rate of 4,062 laparotomies performed in total for a population size of 11 million, giving a rate of 36/100,000 population per year for the entire country [1].

#### Classifying the hospitals

The published trauma center guidelines were used to classify the four district hospitals in Sisonke according to the level of care they are able to provide [5]. Data was extracted from the SAT forms to complete the published guidelines.

## Results

#### Burden of disease

During the 6-month period under review, a total of 3,673 trauma patients were seen at the four district hospitals in the Sisonke District. These comprised 1,008 Road Traffic Collision (RTC) victims, 929 non-intentional blunt

injuries, 943 blunt assault victims, 784 stab victims and nine Gunshot (GSW) victims. This gives a ratio of 1,937:1,736 (1:1) of non-intentional to intentional injury. The ratio of blunt to penetrating trauma is 1,872:793 (2:1). The national census indicates that the total population of the Sisonke District is 461,419. Using this denominator, the annual incidence of trauma in the Sisonke District is  $7,346/461,419 = 0.0159$  or 1,590 per 100,000 population.

#### Severity of disease

There were 29 Blue codes and 17 inpatient deaths recorded. This gives a mortality rate of 1 %. A total of 48 (1 %) red code patients were received and a total of 111 (3 %) patients required transfer up to a higher level of care. All the red code patients were transferred to a regional center after stabilization. A total of 680 (19 %) trauma patients were admitted.

#### Surgical capacity

Situational analysis forms were completed by all four hospitals in the district.

#### • Infrastructure

All four of the hospitals that were audited reported that the appropriate emergency equipment were available for all patients all of the time, and each hospital had two functioning operating rooms.

#### • Human resources

Table 1 lists the staff available to perform anesthesia and general surgery. There were no specialists available in any of the institutions. In terms of general doctors who

**Table 1** Situational analysis data per hospital

	CTK	EG Usher	Rietvlei	SAH
Number of operating rooms	2	2	2	2
Distance to referral center	100–200	250	100–200	80–100
Surgeon	–	–	–	–
Anaesthetist	–	–	–	–
Obstetrician	–	–	–	–
General doctors who perform surgery	1	4	4	5
General doctors who administer anaesthesia	–	4	6	6
ATLS	–	2	–	–
ACLS	–	2	1	–
Diploma in Anesthetics	–	1	–	–

CTK Christ the King Hospital, EG Usher Memorial Hospital, Rietvlei Hospital; SAH Saint Apollinaris Hospital; ATLS Advanced Trauma Life Support course; ACLS Advanced Cardiac Life Support course

were comfortable with either general surgical procedures or general anesthetics, the picture was heterogeneous. A single hospital had one staff member capable of performing surgery and no staff comfortable with the administration of a general anesthetic. The number of staff who had completed one of two acute care courses is summarized in the table and was low. Only a single doctor had completed a Diploma in Anesthetics from the College of Medicine of South Africa. No doctors had completed a Diploma in Surgery or a Diploma in Emergency Care.

#### The unmet need

During the 6-month period, 58 orthopedic reductions and 11 laparotomies were performed at the district hospitals in the Sisonke District. A total of 680 trauma patients were admitted, with a ratio of blunt to penetrating trauma of 2:1. Using the estimate that half of all trauma admissions need some form of fracture reduction, about 340 patients required an orthopedic reduction. Only 58 reductions were performed during this period, implying a deficit of 290 orthopedic reductions. Similarly, using the reported incidence of laparotomy from rural Pakistan of 1,364/100,000 of the population would suggest that there should be 3,419 laparotomies every 6 months in the Sisonke District. The actual number of 11 in the four district hospitals implies a considerable unmet need.

#### Classifying the hospitals

We attempted to classify each of the four district hospitals according to the described levels of care. Table 2

summarizes this by listing the procedures that must be available according to level of care and levels of care with data from the completed SAT forms for each of the four institutions.

#### Discussion

This study has confirmed the findings of several other studies of injury patterns in South Africa. The ratio of intentional to non-intentional trauma is one is to one, and an exceedingly high level of interpersonal violence blights rural South Africa [2]. This phenomenon seems to be stubbornly resistant to injury prevention programs and crime enforcement, and remains a cause for concern. However, the low rate of GSWs reported from Sisonke suggests that gun control policies are reducing the availability of these weapons and is cause for cautious optimism. Trauma patterns in South Africa are changing and the emerging new aspect of the epidemic is that of road traffic related injury. Rapid urbanization and the increasing numbers of vehicles on the roads contribute to major burden of disease and RTCs are associated with significant morbidity, mortality and cost [8, 9].

The accuracy of epidemiological data in South Africa and the developing world in general remains of concern. The information obtained from this 6-month review of hospital-reported figures suggests an incidence of 1,590 per 100,000. This is almost double the estimated incidence from a recent report that was based on a province-wide survey of 2 months extrapolated to a year, which suggested

**Table 2** The TSSA guidelines for the classification of trauma centers as they pertain to the district Hospitals of Imabli

Level III and Level IV	Level III	Level IV	CTK	EG Usher	Rietvlei	SAH	Tayler Bequest
On call and available within 20 min							
General surgery	D	D	No	No	No	No	No
Anaesthesiology	D	D	No	No	No	No	No
On call and available within 60 min			General doctor available	General doctor available	General doctor available	General doctor available	General doctor available
Anaesthesiology	E	E	–	–	–	–	–
General surgery	E	E	–	–	–	–	–
Emergency medicine	E	E					
Resuscitation	E	E	Y	Y	Y	Y	Y
Surgical airway	E	E	N	N	N	N	N
Intercostal chest drain	E	E	Y	Y	Y	Y	Y
Acute burn management	E	E	Y	Y	Y	Y	Y
Closed reduction	E	E	Y	Y	Y	Y	Y
Open treatment	D	D	N	N	N	N	N
Joint dislocation	E	E	Y	Y	Y	Y	Y

*E* essential, *D* desirable

a figure of 840 per 100,000 [2]. Nordberg estimated the incidence in Kenya to be 3,000/100,000, Kobusingye in Uganda estimated it to be 1,690/100,000 and Ahmed in Pakistan estimated it to be 1,531/100,000 [7, 10, 11]. It has been shown repeatedly in research from South Africa that hospital-based mortality data does not capture the actual mortality rate, as many corpses are taken directly to the state mortuary. This results in a significant under-reporting of trauma-related mortality rates [12, 13]. The rate of 1 % reported in this audit is almost certainly a case of gross under-reporting. The development of an appropriate trauma registry and injury surveillance program is urgently needed, and this registry must incorporate forensic data if it hopes to provide meaningful information [13, 14].

We have identified an unmet need for laparotomy in Sisonke District. This is not unusual in Africa, and data from Malawi has reported a rate of 4,062 laparotomies performed in total for a population size of 11 million, giving a rate of 36/100,000 population per year for the entire country [1, 7]. We have previously documented that there is a very low rate of appendectomy in the rural hospitals of Sisonke District. Almost all patients requiring a laparotomy will be referred through to the regional hospital [14, 15]. This means that the procedures are being performed, but not at the district hospitals to which they initially present. However, we have shown in other studies that there is a high rate error of assessment associated with trauma care and that there is a significant degree of diagnostic delay in recognizing the need for surgical exploration in patients with acute appendicitis [14–16]. This suggests that the system is not functioning optimally and that district hospitals are not achieving their objectives, which should be resuscitation, assessment and appropriate referral of patients with acute abdominal pathology. [17, 18] The low rate of fracture fixation is perhaps a better proxy marker for the state of rural trauma care in South Africa, as simple closed reductions should be performed in district hospitals. Some of these reductions may have taken place in sites other than the operating room and our figure may under-estimate the actual rate of fracture reduction.

This situational analysis data demonstrates that the district hospitals in the Sisonke District are relatively well equipped in terms of infrastructure and equipment. Almost all the equipment listed as necessary for resuscitation was available all the time for all the patients. The human resource component, however, is deficient. This is both in terms of number of staff available and in the level of training the staff have undergone. The two standard courses for emergency care competency are the Advanced Trauma Life Support (ATLS) and Advanced Cardiac Life Support (ACLS) courses. In none of the hospitals have all the staff completed all of these courses, and in certain hospitals none of the staff have completed any of these courses.

Although the hospitals had medical staff available for emergencies, there was minimal capacity for task differentiation. The Diploma in Anesthetics is a pragmatic and useful qualification, which ensures that a non-specialist anesthetist is competent to administer a general anesthetic. At time of the survey, there was only a single doctor in one of the hospitals who had completed this qualification.

The deficits identified in this audit are not deficits in physical infrastructure, but rather inadequate human resources. The Bellagio Essential Surgery Group published recommendations for increasing access to surgical care in sub-Saharan Africa [19]. They recommended that services be strengthened at the district hospital level. The WHO in the text “Surgical Care at the District Hospital” states that basic abdominal surgery should be undertaken at district hospitals [17, 18, 20]. There is a gap between what the WHO text describes and what is actually delivered in rural district hospitals in the Sisonke District, and there have been similar findings in other rural health districts in South Africa [17, 18]. To close this gap requires a major investment in educational programs, as well as a change in focus. Any educational course needs to develop surgical and anesthetic capacity amongst rural staff. The role of the diploma in surgery needs further definition, as this should directly train a cohort of generalists in basic emergency surgery. It must include a major component dealing with obstetrical surgery. The Diploma in Anesthetics needs to be propagated to teach the appropriate skills needed [17, 18]. The Department of Health has run a surgical outreach program for over a decade and although this has managed to deliver specialist care to rural hospitals, it has been less successful at developing surgical capacity in the rural hospitals [17, 18].

There is interest in developing a trauma systems approach to acute trauma care in South Africa [5, 21]. There is evidence to show that patients taken directly to a level I center have a better outcome than those taken to non-trauma centers initially [21]. The transfer of red-code patients to district hospitals with limited surgical capacity is problematic. The four hospitals reviewed collectively have limited capacity to deal with critically injured trauma patients and all the red code patients ultimately required transfer to a regional center. We have shown that there is a high rate of error associated with the assessment and transfer of trauma patients from rural hospitals to regional centers [16].

The solution to this problem needs to be innovative. It is unlikely that a blanket, one size fits all, solution is feasible. There appear to be two distinct strategic options. Option one is to decide that district hospitals have a minimal role to play in acute surgical care, and rather increase the capacity of regional centers until they are capable of dealing with huge volumes of trauma patients. In such a

system, injured patients would bypass district hospitals and be taken directly to a regional center. This would require the development of new regional trauma centers and the strengthening of current ones. The other option is to strengthen care at the district centers. However, it may be that strategic planners need to select a number of pilot district hospitals where conditions are suitable for such a development. It is unlikely that all district hospitals would be willing or capable of taking part in such a program.

## Conclusion

There is a significant burden of trauma in the Sisonke District. The capacity to deal with this burden of disease is inadequate. Whilst the physical infrastructure is adequate, the deficits involving the human resources to deal with and manage acute trauma are significant. It would appear that this situation is not just confined to Sisonke, but applies to many rural health districts in South Africa, and this must be regarded as a major public health problem. We need to adopt a structured coordinated public health approach to develop innovative locally appropriate interventions to help reduce the impact of this epidemic. The strategic choices are between enhancing the district hospitals capacity to deal with acute trauma patients, or deciding to bypass them completely and deliver all acute trauma patients to large regional trauma centers. If the first option is chosen, urgent intervention is required to build up the human resource capacity of district hospitals by training healthcare personnel in safe surgery and anesthesia.

**Conflict of interest** None.

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# An audit of the quality of care of traumatic brain injury at a busy regional hospital in South Africa

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## Summary

Access to care by a dedicated neurosurgical unit is limited in the developing world, and the vast majority of patients who sustain a head injury are managed by general surgeons. Prevention of secondary brain injury is paramount. While the principles of management are relatively straightforward, delivering this care may be difficult. This audit looks at the spectrum of head injuries presenting to a busy regional hospital and attempts to measure the quality of care offered to these patients.

*Patients and methods.* The audit includes three separate sections. The first is a prospective audit of all patients with a traumatic brain injury presenting to the Accident and Emergency (AE) department at Edendale Hospital, Pietermaritzburg, over a 2-month period. The next two sub-audits consist of a random review of referral letters and AE clerking notes to assess the quality of care received by these patients. A total of 25 referral letters and 28 AE inpatient notes were randomly chosen for review and compared with agreed standardised markers for quality of care.

*Results.* Over the 2 months October and November 2007, 150 patients with a head injury were seen in the AE department. Of these 117 were male. A total of 76 were discharged home after investigation with a head injury warning chart, 49 were admitted to the general wards, 11 were admitted to the surgical intensive care unit, 10 were referred to the neurosurgical centre in Durban, and 4 died in the AE department. Of the 10 who needed advanced neurosurgical care, 3 required urgent burr-holes before referral. One of these patients died. All the remaining 9 patients who were transferred to the neurosurgery unit survived. The referral letters and AE clerking notes revealed major deficits.

*Conclusion.* Traumatic brain injury is a common problem. Only a small subset of patients require specialised neurosurgical care. Although many patients with intracranial injury can tolerate the delay associated with transfer, some cases are acute and urgent intervention by non-neurosurgeons is needed. Prevention of secondary brain injury is poorly understood and not prioritised. This situation needs to be improved. The introduction of formalised standard referral and management sheets may help to improve care.

Traumatic brain injury (TBI) is a common clinical problem with significant long-term morbidity. Minimising this morbidity requires aggressive attempts to prevent secondary brain injury. The major early causes of secondary brain injury are hypoxia, hypovolaemia, hypoglycaemia and raised intracranial pressure (ICP). The first three conditions may be prevented by relatively simple clinical interventions that can be performed at almost any level of health facility. However, a subset of patients will have an acute space-occupying lesion contributing to raised ICP, which exacerbates the ischaemic insult to the brain; reducing ICP is more difficult and may require more complex interventions. These range from simply placing the patient in the reverse Trendelenburg position to facilitate venous drainage of the cranium to administering mannitol and hypertonic saline, progressive hypocapnia, pharmacological manipulation using intravenous barbiturates, and possibly neuromuscular blockade, ventricular drainage and decompressive craniectomy. These interventions can only be undertaken at advanced facilities where specialist neurosurgical and intensive care is available. Limitations on resources mean that it is unlikely that all head-injured patients will have the benefit of care in a dedicated neurosurgical unit. The vast majority will continue to be managed by non-neurosurgeons, be they referring staff,

accident and emergency staff, paramedics, trauma surgeons or intensivists. This audit attempted to quantify the volume of TBI in a busy regional hospital with geographically remote specialised neurosurgical services and to assess the quality of the care rendered at the regional hospital to patients with TBI.

## Methodology

Edendale Hospital is a large regional hospital in Pietermaritzburg and admits over 300 trauma patients a month. It is the regional referral centre for western KwaZulu-Natal and serves a population of 3 million people. Although there is a tertiary hospital in the Pietermaritzburg metropolitan complex with advanced intensive care and radiological services, the nearest neurosurgical unit is situated at Inkosi Albert Luthuli Hospital in Durban, 80 km away. We follow the guidelines from the academic Department of Neurosurgery at the University of KwaZulu-Natal for the investigation and assessment of head injuries at our centre. Fig. 1 summarises these guidelines.

A prospective audit of all patients with a head injury presenting to the AE department at Edendale over a 2-month period was undertaken. Two sub-audits were performed. These consisted of a random review of referral letters and a random review of AE clerking notes and inpatient observations to measure the quality of care received. A total of 25 referral letters and 28 AE and inpatient observations were selected for review and compared against previously agreed standards for referral and management. These standards were agreed upon by the authors and were based on the management guidelines from the University of KwaZulu-Natal's Department of Neurosurgery and published international guidelines (listed in Figs 1 and 2). Fig. 3 is a copy of the head injury warning chart given to all caregivers of patients who are discharged from our institution after a head injury.

## Results

Over the 2 months October and November 2007, 150 patients with a head injury were seen in the AE department. Of these 117 were male. A total of 76 were discharged home, 49 were admitted to the general wards, 11 were admitted to the surgical intensive care unit, 10 were referred to the tertiary neurosurgical centre 80 km away, and 4 died in the AE department. Table I summarises details on the patients who required admission. The mechanism of injury was assault (41%), motor vehicle collision (28%), fall from a height (3%), and gunshot wound to the head (3%). In the remaining 25% of cases the mechanism was unrecorded. Of the 10 patients who required transfer to a neurosurgical unit 9 were males. The average age was 27 years (range 8 - 78 years). The mechanism was assault in 8 cases and a fall in 2. The documented pathology was extradural haematoma (4 cases), subdural haematoma (3), depressed skull fracture and contusion (2), and traumatic hydrocephalus (1). Of the group requiring transfer to the neurosurgical centre only 5 presented to the AE department on the day they were injured. In the remaining 5 the delay between injury and presentation was 2 days (2 cases), 4 days (1), 12 days (1) and 14 days (1). An operation was required in 8 of the referred group. The average length of stay was 9.8 days (range 1 - 16 days). There was 1 death in the operative group. The remaining patients who underwent

operations were all subsequently discharged. The average delay in transportation of patients to the neurosurgical centre was 7 hours. In 3 of the patients with an acute extradural haematoma long delays in transfer and acute neurological deterioration necessitated emergency burr-holes being performed by the general trauma surgeons before transfer to the neurosurgical centre. One of these patients died. The patients who died in the AE department all had a GCS of 4 on presentation. Autopsy revealed diffuse axonal injury in all cases.

A random sample of 25 referral letters was selected for review. Table II summarises the referral letters. The history was recorded in all the referral letters reviewed, the GCS in 88%, a management plan in 75%, associated localising signs in 50%, and the condition of the pupils in 13%. In none of the referrals was an assessment of the integrity of the cervical spine recorded. A random sample of 28 inpatient records was also selected for review. Tables III and IV summarise the inpatient records and observations. In 57% of cases the reason for admission was not recorded, in 42% a skull radiograph was omitted despite being indicated, and in 15% a computed tomography (CT) scan was omitted despite the case meeting our criteria for this investigation. In the management plans of this group there were no recorded orders for supplemental oxygen and intravenous (IV) fluids. Clear instructions to perform neurological observations were omitted in all cases. In the observation charts of this group the GCS was recorded in 92%, the state of the pupils was recorded in 71%, pulse rate and blood pressure were documented in 70%, oxygen saturation was only recorded in 42%, and neither blood glucose readings nor core body temperature were ever recorded.

## Discussion

TBI is a major global public health problem and the World Health Organization (WHO) estimates that approximately 10 million people are affected annually.<sup>1,2</sup> This burden is spread throughout the world, but is especially acute in developing countries. WHO statistics show that Latin America and sub-Saharan Africa have a significantly higher incidence of TBI (150 - 170 per 100 000) than the global rate of 106/100 000. In the developing world there are many risk factors for TBI. Of note is that intentional trauma is more common than unintentional trauma as a cause of TBI. This is in keeping with most reported forms of trauma in South Africa.

Throughout the world, access to acute specialist neurosurgical services is limited.<sup>3-6</sup> This is especially true in our environment, and the situation is unlikely to change in the foreseeable future. The care of TBI will remain largely in the hands of generalists: referring staff, paramedical staff, AE doctors, trauma surgeons and intensive care staff. These diverse groups will interact with the patient as he or she passes along a continuum of care from initial receiving point to definitive management. It is imperative that the 'chain of care' should not be broken at any point. If the chain of care is broken, hypoxia, hypovolaemia or hypoglycaemia may develop and exacerbate the neurological damage.<sup>7,8</sup> The generalist's role is to co-ordinate this chain of care to prevent secondary brain injury while identifying patients who will benefit from advanced neurosurgical care. Once the need for specialist neurosurgical intervention has been identified, it is the responsibility of the managing generalist to ensure timely, safe and appropriate transfer to a definitive centre.

Referral of patients from peripheral hospitals to the regional centre appears to be problematic. The lack of information on key physiological parameters in the reviewed referral letters suggests that the pathology being treated is poorly understood. Poor referral and communication translates into poor management. The problem we have identified in our series is a common one throughout the literature.<sup>9-13</sup> Strategies designed to improve the level of communication generally revolve around the use of standardised referral letters and enforced protocols. These have been shown to improve the level of communication between units and hospitals and when combined with tick box style checklists act as prompts and stimuli for appropriate investigation and treatment.<sup>9-13</sup> Such a letter needs to be introduced on a region-wide basis to be effective.

More than half of the patients in our study did not require admission and were discharged to the care of their families. Provided there is no skull fracture and the patient is fully conscious with no significant loss of consciousness or amnesia, we are happy to discharge a patient into the care of accompanying and responsible family members. A document detailing signs of raised ICP and instructing the patient to return urgently if indicated is given to the accompanying family on discharge (Fig. 3). Loss of consciousness with amnesia, and signs and symptoms of raised ICP such as blurring of vision, headache, vomiting or a skull fracture, prompt admission.<sup>7,8</sup> The guidelines for CT scanning published by the academic department of neurosurgery are relatively conservative with regard to its use (Fig. 1). A GCS of 10 or lower and any depressed level of consciousness in the presence of a skull fracture or localising sign are indications for an urgent CT scan. Patients with a GCS of 11 - 14 and no localising signs or skull fractures only qualify for a CT scan during working hours. However, the international trend seems to be towards more liberal use of the CT scan.<sup>14-17</sup> The emphasis on managing patients who do not meet the criteria for emergency CT scan is admission and regular 'neurological observation'. The principle is that with adequate observation acute deterioration will be detected early and appropriate interventions instituted. However, our series highlights the concerns that physiological parameters are poorly monitored and that there is very little quality control of the neurological observations.

Inadequate observation of the head-injured patient in hospital is not unique to South Africa. In the USA it has been shown that the frequency of observations performed by the attending staff was inadequate to detect subtle and early signs of deterioration.<sup>8,14,15</sup> In the UK 'neurological observations' are generally performed by non-specialist nursing and medical staff without any neurological training. The situation is similar in our environment. Lack of basic observation as well as failure to check blood glucose and oxygen saturation levels imply that care is substandard. In a busy general ward with no dedicated neurosurgical nursing staff and without dedicated observation areas it is unlikely that we will be able to improve the quality of observation. Staff not adequately trained in neurological assessment are unlikely to detect subtle changes in the patient's condition.

One solution is to liberalise the indications for CT scanning. This has been the trend in most guidelines published in the developed world,<sup>8,14-17</sup> and there is good evidence that a negative CT scan after a head injury allows a clinician to discharge a patient safely. The international trend is towards

a much more aggressive use of CT scanning than our local guidelines. However, this approach may not be easily applicable in our setting as our radiological services are already overburdened. Liberalising the indications for CT scanning would place further demands on an already stretched system. A more practical solution may be to improve the quality of the observations being performed and to provide additional training for the staff performing these observations. Centralising all acute TBI patients into an acute high-care/observation area for at least 12 - 24 hours would be necessary to achieve this.

Of patients who require surgical admission, slightly less than 10% will require neurosurgical referral. This is consistent with most reported series. In our population patients requiring neurosurgical care seem to be a self-selected group. The fact that despite a significant delay in seeking help outcome is relatively good suggests that these pathologies are indolent and chronic rather than aggressive and acute. Considering the long delays in transfer inherent in our system, it would seem likely that many patients with a severe TBI die before reaching hospital.<sup>18</sup> Some patients with aggressive intracranial pathologies such as acute extradural haematomas do reach regional hospitals alive. These rapidly expanding lesions raise the ICP, resulting in death if intervention is delayed. Long delays in transportation between hospitals mean that patients with acute and aggressive intracranial lesions will be compromised unless temporising surgery can be performed on site. In our environment, where neurosurgical expertise is geographically remote, decompressive burr-holes performed by general surgeons as an emergency procedure are life saving.<sup>19</sup> The creation of burr-holes is a skill in which general and trauma surgeons need to be competent. Provided there are clear indications, burr-holes performed by non-neurosurgeons have been shown to be a safe and viable option. The deaths in the AE department represent unsalvageable injuries. All these patients had extremely poor coma scores on presentation and autopsy confirmed diffuse brain injury in all these patients. It is unlikely that any interventions would have been able to salvage these patients.

In our audit most of the deficits in care were acts of omission, i.e. failure to perform a necessary procedure. Although managing patients by protocol has disadvantages, it may help reduce errors of omission by forcing particular courses of action onto staff. This acts as a mechanical lock-out system. For example, failure to perform a CT scan or to obtain a skull radiograph would become a protocol violation. If a step in the protocol is omitted the onus is on the managing staff to justify deviation from protocol in the management of that patient. The successful use of protocols is widespread in the literature.<sup>20</sup> There are no national clinical guidelines in South Africa for TBI at present, although various local guidelines are in use (Fig. 1). However, our series revealed poor compliance with these. Skull radiographs were not done despite being indicated in just under half of the cases reviewed, and cervical spine assessment was not done at all. Compliance with CT scanning was much better, with only 15% of patients not being scanned when indicated. It would appear that our local guidelines are not being followed, and we need to find the reasons for such non-compliance.

To address the deficiencies highlighted by this study requires serious commitment. Generalist, trauma and neurosurgeons need to provide leadership and to be involved in ongoing outreach and education programmes at both



peripheral and regional hospitals. It is apparent that the pathophysiology of TBI is poorly understood by health care providers along the chain of care. This needs to be addressed directly. Implementation and enforcement of standardised referral letters and protocols are essential. Dedicated and appropriately staffed and equipped observation areas need to be developed in busy hospitals. TBI is a major problem, and patients deserve a better level of care than that currently being offered.

## Conclusion

TBI is a major problem in South Africa. The vast majority of these patients will never see a neurosurgeon and their care will continue to rest with generalists. Unfortunately the care of TBI appears to be deficient in many respects, and TBI is a neglected problem in our hospitals. The quality of referral is poor and communication is lacking; in hospital there are major protocol violations and omissions. Failure to institute basic clinical interventions such as blood glucose level monitoring, intravenous fluid administration and supplemental oxygen will result in secondary brain injury which serves to exacerbate the primary injury. Many of the patients who are referred through to neurosurgical units are a self-selected group who have relatively chronic and indolent pathologies. In large general hospitals remote from specialised neurosurgical services, generalist trauma surgeons will need to be able to perform burr-holes as temporising measures in a select group of patients. It is important that this skill be taught and maintained.

In view of the volume of patients sustaining TBI it is of concern that care is poor. Referral and inpatient documentation implies that the pathophysiology is poorly understood and that relatively simple clinical interventions are being omitted. In general, protocols and guidelines are not being adhered to. It is unlikely that access to advanced acute neurosurgical care will improve in the immediate future in South Africa, and it will remain the responsibility of generalists to care for these patients. Surgeons involved in acute care at all levels need to provide leadership if we hope to improve the care offered to patients with TBI. We need to develop and enforce protocols and to agitate for resources to manage these patients more appropriately.

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TABLE I. DETAILS ON THE PATIENTS WHO REQUIRED ADMISSION

	No.	Average GCS	Range
Ward	49	8	3 - 13
ICU	11	10	9 - 12
Referred to neurosurgery	10	11	9 - 13
Died in AE	4	4	<5

TABLE II. SUMMARY OF REFERRAL LETTERS (N=25)

	Documented	Not documented
GCS	22	3
Neurology	13	12
Pupils	3	22
Cervical spine assessment	-	25
Management plan	19	6

TABLE III. SUMMARY OF AE ADMISSION NOTES (N=28)

	Performed as indicated	Not performed despite being indicated
CT scan	24	4
Skull X-ray	16	12
Reason for admission	12	16
Instructions to perform neurological observations	-	28
Need for IV line	-	28
Need for oxygen	-	28

TABLE IV. SUMMARY OF RECORDED OBSERVATIONS (N=28)

	Recorded	Not recorded
Glucose	-	28
Oxygen saturation	12	16
Core body temperature	-	28
Pulse rate	20	8
Blood pressure	20	8
GCS	26	2
Pupils	20	8

**Indications for urgent CT scan**

All with GCS 5 - 10

GCS 11 - 14 with

- Skull fracture
- Focal neurological signs

All with fixed dilated pupils

Any deterioration in level of consciousness

**CT scan during working hours**

GCS 11 - 14 for 48 hours

GCS 15 with a focal sign

GCS 15 with stab wound to head or deeply in-driven bone fragment

**Indications for a skull X-ray**

Loss of consciousness

Neurological symptoms

CSF from nose or ear

Suspected penetrating injury

Scalp bruising

Difficulty in assessing patient

No need for skull X-ray if CT scan indicated

**Indications for admission**

Loss of consciousness >5 minutes

Skull fracture

Neurological symptoms or signs

Difficulty in assessing

Other medical conditions

All patients with a GCS of <9 must be intubated

Oxygen 40% via facemask or endotracheal tube if intubated

Elevated head of bed

Functional intravenous line

Glucose-containing fluid

Four-hourly glucose level assessment

Hourly BP, pulse, respiratory rate

Hourly GCS

Hourly record of state of pupils

Hourly neurological examination

**Fig. 2. Minimum expected level of care for a patient with TBI at Edendale Hospital.**

**Fig. 1. Head injury management criteria, University of KwaZulu-Natal.**

Head Injury

Date

\_\_\_\_\_ has had a head injury and is being discharged well from this hospital.

The following information is for the guidance of family and friends. Should any of the following occur please bring him back to hospital immediately:

- Increasing severe headache
- Persistent vomiting
- Confusion or abnormal behaviour
- Unconsciousness or difficulty in 'waking up'
- Convulsions (fits)

**Fig. 3. Edendale Hospital head injury warning chart (English version only).**

# Variations in levels of care within a hospital provided to acute trauma patients

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## Summary

**Introduction.** Caring for trauma patients is a dynamic process, and it is often necessary to move the trauma patient around the hospital to different locations. This study attempted to document the quality of observations performed on acute trauma patients as they moved through the hospital during the first 24 hours of care.

**Methodology.** This study was a student elective and was undertaken at Grey's Hospital, Pietermaritzburg. A third-year medical student was assigned to follow acute trauma patients throughout the hospital during the first 24 hours after admission. This single independent observer recorded the frequency with which vital signs were recorded at each geographical location in the hospital for each patient. A scoring system was devised to classify the quality of the observations that each patient received in the different departments. The observer recorded all the geographical movements each patient made during the first 24 hours after admission.

**Results.** Fifteen patients were recruited into this study over a 4-week period. There were 14 adult males (average age 28 years, range 18 - 56 years) and a 7-year-old girl in the cohort. There were significant differences in the quality of the observations, depending on the geographical location in the hospital. These variations and differences were consistent in certain locations and highly variable in others. Observations in the intensive care unit (ICU) and operating theatre were uniformly excellent. In the radiology suite the level of observations was universally poor. In casualty and the wards there was great variability in the level of observation. A total of 45 distinct geographical visits were made by the study cohort. Each patient made an average of 3 (range 2 - 5) visits during their first 24 hours after admission. All patients attended casualty, and there were 11 patient visits to the ward, 10 to radiology, 4 to ICU and 5 to theatre.

**Conclusion.** Significant variations exist in the level of observations of vital signs between different geographical locations within the hospital. This is problematic, as acute trauma patients need to be moved around the hospital as part of their

routine care. If observations are not done and acted upon, subtle clinical deterioration may be overlooked and overt deterioration may be heralded by a catastrophic event.

It has become clear that clinical deterioration and sudden death in surgical patients is usually preceded by changes in the so-called vital signs.<sup>1,4</sup> These vital signs are easily observable and recordable physiological parameters include respiratory rate, pulse rate, blood pressure, oxygenation and mental function. Prompt recognition of alterations in vital signs may allow appropriate therapeutic interventions to be instituted.<sup>1</sup> This has led to a change of emphasis away from cardiopulmonary resuscitation after the event to a more pro-active philosophy of so-called 'early warning trigger and response systems'.<sup>2,3</sup> Acute changes in physiology should trigger an assessment by a team capable of assessing critical illness and instituting appropriate interventions. To implement such a system effectively, vital signs must be actively recorded on a continuous basis and acted upon throughout a patient's stay in hospital. Caring for trauma patients is a dynamic process involving many specialties and it is often necessary to move the trauma patient around the hospital to different locations, which makes continuous and accurate measurement of the vital signs difficult. This study attempted to document the quality of observations performed on acute trauma patients as they moved through the hospital during the first 24 hours of care.

## Methodology

This study was a student elective and was undertaken at Grey's Hospital, Pietermaritzburg. Ethical approval was received from the University of Pretoria Ethics Committee and the Grey's Hospital Chief Executive Officer. A third-year medical student was assigned to follow acute trauma patients throughout the hospital during the first 24 hours after admission. The observer recorded all the geographical movements each patient made during this time. A visit to a geographical location within the hospital was recorded as a distinct patient visit. The total number of distinct patient visits and the frequency of visits to each specific location were recorded.

Patients were eligible for inclusion based on mechanism of injury and/or Revised Trauma Score (RTS). Patients who sustained

penetrating neck or torso trauma, high-velocity blunt polytrauma or direct head trauma were eligible for this study. Patients with an initial RTS of <11 were also included. Observations were divided into continuous observations (pulse and oxygen saturation) using a pulse oximeter and intermittent observations (manual blood pressure, respiratory rate, Glasgow Coma Scale and body core temperature). Urine output was not included as an essential observation for the purposes of this study. The expected and realistically achievable standard of observation for high-risk trauma patients in our centre is set out in Table I. The single independent observer documented the observations for each patient at each distinct geographical location in the hospital during the first 24 hours. In conjunction with the second author, the observations were reviewed and given a quality rating out of five levels ranging from excellent to incomplete. Points were ascribed to each level of observations, from 5 points for excellent to 1 point for incomplete. This enabled the authors to ascribe a numerical value to the quality of the observations, so allowing for comparison (Table II).

## Results

Fifteen patients were recruited into this study over a 4-week period. There were 14 adult males (average age 28 years, range 18 - 56 years) and a 7-year-old girl in the cohort. Of the patients 4 had been injured in a motor vehicle accident, 3 had stab wounds of the neck, 6 had penetrating torso injuries, and 1 had fallen from a height. The patient demographics and results are summarised in Table III. Five patients required operative intervention in theatre and 4 required ICU admission. Table IV shows the quality of the observations for each patient at each distinct geographical location during the first 24 hours in hospital.

There was great variability in the quality of the observations each patient received during the first 24 hours in our institution, the quality of the observations differing significantly depending on the geographical location in the hospital (Fig. 1). These variations and differences were consistent in certain locations and highly variable in others. Observations delivered in the ICU and the operating theatre were uniformly excellent. In the radiology suites the level of observations was universally poor. In casualty and the wards there was great variability in the level of observation.

A total of 45 distinct geographical patient visits were made by the study cohort. Each patient made an average of 3 (range 2 - 5) visits during their first 24 hours after admission. All patients attended casualty. There were 11 patient visits to the ward, 10 to

**TABLE I. VITAL SIGNS – THESE LEVELS OF OBSERVATION FOR SERIOUSLY INJURED PATIENTS SHOULD BE PRACTICALLY ACHIEVABLE IN OUR SETTING**

	Expected frequency
<b>Pulse</b>	<b>Continuous</b>
<b>Oxygen saturation</b>	<b>Continuous</b>
<b>Respiratory rate</b>	<b>30 minutes</b>
<b>Manual blood pressure</b>	<b>30 minutes</b>
<b>Glasgow Coma Scale</b>	<b>Hourly</b>
<b>Temperature</b>	<b>Hourly</b>

**TABLE II. QUALITY OF OBSERVATIONS**

Quality of observations	Numerical score	
<b>Excellent</b>	<b>5 points</b>	<b>Continuous pulse oximetry Manual vitals recorded every 15 - 30 minutes</b>
<b>Good</b>	<b>4 points</b>	<b>Pulse oximetry 70 - 80% of time in department Manual vitals recorded every 15 - 30 minutes</b>
<b>Average</b>	<b>3 points</b>	<b>Pulse oximetry 50 - 70% of time spent in department Manual vitals recorded every hour to 2 hours</b>
<b>Poor</b>	<b>2 points</b>	<b>Pulse oximetry &lt;50% of time in department Manual vitals recorded after 2 or more hours</b>
<b>Incomplete</b>	<b>1 point</b>	<b>No pulse oximetry Manual vitals either partially or wholly not recorded</b>

radiology, 4 to ICU and 5 to theatre. Specific 'observation gaps' were identified by the independent observer. In 4 cases patients were left in the triage area of casualty and checked on intermittently by staff. They were not continuously monitored and vital signs were manually recorded at variable intervals. Another 'observation gap' occurred with delay in transfer of a patient from casualty to the next location of care. This was documented in 3 patients. Patients sent to radiology were transported by hospital porters unaccompanied by medical staff in 3 cases. One patient had to wait in the adjacent passage outside radiology without any observations while awaiting investigation.

## Discussion

There is growing interest in a pre-emptive approach to acute clinical deterioration rather than a reactive one.<sup>1,4</sup> The emphasis is currently on recognising the early phase of a deterioration and implementing interventions designed to reverse the deterioration. The 'acute care team' (ACT) or 'ICU outreach' (ICUO) concepts are examples of pre-emptive approaches. The ACT or ICU outreach team consists of doctors and nurses who have been trained in critical care and are capable of recognising an acutely ill patient and initiating therapeutic interventions. Ward staff must initiate an early consultation with the ACT or ICUO team on the basis of recorded physiological changes. These changes are formalised by the creation of so-called 'early warning systems' (EWS). An EWS is a weighted clinical assessment that uses easily recorded common physiological parameters. The EWS make use of changes in these observations as criteria for initiating a consultation with the ACT or ICUO team. The EWS developed by Bellomo *et al.* is depicted in Table V.<sup>1,5</sup> Once consulted these teams review the patients and initiate interventions designed to prevent further deterioration. Such a system depends upon the ability to monitor patients accurately and reliably and to initiate a consultation with the ACT/ICUO team appropriately. The pre-emptive approach is also readily applicable to the management of acute trauma patients.

TABLE III. PATIENT DETAILS

Patient No.	Gender	Age (yrs)	RTS	Injury
Patient 1	Male	29	11	GSW abdomen
Patient 2	Male	56	12	MVA polytrauma
Patient 3	Male	25	12	Multiple precordial stab wounds
Patient 4	Male	36	NA	Head injury following assault
Patient 5	Male	34	NA	Stab abdomen with disembowelment
Patient 6	Male	18	9	Stab chest
Patient 7	Male	25	12	GSW right chest with haemopneumothorax
Patient 8	Female	7	12	MVA with head injury
Patient 9	Male	29	8	Fell from scaffolding
Patient 10	Male	24	12	MVA bilateral fractured femurs
Patient 11	Male	37	12	Stab wound to cubital fossa
Patient 12	Male	24	12	Stab wounds to neck
Patient 13	Male	25	11	Stab wounds to neck
Patient 14	Male	19	NA	Stab wounds to neck
Patient 15	Male	16	11	MVA head injury

RTS = Revised Trauma Score; GSW = gunshot wound; MVA = motor vehicle accident; NA = not applicable.

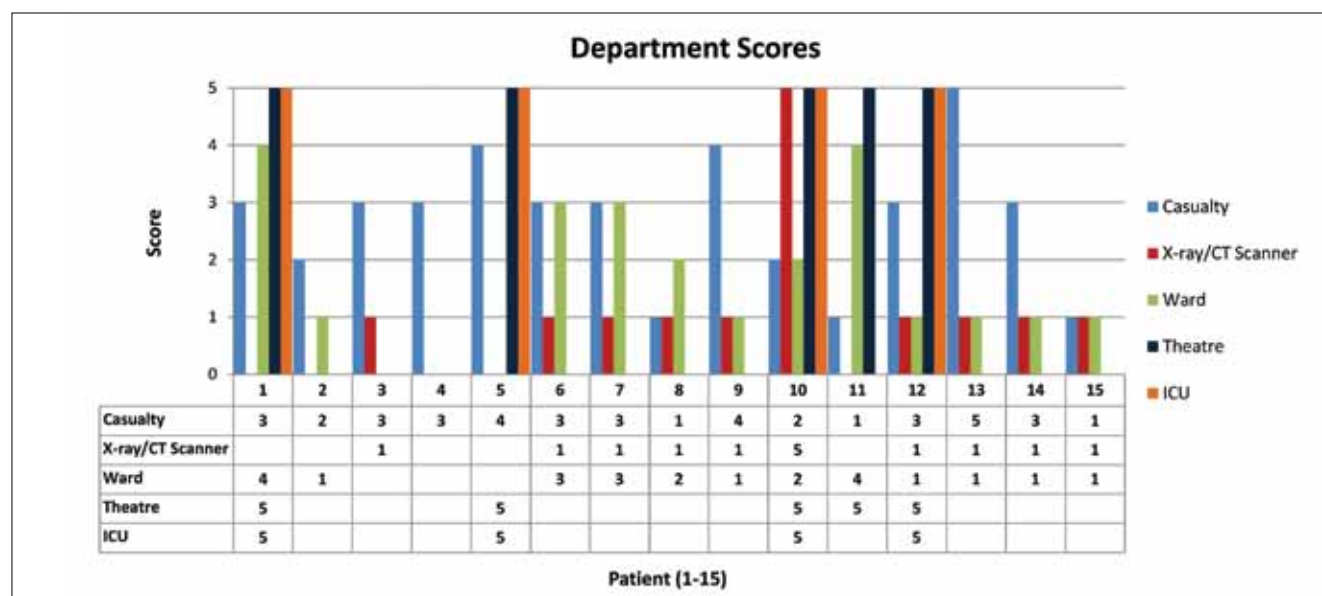


Fig. 1. Quality of observations for each patient in the five departments.

The acute care of a trauma patient is dynamic, and sudden deterioration may necessitate dramatic alterations in therapeutic plans. Ongoing continuous observation is essential if attending staff are to detect clinical changes. However, the severity and extent of an injury may not be obvious on initial survey. Accurate quantification of the extent of an injury often necessitates movement of an acute trauma patient around the hospital for specialised investigation and intervention. These movements make it difficult to perform continuous observations. It is also difficult to ensure consistency in the levels of observations performed, and our results demonstrate exactly this. There is great variability in the observations trauma patients receive during their first 24 hours

in our institution. This variability results in 'information gaps' in patient observations, and there are significant periods of time during which observations are not done or not recorded. This may not necessarily be totally negative, as a skilled staff member may be able to assess a patient accurately by the so-called 'eyeball approach'. Qualitative research has shown that experienced registered nurses often visually assess patients and tend not to use formal EWS until they need to quantify a deterioration after recognising it.<sup>6,7</sup> The same tendency may be observed in experienced clinicians. There is little doubt that this type of qualitative assessment occurred in our cohort: patients sent to X-ray accompanied only by their friends or the hospital porter, for example, had passed the

**TABLE IV. SCORES FOR EACH GEOGRAPHICAL LOCATION**

Patient No.	Casualty	Radiology	Theatre	ICU	Ward
1	3	-	5	5	4
2	2	-	-	-	1
3	3	1	-	-	-
4	3	-	-	-	-
5	4	-	5	5	-
6	3	1	-	-	3
7	3	1	-	-	3
8	1	1	-	-	2
9	4	1	-	-	1
10	2	5*	5	5	2
11	1	-	5	-	4
12	3	1	5	5	1
13	5	1	-	-	1
14	3	1	-	-	1
15	1	1	-	-	1
<b>Average score</b>	<b>2.7</b>	<b>2.5</b>	<b>5</b>	<b>5</b>	<b>2</b>

\*Patient brought from ICU to computed tomography scanner, so level of care the same as in ICU.

**TABLE V. EARLY WARNING SYSTEM DEvised BY BELLOMO ET AL.<sup>5</sup>**

**Staff member is worried about the patient**  
**Acute changes in heart rate to <40 or >130 beats/min**  
**Acute change in systolic blood pressure to <90 mmHg**  
**Acute change in respiratory rate to <8 or >30 breaths/min**  
**Acute change in pulse oximetry saturation to <90%**  
**Despite oxygen administration**  
**Acute change in conscious state**  
**Acute change in urine output to <50 ml in 4 h**

'eyeball test' of the staff in casualty. Although this type of assessment may be reliable, it depends on individual experience and as such is not reproducible. This is especially a problem when staff providing care are heterogeneous in terms of experience. Formal EWS are designed to generate both reliable and reproducible observations.<sup>3,6-8</sup>

The gaps in our observations imply that subtle acute signs may go unnoticed until a catastrophic deterioration occurs. These variations in observations correlate with changes in geographical location within the hospital.<sup>3</sup> However, in specific locations there is a fairly consistent quality of observations. In the ICU and theatre the quality of the observations was consistently excellent, and in radiology the quality of the observations was consistently poor. The single exception to this in radiology was a patient brought from the ICU for a computed tomography scan and accompanied

by ICU staff with full electronic monitoring. The operating theatre and ICU are designed to undertake close monitoring of patients at all times. In the operating theatre an anaesthetist is present with the patient during the entire procedure. After the procedure the patient is nursed in the recovery room, where there is dedicated nursing staff and ongoing non-invasive monitoring of blood pressure, pulse and oxygen saturation. Once in the ICU again each individual patient is cared for by a dedicated nurse and has continuous invasive and non-invasive monitoring. This level of care, however, is very expensive and is a limited resource. There were 4 ICU visits (8%) and 5 visits to theatre (11%) in this small cohort. The most infrequently visited locations have the best observations. It is unlikely that this level of care can be reproduced throughout the entire hospital.

Radiology is a weak point in the care of the trauma patient. This is especially important in view of the frequency (22%) of distinct visits to the radiology suite. Radiological imaging is an essential aspect of trauma care, but radiology departments have the most poorly developed infrastructure for ongoing monitoring of acutely injured patients. The radiology suite has limited capacity to deal with acute changes in condition. The primary responsibility of radiology is to produce and interpret diagnostic images, and to perform specific imaging-guided diagnostic and therapeutic procedures. Radiologists and radiographers are not trained to provide emergency care or resuscitation. Continuous monitoring and evaluation of acute patients remains the responsibility of the managing clinicians. Generally radiology has no nursing staff to provide monitoring after hours, and monitoring facilities during normal working hours are limited. This has long been recognised as a problem, and most trauma courses emphasise the dangers of sending acutely ill patients to radiology suites where observations are difficult to perform. Acute deterioration in these locations may well go unnoticed.

Within specific locations such as casualty and the ward great variations in the level of care exist. Casualty is a location where close monitoring is essential and should be achievable. It is the receiving area for acutely ill patients and as such should be staffed and equipped to deal with these patients. Variability in the levels of observation in casualty is cause for concern. The situation in the general wards is also highly variable. The general wards are busy and often under-staffed. The paucity of senior professional nursing staff results in inadequate supervision of junior staff.

Developing a pre-emptive approach requires a change in mentality among all categories of staff. Geographical parochialism needs to be challenged and reversed. It makes little sense to be able to perform high-level observations in particular areas with relatively low visitation rates but to accept large information deficits in other geographical areas with much higher visitation rates within the same institution. Acute care of trauma patients is ongoing and dynamic. Deterioration may occur suddenly and radically change the therapeutic plan for the patient. Without ongoing observation, deterioration is not recognised early and therapeutic interventions that may have been able to prevent further deterioration will not be implemented in time. Dealing with the problem of variability in the quality of observations requires a multi-faceted strategy. Ongoing educational efforts that emphasise the importance and significance of routine observations are essential. The development of formal mechanical

lock-out-type systems that prevent the inappropriate movement of potentially seriously injured patients is another approach. The introduction of formal tick sheets in the form of a sticker that must be completed and stuck onto the patient's file would force staff to formally classify patients according to both physiology and mechanism of injury, before moving the patient. It is also essential that we begin to develop high-care facilities in our public hospitals where patients who do not require intensive care or mechanical ventilation can remain for 12 - 48 hours until they are fit to be moved to the general wards. In the high-care area there should be adequate nursing staff to provide ongoing monitoring and to intervene as required. Ensuring that enough functioning non-invasive monitors are available in wards and casualty receiving areas is an ongoing challenge.

### Conclusion

There has been a change of emphasis away from a reactive 'crash team' approach to critical illness and sudden clinical deterioration towards a pre-emptive approach based on early recognition of changes in physiology and acute response teams. This means that accurate recording and interpretation of vital signs on a continuous and ongoing basis are essential. We have highlighted the existence of significant variations in the level of observations of vital signs between different geographical locations within a hospital. This is problematic, as acute trauma patients need to be moved around the hospital. If observations are not done and acted upon, subtle clinical deterioration may occur and overt deterioration may be heralded by a catastrophic event. There are areas that have a

consistently high level of care and areas in which levels are consistently poor. Of concern are the areas where there is an inconsistent level of care. Part of the problem remains institutional in the sense that there is an ingrained sense of geographical parochialism. This mindset must be addressed, and it is vital that we inculcate in all staff a sense of the importance of the continuity of care of the acute trauma patient. Educational programmes alone are unlikely to be effective, and the implementation of formal scoring systems or EWS may be of considerable benefit. Designing a system that ensures a consistently high level of observations across the entire institution remains a challenge.

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## Publication 7

### Establishing the feasibility of a nursing driven modified early warning score (MEWS) in a regional hospital in South Africa

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#### Abstract

##### Introduction

Nursing-driven early warning systems are designed to detect physiological deterioration and institute appropriate interventions prior to catastrophic collapse. This audit of the quality of nursing observations in the acute surgical ward of Edendale Hospital is intended to establish the feasibility of implementing such a system in regional hospitals in South Africa.

##### Methods

This study was carried out in the Acute Care ward of Edendale Hospital from the beginning of February 2013 till the end of March 2013. The demographic details of all patients in the Acute Care ward were collected. Each morning at 07:30 the primary investigator reviewed the previous day's observation to assess the quality of the nursing observations. A MEW(1) score for each patient was then calculated using the most recently documented set of observations. The primary investigator then performed and documented the routine observations and used these recordings to work out a second MEW(2) score. The two scores MEW(1) and MEW(2) scores were then compared.

##### Results

The details of 181 patients were collected. Just under two thirds (59%) of patients had a respiratory rate of exactly 20 and about one third (27%) had a respiratory rate of exactly 15. Less than 3% had a low GCS but four patients had aberrant readings; 3 with a GCS of 16 and 1 with a GCS of 18. The recorded heart rate correlated positively with the primary investigator's measurement (Pearson's correlation coefficient of 0.76). The average respiratory rate as measured by the primary investigator was 22, with an average MEW score of 2. This did not correlate with the recorded respiratory rate. (Pearson's correlation coefficient of 0.02). The average MEW (1) score was 2 (range: 0-7). The average MEW (2) score was also 2 (range: 0-9). Only a third (33%) of the MEW (1) and MEW (2) scores correlated and in 60% of cases MEW (1) was significantly underestimated compared to MEW (2) (by a 1 point to 4 point difference). In 86% of the patients the MEW (1) score was less than 3 (not necessitating escalation of care). However, (33%) had an investigator MEW (2)

score that required escalation of care (score 3-6). A single patient had a MEW (1) score of 7, but no emergency measures were instigated. This patient had a MEW (2) score of nine.

**Conclusion**

The introduction of MEWS without a programme designed to address the deficiencies highlighted in this study will not result in improved outcomes. Educational initiatives aimed at improving the quality of nursing care related to the assessment and appropriate reporting of vital signs is urgently required. Empowering nursing staff to implement consultation with senior medical staff may also be a potential avenue for quality improvement.

## **Introduction**

The realisation that there is a poor outcome from cardio-pulmonary resuscitation has led to an increased interest in preventing rather than treating catastrophic physiological collapse in surgical patients.<sup>1-5</sup> The early recognition of impending collapse allows for the timely institution of potentially lifesaving therapies. Physiological deterioration is a common antecedent of cardiac arrest, unplanned ICU admission and unexpected death. This means that continuous monitoring of physiological parameters is essential if we wish to identify and treat impending acute catastrophic deterioration in surgical patients. This makes the accurate recording and interpretation of vital signs essential. The ideal setting for ongoing physiological monitoring is a formal ICU or High Care unit. Unfortunately these are limited resources and most surgical patients will continue to be managed in a general surgical ward. In such a setting the quality of the observations is variable. In an attempt to standardise the observations in general surgical wards a number of so-called early warning systems have been developed. The Modified Early Warning Score (MEWS) determines the need for intervention based on the following vital signs, heart rate (HR), respiratory rate (RR), systolic blood pressure (SBP), temperature (T) and Glasgow Coma Scale. Each parameter is scored according to the extent of derangement (see Appendix 1) and the total score for all parameters is tallied. A score of 1-2 should instigate four hourly vital recordings; a score of three to six necessitates half hourly vital checks and the escalation of care to a doctor's attendance. A MEWS of 7 or more is a clinical emergency. The purpose of MEWS is to detect physiological deteriorations when they first appear in the patient's observation chart, and to provide a system for quick communication between nursing and medical staff to reduce delays in intervention.<sup>3-5</sup> The impact of an early warning system is highly dependent on the quality of the routine observations. The quality of nursing care in South African hospitals is variable and this means that the introduction of such a nurse-lead quality improvement initiative requires careful thought and planning if it is to be effective. This audit is of the quality of the nursing observations in the acute surgical ward of a regional hospital in South Africa with the objective of determining the feasibility of implementing MEWS into South African hospitals.

## **Setting**

Edendale Hospital is a regional hospital in the South African city of Pietermaritzburg in the province of KwaZulu-Natal. It drains patients from the peri-urban settlements around the city and from the four deep rural hospitals of Sisonke Health District. There are ten Intensive Care Unit (ICU) beds and five high-dependency (HDU) beds in the Pietermaritzburg complex. These units generally run at a hundred per cent occupancy and have extremely high patient turnover. For example in 2012, a total of 333 trauma patients were admitted to ICU/HDU in Pietermaritzburg. This is in addition to a significant volume of patients with obstetrical and medical emergencies who also require ICU/HDU care. Surgical patients who are not admitted to the ICU or HDU for whatever reason remain under the care of the Surgery Department. The Acute Care ward at Edendale Hospital is a step-down surgical ward from High Care,

where sicker patients are monitored more closely than in the general ward. The Acute Care wards attempt to provide a higher level of care than is available in the general ward, within the constraints of limited resources. The Acute Physiological Support Team (APST) runs the Acute Ward and has fifteen male beds and ten female beds. Each bed is equipped with non-invasive monitoring equipment as well as oxygen points and infusion pumps.

### **Methods**

This study was carried out in the Acute Care ward of Edendale Hospital, from the beginning of February 2013 till the end of March 2013. The demographic details of all patients in the Acute Care ward were collected. Each morning at 07:30 the primary investigator reviewed the previous day's observation and fluid charts to assess the quality of the nursing observations. She noted, which of the routine vital signs (heart rate, blood pressure, respiratory rate, temperature and Glasgow Coma Scale (GCS) were recorded. A MEW(1) score for each patient was then calculated using the most recently documented set of observations. The primary investigator then performed and documented the routine observations herself and used these recordings to work out a second MEW(2) score. The two scores MEW(1) and MEW(2) scores were then compared.

### **Statistical analysis**

All recordings were entered onto an EXCEL spread sheet for basic statistical analysis. Detailed statistical analysis was performed to compare the two MEW scores. The Pearson Chi-Square test was used when the sample size assumption was adhered too; Fischer Exact test was utilised in cases where the Chi-square assumption was not fulfilled. Statistical significance level was set at  $p < 0.05$ . All statistical analysis was performed using SPSS version 19 (IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp.).

### **Results**

The details of 181 patients were collected. Table 2 shows the completeness of recordings for the parameters constituting the MEW score as well as the average recorded values and the average calculated MEW(1) score. Just under two thirds (59%) of patients had a respiratory rate of exactly 20 and about one third (27%) had a respiratory rate of exactly 15. Less than 3% had a low GCS but four patients had aberrant readings, three with a GCS of 16 and one with a GCS of 18. The recorded heart rates correlated positively with the primary investigator's measurement (Pearson's correlation coefficient of 0.76). The average respiratory rate as measured by the primary investigator was 22, with an average MEW score of 2. This did not correlate with the recorded respiratory rate. (Pearson's correlation coefficient of 0.02). The average MEW(1) score was 2 (range: 0-7). The average MEW(2) score was also 2 (range: 0-9). Only a third (33.%) of the MEW(1) and MEW(2) scores correlated and in 60% of cases MEW(1) was significantly underestimated compared to MEW(2) (by 1 point to 4 points difference). In 86% of the patients the MEW(1) score was less

than 3 (not necessitating escalation of care). However, (33%) had an investigator MEW(2) score that required escalation of care (score 3-6). A single patient had a MEW(1) score of 7, but no emergency measures were instigated. This patient had a MEW(2) score of nine.

### **Discussion**

There is growing interest in a pre-emptive rather than reactive approach to acute clinical deterioration.<sup>1-5</sup> The emphasis is currently on recognising the early phase of deterioration and implementing interventions designed to reverse the deterioration. These changes are formalised by the creation of so-called 'early warning systems' (EWS). An EWS is a weighted clinical assessment that uses easily recorded common physiological parameters. The MEW score is an example of such a system. Such a system depends upon the ability of ward staff to monitor patients accurately and reliably, and to initiate consultation appropriately. We have previously shown that there is great variability in the observations trauma patients receive in our institution as they move from one geographical location to the next.<sup>6-8</sup> This study demonstrates a similar poor quality of observations. As in our previous reports, there was a variable rate of recording vitals, from 40% of patients having a GCS recorded, to 98% of patients having a blood pressure recorded. Heart rate and oxygen saturation also had relatively high rates of completion (81% and 98% respectively). The fact that 86% of patients had a respiratory rate of exactly 15 or 20 (27% and 59% respectively), suggests that these measurements are not accurate. The recorded respiratory rates did not correlate with the rates as determined by the primary investigator. The use of mechanical recording devices for blood pressure and pulse rate resulted in recorded measurements that correlated more closely with the measurements obtained by the primary investigator. A third of patients with a MEW(1) score of less than three, not requiring escalation of care, did, in fact, have a MEW(2) score mandating an escalation of care. This was not implemented. Eighty per cent (80%) of patients had a MEW score mandating four hourly observations, but this was performed in only two per cent of these patients. One patient qualified for emergency care (MEW score greater or equal to 7). This patient's MEW score was actually underestimated by two points. No remedial action was taken. The MEW score system is an appropriate method of increasing the pick-up rate of deteriorating patients, however, it requires good quality observations to be effective.

The results of this audit demonstrates the difficulty in implementing quality improvement initiatives in complex health systems. The introduction of MEWS without a programme designed to address the deficiencies highlighted in this study will not result in improved outcomes. Any health care system is tightly interlinked and complex – altering one component may have significant effects on the others. Poor outcomes tend to reflect systemic rather than individual failures. Without an overarching framework to provide a structure, strategic planning aimed at quality improvement risks becoming haphazard, ineffectual and even counter-productive. Improving a health care system requires multiple co-ordinated rather than isolated, unco-ordinated interventions. A multi-faceted approach is needed, which

combines administrative interventions, making it easier to record vital signs and fluids correctly, with educational interventions and with ergonomic restructuring of the process of care. Educational initiatives aimed at improving the quality of nursing care related to the assessment and appropriate reporting of vital signs is urgently required. Ergonomic restructuring is important and possible interventions include the establishment of dedicated teams to support the physiology of patients and improved pre-printed integrated sheets to record fluid intake and nursing observations.<sup>8</sup> Empowering nursing staff to implement consultation with senior medical staff may also be a potential avenue for quality improvement.

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**Table 1 Recorded results**

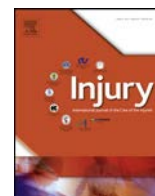
<b>Physiological parameter</b>	<b>Percentage recorded</b>	<b>Percentage of those recorded that are in the normal range</b>	<b>Average value recorded</b>	<b>Average MEW score</b>
Heart rate	81	80	88	0
Respiratory rate	87	2	19	1
Systolic blood pressure	98	78	115	0
Temperature	92	88	36.5	0
Glasgow Coma Scale	40	91	15	0

**Appendix 1 MEW Score**

<b>Score</b>	<b>3</b>	<b>2</b>	<b>1</b>	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>
<b>Heart Rate</b>		<40	41-59	59-100	101-110	111-129	>130
<b>Respiratory Rate</b>		<8		9-14	15-20	21-29	>30
<b>Temperature</b>		<35		35-37	37-38	>38	
<b>CNS</b>		Confused		Alert	Responds to voice	Responds to pain	No response
<b>Systolic BP</b>	<70	71-80	81-100	101-199		>200	

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## The implications of the patterns of error associated with acute trauma care in rural hospitals in South Africa for quality improvement programs and trauma education

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### ABSTRACT

**Introduction:** This audit uses error theory to analyze inappropriate trauma referrals from rural district hospitals in South Africa. The objective of the study is to inform the design of quality improvement programs and trauma educational programs.

**Methods:** At a weekly metropolitan morbidity and mortality meeting all trauma admissions to the Pietermaritzburg Metropolitan Trauma Service are reviewed. At the meeting problematic and inappropriate referrals and cases of error are identified. We used the (JCAHO) taxonomy to analyze these errors.

**Results:** During the period July 2009–2011 we received 1512 trauma referrals from our rural hospitals. Of these referrals we judged 116 (13%) to be problematic. This group sustained a total of 142 errors. This equates to 1.2 errors per patient. There were 87 males and 29 females in this group. The mechanism of injury was as follows, blunt trauma (66), stabs (32), gunshot wounds (GSW) (13) and miscellaneous five. The types of error consisted of assessment errors (85), resuscitation errors (26), logistics errors (14) and combination errors (17). The cause of the errors was planning failure in 68% of cases and execution failure in the remaining 32% of cases. The assessment errors involved the abdomen (50), chest (9), vascular system (8) and miscellaneous (18). The resuscitation errors involved airway (4), chest (11), vascular access (8) and cervical spine immobilization (3).

**Conclusions:** Rural areas are error prone environments. Errors of execution revolve around the resuscitation process and current trauma courses specifically address these resuscitation deficits. However planning or assessment failure is the most common cause of error with blunt trauma being more prone to error of assessment than penetrating trauma.

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### Introduction

The scientific study of error has developed from the work of accident investigators who have researched incidents such as the space shuttle disasters, the Chernobyl and Three Mile Island Nuclear accidents as well as aviation accidents.<sup>1,2</sup> Modern error theory has generated the primary insight that errors are not random and unpredictable, but follow patterns and have their roots deep within the organizations in which they manifest. The application of modern error theory to the aviation industry has resulted in an enviable safety record, which has not as yet been emulated in health care.<sup>3,4</sup> It has been estimated that error accounts for up to ten per cent of

fatalities amongst patients with salvageable injuries in the United States.<sup>5–7</sup> This study focuses on the problem of error associated with rural trauma care in a developing country and uses a modified taxonomy of error to quantify and classify these errors.

### Patients and methods

#### Setting

Edendale Hospital is a regional hospital in Pietermaritzburg in Kwa-Zulu Natal Province of South Africa. It receives patients from the urban and peri-urban areas around Pietermaritzburg as well as from the rural Sisonke Health District. Sisonke has roughly half a million inhabitants and is served by four district hospitals all staffed by non-specialist staff. None of these hospitals have advanced radiology facilities and operative capacity is limited. At the weekly morbidity and mortality meeting all trauma admissions are reviewed and inappropriately managed cases are

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identified and discussed. We have adapted the JCAHO taxonomy to analyze cases of error in our system (4). The JCAHO taxonomy breaks error down into five root nodes.

#### Impact

The degree of harm experienced as a result of the error.

#### Type

This refers to the processes of care that failed. We divide the processes of care up into three broad categories namely errors of resuscitation, errors of assessment and logistical failure. A patient may experience any number of a combination of failed processes.

#### Domain

The domain in which these errors occurred, was the rural hospitals of Sisonke District.

#### Cause

- Input error: Sensory input and information is incorrectly perceived, resulting in an inappropriate plan.
- Intention error: Sensory data and information is correctly perceived but an inappropriate plan is formulated.
- Execution error: Input data are correctly perceived and the correct intention is formed, but the wrong action is performed.

We find it difficult to distinguish input error from intention error as this requires detailed psychological analysis of the event and that is not always possible. We therefore simply divide the causes into errors of planning errors and errors of execution and omit the distinction of input error or intention error. Resuscitation and logistical failures are errors of execution whilst assessment failures are errors of planning.

#### Prevention

All error reduction programs need to develop interventions to reduce the incidence of error and to limit its effect.

### Results

During the period under review there were a total 1512 trauma referrals from our rural referral hospitals. Of these referrals we judged 116 (13%) to be problematic. This group sustained a total of 142 errors. This equates to 1.2 errors per patient. There were 87 males and 29 females in this group. The mechanism of injury was as follows, blunt trauma (66), stabs (32), gunshot wounds (GSW) (13) and miscellaneous five. The types of error consisted of assessment errors (85), resuscitation errors (26), logistics errors (14) and combination errors (17) (Fig. 1). The cause of the errors was planning failure in 68% of cases and execution failure in the remaining 32% of cases. The assessment errors involved the abdomen (50), chest (9), vascular system (8) and miscellaneous (18). The resuscitation errors involved airway (4), chest (11), vascular access (8) and cervical spine immobilization (3). The overall mortality rate in this group of patients was 15% (18). Morbidity in this group was significant and included, major amputation (7), stomas (3), acute renal failure (3), untreated pneumothoraces (2), missed cervical spine injury (2), prolonged ICU admission (44) and delayed diagnosis of peritonitis (20).

#### Resuscitation failure

The resuscitation errors involved airway (4), chest (11), vascular access (8) and cervical spine immobilization (3). The

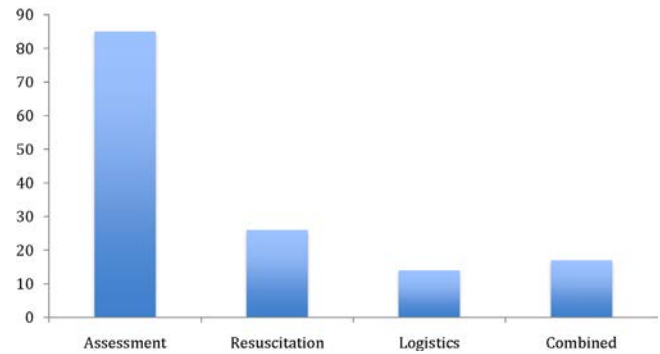


Fig. 1. Type/process error.

airway problems included two un-intubated head injury patients with a GCS less than nine, one patient with a failed crico-thyroidotomy and misplaced para-tracheal tracheostomy, and one esophageal intubation. In eight patients there were inadequate intravenous lines. Three patients with cervical spine injuries were transferred without any attempt at cervical spine immobilization. The errors involving the chest involved the inappropriate insertion of intercostal chest drains. One drain injured the liver, one injured the lung and two were placed in the setting of acute diaphragmatic herniation. Two intercostal drains were inserted in a low position although they did not cause any visceral injury and were considered as near misses. In two cases significant intra-pleural collections were not drained.

#### Assessment failures

##### Abdominal injuries

There were fifty cases of assessment failure which resulted in the delayed recognition of the need for surgical exploration of abdominal injuries. The mechanism of injury was blunt trauma (23), penetrating stab (21) and penetrating GSW (6). In the blunt group the breakdown of the injuries was duodenum (4), small bowel (14), colon (2) and solid viscera (3). The injuries in the penetrating group were as follows colon (11), small bowel (8), duodenum (2), gastric (1), diaphragm (3), spleen (1). In two cases the penetrating wounds were ultimately managed conservatively in our unit. These two cases would be classified as near misses as although the management plan was ultimately the correct one this was achieved by default. The impact was significant with 10 (20%) deaths, three cases of renal failure, a duodenal fistula and prolonged ICU admission (greater than five days) in sixty percent.

##### Thoracic injuries

There were nine errors of assessment which involved thoracic injuries. There were four cases of blunt trauma and five stabs. All the stab wounds involved left sided thoraco-abdominal stab wounds with diaphragmatic injuries and intra-abdominal injuries. The blunt trauma cases involved the failure to recognize pneumothoraces in two and failure to realize that multiple rib fractures represent the potential for significant pulmonary contusion which will require respiratory support. The impact of these errors was significant with all the five patients with missed thoraco-abdominal injuries requiring emergency surgery. In the blunt group one patient with an unrecognized tension pneumothorax died and the remainder required urgent entubation and mechanical ventilation.

### Vascular injuries

There were eight cases of assessment failure which resulted in missed vascular injuries. These included six injuries to the femoral or popliteal artery, two brachial artery injuries and three false aneurysms. These injuries were secondary to a dislocated knee (3), a fractured femur (2), a GSW of the thigh (1), lacerations to the forearm (2) and a single traumatic false aneurysm that was inappropriately incised and drained in the periphery. In all cases the staff managing the patient did not appreciate the potential for a vascular injury and failed to either exclude one or refer the patient through to our centre. The impact was significant and there were seven amputations in this group.

### Logistical errors

There were fourteen logistical errors. These included nine lengthy delays of over 14 h between referral and arrival at our institution. There was one case of poor communication where the patient arrived intubated and ventilated after the receiving staff had been informed that the patient was breathing spontaneously. In three cases the patient arrived inadequately resuscitated and hypoglycemic with non-functioning intravenous lines. One patient arrived with a clamped intercostal chest drain and a tension pneumothorax and a patient with an actively bleeding groin wound arrived with the paramedic compressing the wound. He demised shortly thereafter.

### Discussion

Error is a problem in rural trauma care in our environment and is associated with significant morbidity and even mortality.<sup>8,9</sup> Any interventions designed to improve the quality of rural trauma care will need to be multi-faceted and part of a comprehensive quality improvement program. The implementation of a trauma system, which ensures that critically injured patients are taken directly to trauma centers and bypass small rural hospitals, is essential. However this involves multiple stakeholders and will require political will and drive to implement.

Our analysis of error has led us to review our educational strategies in trauma care. The Advanced Trauma Life Support (ATLS) program is well established and focuses on teaching resuscitation skills. The ATLS course provides a core knowledge base, which is converted into a rules-based approach via the use of simulation and role-play and then into a skills-based approach via an assessment. From our results it would appear that the methodology of the ATLS course is an appropriate one, which correctly addresses priorities in resuscitation. The resuscitation errors documented in this study are specifically addressed and emphasized in the ATLS course. However over two thirds of the errors in this series were errors of assessment rather than errors of resuscitation and these are not as well covered in the ATLS course. It would appear that the association between mechanism of injury and pattern of injury is poorly understood. This is especially a problem with blunt trauma.<sup>8,10</sup> For example the potential for a popliteal artery injury associated with a posterior dislocation of the knee or a displaced mid-shaft fracture of the femur does not appear to be appreciated by junior staff. Similarly the association between blunt abdominal trauma and hollow visceral injury and between pulmonary contusion and blunt thoracic trauma is not appreciated. Penetrating thoraco-abdominal injuries are also associated with error and may need to be specifically addressed in trauma courses.<sup>9</sup> Educational programs need to provide insight into these error-prone injuries to assist junior staff, who may be confronted by unfamiliar clinical situations.

Training pilots to be “error wise” is a central component of aviation safety training programs. We need to try and adapt some of the lessons of aviation training into trauma training. Cognitive dissonance is a theory of human motivation that asserts that it is psychologically uncomfortable for an individual to hold contradictory views of an external reality.<sup>1,2,11,12</sup> These views are referred to as cognitions. As psychological dissonance is unpleasant a person experiencing dissonance attempts to change his/her cognition, attitude, or behavior so as to eliminate the feeling. This may explain the high incidence of assessment failure in our series. Assessing staff may actively suppress clinical data that leads them to realize that the pathology being treated is actually more serious than initially believed.<sup>10,13</sup> Reason has proposed a “three-bucket” model to help individuals recognize the degree of potential for error in each situation. The buckets represent<sup>1</sup> the current state of the individual health care worker,<sup>2</sup> the context of the task, and<sup>3</sup> the inherent error potential of the task. The number of “bad things” in each bucket should alert one to the potential for error. Any educational program that attempts to address the issue of assessment failure will have to take these theories into account.

### Conclusion

Rural trauma patients are exposed to several error prone environments and if error occurs it translates into considerable morbidity and mortality. Modern error theory provides us with a working framework to classify and analyze errors. Errors of execution revolve around the resuscitation process. The current ATLS course is designed to address these deficits. However errors of assessment or planning are the most common cause of error in our series and it is uncertain whether or not our current educational initiatives are addressing this problem. Blunt trauma seems to be more prone to error than penetrating trauma. Interventions to limit the incidence and effect of human error would need to combine systems engineering with psychological strategies. Our educational efforts must directly address the deficits in acute trauma care, which have been identified. The implementation of a trauma system that delivers severely injured patients directly to a higher level of care than a small rural hospital is essential but may be difficult to realize. It is unlikely that a single quality improvement intervention will succeed and a multifaceted quality improvement program will be required to uplift the quality of trauma care in rural hospitals in South Africa.

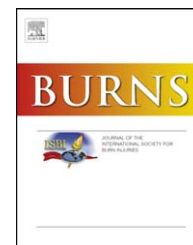
### Conflict of interest statement

No competing financial interests to declare.

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## The spectrum and outcome of burns at a regional hospital in South Africa

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### ABSTRACT

**Introduction:** Burns remain a major cause of morbidity and mortality in Southern Africa. The more vulnerable of our population, namely the urban poor, children and epileptics, are most often affected. This audit documents our experience with burns in a busy regional hospital in Southern Africa.

**Patients and methods:** A prospective data base was maintained from September 2006 to February 2008 of all burn wound patients admitted in Edendale hospital. Standard demographic data, detailed description of the burn, surgical intervention, outcome and length of stay are recorded. The size and depth of the burn, as well as the initial fluid management are also recorded.

**Results:** A total of 450 patients were admitted. Two hundred and thirty-five were male. There were 203 burnt children with an average age of 3 years (range 6 months to 12 years). Average age for adults was 40 years (range 13–82 years). The average surface area burnt in children was 7.5% versus 23% in adults. Of those who died, the average surface area burnt was 54%. In adults the average burn depth was superficial in 30%, deep dermal in 20% and full thickness in 50%. The aetiology of the burn was flame 70%, hot water 25% and miscellaneous 5%. In children the breakdown of burn depth was superficial in 77%, deep dermal in 15% and full thickness in 8%. The aetiology was hot water 83%, fire 6%, electrical 6% and miscellaneous 5%. The last mentioned included hot oil or porridge (15), electrical (10), chemical (6), flash burns (8) and lightning (4). Fifty percent of adults were epileptic and had sustained their burn wound during a seizure. In this group, over 40% had previously sustained burns. Fifteen percent had a delayed presentation on an average of 11 days. Hospital stay averaged 68 days (3.5 days per percent burn: range 1–161 days). Two hundred and two (45%) patients required skin grafting. The average time from burn to graft was 51 days (range 12–138). There were 40 deaths (9%) with an average age of 50 years (range 6 months to 82 years) and an average total burn surface area of 50% (range 14–85%). Aetiology of the burn in the deaths was fire in 30, lightning 4 and hot water 6. Cause of death was burn wound sepsis in 38 and inadequate resuscitation in 2.

**Conclusion:** Young children and epileptics are particularly vulnerable to sustaining burns. Our hospital sees a large number of burns predominantly involving smaller surface areas. Patients with small burns have a prolonged hospital stay and delayed grafting due to a conservative surgical approach and lack of resources. Large burns are fatal in our hands.

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## 1. Introduction

In 1974 Nuss et al. [1] stated that burns in South Africa are “an unrecognised epidemic”. They pointed out that the high burden of thermal injury and the long term physical and emotional morbidity were costly both to the country and the patient. In the intervening three decades since this article highlighted the issue, the burden of thermal injury in Southern Africa has remained high [1–4]. Burns tend to affect the more vulnerable portion of our population such as the urban poor who live in informal housing. These homes are overcrowded and have unsafe energy sources [5–8]. Children and epileptics are also particularly at risk. In developed countries with dedicated centres the results of modern burn therapy are very good. Dedicated burn units however, are a scarce resource in Southern Africa and many burns are managed by generalized surgeons. This audit comes from a busy regional hospital that services an urban and a large rural population. The prevailing approach of conservative management had long been established and burns were managed by individual surgical firms. This audit seeks to highlight the problem of thermal injury and reports on the results of a conservative approach to burn care.

## 2. Patients and methods

Edendale Hospital is a regional hospital in a metropolitan complex that includes a tertiary hospital and a district hospital. The complex provides specialized surgical services to a population of approximately three million people in the western part of Kwa-Zulu Natal Province. Edendale Hospital has no ICU facilities for burn care. We treat all burns that do not require complex reconstructive techniques or ICU. Complex plastic and reconstructive surgery is performed at the tertiary hospital in the complex. Burns requiring ICU care are referred to the Quaternary Burns Unit in Durban. The area around Pietermaritzburg is classified as urban and peri-urban, but we drain a large rural population as well. At the time of this audit burns were managed by individual surgical teams. A detailed burn proforma was filled out for each new admission and completed on discharge. Standard demographic data, detailed description of the burn, surgical intervention, outcome and length of stay were recorded. The size and depth of the burn, as well as the initial fluid management were also recorded. All patients admitted with thermal injuries from September 2006 to February 2008 were reviewed. Specific subgroups of burns such as those of the hands, non-accidental burns, electrical burns and lightning burns were reviewed as subsets of the main cohort.

## 3. Results

A total of 450 patients were admitted. Two hundred and thirty-five were male. There were 203 burnt children with an average age of 3 years (range 6 months to 12 years). Average age for adults was 40 years (range 13–82 years). There were significant differences between adult and paediatric burns. These differences are summarised in Table 1. Adults were more likely to

**Table 1 – Comparison of adult and pediatric burns.**

	Adults N = 247	Children N = 203
Degree of burn		
Superficial	30%	77%
Deep	20%	15%
Full thickness	50%	8%
Average total body surface area	23%	7%
Etiology of burn		
Flame	70%	6%
Hot water	25%	83%
Miscellaneous	5%	11%

sustain deeper burns than children. This reflected the aetiology of the burn with the majority of paediatric burns being due to boiling water whereas those in adults were due to open flames. Fifty percent of the adults were epileptic and had sustained their burn wound during a seizure. Approximately 40% of the epileptic patients had previously sustained a burn. Fifteen percent of all patients had a delayed presentation on an average of 11 days. There were 46 cases of intentional burns in adults, including 6 cases of self-immolation. The burns secondary to an assault are summarised in Table 2. All the self-immolation patients were female, the age range was between 21 and 32 years. The mechanism was self-immersion in either petrol or paraffin followed by ignition using a match. The burn distribution was typically to the face, chest and arms. The average burn area was of 18% TBSA and none of these patients died. Child abuse was seen in 12 paediatric admissions. The average age of the victim was 2 years (range 4 months to 4 years). The majority of these intentional burns were due to immersion in hot water (10) and the remaining 2 were flame burns. The total area burnt was small when due to hot water (4% TBSA) but significantly bigger (27%) when open flame. The torso, hands and the feet were at equal risk of being burnt. Genital burns were seen in two of these victims (17%). All suspected cases of intentional burns in children were referred to our social work department and reported to the child protection services of the South African Police Service. Miscellaneous causes included hot oil or porridge (15), electrical burns (10), chemical burns (6), flash burns (8) and lightning (4). All electrical burns were to the hand

**Table 2 – Demographics, etiology and extent of burns as assault in adults.**

Intentional burns in adults	N = 40
Males	22
Females	18
Average TBSA	13% (range 1–34%)
Hot water	11
Hot food	9
Petrol bomb	8
Chemical	6
Dousing and igniting	6
Arms	55%
Chest	45%
Face	35%
Back	25%
Legs	5%

**Table 3 – Etiology of fatal burns.**

Deaths	N = 40
Fire	30
Lightning	4
Hot water	6
Inadequate resuscitation	2
Sepsis	15
Palliation from admission	23

and uniformly as a result of loose wires at home. These all were small burns with entrance and exit wounds but minimal tissue necrosis. All electrical burns to the hand healed well with minimal loss of function. All four lightning victims died. The TBSA exceeded 60% in all cases. There was significant delay of greater than 48 h in all cases and all 4 patients presented in renal failure. Significant burns of the entire dorsum of the hand were seen in 35 patients during the specified time period. There were 16 children. Fifteen of these were hot water burns of superficial dermal depth. These healed with conservative treatment. The remainder were full thickness burns. The aetiology was flame burns (13), flash burn (4), chemical (1) and hot plastic (2). Outcome in these major hands burns was poor with delayed healing and significant limitations in function being a problem in all 20 full thickness burns. Definitive amputation was required in 1. Hospital stay averaged 68 days (range 1–161 days) or 3.5 days per percentage of TBSA burnt. Just under half of all admissions (45%) of patients required surgical management. The average time from burn to graft was 51 days (range 12–138). There were 40 deaths (9%) with an average age of 50 years (range 6 months to 82 years). The average TBSA burnt in the patients who died was 50% (range 14–85%). The deaths are summarised in Table 3. Table 4 is a comparative table comparing our results with the published results from other large regional hospitals in Southern Africa.

#### 4. Discussion

Burns are major preventable health problem in Southern Africa [1–4]. A lack of housing results in numerous informal

settlements which are overcrowded and often devoid of basic infrastructure. Inadequate electricity supplies result in widespread use of alternative sources of power, such as open fires and paraffin stoves. These are fire risks. Electricity where available is often inadequately maintained and illegally connected making it unsafe [5–8].

Burns affect the most vulnerable groups in the society. Poverty and informal housing are risk factors for sustaining a burn with toddlers (age 2–4) being at major risk of burn injury [9]. The most common mechanism of burn in this group is a hot water burn or scald. These are sustained when an unsupervised child reaches up and pulls down a container of boiling or hot water. The wound distribution is typically the face, chest and hands. Generally these are superficial partial thickness burns that heal well. Surgical treatment is generally not indicated in these patients. Child neglect plays a not insignificant role in these hot water induced injuries [10].

Intention injury accounts for just under 10% of paediatric burn injuries. Typically these are sustained by immersion in hot water and involve the feet or hands. It is important to actively exclude non-accidental burn injury in children as without intervention these children remain at major risk for further injury and even death. All suspected cases of child abuse are kept in hospital and referred to the social services who liaise with the police.

Most adult burns are as a result of open flames and are typically much deeper than those seen in children. Epilepsy is a major risk factor. The typical history is of the patient experiencing a seizure and falling onto open flames or knocking over heating or cooking devices which then cause a fire in the dwelling. The patient is unable to withdraw from the flame without assistance and hence the burn is usually deep. We have a very high incidence of epilepsy in our series. We are surprised by this high incidence and are unable to explain it. The term epilepsy is used loosely by patients to describe a wide variety of chronic mental illnesses. Substance abuse of both ethanol and marijuana is a common exacerbating problem.

In our series all electrical burns in both adults and children were to the hand as a direct result of contact with loose wires or connections. Hand burns pose particular problems. The

**Table 4 – Comparison of various series from Southern Africa 1992–2008.**

	Bauling et al. [2] <sup>a</sup>	Bauling et al. [2] <sup>a</sup>	Bauling et al. [2] <sup>a</sup>	Mzezewa et al. [3]	Eyal et al. [4]	Current author's series
Time period	8 months	8 months	8 months	12 months	10 years	18 months
Total	194	96	193	451	1046	450
Mortality	16.2%	13.3%	11%	22%	18%	9%
Average TBSA burn			20.8% (10–60)	13%	NS	23% adults and 7.5% children
Average fatal TBSA	30–35%	50–55%	60%	30–65%	55%	54%
Suicide	NS	NS	NS	11%	5%	2.5%
Average length of stay	NS	NS	NS	15 days (0–229)	NS	48 days (range 1–161 days)
Time per percent TBSA burn	2.9 days per percent TBSA	3.4 days per percent TBSA	1.9 days per percent TBSA		NS	3.5 days per percent TBSA

<sup>a</sup> Bauling et al., reported results from three cohorts of patients treated over sequential 8-month periods. Each period coincided with a major innovation in their approach to the care of burns. Period one was the introduction of a single team, period two coincided with the creation of a separate ward for their burns patients and in period three they adopted early excision and grafting as a management approach.

electrical burns we treated were usually pin point and healed with little or no loss of function. Hot water burns to the hand were superficial dermal and healed well. Full thickness flame burns to the hand are particularly problematic. If conservative treatment is embarked upon then dressing and adequate splinting are essential. Although we were aggressive about having splints made it is apparent that it is difficult for nursing staff to repeatedly re-apply these splints at each dressing change. Failure to keep all the fingers completely extended and individually dressed results in loss of flexion at the metacarpophalangeal joint and subsequent tendon exposure and loss at the interphalangeal joints.

Thermal injury as a means of assault is not an unfamiliar occurrence in Southern Africa [11–14]. Our series shows a fairly even distribution between men and women. The burn is usually to the torso, face and upper limbs. Hot water and hot food are commonly used during these assaults. However the use of Molotov cocktail-type devices and immersion with petrol or other flammable chemicals followed by ignition are still a not uncommon form of assault. In the turbulence associated with political change in the country during the 1980s the “necklace murder” became notorious [12]. A victim was surrounded and a tyre placed around his/her torso. The victim was doused with fuel and set alight. We did not see any of these assaults in our series. Self-immolation is a rare condition in the developed world (less than 1% of all suicides) but is more frequent in the developing world [15–18]. It is predominantly a female pathology and the reported in hospital mortality rate is high. In keeping with the literature self-immolation occurred exclusively in woman in our series. Contrary to other reports these burns behaved like the other adult burns with relatively small TBSA and no increase in mortality was observed.

Flame burns are more likely to be fatal than hot water burns. Lightning injury is also very likely to be fatal. The low incidence of death due to inadequate resuscitation reflects well on our acute management of burns. However large burns of greater than 40% remain fatal in our hands. This represents a lack of resources such as isolation cubicles and dedicated intensive care facilities. Without a major investment in infrastructure it is unlikely that we would be able to improve our results in large burns. The generally accepted methods of assessing quality control in burns are length of hospital stay. Most international guidelines would regard a rate of 1 day per percent of TBSA burnt as acceptable. Our results are not in keeping with these international benchmarks but are similar to the results reported from other major centres in Southern Africa. Table 4 attempts to summarise reported studies from region over the last 20 years. It would appear that a conservative approach is practiced in most reported series and prolonged hospitalization of predominantly small burns appears to be the norm. Large burns are invariably fatal in all these series [2–4].

There are a number of strategies which could improve burn care [19–24]. These include early excision and grafting of the burn wound and the use of modern dressings and wound care systems [19]. Bauling et al. [2] showed that the establishment of a dedicated team and the adoption of an aggressive surgical approach can dramatically improve outcomes in a Southern African setting. However, the burden of disease is great and both early excision and modern wound care systems are still

perceived as being prohibitively expensive. Despite Bauling et al.’s [2–4] success in many hospitals, a conservative approach continues to be practiced (see Table 4). Our results indicate that treating large volumes of small TBSA full thickness burns expectantly translates into prolonged hospital stay and delayed surgical therapy and increased cost. Expectant treatment requires daily dressing changes and wound exposure as well as increased pain. There is also an associated increase in morbidity with scarring and contracture formation being common [20,21]. Access to modern burn therapy is restricted. Such an approach is seen as expensive and belonging at tertiary institutions treating major burns not at a regional centre treating small to moderate size burns. However patients with small burns are being subjected to prolonged and debilitating therapy. These large volumes of patients with small burns with prolonged hospitalizations clog up the system and consume resources.

## 5. Conclusion

Thermal injury is a major problem in Southern Africa. The risk factors for sustaining a thermal injury include poverty and lack of formal housing. Within this major risk group there are particular subgroups which are at higher risk and these include toddlers and epileptics. Non-accidental thermal injury is a not uncommon event. Our service is focused around the treatment of a large volume of small burns. Our resuscitation protocols work well however, we are unable to salvage burns of a large surface area. We have persisted with a conservative approach to wound healing based on a perceived cost benefit. However this approach is time consuming, costly and morbid. If we hope to improve our results we will need to adopt a more aggressive approach to burn wound healing.

## Conflict of interest

The authors have no conflict of interest to declare.

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## Summary

*Publication 4: Assessing the gap between the acute trauma workload and the capacity of a single rural health district in South Africa*

This paper introduces the chapter and provides a broad overview of the four hospitals in the region in terms of their capacity to deal with trauma and acute surgical conditions and the burden of trauma they are expected to manage. The paper estimates the overall rate of trauma in the region from hospital admission data and uses the WHO situational analysis tool and published national guidelines to assess the capability of these hospitals. The conclusion is that these hospitals are not adequately prepared to deal with this large burden of disease and that the deficits mostly revolve around inadequate human capacity rather than around inadequate physical resources. A number of possible solutions are suggested which include either strengthening these hospitals or trying to bypass them for trauma and acute surgical conditions.

*Publication 5: An audit of the quality of care of TBI at a busy regional hospital in South Africa.*

This paper describes a prospective audit of 150 trauma patients with traumatic brain injury treated at Edendale Hospital and goes on to audit the quality of the process of care by reviewing referral letters, documentation and observations. This paper supports the findings and conclusions of the first paper by demonstrating a high burden of disease with inadequate resources to deal with it, as well as by documenting poor processes of care. This translates into poor outcomes for patients with TBI in this environment. The authors discuss a number of potential quality improvement interventions and explore the use of standardised tick-box referral notes. This sets the scene for the introduction of tick-box style clerking sheets in a subsequent publication.

*Publication 6: Variations in levels of care within a hospital provided to acute trauma patients*

This paper follows a small cohort of trauma patients all with a significant mechanism of injury through the first 24 hours of their hospital admission. The authors assessed the quality of routine nursing observations and identified discrepancies in the levels of monitoring between patients and across different areas in the hospital. This paper supports the findings and conclusions of the first two papers and shows that the process of care, even at the major referral hospital for the region, is inadequate. This theme is explored in greater detail further in the thesis when the authors review their experience with the introduction of formal tick-box clerking sheets and with structured morbidity and mortality meetings and error awareness programmes.

*Publication 7: Establishing the feasibility of a nursing-driven modified early warning system in a South African regional hospital*

This simple audit reinforces the finding that there are major deficits in the process of care of trauma and acute surgical patients in Sisonke Health District. This paper reviews the quality of observations of 181 acute care patients and applies an early warning score to the recorded observations to assess the feasibility of introducing the same early warning score at Edendale Hospital. Major gaps in the nursing observations were identified and this once gain supports the general findings of this chapter that the process of care of trauma and acute care patients in Sisonke Health District is inadequate.

Publication 8: Implications of the pattern of error associated with acute trauma care in rural hospitals in South Africa, for quality improvement programs and educational initiatives

This paper is central to the thesis as it incorporates a number of the constructs, which were introduced in the preceding chapters, and identifies a number of potential interventions, which are explored in subsequent chapters. These include the use of modern error theory and the introduction of structured morbidity and mortality meetings to assess the quality of the care of trauma patients in rural Sisonke Health District. The study reviews errors in 116 out of the total of 1512 patients who were referred to the PMTS from the rural hospitals in Sisonke Health District and uses the JCAHO taxonomy of error to classify the errors. A total 134 errors were recognised in these 116 patients and were categorised as errors of 'Assessment', 'Resuscitation', 'Logistics' or 'Combined errors'. Errors of assessment predominated and this is in keeping with the type of errors reported from other series. The authors discuss the significance of these errors for quality improvement initiatives and focus, in particular, on the strengths and weaknesses of current trauma educational programmes. The insights generated by this work influence subsequent educational interventions where the authors used error-awareness training to increase awareness of human error and its contribution to adverse outcomes amongst junior staff. The results of this study also inform the development and implementation of tick-box style clerking sheets for trauma patients.

*Paper 9: The spectrum and outcome of burns in a regional hospital in South Africa*

This audit of the quality of the process of care and the outcome of care of patients with burns in Edendale Hospital and Sisonke District between 2006 and 2008, describes the epidemiology and burden of injury, the management of these patients and the subsequent length of stay and clinical outcome. The authors identify the fact that the unstructured process of care, which existed at the time, resulted in poor outcomes as reflected by prolonged hospital stays and poor functional outcomes. The authors went on to suggest a number of quality improvement initiatives designed to improve the process of care of burns patients. These included the introduction of a dedicated burns team and the development of a team approach to the management of these patients. A subsequent ancillary paper reviewed the effect of this restructuring of burn care five years later and documented a number of areas of improvement as well as areas of ongoing concern in the management of burn patients.

This ancillary paper is situated in the final grid structure at the end of the thesis. These insights were incorporated into the design of the PMTS, in the form of the development of dedicated trauma teams and into the development of the structured departmental Morbidity and Mortality (M and M) meeting.

Collectively these six papers use a number of different methodologies and review a number of different aspects of trauma care in Sisonke District and Edendale to provide an overview of the quality of trauma care. They identify a number of deficits both in the inputs and the processes of care. The findings from this chapter inform several of the interventions discussed in Chapter Four and include the implementation of structured M and M meetings, the idea of error-awareness training, the use of tick-box clerking sheets and the idea of a defence in-depth strategy for error prevention as epitomised by the development of an acute physiology support team to care for high-risk surgical patients.

## Chapter Four: Synthesis and implementation

### Overview

The Pietermaritzburg Metropolitan Trauma Service (PMTS) has attempted to integrate all quality improvement interventions into an overarching strategic plan. This chapter discusses a series of interventions and assesses their impact on the quality of trauma care in Edendale and Sisonke Health District. These specific programmes are designed to target both the inputs and the processes of care within the constraints of the available resources and follow a number of themes, which were identified in the previous chapter. These themes include strengthening the surgical capacity of rural hospitals as well as attempting to use the lessons of error theory to develop targeted interventions designed to reduce the incidence and impact of human error in trauma care.

### Inputs

The plan to improve care in Sisonke District involved the development of a surgical outreach programme, which is intended to improve the surgical capacity of the staff in the district. Publication 10 looks at the impact the surgical outreach programme is currently having on surgical capacity in Sisonke District.

### Processes of care

The next set of interventions all focus on improving the processes of care and take the data presented in the situational analysis and the general theme of human error and error theory as a starting point. The central driver of this programme is the restructured morbidity and mortality meeting which drives the process of quality improvement by functioning as a mechanism to create awareness of human error in surgical care and to identify areas requiring quality improvement programmes. The study team then proceeded to qualitatively assess the impact of error teaching on the understanding junior doctors have of human error in trauma.

Based on the results of previous studies, the study team attempted to reduce error and improve the quality of care by improving the quality of documentation and providing clinical-decision support. Publication 13 looks at the implementation of tick-box style clerking sheets designed to improve the quality of the documentation of acute trauma patients and to direct clinical care down appropriate pathways.

Following on from these interventions, the authors then proceeded to restructure the process of care in the regional hospital. This intervention is based on previously reported data and on

the principles of modern error theory and the concept of a defense in-depth strategy to reduce the incidence of medical error. This paper goes on to review the experience of the introduction of an acute physiology support team as an example of an error-reduction and quality improvement programme.

### **Outcomes**

The final paper (Publication 15) in this chapter uses the outcomes of a common traumatic condition as a proxy marker for the quality of trauma care in Sisonke Health District. It contextualises the situation by explaining how the process of trauma care has been restructured and compares the outcome of penetrating abdominal trauma (PAT) before the period of restructuring with the contemporary period.

## Surgical outreach in rural South Africa: Are we managing to impart surgical skills?

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**Background.** The Department of Health in KwaZulu-Natal (KZN) has run a surgical outreach programme for over a decade.

**Objective.** To quantify the impact of the outreach programme by analysing its effect on the operative capacity of a single rural health district.

**Methods.** During 2012, investigators visited each district hospital in Sisonke Health District (SHD), KZN, to quantify surgery undertaken by resident staff between 1998 and 2013. Investigators also reviewed the operative registers of the four district hospitals in SHD for a 6-month period (March - August 2012) to document the surgery performed at each hospital. The number of staff who attended specialist-based teaching was recorded in an attempt to measure the impact of each visit.

**Results.** From 1998 to 2013, 35 385 patients were seen at 1 453 clinics, 5 199 operations were performed and 1 357 patients were referred to regional hospitals. A total of 3 027 staff attended teaching ward rounds and teaching sessions. In the four district hospitals, 2 160 operations were performed in the 6-month period. There were 653 non-obstetric operations and the obstetric cases comprised 1 094 caesarean sections, 55 sterilisations and 370 evacuations of the uterus.

**Conclusion.** The infrastructure is well established and the outreach programme is well run and reliable. The clinical outputs of the programme are significant. However, the impact of this programme on specific outcomes is less certain. This raises the question of the future strategic choices that need to be made in our attempts to improve access to surgical care.

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It has been estimated that just over 10% of the global burden of disease requires surgical treatment. However, access to surgical services is unevenly distributed across the world and across regions within the same country.<sup>[1-6]</sup> Currently, less than one-third of the estimated 234 million operations that take place each year are performed in the developing world. Lack of access to surgical services results in significant morbidity and mortality. Strategies to improve access to surgical services focus on improving the surgical capacity of district hospitals. The Bellagio Essential Surgery Group (BESG) and the World Health Organization (WHO) recommend that services at the district hospital level be strengthened by ongoing surgical training.<sup>[7-9]</sup> One strategy to achieve this is to take surgical

expertise to the district hospitals with the aim of delivering clinical care and imparting surgical skills – known as the surgical outreach programme.<sup>[10-14]</sup> The Department of Health (DoH) in KwaZulu-Natal (KZN) has run such a programme since the turn of the millennium. The programme is co-ordinated by the staff of the Red Cross, based initially at the old Durban International Airport and now at King Shaka International Airport, north of Durban. The programme makes use of fixed-wing aircraft to visit the more remote district hospitals in the KZN Province and ground transport to visit the more geographically accessible hospitals. Surgical consultants from Pietermaritzburg and Durban are transported to each hospital in the province on a monthly basis. When available, anaesthetists accompany the visiting surgeons. This audit reviews the outreach programme and attempts to quantify

its impact by analysing the operative capacity of the rural Sisonke Health District (SHD).

### Setting

KZN lies on the east coast of South Africa (SA) and consists of three broad regions, the urbanised coastal area around Durban, the western, inland part, stretching from the coast westwards to the Drakensberg mountains and the northern area which extends up to the border with Mozambique in the north, and westwards to Mpumalanga Province and Swaziland.

There are 70 provincial hospitals, two central hospitals, two tertiary hospitals and six regional hospitals in KZN. Both central hospitals and two regional hospitals are in the eThekweni Metropolitan Municipality. The coastal area is highly urbanised and has two other regional hospitals. The inland area has the single city of Pietermaritzburg with a well-developed infrastructure, a tertiary hospital and three regional hospitals. However, the western part of the province is predominantly rural, while the northern region is remote and deeply rural. The urban centre serving the north is the least developed of the three urban conurbations and is centred on the towns of Richards Bay and Empangeni. There is a single tertiary hospital serving the northern part of the province. The population of KZN is approximately 11 million, with half the population living in the rural areas outside the three conurbations of Durban, Pietermaritzburg and Empangeni/Richards Bay.

SHD is a rural area in south-western KZN with a population of roughly 500 000 people. Edendale Hospital in Pietermaritzburg serves as the regional referral hospital for the four district hospitals in SHD. Each district hospital is visited once a month by a surgical specialist from Edendale Hospital.

KZN thus has a large rural population living in relatively remote areas that are poorly served by transport infrastructure and far from surgical services. The South African Red Cross Air Mercy Service (AMS) is a non-profit organisation that focuses on health support and the upliftment of local communities through health initiatives. In KZN it has two helicopters and one fixed-wing aircraft dedicated to emergency services, two fixed-wing aircraft dedicated to the surgical outreach programme and one vehicle based in Pietermaritzburg and dedicated to the ground-based outreach. The operational costs of the programme are borne by the DoH. The flying doctor outreach programme has run since 1998 and in 2007 was supplemented with a 'drive clinic' intended to support areas that could not be reached by air. Doctors and healthcare workers travel daily to the outlying healthcare facilities to assist with clinical consultations, to undertake teaching ward rounds and to perform operations. The following specialist surgical departments at the School of Clinical Medicine, University of KwaZulu-Natal (UKZN) contribute to the programme: General Surgery, Ophthalmology, Orthopaedics, Plastic Surgery and Ear, Nose and Throat (ENT) Surgery. Visits are structured not only to focus on the delivery of clinical care, but to implement ongoing quality improvement initiatives by building clinical governance structures and imparting clinical skills. Each visit attempts to address the following objectives: clinical care by means of a ward round and a dedicated outpatient clinic, clinical teaching, and an operative list. Quality control and clinical governance initiatives are developed by assisting with morbidity and mortality meetings while system and infrastructure development is facilitated by undertaking needs assessments in each hospital. As far as possible, all staff at the district hospitals are directly involved in the outreach visits.

### Objective

This audit of the past 12 years of the outreach programme documents the activities of outreach staff and assesses the impact of the programme by auditing the surgical output within a single health district (Sisonke) to determine whether surgical (and anaesthetic) skills have been imparted.

### Methods

The AMS staff maintained a log of all flights from the base in Durban. Details of the number of specialist visits undertaken both by air and land transport were captured. Data recorded for each visit included the number of patients seen, the number of operations done and the number of patients transferred to the referral centre. The number of staff who attended specialist-based teaching was recorded in an attempt to qualitatively measure the impact of the visit.

### Assessment

During 2012 the investigators visited each district hospital in SHD to quantify the operations undertaken by resident staff at those hospitals between 1993 and 2012. Surgical registers were reviewed for the period between March 2012 and August 2012. The following obstetric procedures were recorded: caesarean section, evacuation of the uterus, and sterilisation. Orthopaedic and general surgical cases were categorised thus: orthopaedic reduction and amputation, hernia repair, laparotomy and split skin graft and ophthalmological procedure. All other cases were classified as miscellaneous.

### Results

From 1998 to 2013, 35 385 patients were seen at 1 453 clinics; 5 199 operations were performed and 1 357 patients were referred to regional hospitals. A total of 3 027 staff attended teaching ward rounds and teaching sessions. Tables 1 and 2 summarise the number of flying hours for each year and kilometres travelled each year.

#### General surgery

The Department of Surgery, UKZN visited 24 hospitals and conducted 332 clinics at which 4 456 patients were seen. A total of 235 patients were referred, 668 operations performed and 2 462 doctors and nursing staff trained.

#### Plastic surgery

Staff of the Department of Plastic Surgery, UKZN visited eight hospitals, conducted 83 clinics, saw 915 patients, performed 144 operations and trained 31 doctors.

#### Orthopaedic surgery

Staff of the Department of Orthopaedic Surgery, UKZN visited 21 hospitals and conducted 427 clinics at which they saw 12 438 patients. A total of 519 surgical procedures were performed and 161 doctors and nursing staff were trained.

#### ENT surgery

Staff of the Department of ENT Surgery, UKZN visited 22 hospitals and conducted 215 clinics; 10 316 patients were seen, of whom 939 were referred; 329 procedures were performed and 242 doctors and nursing staff trained.

#### Anaesthetics

A total of 28 hospitals were visited by staff of the Department of Anaesthetics, UKZN who conducted 270 clinics. They administered

## RESEARCH

**Table 1. Flying hours for the outreach programme, 1998 - 2012**

Year	Flying hours, <i>n</i>
1998	258.6
1999	272.5
2000	290.2
2001	354.6
2002	469.6
2003	497.4
2004	517.5
2005	505.9
2006	571.8
2007	679.2
2008	689.5
2009	827.1
2010	864.5
2011	794.8
2012	687.4
Total, <i>N</i>	8 280.6

**Table 2. Distance driven on the ground for the outreach programme, 2007 - 2012**

Year	Distance (km), <i>n</i>
2007	16 206
2008	38 094
2009	37 115
2010	46 105
2011	43 554
2012	49 158
Total, <i>N</i>	193 117

**Table 3. Operations over six months in 2012 in the four regional hospitals in SHD**

	Cases per hospital, <i>n</i>				Total, <i>N</i>
	CTK	EG Usher	Rietvlei	SAH	
Non-obstetric	133	333	66	121	653
Caesarean section	414	451	54	175	1 094
Sterilisation	35	17	4	2	58
Evacuation of uterus	122	175	36	37	370
Orthopaedic	6	41	11	0	58
Eye	0	14	54	0	68
Laparotomy	1	10	0	0	11
Skin graft	0	1	0	0	1
Hernia	0	1	1	0	2
Miscellaneous	126	266	24	121	537
Total, <i>N</i>	704	976	184	296	2 160

SHD = Sisonke Health District; CTK = Christ the King; EG Usher = EG Usher Memorial; SAH = St Apollinaris Hospital.

880 general anaesthetics and 131 doctors and nursing staff were trained.

### Operative data

Review of the surgical registers at the four district hospitals in SHD revealed that 2 160 operations were performed. There were 653 non-obstetric operations including 58 orthopaedic reductions and amputations, 68 ophthalmology operations, 11 laparotomies, 1 split skin graft, 1 abdominal wall hernia repair and 537 miscellaneous operations. The obstetric cases comprised 1 094 caesarean sections, 55 sterilisations and 370 evacuations of the uterus. These data are summarised in Table 3.

### Discussion

The BESG recommended that access to surgical care be increased by strengthening services at the district hospital level through enhanced surgical training programmes.<sup>[7-9]</sup> Such surgical outreach programmes, if not well planned, may merely deplete the regional referral hospital of skills and expertise and be of little benefit to the district hospital. It is essential to assess both the outputs and the outcomes of such programmes and audit their results. Outputs are generally quantifiable and include easily captured metrics such as the number of patients seen and number of operations performed. Outcomes are more difficult to measure. This report documents the outputs of the outreach system but acknowledges the difficulty with regard to precise measurement of outcomes.

The WHO in *Surgical Care at the District Hospital* states that basic abdominal surgery should be undertaken at district hospitals.<sup>[7]</sup> Although the exact definition of basic abdominal surgery is unspecified, the following procedures are listed: laparotomy for trauma, laparotomy for the diagnosis and management of intestinal obstruction, peritonitis, complicated peptic ulcer disease and appendicitis. The following trauma procedures are described: splenectomy, packing of liver lacerations, small bowel repair, intestinal anastomosis, fashioning of a colostomy, and repair of a ruptured bladder. There is a chapter that describes the diagnosis and management of the following surgical conditions: small bowel obstruction, complicated peptic ulcer disease, as well as the technique of open cholecystectomy for complicated gallbladder disease, non-surgical management of sigmoid volvulus and the surgical management of inguinal hernias, femoral hernias and



umbilical hernias. Our review of the operative data in SHD suggests that, despite an active surgical outreach programme, there remains a significant gap between the range of surgeries the WHO believes should be performed in a district hospital and what is actually delivered within SHD hospitals. Nevertheless, in terms of the numbers of patients seen, and the large number of operations performed, potential congestion at regional and tertiary hospitals over the 12-year period would have been significantly mitigated.

Our results are similar to those published by Voss and Duvenage<sup>[15]</sup> who audited the surgical output of seven district hospitals in the rural Western Cape. The volume of general surgical procedures undertaken is low and almost no abdominal surgery is undertaken. In their year-long review only 21 appendicectomies were performed (19 in one hospital, 2 in another) at the seven referral hospitals! The situation is similar in SHD and we have reported on the poor outcome of acute appendicitis in our environment.<sup>[16]</sup> The WHO defines a high priority procedure as one which primarily addresses emergencies such as injuries and obstetric complications. These procedures include laparotomies for trauma and acute abdominal conditions as well as open reduction of fractures, split skin graft and abdominal hernia repair. In our study there was a very low rate of abdominal hernia repair, split skin graft and laparotomy. A large number of smaller miscellaneous procedures are performed that include incision and drainage of abscesses, biopsy and excision of cutaneous and sub-cutaneous lesions and suturing of wounds.

Our findings are in keeping with data reported from a review of the unmet surgical need in sub-Saharan Africa.<sup>[2,3]</sup> It would appear that in the region as a whole, caesarean section is the most commonly performed operation and despite a high prevalence of trauma, burns and intestinal obstruction in the region, the number of fracture reductions, laparotomies and skin grafts is small. Most of the procedures performed are in the so-called miscellaneous category and include incision and drainage of abscesses and wound management and suturing, many of which, if performed in the outpatient department, would not have been formally recorded in the surgical registers.

Surgical outreach is proposed as a strategy to increase the surgical output of district hospitals. Although our programme has succeeded in delivering point-of-care need it has been less successful in building operative capacity. This raises specific questions as to the way forward for rural surgical care in SA. The strategic options are to continue working to build up district level surgical capacity by means of enhanced training programmes – involving a fairly massive investment in human resource development – or to deliberately

bypass the district system for pathologies requiring surgery, in favour of referral to regional centres with comprehensive surgical capacity.

## Conclusion

The DoH has run an active surgical outreach programme for more than a decade. The infrastructure is well established and the programme is well managed and reliable, and the clinical outputs are significant. However, the impact on strengthening surgical and anaesthetic capacities, which were key objectives, is less certain. Our audit suggests that the outreach programme has not succeeded in transferring surgical skills to the staff of the district hospitals. This raises the question of which future strategic choices need to be made to improve rural patients' access to surgical care?

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## GENERAL SURGERY

# Using a structured morbidity and mortality meeting to understand the contribution of human error to adverse surgical events in a South African regional hospital

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**Background.** Several authors have suggested that the traditional surgical morbidity and mortality meeting be developed as a tool to identify surgical errors and turn them into learning opportunities for staff. We report our experience with these meetings.

**Methods.** A structured template was developed for each morbidity and mortality meeting. We used a grid to analyse mortality and classify the death as: (i) death expected/death unexpected; and (ii) death unpreventable/death preventable. Individual cases were then analysed using a combination of error taxonomies.

**Results.** During the period June - December 2011, a total of 400 acute admissions (195 trauma and 205 non-trauma) were managed at Edendale Hospital, Pietermaritzburg, South Africa. During this period, 20 morbidity and mortality meetings were held, at which 30 patients were discussed. There were 10 deaths, of which 5 were unexpected and potentially avoidable. A total of 43 errors were recognised, all in the domain of the acute admissions ward. There were 33 assessment failures, 5 logistical failures, 5 resuscitation failures, 16 errors of execution and 27 errors of planning. Seven patients experienced a number of errors, of whom 5 died.

**Conclusion.** Error theory successfully dissected out the contribution of error to adverse events in our institution. Translating this insight into effective strategies to reduce the incidence of error remains a challenge. Using the examples of error identified at the meetings as educational cases may help with initiatives that directly target human error in trauma care.

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The realisation that error contributes significantly to mortality and morbidity in trauma and acute-care surgery has generated interest in quality improvement initiatives that directly target human error.<sup>11-61</sup> The starting point for the development of appropriate quality improvement programmes is to create a mechanism to identify cases of error. Once the error has been recognised, it needs to be dissected using an appropriate taxonomy. This will facilitate understanding of the problem and has the potential for the development of appropriate error reduction interventions. The traditional forum for identifying and discussing surgical complications is the morbidity and mortality meeting.

The traditional morbidity and mortality meeting has not been an effective driver of improved patient safety. In 2003, Pierluissi *et al.*<sup>71</sup> reported their audit of these meetings at four US medical schools. Error was discussed at 10% of the internal medicine meetings and at 34% of all surgical meetings. Internal medicine meetings tended to focus on didactic lectures, whereas the surgical meetings focused on case presentations and discussion. Although surgical residents were exposed to discussion on error more

frequently than their counterparts in internal medicine, in both disciplines error was infrequently discussed or even acknowledged. Several authors have attempted to use the morbidity and mortality meeting to highlight error and patient safety. Unstructured meetings are unlikely to provide such a platform and often degenerate into an overview of the literature on a particular topic. We therefore attempted to develop a structured morbidity and mortality meeting that focuses on assessing the contribution of error in its totality to an adverse event. The objective of these restructured meetings is to separate adverse outcomes into those that are a direct consequence of the pathology being treated, and those that are a result of error. Once the error has been identified we seek to analyse the cause, using a modern taxonomy of error. These data are collated at the end of the semester and reviewed with the intention of identifying the common themes in error and developing targeted strategies to attempt to prevent or reduce the incidence of error in the future.

This report discusses our experience with these structured morbidity and mortality meetings and attempts to classify our findings.

## Methods

Previously, the surgical morbidity and mortality meetings were run by each individual surgical unit. The meetings were unstructured, and involved the unit concerned listing all the patients admitted and operated on for the previous month. Each death was discussed and any complications were listed and discussed. A single complication was then discussed in depth and a brief overview of the academic literature on the topic was given.

A new structured format was introduced in June 2011. The morbidity and mortality meeting is now run by a dedicated moderator and presenter who works in the acute ward of the hospital. The acute team looks after all high-risk patients who do not qualify for admission to the formal intensive care unit (ICU) or high-care unit. Surgical care is undertaken by the admitting surgical team. This means that the presenter has a good knowledge of all high-risk patients and the patients who experience morbidity, but is not directly involved in their surgery, so reducing bias.

A standard PowerPoint template is used for each meeting. This consists of a table that divides the week's admissions into trauma and non-trauma admissions. The next two slides list all the transfers out of the acute ward, either to the ICU or to another institution, and all the transfers or down-referrals into the acute ward from the ICU. The rest of the presentation lists all the recorded morbidity and mortality for the week.

### Analysing mortality

Mortality data are obtained from the ward and the accident and emergency registers. We used a grid to analyse mortality and classify it as (i) death expected/death unexpected; and (ii) death unpreventable/death preventable. The initial classification of the death is established by the moderator and the trainee who presents the meeting. At the meeting, which is attended by senior staff, the classification is discussed and consensus is reached. This is then recorded as the final classification.

### Analysing morbidity

Morbidity data are obtained by monitoring sentinel events, including unexpected patient returns to the operating theatre,

re-admissions to the acute ward or the ICU, and surgical site sepsis. Morbidity is identified from self-reporting by the surgical team concerned as well as by analysis of morning hand-over data, theatre emergency list data and ICU admission data. The moderator and presenter classify each adverse event as pathology-related, error-related or combined adverse events. An error is defined as failure of a planned action to be completed as intended, or use of a wrong plan to achieve an aim. An error-related adverse event is defined as an unintentional, definable injury that is the result of medical management. Error-related adverse events are subjected to a detailed analysis.

### Dissecting out error

Once an adverse event has been classified as either error-related or combined, the individual case is analysed using modern error taxonomies. We have modified Chang's taxonomy,<sup>[2]</sup> which the Joint Commission on Accreditation of Healthcare Organizations adopted to produce a standardised nomenclature for the taxonomy of adverse outcomes. This taxonomy classifies error into five complementary root nodes, which equate to the general descriptive terms in parentheses below.

**Impact (How bad was the error?).** The degree of harm experienced as a result of the error.

**Type (What went wrong?).** This refers to the processes of care that failed. We divide the processes of care into broad categories, namely errors of resuscitation, errors of assessment, operative or technical error, and logistical failure. A patient may experience any number of combinations of failed processes.

**Domain (Where did it go wrong?).** In this report, the errors occurred in the acute-care ward of the hospital.

**Cause (Why did it go wrong?).** We divide the causes into errors of planning, errors of execution, errors of omission (failure to undertake a necessary action), and errors of commission (the performance of an inappropriate action). Resuscitation and logistical failures are errors of execution, while assessment failures are errors of planning.

**Prevention (What are we going to do about it?).** All error reduction programmes need to develop interventions to reduce the incidence of error and to limit its effect.

## Results

During the period June - December 2011, a total of 400 patients were managed by the acute admissions firm at Edendale Hospital, Pietermaritzburg, South Africa. There were 195 trauma admissions and 205 non-trauma admissions. During this period, a total of 20 morbidity and mortality meetings were held, and a total of 43 process errors were recognised and discussed. Table 1 summarises the attribution of errors presented at our meetings, using Chang's taxonomy. The vast majority were assessment failures, with logistical and resuscitation failures accounting equally for the remaining 23.2%. There were 35 errors of omission, 8 errors of commission, 16 errors of execution and 27 errors of planning. We did not identify any technical or operative errors in this period. There were 10 deaths, of which 5 were unexpected and potentially avoidable (Table 2). Of the 7 patients who experienced multiple errors (Table 3), 5 died. There were 8 drug-related errors. Drugs were not given when they

**Table 1. Errors (N=43) classified by Chang's taxonomy<sup>[2]</sup>**

Taxonomy	
Domain	Acute-care ward, Edendale Hospital, Pietermaritzburg
Impact	Death unexpected and preventable (5), death expected and unpreventable (5)
Type/process	Assessment (33), logistics (5), resuscitation (5), operative (0)
Cause	Planning (27), execution (16); omission (35), commission (8)
Prevention	Educational, targeted at recurrent errors

**Table 2. Error profile of unexpected and potentially preventable deaths**

Errors	Pathology	Cause of death	Primary error	Contributory errors
Planning				
40 years, M	Floor of mouth sepsis	Sepsis, airway occlusion	Significance of airway swelling unappreciated	None
57 years, M	Anastomotic leak following gastrectomy	Sepsis	Failure to recognise presence of abdominal sepsis	Sepsis-induced hypoglycaemia
Planning and execution				
23 years, M	Bowel obstruction post stabbed abdomen	Sepsis	Missed diagnosis	CT scan requested but not done Consultant away Blood results not reviewed Missed pneumothorax
87 years, F	Obstructed umbilical hernia	Myocardial infarction	Failure to appreciate need for postoperative intensive care	Poor co-ordination of surgery with postoperative care
61 years, F	Upper GI bleed	Myocardial infarction	Failure to appreciate need for postoperative intensive care	Poor co-ordination of surgery with postoperative care

M = male; F = female; GI = gastrointestinal; CT = computed tomography.

ought to have been given in 6 cases, and a patient with acute renal impairment was given a non-steroidal anti-inflammatory drug; the same patient experienced opioid toxicity (Table 3). In 4 cases, the radiologist reported a computed tomography scan as normal and missed significant pathology, and in 12 cases staff failed to recognise significant pathology. These are errors of assessment, and are listed in Table 4. Failure to associate pathology with the mechanism of injury, or complications with the surgery performed, were the most common problems. Logistical failures included miscommunication about the availability of an ICU bed and miscommunication during the transfer of patients between hospitals in the metropolitan complex.

## Discussion

Since the turn of the millennium when the Institute of Medicine (IOM) released the monograph *To Err is Human: Building a Safer Health System*,<sup>[11]</sup> there has been much interest in the issue of error in healthcare. The IOM recommended that, when discussing error, we should recreate the story and attempt to understand the meaning of the error. This will allow the development of strategies to reduce the incidence of error. The morbidity and mortality meeting is ideally placed to fulfil this role. We have attempted to use current taxonomies of error to help analyse the errors identified in our meetings.<sup>[8-12]</sup>

Assessment failure was the biggest source of error in this series. Junior staff tend to see what they know and make what they see fit their preconceived view of reality. We have commented on this tendency to ignore alterations in clinical signs and early mild changes in laboratory results rather than act upon them.<sup>[13-15]</sup> The phenomenon of cognitive dissonance helps to explain this finding.

Decision making is a complex process, and human beings have a tendency to make a superficial assessment and then resist prompts that should make them reconsider their initial assessment.<sup>[16-19]</sup> Our findings are consistent with previously published data on error and on human decision making. If we are going to err, we would prefer to err by not acting than by acting. This is illustrated by the finding in our study that errors of omission far outweigh errors of commission. The psychological tendency to stick with an incorrect assessment and persist with a predetermined course of action needs to be addressed in surgical education. Table 1 summarises the potentially preventable deaths in our series. The common theme in all the preventable deaths is one of staff not appreciating the significance of a clinical scenario. Not understanding the tenuous nature of a swollen infected upper airway resulted in a death. Not appreciating the importance of postoperative intensive care for elderly patients with several comorbidities requiring surgery resulted in 2 deaths. Failure to realise that new signs of sepsis after gastrectomy may herald anastomotic breakdown shows limited understanding of gastrointestinal surgery.

Table 4 summarises the 12 cases in which failure to make the correct diagnosis contributed to the adverse events. There were 4 trauma cases in which staff did not make the connection between the mechanism of the trauma and the potential injuries. Massive blunt chest trauma can result in a cardiac contusion. Similarly, a penetrating wound of the neck can result in an aerodigestive tract injury. Based on the mechanism and history alone, the managing staff should elevate their level of concern and dramatically increase either the level of investigation or the level of care. Working in a busy, under-resourced environment reduces the time available to thoroughly assess and properly manage these patients. This

**Table 3. Error cascades related to assessment process and outcome**

Cause	Pathology	Type, process	Primary error	Contributory errors	Outcome
Planning					
59 years, M	Diabetic foot sepsis with acute renal failure	Assessment Resuscitation Logistics	Inadequate fluids	Fluid-depleted state not recognised NSAIDs Opioid overdose	Died
51 years, M	Malignant gastric outlet obstruction	Assessment Resuscitation Logistics	Inadequate resuscitation	Delayed CVP insertion Delayed endoscopy and CT scan No definitive management plan	Died
42 years, F	Necrotising fasciitis	Assessment Resuscitation Logistics	Septic arthritis of shoulder	Debridement abandoned due to instability Delay to theatre, initially sent to ward Bled in ward and not detected	Survived
37 years, M	Stab neck with pharyngeal injury Developed neck sepsis	Assessment Resuscitation Logistics	Failure to actively exclude pharyngeal/oesophageal injury	Antibiotics not given Nasogastric tube not inserted Gastrograffin study not done CT scan neck not done Radiologist unavailable	Survived
Planning and execution					
87 years, F	Obstructed umbilical hernia	Assessment Resuscitation Logistics	Myocardial infarction	No ICU bed for postoperative care Poor co-ordination of surgery with postoperative care	Died
61 years, F	Upper GI bleed	Assessment Resuscitation Logistics	Myocardial infarction	No ICU bed Poor co-ordination of surgery with postoperative care	Died
23 years, F	Bowel obstruction post stabbed abdomen	Assessment Resuscitation Logistics	Missed diagnosis	CT scan requested but not done Consultant away Blood results not reviewed Missed pneumothorax	Died

M = male; F = female; GI = gastrointestinal; NSAIDs = non-steroidal anti-inflammatory drugs; CVP = central venous pressure; CT = computed tomography; ICU = intensive care unit.

almost certainly contributed to the death of a patient with a subdural haematoma who was inappropriately discharged. Adverse events frequently revolved around the failure to associate a clinical diagnosis with systemic pathology. Sepsis of the floor of the mouth can lead to an obstructed airway, and diabetic sepsis is associated with gross fluid depletion.

The concept of an error cascade refers to the fact that a final poor outcome is often the result of the interaction of numerous factors (Table 3). Once the initial error occurs, it is reinforced by other errors. For example, the diabetic patient with a septic foot was not given sufficient fluid. This error was compounded by two drug-related errors, namely administration of non-steroidal anti-inflammatory drugs in the setting of renal dysfunction, and excessive administration of opioids. The staff did not appreciate that renal

dysfunction may result in the decreased clearance of opioids. The mortality rate in the group of patients who suffered an error cascade was high at 71.4% (5/7).

While it is clear that our previous reliance on self-reporting of morbidity by individual units was inadequate,<sup>[20,21]</sup> a tendency to under-report morbidity remains a problem, as implied by the fact that we did not detect any technical errors in this series. Identifying and developing mechanisms such as sentinel event monitoring to capture morbidity ensures that most significant morbidity will be discussed at the meeting. Ideally, the culture of an organisation should be one in which adverse events are self-reported, but this is difficult to achieve. Developing mechanisms to reduce the errors we have identified requires creative and innovative approaches. It is unlikely that the resources available to us will increase or that the burden of pathology we

treat will decrease. This means that we are left with altering the process of care. There are several ways to do this: attempting to restructure the ergonomics of the patient care situation (e.g. by establishing an acute-care ward with dedicated staff to care for all new admissions) as well as ongoing targeted educational programmes. The data from our ongoing morbidity and mortality meetings are a useful starting point for such programmes.

## Conclusion

By using a structured format, we have been able to dissect out the human error involved in adverse surgical events in our institution. We have formalised our mechanisms to capture morbidity, have found the available taxonomies to be appropriate and user friendly, and have confirmed that the most common errors are those of assessment and omission. This is in keeping with the

**Table 4. Patients in whom significant pathology was not recognised**

Pathology	Assessment failure
Renal failure, diabetic foot sepsis	Failure to recognise fluid-depleted state
Stab neck	Failure to suspect and exclude aerodigestive tract injury
Floor of mouth sepsis	Failure to recognise source of sepsis and potential airway obstruction
Fractured pelvis	Missed on examination
Subdural haematoma	Patient initially sutured and sent home
Liver laceration in a polytrauma patient	Failure to appreciate severity of injury based on mechanism
Cardiac contusion following massive chest trauma	Failure to appreciate severity of injury based on mechanism
Perforated appendix with four-quadrant sepsis	Failure to predict need for ICU
Severe pancreatitis	Failure to predict need for ICU
Significant upper GI bleed	Failure to recognise risk factors
Septic arthritis post stab wound	Failure to diagnose necrotising fasciitis
Bowel obstruction post laparotomy for stabbed abdomen	Failure to recognise bowel obstruction

GI = gastrointestinal; ICU = intensive care unit.

literature on error from healthcare and other high-risk environments. Although we suspect that a problem with under- or non-reporting of technical errors still exists, we are beginning to develop an understanding of error in acute care. The challenge is to use this understanding to develop strategies to prevent or limit the impact of errors. Incorporating error training into educational courses is a potential strategy, and cases highlighted at our meetings can be converted into compact case studies for use by small focus groups.

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# An educational programme for error awareness in acute trauma for junior doctors

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**Background.** In resource-poor environments of the developing world, young and inexperienced interns and community service doctors are often responsible for treating trauma patients without sufficient supervision. Time and experience are required for competency to develop, but in the understaffed environment of many hospitals time is often a constraint. Educational interventions are needed to accelerate competency development of the novice doctor.

**Method.** The researchers designed an intervention using real cases and error theory to expand young doctors' experiences of common trauma errors made in our setting. We analysed cases at the regular morbidity and mortality meetings and selected cases where error contributed to the condition of the patient. Using error theory, these cases were presented to doctors with the objective to increase error awareness. To assess the success of this intervention, three doctors who were exposed to the intervention and three who were not exposed to it were included in the study using a structured interview.

**Results.** This study demonstrated that interns who had been exposed to the intervention had a broader understanding of how errors can compound a patient's pathology and are often the result of systematic rather than individual failure.

**Conclusion.** The researchers focused on the rationale for and the development of an intervention for novice doctors to expose them to trauma experiences in the framework of understanding error. The immediate success of the intervention is illustrated in the structured interviews. Further development of this intervention and more formal research into its pedagogical value are planned after formalisation of the intervention into a teaching curriculum for trauma doctors. This educational initiative will have to be part of a comprehensive multifaceted quality-improvement programme if it hopes to be successful.

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Trauma is a ubiquitous reality in South Africa and severely injured patients may present to a range of institutions.<sup>[1-6]</sup>

Junior staff may be required to care for these patients in settings where they are not well supervised. Many courses have been designed with the following educational outcome

in mind: the improvement of the knowledge and skills of junior staff in the resuscitation and management of a trauma patient.

The best-known such course is the Advanced Trauma Life Support (ATLS) course of the American College of Surgeons, which was famously inspired by an incident over three decades ago when an orthopaedic surgeon and his family were involved in a plane accident in rural Nebraska and received poor trauma care at the local hospital.<sup>[2,3]</sup> Since then, the ATLS course has been propagated worldwide and has come to be regarded as the gold standard in terms of trauma education.<sup>[2,3]</sup> The ATLS course focuses on techniques and not on what could go awry in the trauma setting.

Since the turn of the millennium, there has been a growing awareness that error in healthcare is a significant cause of morbidity and mortality.<sup>[1-4]</sup> International and local research have demonstrated that human error is problematic in trauma care at dedicated high-volume centres and even more so in smaller centres where severely injured patients are occasionally seen by less experienced doctors. Error theory suggests that the making of mistakes is not random, but follows specific patterns. If teaching staff are

aware of possible errors, it may contribute towards reducing error incidence and impact.<sup>[3-6]</sup> Educational programmes on error prevention and reduction make staff aware of errors.

In light of this, the researchers applied the understanding of error prevention and reduction to trauma care education. Cases where error contributed to an adverse outcome were documented and examined in detail using a taxonomy of error. This allowed educators the opportunity to convert individual cases into structured interactive teaching interventions. Examples of four such cases are included in Appendix 1. This study reports on the development and use of these anonymous case studies of human error as interactive teaching interventions for small groups of junior staff. To gauge the effectiveness of this intervention, we interviewed three interns who were exposed and three who were not exposed to the intervention about their understanding of human error.

The intervention consisted of a seminar where junior doctors were given a brief overview of error theory followed by a detailed discussion of cases selected from morbidity and mortality meetings. This error training was mandatory for all junior doctors working in surgery. They were asked to analyse and discuss the cases in terms of Chang's taxonomy of error,<sup>[2]</sup> and to discuss the cases with senior clinicians.

Chang's taxonomy classifies error into the following five complementary nodes, which equate to the general descriptive terms in brackets:

- Impact (how bad was the error?). This refers to degree of harm experienced as a result of the error.
- Type (what went wrong?). This refers to the failed processes of care, which we divided into broad categories, i.e. errors of resuscitation, errors of assessment, operative or technical errors and logistical failure. A patient may experience any number of a combination of failed processes.
- Domain (where did it go wrong?).
- Cause (why did it go wrong?). The researchers divided the causes into:
  - errors of planning
  - errors of execution
  - protocol violations
  - errors of omission
  - errors of commission.
- Prevention (what are we going to do about it?). All error reduction programmes need to develop interventions to reduce the incidence of error and limit its effect.

Four typical cases of error used in these seminars are provided in Appendix 1.

## Methods

### Development of the intervention

The researchers identified and analysed cases of error at the structured morbidity and mortality meetings, using a standard modern taxonomy of human error. The senior staff of the Pietermaritzburg Metropolitan Trauma Service were present at these weekly meetings. They provided a quorum of experienced trauma surgeons who identified appropriate cases, which were recorded for future use. They also identified human and systems errors in these cases by noting a number of sentinel events, which the researchers identified as indicators of error. These events included an unexpected readmission to the operating theatre, readmission to the ICU, surgical site sepsis and delay in definitive treatment. An adverse event was defined as an unintentional, definable injury because of medical management, while an error was defined as failure to complete a planned action as intended, or use of an incorrect plan to achieve an objective.

On review of the data from the morbidity and mortality meetings, we established that assessment failure is the major source of error and that junior staff tend to apply their observations to their preconceived view of reality, which more experienced staff are less likely to do. This phenomenon is referred to as cognitive dissonance. Decision-making is a complex process and one tends to make a superficial assessment, especially in unfamiliar or stressful situations, and then resist prompts that should make one reconsider one's initial assessment. Furthermore, less experienced staff are more inclined to err by failing to act than by acting, and errors of omission far outweigh errors of commission.<sup>[3,4]</sup> We designed a trauma education intervention plan by working backwards from the known deficits towards a targeted learning programme that teaches the concept of error awareness.

### Assessing the efficacy of the intervention

A structured interview was designed to assess the efficacy of this intervention before implementing it as part of a formal curriculum for interns rotating through trauma surgery. Interns ( $n=3$ ) who had been exposed to the

intervention >2 months before the interview, and those ( $n=3$ ) who had not been exposed to it, were interviewed. The interview was conducted by an educationalist who had not been present at any of the seminars. After establishing whether the doctor had been exposed to the intervention or was familiar with the test case (Case 1 (Appendix 1)), it was presented to them. The following questions were asked:

Question A. Mention the problems that occurred in the management of the child in Case 1.

Question B. Who, in your view, should be held accountable for the mistakes made in the treatment of this child? Explain your response.

Question C. Would you say that any of the problems were caused by lack of knowledge or semi-automatic behaviour? Explain your response.

Question D. Which mistakes were preventable? Explain your response.

## Results

Question A. Both groups identified a range of problems that occurred in the management of the patient, lack of consultation with senior staff and various other issues concerning management of the patient. There was no qualitative difference between the responses of the exposed and the non-exposed groups.

Question B. The exposed group named several people who could be accountable, including the admitting doctor, doctors who continued with the treatment and nursing staff, whereas the non-exposed group mentioned only the admitting doctor. One response from a non-exposed doctor was as follows: 'The admitting doctor who did the initial patient assessment is at fault. They should have asked for CVP insertion from someone else. There was poor communication with the Burns Unit. They did not follow protocols.'

The response from a doctor who was exposed read: 'Firstly, the admitting doctor ...' followed by an explanation. 'Secondly, the follow-up doctor ...' followed by an explanation. 'Thirdly, the nursing staff ...' followed by further explanation.

Question C. There was no qualitative difference between the responses of exposed and non-exposed groups. Both groups cited semi-automatic behaviour because of work burden as the source of the problem as opposed to lack of knowledge.

Question D. When asked which mistakes were preventable and for an explanation, all the respondents said that all the errors were preventable, but the exposed group gave more comprehensive answers. To illustrate, a response from a non-exposed doctor stated: 'All were completely preventable. The doctor did not follow the guidelines.' A doctor in the exposed group gave the following response: 'All errors were preventable. There should have been senior cover to ensure proper all-round care of this child. The nursing staff should have had enough basic knowledge of treatment of an injured child and ensured that proper treatment was given. There should have been a handover responsibility between interns and nurses and a senior in terms of wound treatment, fluid management and feeding.'

The three doctors who had been exposed to the intervention responded positively to the following questions:

- Did you find value in understanding error in trauma?
- Does your awareness of error in trauma affect the way you work?
- Do you view the morbidity and mortality meetings differently since you have been made aware of error in trauma?



## Discussion

Any course aimed at training with regard to reduction in error or bias in trauma settings and care, especially as part of ongoing professional development, needs to be informed by learning theories that take account of the complex and dynamic nature of such situations, the range of choices medical staff can make and how they make them. Because these relate not only to knowledge but also to professional practice, there is an emphasis on situated, experiential learning. Case studies provide the means to do this. Key theories that focus on learning in unstructured, multifaceted practical contexts relate to judgement and decision-making and the differences between novice and expert engagement in professional situations. These theories should inform training interventions, which need to be experiential, encourage interactive and collaborative learning and foster reflective practice if they are to ensure optimal learning.

Bleetman *et al.*<sup>[7]</sup> noted that 'Humans make errors in predictable and patterned ways. Novices make errors due to incomplete knowledge, while experts make errors due to the intrinsic hazards of semi-automated behaviour.' They identified four triggers of error, i.e. disturbance or interruption, disruption of normal sequencing, unexpected new tasks, or need for multitasking. Cases incorporating these and the taxonomy of error can increase practitioner awareness and understanding. Attempts to use such intuition in teaching or to raise awareness of these processes, require materials focused on improving metacognitive function through practice and reflection. Therefore, the use of simulations and case studies provides useful methods to involve students actively in context-rich activities, providing a means to accumulate further experience through intensive practice and reflection in safe environments within a relatively short period.

The interactive nature allows for feedback, which can contribute to improved reasoning processes and pattern recognition and create awareness of intuitive decision-making through reflection. Cases may require participants to move rapidly through a process of recognition, decision and action, which Fadde<sup>[8]</sup> terms reaction skills compared with deliberate and controlled actions. He indicates that it may take up to 10 years of practice and reflection to become an expert, and thus the role of instructional design is important in speeding up parts of the process. Learners must move rapidly from surface features of a context which focuses on technical aspects to a more non-analytical pattern recognition process in order to generate early hypotheses, such as those of experts during stressful situations. He claims that scenario-based case studies aid transfer of learning because cases reflect authentic task design in a holistic fashion. In this study, drawing on these theories and using Kolb's reflective cycle, which moves participants from a concrete experience through reflective observation and abstract conceptualisation to active experimentation, the participants were able to reflect on various points of error.<sup>[9]</sup>

In high-pressure situations novices ask questions about general things and work from more abstract principles, while experts ask more focused questions in the context of their hypotheses.<sup>[10-14]</sup> Exposure to simulations, case studies and vignettes may be used to develop appropriate questioning

processes, which provide the possibility to repeat practices regularly. Importantly, simulations allow the introduction of various unexpected situations so that participants can respond to different cues. By using cases of error as teaching tools the researchers created a mechanism to introduce junior doctors to the unspoken issue of decision-making and priority setting in high-pressure situations where the information was incomplete.

At least two months after their exposure to the intervention, the relevant doctors already showed a broader reasoning regarding error in trauma care. They perceived that errors can compound and accumulate and that the patient is also the responsibility of the healthcare system. The doctors who received training acknowledged experiential learning as an important outcome. Trauma education and assessment have evolved significantly over the past three decades. Several trauma courses for primary healthcare professionals have been developed, aiming towards a standardised approach to the acute care of the trauma patient. However, a major problem with acute trauma care in our environment is failure of assessment, which revolves around the inability of junior staff to associate potential pathology with a mechanism of injury. Developing an intervention that teaches junior staff to be aware of error may assist with this problem.

It is acknowledged that this assessment was carried out only once using a qualitative research approach that included three participants who were exposed to the intervention and three who were not exposed to it. Further research into the didactic and pedagogical approach of the intervention and the long-term learning effects should still be done.

## Conclusion

Incorporating cases of error and the formal discussion of error theory into clinical meetings assist junior doctors to become aware of the problem. As an isolated intervention, it is unlikely to reduce the incidence of the impact of human error and as such needs to be part of a multifaceted programme aimed at improving the quality of care.

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## Appendix 1. Error cases

### Case 1

A 10-month-old baby sustained hot water burns to the face. The protocol at our institution states that all such patients must be admitted to the high-care unit, have intravenous access secured, and be discussed with the burns unit consultant on call for the night. Although the extent of the burn was small, the distribution on the face and the baby's age made this a potentially much more severe injury than a similar burn on another part of the body. Because of a technical difficulty, an intravenous line was not inserted; therefore the baby was admitted with instructions for oral feeds. The baby was admitted to the general ward, as the admitting staff thought it was a relatively minor burn. He did not feed well owing to facial swelling and became dehydrated. As the baby was in the general ward, he was overlooked during the weekend ward round. He was finally reviewed 48 hours after admission, was profoundly dehydrated and required urgent fluid resuscitation. He made an uneventful recovery and was discharged well 10 days later.

### Case 2

A 28-year-old man was set alight during a domestic dispute. He sustained 60% mixed full-thickness burns. He was admitted to the nearest hospital (Hospital 1), which discussed his care with the major burns centre (Hospital 2). The latter hospital accepted him as they had an intensive care unit (ICU) bed available. As the original receiving hospital did not have any ICU facilities, he was transferred to a holding hospital in the metropolitan complex (Hospital 3), which did have temporary ICU facilities. He would be kept there pending transfer to Hospital 2. He arrived at Hospital 3 being ventilated. At this point Hospital 2 was contacted again, but it did not, as previously thought, have an ICU bed available. The patient could therefore not be transferred. In light of the fact that there was no definitive ICU bed available at the temporary hospital and the burn was more extensive than previously thought, the therapeutic plan had to be altered to a palliative plan.

### Case 3

A 31-year-old man was admitted to our institution within 30 minutes of being stabbed in the precordium. He had a massive left haemothorax, which was drained empirically with an intercostal chest drain. At insertion of the drain, he was noted to have palpable central pulses. He was transported to the operating room and underwent an emergency thoracotomy, which revealed an injury to his left ventricle. This was repaired, but the patient died an hour after the procedure. His peri-operative arterial blood gas revealed that he had been profoundly acidotic (Table 1). On review of the case, it became apparent that the patient had spent at least 20 minutes in the Emergency Department prior to the surgical team being informed. At that point the patient could potentially have survived (Table 2). During the time in the Emergency Department the staff had attempted to insert a central venous catheter, but this was abandoned when the patient deteriorated. It is likely that this delay converted a potentially salvageable injury into a fatal one.

### Case 4

This patient arrived at 13h35 on a Friday afternoon. She was a 29-year-old woman with a painful submandibular swelling of about 2 weeks' duration secondary to a painful tooth. The nursing staff recorded a blood pressure of 75/50 mmHg and a pulse rate of 150 beats/minute. Her temperature was 38.5°C. These readings were written in red pen in the outpatient folder, where there was no documentation of a diagnosis of septic shock. Antimicrobials were given early; hence the icon of a tick. However, management of the patient did not follow the current Surviving Sepsis Guidelines. These guidelines advocate rapid goal-directed fluid resuscitation and early administration of broad-spectrum antibiotics, followed by urgent surgical source control. Although intravenous fluids were prescribed, there was no documentation of the type or volume of fluid, choice of intravenous line, whether a central venous pressure line was inserted and if there was any response to resuscitation. The admitting surgical staff member failed to recognise a patient in severe septic shock. He/she failed to recognise the need to secure a definitive airway followed by urgent surgical drainage and ICU admission. The patient was sent to a general ward, where two hours later she deteriorated. By 19h10 she had impending upper airway obstruction with poor saturation readings. She required an emergency intubation followed by surgical debridement.

**Table 1. Peri-operative blood values**

Parameter	Value
Arterial blood gas	21.30 mmHg
pH	6.95
HCO <sub>3</sub> <sup>-</sup>	8.8 mEq/L
Base excess	-23.3 mmol/L
Lactate	7.7 mmol/L

**Table 2. Blood values after resuscitation**

Parameter	Value
Arterial blood gas	21.00 mmHg
pH	7.13
HCO <sub>3</sub> <sup>-</sup>	13.3 mEq/L
Base excess	-15.9 mmol/L
Lactate	8.3 mmol/L

## Tick-box admission forms improve the quality of documentation of surgical emergencies, but have limited impact on clinical behaviour

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**Introduction.** We used modern error theory to develop a tick-box admission form for emergency surgical patients. The tick boxes were designed to actively direct care down appropriate clinical algorithms by encouraging staff to make decisions based on recorded clinical data.

**Objective.** To audit the effect of these tick-box forms on the quality of documentation and the resuscitation process.

**Methods.** We designed and implemented a standardised tick-box admission form, and audited its impact by comparing 100 emergency surgical admissions before the intervention with 100 thereafter. We assessed the quality of the documentation in both groups and analysed the effect of use of the tick-box admission form and the decision nodes on the clinical behaviour of the admitting clinicians.

**Results.** The introduction of standardised tick-box admission forms dramatically improved the quality of documentation of acute surgical admissions. However, the impact of the decision nodes on clinical behaviour was less obvious. We demonstrated a tendency to cognitive dissonance in that, even though clinicians recorded abnormal physiological data, they did not consistently interpret this information correctly.

**Conclusions.** Although the use of tick-box admission forms improves the quality of documentation, the impact on clinical behaviour is less certain. Quality improvement is a multifactorial endeavour, and without a pervasive culture of patient safety, tick-boxes alone may well be ineffective.

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## RESEARCH



Human error is a significant problem in complex human organisations such as the aviation and nuclear power industries, and in modern trauma systems. However, the aviation and nuclear power industries have used insights provided by modern error theory to develop enviable safety records. To date, the healthcare system has not achieved a comparable record.<sup>[1-3]</sup> The challenge to healthcare managers and clinicians is to use modern error theory to improve the quality of healthcare systems. Modern error theory provides insights into the evolution of error in healthcare systems by recognising that it is predominantly the system, rather than the individual, that fails. While individuals may make mistakes, it is the system that allows human error to affect patient care. A robust system directs care along certain desired pathways. If care does not follow the appropriate pathway, a robust system will autoregulate to redirect care down an appropriate pathway. If a system is not robust, it is possible for an individual to override it and violate protocols. Violations remain a significant cause of human error in healthcare systems.

A study from the University of Pittsburgh demonstrated a correlation between inadequate documentation of prehospital care and mortality.<sup>[4]</sup> The authors reviewed all emergency medical service records for 2002 and 2003 in King County, Washington, USA. Multivariate analysis demonstrated that failure to record one or more physiological parameters at the scene of the injury predicted an increased risk of death.<sup>[4]</sup> The authors concluded that inadequate record keeping reflected poor care. They rejected the hypothesis that the severity of the pathology treated by the prehospital staff meant that poor documentation merely reflected lack of time to make appropriate notes, and concluded that poor documentation is a proxy marker for poor care. We have previously audited the quality of documentation of trauma patients in our institutions and found it to be inadequate.<sup>[5,6]</sup>

## Objective

We set out to address this deficit, and in light of the modern understanding of human error, sought to implement a standardised tick-box style admission form that would fulfil the dual role of improving the admission documentation of surgical patients and creating decision nodes to actively direct care down appropriate clinical algorithms (Appendix 1, available in the online version of this article).<sup>[7,8]</sup> By way of example, after making the admitting clinician document basic physiological data, a 'yes' or 'no' tick-box asking a clinical question such as 'is shock present?' or 'does the patient require active rewarming?' was included. This was intended to force a clinical decision and prompt an appropriate clinical response.

## Methods

The study assessed the impact of the tick-box admission forms on patient safety by reviewing the quality of the data recorded and the impact of the forms on patient care. Before implementation of this intervention, all admission assessments were performed without any preprinted standardised rubric and it was our impression that the general quality of admission documentation was below an acceptable standard.

We audited 100 consecutive admissions before the introduction of this intervention. The issue of establishing an adequate benchmark for quality of documentation was discussed among senior departmental colleagues. We collectively came to a consensus that the following 29 criteria should be present in the assessment of any emergency surgical admission: admitting doctor's first and last name; patient's name and

surname; a clear definition of the acute surgical pathology; time and date of clinical assessment; clarification of any significant previous medical history; clarification of any significant previous surgical history; clarification of any known allergies; clarification of any significant social history; pulse rate; blood pressure; respiratory rate; saturation of oxygen in haemoglobin (PaO<sub>2</sub>); core body temperature; findings on examination of the central nervous system; findings on examination of the cardiovascular system and lungs; findings on abdominal examination; use of adjuncts during resuscitation; the type(s) of resuscitation fluids utilised; the volume of resuscitation fluids utilised; urine output volumes following resuscitation; requirement for antimicrobials; requirement for analgesia; laboratory investigations utilised; interpretation of laboratory investigation results; imaging investigations utilised; interpretation of imaging investigation results; communication with senior surgical staff; definitive clinical assessment; and definitive management plan.

The tick-box clerking form was designed by the authors. It was presented to all members of the surgical department using Microsoft PowerPoint with digital projection, together with hard copies of the form. The presentation involved a lecture on error theory and the importance of standardisation of accurate documentation (for the purposes of quality improvement), followed by a thorough orientation in the use of the form. This document was then implemented as departmental policy for the admission of all surgical patients. Medical doctors were the only staff permitted to admit surgical patients, with the demand that the tick-box form be completed following initial patient examination and stabilisation. No other ancillary staff member was involved in the exercise of using the form.

All surgical patients admitted to the Department of General Surgery at Grey's Hospital, Pietermaritzburg, KwaZulu-Natal, South Africa, were included in the study. We categorised the admission process into the following discrete steps based on current approaches to the acute management of trauma and sepsis: resuscitation (airway, breathing, circulation, core temperature, and neurological deficit), response to resuscitation (urine output), drugs used (antibiotics and analgesia), and need for added special investigations. The ten decision nodes illustrated in Table 1 were incorporated into the clerking sheet.

The study assessed the impact of this tick-box admission form on both the quality of the admission documentation and the clinical behaviour of the admitting clinician.

One month after implementation of the system, 100 tick-box admission forms were audited and compared with the previous method of admission in respect of quality. The authors performed the audit. We assessed the impact of the decision nodes on clinical behaviour by classifying responses as either compliant (tick-box was selected) or not compliant (tick-box was not selected). Thereafter, we analysed whether the compliant nodes were accurately or inaccurately selected using the following classification:

- compliant + accurate (pathology present and appropriately recognised)
- compliant + inaccurate (pathology present without recognition or intervention).

## Results

Use of the tick-box admission form resulted in a significant improvement in the quality of recorded data (unpaired Student's *t*-test;  $p=0.0006$ ). Table 2 compares the quality of the data recorded before and after the intervention, and illustrates improved data entry for all parameters. How this affected clinical care is less

**Table 1. Decision nodes**

Process	Clinical data	Decision node
Resuscitation	Airway	Is an emergency airway required?
Resuscitation	Arterial oxygen saturation (SaO <sub>2</sub> )	Is supplemental oxygen required?
Resuscitation	Blood pressure and pulse	Is shock present?
Resuscitation	Core body temperature	Is active rewarming of patient required?
Response to resuscitation	Urine output	Is urine output normal or low?
Drugs	Indication for antimicrobials	Are antibiotics required?
Drugs	Pain	Is analgesia required?
Investigations	Arterial blood gas	Is the arterial blood gas normal or abnormal?
Investigations	Full blood count	Is full blood count normal or abnormal?
Investigations	Urea and electrolytes	Are urea and electrolytes normal or abnormal?

certain; Table 3 summarises the analysis of the decision nodes.

Compliance was good for status of the airway, the need for supplemental oxygen and the haemodynamic status of the patients. It was poor in terms of assessing adequacy of urine output, the need for antibiotics and analgesia, and the need for review of blood results. However, despite compliance with completion of decision nodes, the interpretation of basic clinical data was not consistently correct. Six patients in this cohort were shocked on presentation: in one case the data were not recorded, and in four cases the data were recorded but the doctor failed to recognise the pathological condition. Similarly, in three patients with a core body temperature <35°C, the clinician did not recognise that active rewarming was indicated. No patients who required antibiotics were administered the appropriate drug, and 14 who required analgesia were not given it, despite the decision node

**Table 2. Quality of the data recorded before and after the intervention**

Resuscitation process	Clinical data	A (pre-intervention, N=100), n	B (post-intervention, N=100), n
Resuscitation	Respiratory rate	22	80
Resuscitation	Oxygen saturation	45	84
Resuscitation	Temperature	30	67
Resuscitation	CNS examination	56	85
Resuscitation	Type of fluid	16	84
Resuscitation	Volume of fluid	9	46
End-point of resuscitation	Urine output	5	19
Drugs	Antibiotics	17	69
Drugs	Analgesia	18	61
Investigations	ABG	-	31
Investigations	Urea and electrolytes	-	44
Investigations	Full blood count	-	44

A = documented clinical variables pre-intervention; B = documented clinical variables post-intervention; CNS = central nervous system; ABG = arterial blood gas. Student's *t*-test (unpaired) comparing categories A and B: *p*<0.001.

**Table 3. Summary of analysis of the decision nodes**

Resuscitation process	Decision node	A (compliant, total), N	B (compliant, accurate), n	C (compliant, inaccurate), n
Resuscitation	Emergency airway	99	98	1
Resuscitation	Oxygen required	85	84	1
Resuscitation	Shock present	81	76	5
Resuscitation	Active rewarming required	72	68	4
End-point of resuscitation	Interpretation of urine output	19	14	5
Drugs	Antibiotics administered	56	47	9
Drugs	Analgesics administered	61	47	14
Investigations	ABG	31	30	1
Investigations	Urea and electrolytes	62	53	9
Investigations	Full blood count	44	43	1

A = compliance completing decision nodes; B = compliant and accurate; C = compliant and inaccurate; ABG = arterial blood gas. Student's *t*-test (unpaired) comparing categories B and C: *p*<0.0001.

## RESEARCH

that actively asked whether or not analgesia was indicated. Nodes relating to the quantification of urine output, the administration of antibiotics and analgesics and the interpretation of laboratory results were particularly poorly completed. Fig. 1 shows examples of this cognitive dissonance: the admitting clinicians have recorded low systolic blood pressures and low core body temperature, but have incorrectly selected the 'shock not present' and the 'no need for active rewarming' tick-boxes, respectively. Compliance with documentation of special investigation results was poor: in 19 cases, abnormal urea and electrolyte results were incorrectly interpreted, and in eight cases abnormal full blood count results were not recognised.

## Discussion

Preprinted tick-box forms have been shown to improve communication between units and hospitals, and checklists have been shown to improve safety in the operating room.<sup>[7-10]</sup> This research has been adopted from the aviation industry, where checklist use is routine and has been successful in promoting safety and reducing error.<sup>[9,10]</sup> Checklists fulfil a number of functions. They force staff to record specific data, which then fosters interpretation of and reaction to data results. They also promote teamwork and co-operation. However, checklists need to be implemented within a broader culture of patient safety if they are to be effective. Our experience supports this contention, as while our tick-box admission forms improved documentation, they did not necessarily improve quality of care, our audit revealing persistent violations of safe practice.

Documentation pertaining to the resuscitation process was well recorded, with the exception of the record of core body temperature. The monitoring of urine output as a guide to resuscitative efforts was poorly captured, as was the need for appropriate drugs. This is a significant failing, as delayed initiation of antibiotics predicts increased morbidity from sepsis. The timeous review of blood results was particularly poorly performed; once again this was a significant omission, as delayed recognition of acute kidney injury translates into increased morbidity. In addition to these limitations in the data capture process, the interpretation of data was problematic.

This misinterpretation of physiological data may be a result of cognitive dissonance, which is the psychological discomfort a person experiences when attempting to reconcile conflicting views of reality simultaneously.<sup>[1,2,11]</sup> A view of reality is referred to as cognition. The theory states that people are driven to eliminate a feeling of dissonance by eliminating an existing cognition. In other words, an individual may be biased towards a certain decision, even though the evidence favours an alternative decision. We have previously described the problem of cognitive dissonance in trauma care.<sup>[3]</sup> This study demonstrates that clinicians can fail to interpret abnormal clinical data. The examples cited in Fig. 1 illustrate the phenomenon of cognitive dissonance.

The major limitation of our tick-box admission forms is that it is a paper-based system. It is possible for clinicians to override (omit) the decision nodes, as there is no mechanical lockout system that forces them to comply. A mechanical lockout system is a generic error-reduction strategy that prevents the next step in a process, unless certain preceding tasks have been completed.<sup>[1-3]</sup> The most common example of such a system is an online purchase system. It is designed to prohibit completion if certain mandatory data are not entered. The

Fig. 1. Examples of cognitive dissonance.

purchaser is forced to either comply by entering mandatory data or abandon the process completely. We have shown that this pattern is difficult to achieve with a paper-based system, as it cannot overcome the problem of non-compliance and cognitive dissonance. Our research group's next intended step is to translate the current tick-box admission form into an electronic format. This could theoretically be designed with a mechanical lockout system and function as a clinical decision support system. Such systems include electronic prompts to promote compliance and direction of medical care down appropriate clinical pathways.

## Conclusion

Our tick-box admission forms improved the quality of documentation, but revealed a significant incidence of violations of safe practice. Improving clinical care in our environment is a complex endeavour that requires a multifaceted approach with numerous interventions. A single isolated intervention is unlikely to be successful. Fostering a pervasive culture of patient safety is essential if tick-box admission forms are to be effective in the promotion thereof.

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**SURGERY ADMISSION SHEET**

Admitting Doctor : .....

Patient Name ..... Surname ..... Age ..... Sex .....

IP Number ..... OP Number ..... Race .....

Time of Injury (T) ..... Date of Injury (T) .....

Time of Assessment ..... Date of Assessment .....

Mechanism of Injury (T) ..... Weapon Used (T) .....

**HISTORY**

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## SURGERY ADMISSION SHEET

### PRIMARY SURVEY

**AIRWAY**

Hard collar  YES  NO      Threatened airway  YES  NO      Emergency airway required  YES  NO

**BREATHING**

Trachea central  YES  NO      Oxygen saturation.....      RR .....      Oxygen required  YES  NO

**CIRCULATION**

P .....      BP .....      Shock present  YES  NO      Vascular access .....

**DISABILITY**

GCS .....      **EXPOSURE**      Temperature .....      Active rewarming required  YES  NO

### SECONDARY SURVEY

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Has ATLS Primary and Secondary survey been completed  YES  NO (T)  
 Have all systems been clinically examined and documented above ?  YES  NO





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## International Journal of Surgery

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### Original research

# The introduction of an acute physiological support service for surgical patients is an effective error reduction strategy



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#### ABSTRACT

**Introduction:** Acute surgical patients are particularly vulnerable to human error. The Acute Physiological Support Team (APST) was created with the twin objectives of identifying high-risk acute surgical patients in the general wards and reducing both the incidence of error and impact of error on these patients. A number of error taxonomies were used to understand the causes of human error and a simple risk stratification system was adopted to identify patients who are particularly at risk of error.

**Results:** During the period November 2012–January 2013 a total of 101 surgical patients were cared for by the APST at Edendale Hospital. The average age was forty years. There were 36 females and 65 males. There were 66 general surgical patients and 35 trauma patients. Fifty-six patients were referred on the day of their admission. The average length of stay in the APST was four days. Eleven patients were haemo-dynamically unstable on presentation and twelve were clinically septic. The reasons for referral were sepsis,<sup>4</sup> respiratory distress,<sup>3</sup> acute kidney injury AKI (38), post-operative monitoring (39), pancreatitis,<sup>3</sup> ICU down-referral,<sup>7</sup> hypoxia,<sup>5</sup> low GCS,<sup>1</sup> coagulopathy.<sup>1</sup> The mortality rate was 13%. A total of thirty-six patients experienced 56 errors. A total of 143 interventions were initiated by the APST. These included institution or adjustment of intravenous fluids (101), blood transfusion,<sup>12</sup> antibiotics,<sup>9</sup> the management of neutropenic sepsis,<sup>1</sup> central line insertion,<sup>3</sup> optimization of oxygen therapy,<sup>7</sup> correction of electrolyte abnormality,<sup>8</sup> correction of coagulopathy.<sup>2</sup>

**Conclusion:** Our intervention combined current taxonomies of error with a simple risk stratification system and is a variant of the defence in depth strategy of error reduction. We effectively identified and corrected a significant number of human errors in high-risk acute surgical patients. This audit has helped understand the common sources of error in the general surgical wards and will inform on-going error reduction initiatives.

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#### Article focus

- The peri-operative management of the high risk non cardiac general surgical patient
- Developing a team to manage the acute physiological derangements of acute surgical patients
- Developing an error reduction strategy

#### Key messages

- Defense in depth strategies may detect error
- There are common patterns of error encountered in the non operative care of acute surgical patients
- Fluid and drug errors are the most common problem

#### Strengths and limitations of this study' section.

- This is a single institution study and may not be directly applicable elsewhere
- Pragmatic study that identifies common sources of error in acute care.

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## 1. Introduction

High-risk operations such as cardiac procedures, solid organ transplantation and major oncological resections are centralized in well resourced centers with highly developed systems of care and are generally performed with acceptable morbidity rates and very low mortality rates.<sup>1,2</sup> High-risk non-cardiac general and acute care surgery on the other hand is undertaken in a diverse number of hospitals with variable levels of expertise and resources.<sup>2–8</sup> In the United Kingdom approximately 170,000 patients undergo high-risk, non-cardiac surgery each year and sixty per cent experience significant morbidity and fifteen percent die.<sup>2</sup> There is also an increased awareness that human error contributes significantly to these high levels of surgical morbidity and mortality and there is considerable interest in strategies that try and reduce the incidence and limit the impact of human error on health care.<sup>2–8</sup> Several modern taxonomies of error have been developed to assist with the understanding of the cause of these errors.<sup>3,9,10</sup> Any interventions intended to reduce human error associated morbidity and mortality amongst acute surgical patients, must accurately quantify surgical risk and ensure that the level of risk is commensurate with the appropriateness of the staff caring for the patient and the resources available. To facilitate this the Royal College of Surgeons has defined four levels of care for surgical patients depending on the assessed risk and these are summarized in Table 1.<sup>2</sup>

Edendale Hospital is a regional hospital in the South African city of Pietermaritzburg in the Province of Kwa-Zulu Natal. It drains patients from the peri-urban settlements around the city and from the four deep rural hospitals of Sisonke district. There are ten Intensive Care Unit (ICU) beds five high dependency (HDU) beds in the Pietermaritzburg complex. These units generally run at a hundred percent occupancy and have extremely high patient turnover. For example in 2012 a total of 333 trauma patients were admitted to ICU/HDU in Pietermaritzburg. This is in addition to a significant volume of patients with obstetrical and medical emergencies who also require ICU/HDU care. Surgical patients who are not admitted to the ICU or HDU for whatever reason remain under the care of the surgery department. We have run quality improvement programs at Edendale Hospital for the last five years. These programs arose out of a number of audits of the quality of care at our institution, which identified a number of deficits.<sup>11,12</sup> These deficits included sub-optimal documentation and poor communication leading to preventable errors and morbidity and even mortality.<sup>11,12</sup> In one of these audits a random sample of twenty-five referral letters for patients with Traumatic Brain Injury (TBI) was selected for review. The history was recorded in all the referral letters reviewed, the GCS in 88%, a management plan in 75%, associated localizing signs in 50%, and the condition of the pupils in 13%. In none of the referrals was an assessment of the integrity of the cervical spine recorded. A random sample of 28 inpatient records of patients with TBI was also selected for review. In 57% of cases the reason for admission was not recorded, in 42% a skull radiograph was omitted despite being indicated, and in 15% a computed tomography (CT) scan was omitted despite the case

meeting our criteria for this investigation. In the management plans of this group there were no recorded orders for supplemental oxygen and intravenous (IV) fluids. Clear instructions to perform neurological observations were omitted in all cases. In the observation charts of this group the GCS was recorded in 92%, the state of the pupils was recorded in 71%, pulse rate and blood pressure were documented in 70%, oxygen saturation was only recorded in 42%, and neither blood glucose readings nor core body temperature were ever recorded.<sup>11</sup> Another audit from our institution revealed that the routine monitoring of acute trauma patients was inconsistent and incomplete and varied dramatically across geographical locations within the same hospital.<sup>12</sup>

In response to these audits an Acute Physiological Support Team (APST) was established with the twin objectives of identifying high-risk acute surgical patients who were not admitted to ICU/HDU and reducing the incidence and limiting the impact of human error on these patients. The concept of the APST was based on Reasons “Swiss Cheese” model of human error.<sup>9</sup> In this model error is the arrow that has to penetrate multiple layers of defence to strike the patient. However each layer of defence is full of holes, like a piece of Swiss Cheese. If all the holes align then the error can travel in a straight line and hit the patient. Strengthening the multiple layers of defence is known as defence in depth strategy. The APST consisted of a medical officer and an intern under the supervision of a single dedicated senior specialist surgeon. Although there was close liaison with the nursing staff, we were unable to keep a dedicated nursing team and during the period of the study there was considerable turn over of nursing staff. The parent surgical team would formally request that the APST care for the patient. In effect this meant that all patients were seen several times a day by different teams. These included the parent team, the ICU/HDU team and the APST. Each team can be considered as a layer of defence between the error and the patient. The APST had fifteen male beds and ten female beds. Each bed was equipped with non-invasive monitoring equipment as well as oxygen points and infusion pumps. We were not able to provide advanced respiratory support such as CPAP, or inotropic support. The APST developed a monthly structured morbidity and mortality meeting as a feedback or closed loop system. Each month the statistics for the team were presented at the morbidity and mortality meeting. The meeting commenced with an overview of the role of the APST and then a brief discussion on modern concepts of error theory. Two index cases of error were selected out and discussed in detail using a published taxonomy of error.

## 2. Methodology

All patients who were classified as level II or higher according to the Royal College of Surgeons levels of care and were not admitted to ICU or HDU for whatever reason were referred to the APST. A prospective data-base was established to document each patient referred to the APST. Routine demographic data was recorded as well as data concerning the clinical course. The APST collated all errors detected by the team and the number of interventions to address these errors initiated by the APST. Error was classified according to type or the process that failed, and cause of error. Types of errors were classified as drug related, fluid related, indwelling device related, management decision related and failure to review investigations. Modern taxonomies of error were used to understand the cause of each error. Errors of omission involved the failure to perform an indicated intervention whereas errors of commission involved the inappropriate application of an intervention. Errors of planning involved the incorrect management plan and errors of execution describe an appropriate management plan, which goes awry.

## 3. Results

During the period October 2012–January 2013 a total of 101 patients were cared for by the APST at Edendale Hospital. The average age was forty years. There were 36 females and 65 males. There were 66 general surgical patients and 35 trauma patients. Fifty-six patients were referred on the same day as their admission.

**Table 1**  
Classification of levels of care according to the Royal College of Surgeons of England. (2).

Proposed levels of care (2)	
0 Ward	Basic observations
1: Enhanced ward	At risk of deterioration, more frequent observations, basic resuscitation
2: High dependency	Needs detailed observation, intervention or single organ support
3: Intensive care	Multiple organ support requiring complex interventions

The average length of stay with the APST was four days. Eleven patients were hemo-dynamically unstable on presentation and twelve were clinically septic. The reasons for referral were sepsis,<sup>4</sup> respiratory distress,<sup>3</sup> acute kidney injury AKI (38), post-operative care (31), pancreatitis,<sup>3</sup> ICU down-referral (15), hypoxia,<sup>5</sup> low GCS,<sup>1</sup> coagulopathy.<sup>1</sup> The mortality rate was 13%.

A total of thirty-six (35%) patients experienced 56 errors (1.5 errors per patient) The types of errors were fluid related in (30), drug related in,<sup>11</sup> indwelling device related errors in,<sup>6</sup> decision related errors<sup>5</sup> and failure to review investigations in.<sup>5</sup>

- The fluid related errors included the inappropriate discontinuation of intravenous infusions in three, the failure to institute fluids in twenty-four and the choice of an inappropriate fluid in three patients.
- The drug related errors included the administration of nephrotoxic agents to patients with AKI in four patients and the omission of thrombo-prophylactic agents or antibiotics in another four patients and incorrect dosing in three patients.
- The indwelling device errors involved the incorrect placement of indwelling devices, namely two central venous lines and one nasogastric tube, the inappropriate removal of a urinary catheter in two patients and the failure to remove a CVP in one patient.
- The decision errors involved the timing of endoscopic intervention in management of obstructive jaundice related sepsis in one patient, the operative management of gastro-intestinal bleeding in one, the need for laparotomy in two and the miss assessment of the severity of acute pancreatitis in one.
- Failure to review special investigations timeously was a cause of assessment error in five. In one patient with neutropenic sepsis the surgical team did not follow up on the microbiology results and failure to review routine blood results resulted in patients with AKI being overlooked for twenty-four hours. Failure to review a chest X-ray delayed the diagnosis of a misplaced CVP line and a pneumothorax misplaced feeding tube for twenty-four hours.

Table 2 tabulates the types of errors and classifies them according to cause. Errors of planning exceeded errors of execution and errors of omission, exceeded errors of commission. A total of 143 interventions were initiated by the APST. These included intravenous fluids (101), blood transfusion,<sup>12</sup> initiation or change of antibiotics,<sup>9</sup> management of neutropenic sepsis,<sup>1</sup> central line insertion,<sup>3</sup> optimization of oxygen therapy,<sup>7</sup> correction of electrolyte abnormality,<sup>8</sup> correction of coagulopathy.<sup>2</sup>

#### 4. Discussion

The introduction of an APST was in direct response to our realization that our processes of care were inadequate and our

belief that the post-operative and ward domain is a highly error prone environment. The results of this audit have confirmed that belief. The APST made a high number of interventions in this cohort of patients and detected errors and potential errors in over one third of patients. Furthermore the high mortality rate (13%) in this cohort suggests that human error is not particularly well tolerated in this group of patients. The causes of the error in this audit are in keeping with those reported in the literature where acts of omission are far more common than acts of commission.<sup>5–8</sup>

The majority of the errors and subsequent interventions involved adjusting pre-existing or instituting appropriate fluid management. The failure to initiate fluid management when indicated implies that the pathophysiology of surgical disease is poorly understood. The fluid shifts associated with the management of surgical sepsis and pancreatitis are not appreciated and are associated with poor decision-making. The surgical patients in this cohort were overwhelmingly septic and this is associated with significant fluid shifts. The management of post-operative fluid shifts requires clinical acumen and insight.

Drug related errors, involved either the failure to prescribe drugs when indicated, most commonly the omission of antibiotics for septic patients and the omission of thrombo-prophylaxis in high-risk patients, or the inappropriate administration of drugs, such as potentially nephrotoxic drugs in patients with renal dysfunction. Failure to review results may compound these errors as it may delay the diagnosis of AKI. Two strategies are required here. The first must prompt the question as to whether a new agent must be instituted and the second to must prompt a review of all current agents to see if any can be safely discontinued or are contra-indicated.

Inadequate decision-making is another common source of error. The failure to appreciate the physiological insult of a number of common acute surgical conditions is a frequent cause of error as is the failure to be conscious of the need to actively exclude well-known surgical complications. Delaying the endoscopic drainage of a patient with obstructive jaundice places that patient at increased risk for renal failure and sepsis. Logistical constraints may make it difficult to achieve but poor understanding of the clinical risk exacerbate these delays.

The insertion of indwelling devices is associated with a number of well-described complications. These include incorrect placement and iatrogenic pneumothorax following the insertion of a central venous line and incorrect placement with subsequent aspiration risks with naso-enteral feeding tubes. If these potential complications are not in the fore-front of the attending staffs minds then failure to chase up and review the post insertion X-ray's may result in these complications being undetected. It is important to stress that some of these complications may be detected by diligent clinical examination.

The above data may be helpful in designing further error reducing strategies. The use of tick boxes as a pre-operative safety strategy is well described and this has been adopted from the aviation industry.<sup>13</sup> Tick box style sheets may be useful in the ward situation as well and may even be designed to force clinical decisions and prompt appropriate intervention. A tick box for post operative management could be divided into headings based on the errors identified in this study, namely: Fluids, Drugs, Devices, Decisions and Special investigations. Common procedures such as central line insertion and closed tube thoracostomy are ideally suited to the development of formalized tick boxes. Designing a strategy to improve decision-making requires the defence in depth type approach and the APST system used in this audit is an example of this.<sup>3,8</sup> Patients are assessed, by multiple teams during their admission and this increases the chances of poor decisions being detected and corrected. Appropriate levels of seniority are vital for this to be effective.<sup>2</sup>

**Table 2**

Type of error compared to cause of error.

Type of error	Number	Planning	Execution	Omission	Commission
Drug related	11	8	3	4	7
Fluid related	30	24	6	27	3
<sup>a</sup> Device related	6	3	3	3	6
Decision related	5	4	1	4	1
<sup>a</sup> Failure to review investigations	5	0	5	5	0
Total	56	39	18	43	17

<sup>a</sup> There is overlap in these two groups as failure to review X-rays resulted in complications of indwelling device placement being overlooked. It can be argued that these should have been excluded clinically as well as radiologically.

## 5. Conclusion

High-risk acute surgical patients who are not admitted to ICU/HDU for whatever reason need to be appropriately catered for. This requires a level of care higher than what is available in a general ward. We have attempted to combine modern error theory with a simple risk stratification system to improve trauma and acute care surgery in our institution. This audit confirms that these patients are particularly vulnerable to human error and are not in a good position to tolerate error when it does occur. The high rate of interventions and error detection in this audit indicate that that our intervention has achieved its objective and should be continued and strengthened.

### Ethical approval

This work was part of a Phd Proposal. The committee was the Biomedical Research Ethics Committee of the University of Kwa Zulu Natal BREC 104/010.

### Funding

None.

### Author contribution

Dr Clarke is the surgical consultant who as part of his Phd research has instituted the Acute Physiological Support Team. He supervises it and manages the patients in conjunction with his junior staff.

Dr Kong and Dr Furlong were the first two medical officers to work in the APST. They helped develop it's ethos and style of care.

Dr Naidoo assisted with the collection of the error data.

Dr Aldous is a geneticist with a background in education and works as a post graduate facilitator. She is involved in developing the academic capacity of the Pietermaritzburg Complex.

### Conflict of interest

None.

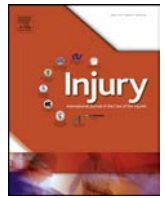
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## A multi faceted quality improvement programme results in improved outcomes for the selective non-operative management of penetrating abdominal trauma in a developing world trauma centre



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### ABSTRACT

**Introduction:** The selective non-operative management (SNOM) of penetrating abdominal trauma (PAT) is well established in our environment. As a quality-improvement initiative, we aimed to re-evaluate patient outcomes with PAT. This follows the application of new imaging and diagnostic modalities using protocolised management algorithms.

**Methodology:** A prospectively maintained digital registry was retrospectively interrogated and all patients with PAT treated by our service from January 2012 to March 2013 were included in this study. **Results:** A total of 325 patients sustained PAT during the fourteen-month study period. This included 238 SWs, 80 GSWs and 7 impalement injuries. 11 patients had eviscerated bowel, and 12 had eviscerated omentum. A total of 123 patients (38%) were selected for a trial of SNOM. This included 103 SWs, 15 GSWs and 5 impalement injuries. Emergency laparotomy was performed on 182 patients (115 SWs, 65 GSWs and 2 impalement injuries) and 21 patients with left sided thoraco-abdominal SWs underwent definitive diagnostic laparoscopy (DL). SNOM was successful in 122 cases (99%) and unsuccessful in one case (1%). In the laparotomy group 161 (88%) patients underwent a therapeutic procedure, in 12 cases (7%) the laparotomy was non-therapeutic and in 9 cases (5%) the laparotomy was negative. In the laparoscopy group (24), two patients required conversion for colonic injuries and one for equipment failure. Seven (33.3%) laparoscopies were therapeutic with the identification and intra-corporeal repair of seven left hemi-diaphragm injuries.

**Conclusion:** We have improved our results with the SNOM of PAT and have also managed to safely and successfully extend the role of SNOM to abdominal GSWs. We have selectively adopted newer modalities such as laparoscopy to assess stable patients with left thoraco-abdominal SWs and abdominal CT scan for the SNOM of abdominal GSWs.

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### Introduction

Shaftan first reported the SNOM of abdominal SWs half a century ago [1]. In the intervening period, the efficacy and safety of this approach has been confirmed by many large series from both the developing and the developed world [2–9]. The SNOM of abdominal gun shot wounds (GSWs) was described at our parent institution two decades ago and has been widely supported in the literature since then [10,11]. Ongoing developments and refinements in technology have resulted in the introduction of newer and improved modalities of imaging, such as computed tomography (CT), the Focussed Assessment of Sonography in Trauma (FAST) and diagnostic laparoscopy (DL) into clinical practice [9].

This makes the management of penetrating abdominal wounds contentious, as these new modalities need to define their place in the management algorithms. We have previously published our experience of the SNOM of abdominal SWs and shown that despite considerable experience and good results with the clinically driven management of PAT, there were specific areas where clinical assessment alone may be inadequate [8].

The aforementioned study was performed prior to the major restructuring of our trauma service. We have since developed a sub-specialist training programme for trauma surgery and implemented dedicated trauma teams led by trauma surgeons. The introduction of an electronic trauma registry [12] and structured morbidity and mortality meetings, have helped us enforce protocols for the management of trauma. We have also selectively adopted newer modalities in response to clearly defined clinical problems identified by our previous study. These modalities include the liberal use of laparoscopy to assess stable,

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non-peritonitic patients with SWs to the left thoraco-abdominal region. In light of these ongoing quality improvement initiatives, we have reviewed our current experience with PAT to document the impact of this multi-faceted quality improvement programme.

## Methodology

The Pietermaritzburg Metropolitan Trauma Service (PMTS) covers two hospitals in the city of Pietermaritzburg and maintains a prospective digital trauma registry [12]. The data from this registry were interrogated retrospectively. Ethics approval to maintain this registry has been obtained from the Biomedical Research Ethics Committee (ethics number BE207/09 BREC) of the University of KwaZulu-Natal and from the Research Unit of the Department of Health. All patients with PAT treated by the PMTS from January 2012 to March 2013 were included in this study.

## Definitions

The boundaries of the abdomen were considered as follows:

1. The anterior abdomen included the subcostal margin forming the superior border, the anterior axillary lines forming the lateral borders and the pubis and inguinal ligaments forming the inferior border.
2. The posterior abdomen included the subcostal margin forming the superior border, the posterior axillary lines the lateral borders and the buttock crease the inferior border.
3. The thoraco-abdominal regions included both the right and left areas between the 4th intercostal space, inferior angle of scapula posteriorly and costal margins inferiorly.
4. The flank was defined as the region between the costal margins superiorly, the anterior superior iliac spine inferiorly, and the space between the anterior and posterior axillary lines.

## Management

Standard ATLS guidelines were adhered to in the resuscitation and acute management of all trauma patients.

### Abdominal stab wounds (Appendix 1)

As in our previous series, emergency laparotomy was considered mandatory for patients presenting with peritonism, hollow visceral evisceration, shock or the presence free intra-abdominal air on erect chest radiograph. All patients with penetrating abdominal wounds from SWs without the aforementioned criteria were considered for a trial of SNOM. Omental evisceration was not considered an indication for mandatory laparotomy. In the absence of clinical signs, the omentum was irrigated, ligated, amputated and replaced into the abdominal cavity and the fascia closed. All patients selected for a trial of SNOM were admitted and kept nil per mouth. Analgesia and intravenous maintenance fluids were administered. Antimicrobials were not routinely administered. The managing surgical trainee reviewed the patient at four hourly intervals. If clinical signs of peritonitis developed, an explorative laparotomy was performed. Following twelve hours of observation, if there was no deterioration in clinical parameters, the patient was commenced on graded oral fluids. A specialist surgeon reviewed all patients the following morning. If well, patients were fed and observed for a complete 24 hour period prior to discharge. Progressive abdominal distension, the onset of peritonitis, shock or sepsis signified failure of the trial of SNOM, and these patients were selected for emergency laparotomy. Patients with left-sided thoraco-abdominal SWs were subjected to semi-elective DL under general anaesthesia to exclude the presence of an injury to the left

hemi-diaphragm. Owing to the protective anatomical position of the liver, asymptomatic patients with right-sided thoraco-abdominal SWs were not selected for DL due to the lesser risk of developing diaphragmatic hernias.

### Abdominal gun shot wounds (Appendix 2)

All patients with an abdominal GSW were considered for laparotomy unless the tract of the bullet was confined to the right upper quadrant, and provided the patient was haemodynamically stable without peritonism. A trial of SNOM was also considered for select cases where the tract was obviously tangential with an extra-peritoneal trajectory. All patients selected for the SNOM of an abdominal GSW were subjected to a 'double contrast' CT scan (IV and oral contrast) to exclude the presence of pneumo-peritoneum, other intra-abdominal injuries and to determine the bullet trajectory. If SNOM was embarked upon, the management protocol followed the same principles as with the abdominal SWs.

## Quality control

All operative cases were discussed at the weekly morbidity and mortality meeting and were classified into:

1. *Therapeutic*: An injury requiring definitive treatment was found.
2. *Non-therapeutic*: An intra-abdominal injury was found that did not require repair, such as a minor liver, mesenteric, or omental injury that had stopped bleeding.
3. *Negative*: When no intra-abdominal injury was found.

## Results

### Demographics

A total of 325 patients sustained PAT during the fourteen-month study period. This included 238 (73%) SWs, 80 (25%) GSWs and 7 (2%) impalement injuries. Of the 80 GSWs, two were from high powered assault rifles (AK-47: 7.62 mm × 39 mm). This deduction was based on the information gathered on clinical history and intra-operative findings. The majority of GSWs, however were typical of lesser muzzle-velocity 9 mm pistols. Eleven patients had eviscerated bowel, and twelve had eviscerated omentum.

There were 294 (90%) male and 31 (10%) female patients, with an average age of 28 years (range 1–85 years). The median Injury Severity Score (ISS) was 9 (IQR 2–9) and the mean duration of in-hospital stay was 7.5 days (range 0–61 days). 62 (19%) patients required admission to either the intensive care unit (ICU) or high dependency unit (HDU), and there were five deaths (1.5%) in the series. There were 173 (53%) cases of isolated abdominal injury and 159 (47%) with additional injuries to other anatomical regions.

### Management

A total of 123 patients (38%) were selected for a trial of SNOM. This included 103 SWs, 15 GSWs and 5 impalement injuries. Emergency laparotomy was performed on 182 patients (115 SWs, 65 GSWs and 2 impalement injuries) and 21 patients with left sided thoraco-abdominal SWs underwent definitive DL.

### SNOM

SNOM was successful in 122 cases (99%) and unsuccessful in one case (1%). All 15 GSWs and the 5 impalement injuries selected

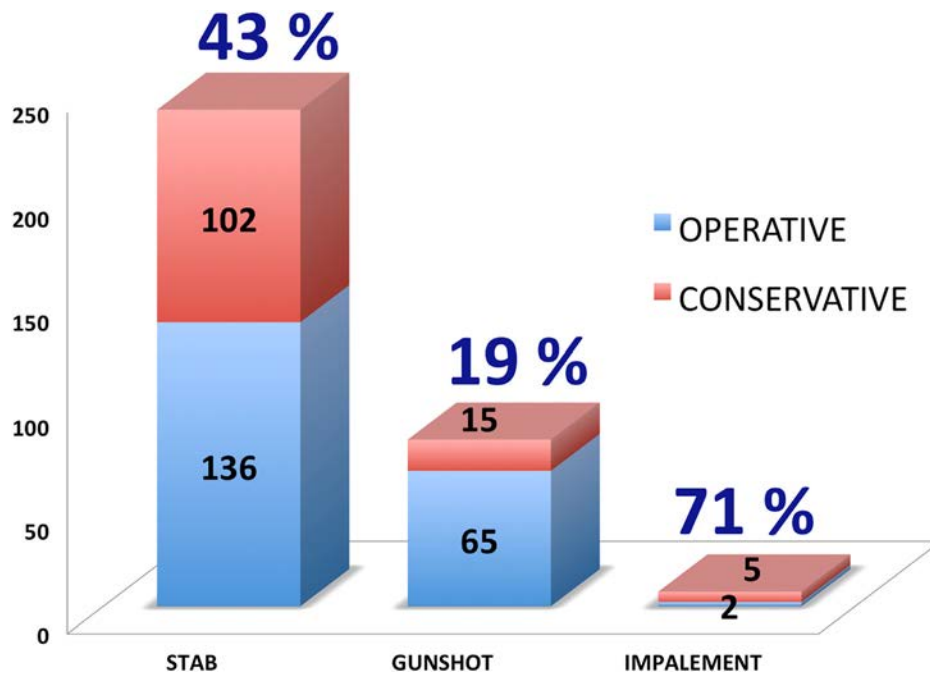


Fig. 1. Numbers and percentages of successful SNOM by mechanism of injury.

for the trial of SNOM were successful. The single case of failed SNOM was a SW to the left subcostal region in the plane of the posterior axillary line. This case complicated with the development of a retro-peritoneal fasciitis, however no intra-abdominal visceral injury was identified at the laparotomy. SNOM was successful in 102 (43%) SWs, 15 (19%) GSWs and 5 (71%) impalement injuries. Of the fifteen GSWs selected for a trial of SNOM, CT scan confirmed injury of the liver in six cases, while the remaining nine were extra-peritoneal without intra-abdominal injury.

Fig. 1 documents the percentage of successful SNOM according to mechanism of injury.

*Eviscerated wounds*

Twelve of 238 SWs presented with eviscerated omentum. Eight (67%) were successfully managed by SNOM. Three had therapeutic laparotomies, while one underwent a non-therapeutic laparotomy.

Eleven SWs presented with eviscerated hollow viscera. This included 10 cases of eviscerated small bowel and a single case of gastric evisceration. All underwent mandatory emergency exploratory laparotomy. Nine patients (82%) had therapeutic laparotomies with the identification and primary repair of hollow viscus injuries. Two (18%) patients had non-therapeutic laparotomies during which no hollow viscus injury was identified.

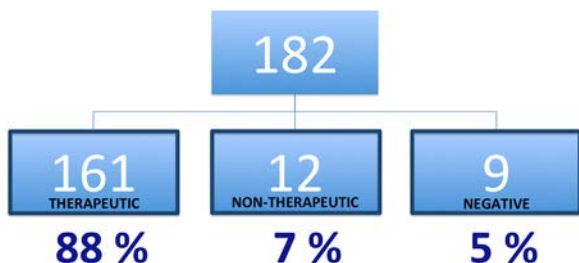


Fig. 2. Outcome of laparotomies.

*Laparotomy*

In the laparotomy group, 161 (88%) patients underwent a therapeutic procedure, in 12 cases (7%) the laparotomy was non-therapeutic and in 9 cases (5%) the laparotomy was negative. These results are illustrated in Fig. 2.

The total number of intra-abdominal injuries included 135 hollow visceral injuries, 97 solid visceral injuries, eight vascular injuries and 37 diaphragm injuries.

*Laparoscopy*

In the laparoscopy group (24), three patients required conversion to laparotomy. Reasons for conversion included the identification of a localised colonic injury at the colonic splenic flexure in two of the cases, and a case of equipment failure. Seven laparoscopies were therapeutic with the identification and intra-corporeal repair of left hemi-diaphragm injuries; one was non-therapeutic with the identification of a grade II splenic injury and thirteen were negative.

Fig. 3 documents the outcome of the laparoscopy group.

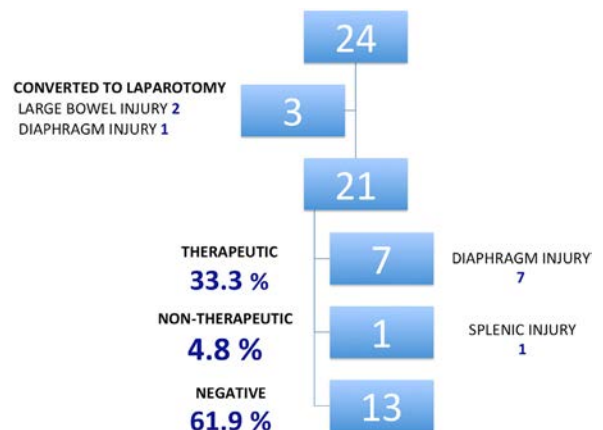


Fig. 3. Operative classification laparoscopies performed for PAT.

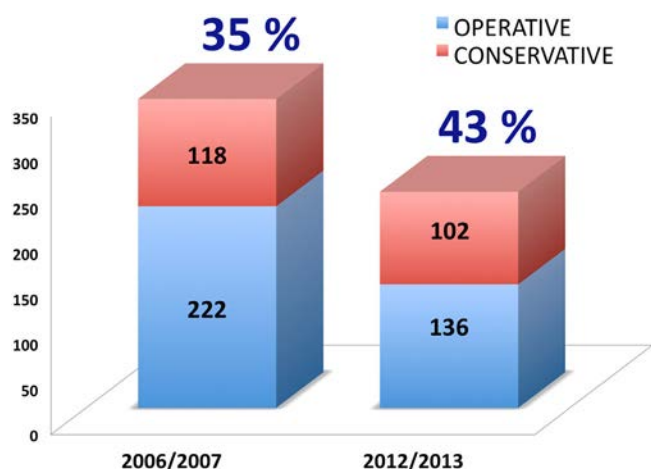


Fig. 4. Comparison of numbers and percentages of SNOM for SWs between studies.

#### Comparison with previous data

We compared our current data with previously published data from our institution. This earlier study focused exclusively on abdominal SWs. The incidence of failed SNOM declined from 30 out of 148 (20%) cases, to 1 out of 103 (1%) cases. The total percentage of abdominal SWs successfully managed by non-operative means, increased from 35% in the previous series to 43% in the current series. There were no delayed laparotomies of greater than twelve hours in the current group. The total percentage of non-therapeutic and negative laparotomies increased from two percent to fifteen percent. A total of five percent of patients underwent a truly negative laparotomy in the current group compared to two percent in the previous series. Figs. 4 and 5 compare the outcomes between 2006 and 2007 study and the current one.

#### Discussion

The philosophy and practice of SNOM of PAT in our environment developed as a direct result of the incredible pressure of a large patient load on extremely limited resources [2]. Although our earlier report confirmed this large burden of disease and our relatively good results with a SNOM approach, it also identified a sub-group of injuries in which serial clinical examination had proved to be misleading [8]. The anatomical area of concern was

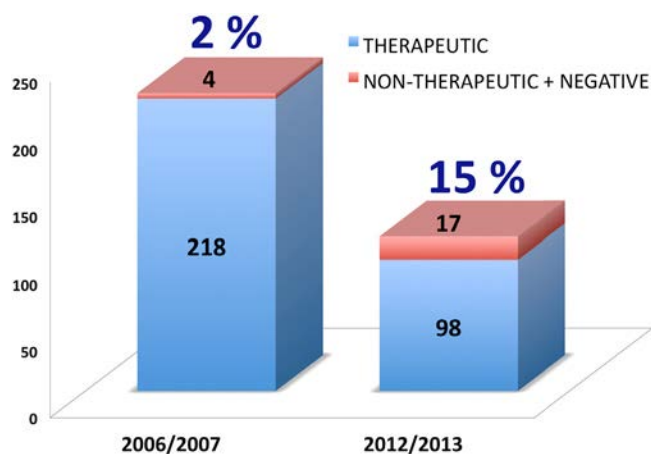


Fig. 5. Comparison of classification of operative findings for SWs between studies.

the left thoraco-abdominal region and the right upper quadrant (RUQ).

Injury to structures in the upper gastro-intestinal tract may not manifest with overt clinical peritonitis. In our previous series the most common visceral injury to result in failure of SNOM was perforation of the stomach and injury to the extra-hepatic biliary tract [8]. Gastric content tended to drain into the RUQ and not cause overt symptoms. Bile collections secondary to extra-hepatic biliary injury might also not precipitate significant abdominal signs. In the cohort of our former study, 13 (7%) patients selected for SNOM only had a therapeutic laparotomy after twelve hours. This delay was associated with increased morbidity. Our earlier report made a number of suggestions as to how to improve the results of SNOM [8]. These included the introduction of protocols and formal observation charts and the judicious use of special investigations.

In light of this we have implemented a number of quality improvement strategies and interventions. We have developed our trauma service extensively since our previous report. We have improved our staffing levels and established dedicated trauma teams. We have introduced structured morbidity and mortality meetings and a sub specialist-training programme in trauma surgery. Formal management protocols are emphasised through regular meetings and educational initiatives.

We have improved the management of PAT by reducing the rate of failed SNOM from twenty percent to one percent. This must be balanced against the fact that the rate of negative and non-therapeutic laparotomy has increased from two percent to fifteen percent. The overall rate of negative laparotomies in the current study was five percent; a value we believe is acceptable within international standards [11]. We have eliminated the problem of delayed recognition of the need for surgery for greater than twelve hours with its associated morbidity, at the expense of an increased rate of negative and non-therapeutic laparotomy. Attempting to reduce the incidence of non-therapeutic laparotomy may be very difficult at the risk of escalating the rate of morbidity of missed injuries and failed SNOM. With continued developments in our metropolitan trauma service and ongoing audits, we aim to ultimately reduce our incidence of non-therapeutic laparotomies for PAT.

In 1990 Muckart et al. described SNOM of abdominal GSWs in Durban [10]. Out of 111 patients with low velocity abdominal GSWs, laparotomy was only undertaken in 89 patients (80 percent). There were seven negative laparotomies in this group. The remaining 22 patients all underwent successful conservative management. Since then there have been many reports documenting the safety and efficacy of this approach [11]. Almost all of the more recent reports use CT to assess the path of the bullet and to assess intra-abdominal injuries. We have introduced SNOM of GSWs at our institution in light of this growing body of evidence. We have enforced strict protocols for these patients and our results have been successful.

A recent large multi-centre review of SNOM of penetrating trauma has shown that it is successful in 40 percent of SWs and 20 percent of GSWs [11]. This is very much in keeping with our current results.

We have adopted a much more aggressive approach with the use of laparoscopy for left sided thoraco-abdominal SWs without any clinical signs of peritonism. We had a very high rate of positive findings in this group of just over forty percent. The left thoraco-abdominal area is difficult to evaluate. The liberal use of laparoscopy for penetrating thoraco-abdominal trauma has also helped to reduce the incidence of failed SNOM and delayed recognition of injury [8]. In our previous series, gastric injuries and injuries to the splenic flexure of the colon



had a propensity for delayed recognition. This was ascribed to the anatomy of the area and the relatively inert nature of gastric content. Our current experience re-enforces this viewpoint with the recognition of splenic flexure colonic injuries in two patients. The high prevalence of occult diaphragmatic injuries provides further support to the approach of routine semi-elective DL for all stable and asymptomatic patients with left thoraco-abdominal SWs.

Our approach to the stab abdomen with eviscerated omentum has been vindicated by our results. Two-thirds of patients with this type of injury were successfully managed by SNOM in our current series. Eviscerated omentum in itself is not an indication for laparotomy [6,7]. Eviscerated bowel or solid organs on the other hand are an indication for surgery. The operative group had a broad spectrum of intra-abdominal injuries as can be expected from a series of PAT. As in similar studies, small bowel and gastric injuries predominated [9]. With regards to solid visceral injury, liver and renal injuries predominated.

**Conclusion**

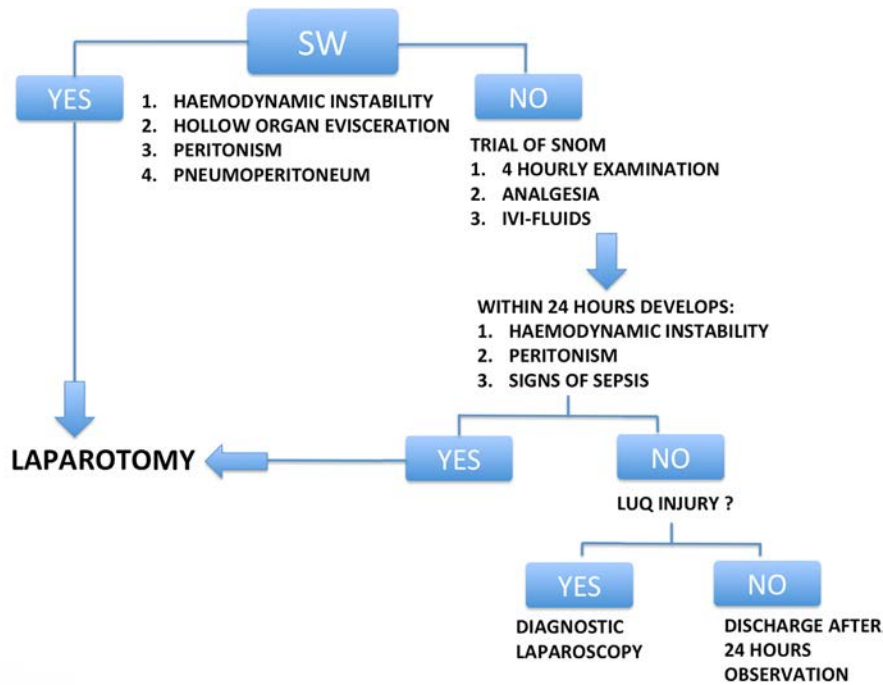
We have improved our results with the SNOM of PAT by implementing a multifaceted quality improvement programme. This involves educational initiatives and the implementation and enforcement of strict protocols. This has allowed us to reduce our rate of failed SNOM dramatically. We have managed to safely and successfully extend the role of SNOM to abdominal GSWs.

We have selectively adopted newer modalities and applied them to specific problem areas, which we have identified from previous audits. The use of DL to assess stable patients with left thoraco-abdominal penetrating injuries has reduced the incidence of delayed diagnosis of hollow visceral injury and of occult diaphragmatic injury. The use of abdominal CT scan is essential in the SNOM of abdominal GSWs.

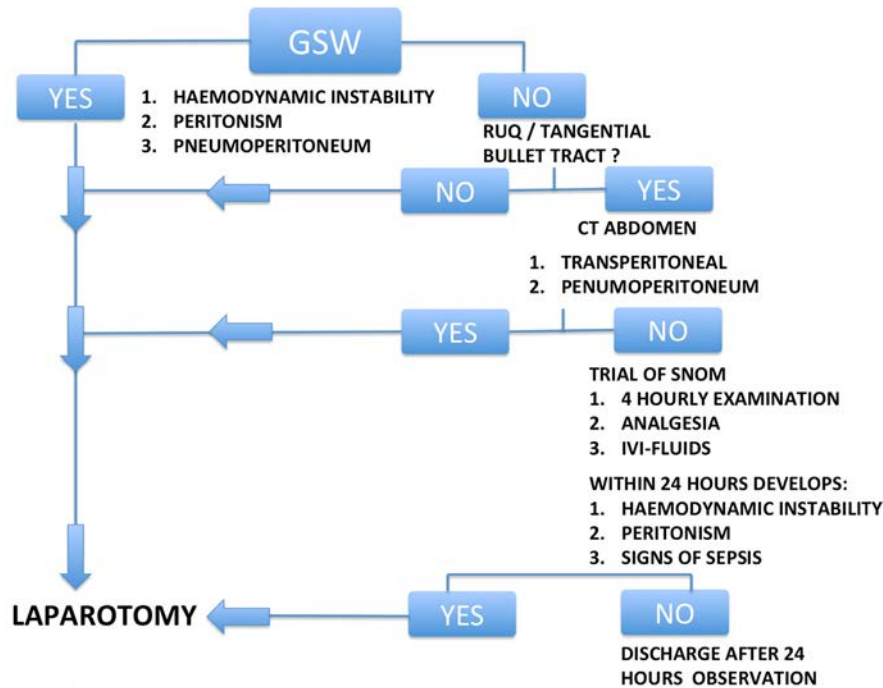
**Conflict of interest**

None declared.

**Appendix 1. PMTS algorithm illustrating the management of abdominal SWs**



## Appendix 2. PMTS algorithm illustrating the management of abdominal GSWs



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## Summary

### *Publication 10: Surgical outreach in rural South Africa: Are we managing to impart surgical skills?*

This paper reviews a major intervention designed to improve the quality of trauma and acute surgical care in rural KwaZulu-Natal and represents an attempt to improve both the inputs and the process of care. The authors assess the impact of this programme by looking at both its immediate outputs (the delivery of surgical care to rural hospitals) and its impact on the development of surgical skills amongst rural staff. The study shows that despite a significant input there has been little transfer of skills to the district staff and goes on to discuss the inherent difficulties in achieving this skill transfer. The article discusses the strategic options, which were covered in Publication 1, which reviewed the capacity of the rural hospitals in Sisonke District. These options are to continue to attempt to strengthen rural hospitals in terms of surgical capacity or to bypass them.

### *Publication 11: Using a structured M&M meeting to understand the contribution of human error to adverse surgical events in a South African Regional hospital*

This is a continuation and extension of the previous publication on error associated with rural trauma care and looks at the structured M and M meetings in more detail. It reviews 30 patients discussed at twenty M and M meetings over a six-month period. The authors identify a set of errors and analyse them according to a modified version of the previously used taxonomy. The methodology of the study has application in a number of ways and feeds directly into the next two publications. These look at the impact of error awareness training using error case studies on the attitudes and knowledge of junior staff and the use of tick boxes to improve the quality of documentation and to provide clinical decision support.

### *Publication 12: An educational programme for error awareness in acute trauma for junior doctors*

The study presents the results of five structured interviews conducted by an educationalist to determine the 'efficacy' of an educational intervention designed to teach to junior doctors about human error and its impact on patient care. The junior doctors who had been exposed to the error awareness programme provided more structured and comprehensive answers to the cases of error they were presented with. This small study provides qualitative support for the ongoing multi-faceted programme to improve trauma care by focusing on error awareness amongst junior doctors.

*Publication 13: Incorporating clinical algorithms into tick box clerking sheets improves the quality of the documentation of acute trauma patients but has a less clear impact on clinical behavior*

The study is an extension of the work on error theory, which is a theme throughout this thesis and audits the introduction of a new trauma tick-box style clerking sheet. This tick-box clerking sheet aims to improve the documentation of patients and to direct care down specific clinical algorithms depending on data recorded. This is in direct response to the poor documentation identified in a number of earlier publications and to the review of the errors associated with resuscitation and assessment of patients in rural hospitals. The authors found that the quality of the recorded data was significantly improved by the introduction of the sheets. However, attempts to direct care down appropriate clinical pathways was less successful. There were a number of reasons for this foremost of which was the poor compliance with the so-called decision nodes in the tick-box sheets. A significant contributor to this non-compliance may have been cognitive dissonance, which was elegantly demonstrated in the study. Cognitive lock out or dissonance is a concept from modern industrial psychology and error theory whereby observers actively suppress stimuli, which challenge a preconceived view of reality. This paper is a central one as it brings together a number of themes, academic constructs and findings from the previous papers, and points the way forward in terms of the introduction of digital clinical records and digital decision support systems which are based on the observed behaviour of junior doctors in this study.

*Publication 14: The introduction of an acute physiological support service for surgical patients is an effective error-reduction strategy*

This work also flows from the discussion on error theory that has taken place throughout the thesis. It reviews 101 surgical patients managed by an 'Acute Physiological Support Team' (APST) and describes the errors in patient management identified by the APST. It makes use of a modified version of previously used taxonomies to analyze these errors and describes a total of 143 clinical interventions which were initiated by the APST in response to the errors they identified. This paper, like the previous two, shows how the academic construct of modern error theory and the findings of the situational analysis can be used to inform the development of a successful targeted quality improvement programme. The paper describes the successful implementation of a so-called defense in-depth error-reduction strategy.

*Publication 15: A multi-faceted quality improvement programme results in improved outcomes for the selective non-operative management of penetrating abdominal trauma in a developing world trauma centre*

This audit of a common trauma-related condition uses the clinical outcomes of this pathology as a proxy marker for the quality of trauma care in general. The authors compare the outcome of the management of penetrating abdominal trauma from an earlier period in the history of the PMTS with a more contemporary period. Since the earlier period there has been

considerable restructuring of the process of care. This restructuring is described in the study. There are dedicated trauma teams and the structured morbidity and mortality meetings are described. This suggests that the ongoing efforts to improve quality are resulting in improved clinical outcomes.

These six diverse papers collectively represent a multi-faceted programme designed to uplift rural trauma care in Sisonke District. Their results have been mixed and provide evidence of the magnitude of the task of improving clinical outcomes in such a complex system. It has to be acknowledged that changing the culture of a system and restructuring its processes has a five to ten-year lead time prior to improved results becoming obvious. The final paper, however, suggests that a sustained multi-faceted strategy does eventually translate into improved clinical outcomes. This leads on to the final chapter, which attempts to put the above work in perspective and identify future projects emanating from this thesis. The final chapter also discusses the contribution this thesis has made to the body of knowledge and demonstrates a number of areas for research flowing from the themes introduced in this work and making use of the tools developed in it.

## Chapter Five: Discussion and Implications

This thesis has generated a unique structure to contextualise and integrate quality improvement programmes using a number of academic constructs from other disciplines. Table 5.1 summarises the entire thesis and places each publication into its context by making use of the overarching grid structure originally presented in Chapter Two. The academic constructs, which have been used in this project, such as strategic planning and error theory, are contextualised under the strategic-planning tools. The various projects, which reviewed the inputs of trauma care in terms of the burden of disease and the capacity of the rural hospitals to manage this load are placed in the analysis/inputs block. The audits, which review the process of care in Edendale Hospital and Sisonke District, are placed in the analysis/process block and the audits which review the outcome of care are placed in the analysis/outcome grid. An audit of the incidence of human error associated with trauma care in rural hospitals revealed a high incidence of preventable error associated with significant morbidity and mortality. An audit of the quality of burn care revealed a number of deficits in the care of burn patients. These two publications are placed in the analysis/outcomes block. This bird's-eye view suggests that the capacity to deal with this huge burden of disease is inadequate and this translates into care of an uneven quality.

In response to this, a multi-faceted quality improvement programme was instituted which attempted to address both the inputs of care and the processes of care. A surgical outreach programme has delivered surgical care to rural hospitals but has been less successful at transferring surgical skills to rural staff. The surgical outreach programme represents an initiative aimed at improving the inputs to the system and, as such, is situated in the appropriate block in the grid structure. Restructured morbidity and mortality meetings and error-awareness programmes, have impacted positively on the understanding and insight of junior staff. These also represent initiatives aimed at improving the inputs of care. Ergonomic restructuring in the form of tick-box clerking sheets and the development of the Acute Physiological Support Team have also improved the quality of care in Edendale Hospital. These represent initiatives designed to improve the process of care. Each of these projects has been situated in the synthesis/implementation part of the grid structure according to which component of the system they are designed to improve.

The development of the Pietermaritzburg Metropolitan Trauma Service and its gradual, but steady, development over the last seven years has improved both the inputs and the processes of care for trauma patients in Pietermaritzburg. The improved results for the management of penetrating abdominal trauma are testament to this. The increased structure associated with the development of dedicated teams for burns and trauma with formal training programmes and academic meetings has undoubtedly improved outcomes.

This project was envisaged as a driver of change and quality improvement in Pietermaritzburg and has already led to a series of more specific projects towards a number of higher degrees as well as for non-degree research. The interest in the quality of care in Sisonke District has led to a project looking at the spectrum and outcome of care of acute appendicitis in the district. An audit of acute appendicitis revealed that there was a problem with delayed referral of acute appendicitis and this resulted in poor outcomes in comparison to the developed world. Further research demonstrated that the outcome of acute appendicitis was worse in patients from Sisonke District than in patients from the peri-urban areas around Pietermaritzburg. This implied that the quality of surgical care as a whole in Sisonke District was sub-optimal. These inadequate processes of care translated into significant preventable costs for acute appendicitis. We have identified that there are significant delays in the diagnosis of acute appendicitis and that this translates into increased morbidity and increased costs. It would appear that the inability of staff to recognise the condition is an important variable that needs to be addressed if we wish to improve the care of acute appendicitis. This led to a study which assessed whether the introduction of a formal scoring system for acute appendicitis such as the Alvarado score would be appropriate in our environment. This work on appendicitis in itself constituted a distinct PhD thesis. All this work reinforced the realisation that projects designed to improve the transfer of appropriate surgical skills to district level staff are urgently needed. However, it may well be that this proves to be too difficult to achieve and that the more strategic approach is for trauma and acute surgery to bypass the district hospital system. Further work is needed to determine the most appropriate solution to this problem.

One of the major deficits of any quality improvement initiative in the past was the lack of any meaningful registry to measure the burden of disease and to quantify and benchmark clinical outcomes. A second project extends the concept of the electronic surgical registry and attempts to use it to improve care, clinical research and clinical governance by allowing more detailed audit and the tracking of quality metrics. This registry has since been expanded to integrate the pre-printed surgical tick-box clerking sheets into a hybrid electronic medical record system which allows for the capture of data in real time. This system also attempts to include the concept of an electronic clinical decision support system. This system has already been successfully piloted and has begun to generate basic clinical audits which provide an overview of the burden of disease and which allow for clinical research and for the identification of ongoing quality improvement initiatives. The data from this system now inform the structured morbidity and mortality meetings, and this work currently forms the basis for another PhD project in the PMTS. Several papers have already been published from this new project and they are listed as ancillary projects in the Declaration of Publications – see p.vi.

Out of these new registries a number of clinical audits have also emanated from these systems. In addition to burns and acute appendicitis, a number of other traumatic conditions

and procedures have been audited using the new information systems and the results from those audits are being used to develop targeted quality improvement initiatives. These include an audit of the complications of intercostal chest drain insertion and of the management of trauma in a number of vulnerable groups with special needs such as pregnant patients. These audits have allowed us to review our protocols and refine our processes of care. Ongoing audits will show whether we have managed to improve outcomes over time.

The restructuring of burns care has been a quality improvement priority for a number of years and a major intervention has been the institution of a dedicated burn team. A unique burn-specific electronic database has been developed and is being piloted. There are plans to develop burn care as a separate department within the PMTS. A follow-up publication on the restructuring of burns care has recently been published and highlights some of the improvements in the service, as well as a number of ongoing challenges and areas of concern. It is intended that all these Quality Improvement Programmes will form the basis of ongoing research endeavours for both higher degrees and non-degree purposes. Table 5.1 concludes this thesis and situates all the publications in the thesis and emanating from the thesis, within the previously described overarching grid structure (Chapter Two).



**Table 5.I: Contextualisation of all the publications within the overarching strategic structure**

Vision	Quality metric	Quality metric	Quality metric	
<p><b>Mission</b></p> <p><b>Analysis</b></p> <p>Quality Metrics</p> <p>Error Theory</p> <p>A concept paper: using the outcomes of common surgical conditions as quality metrics to benchmark district surgical services in South Africa as part of a systemic quality improvement programme.<sup>1</sup></p> <p>Applying modern error theory to the problem of missed injuries in trauma.<sup>2</sup></p>	<p><b>Inputs</b></p> <p>Assessing the gap between the acute trauma workload and the capacity of a single rural health district in South Africa. What are the implications for systems planning?<sup>3</sup></p> <p>Understanding the burden and outcome of trauma care drives a new trauma systems model.<sup>4</sup></p>	<p><b>Processes</b></p> <p>An audit of the quality of care of traumatic brain injury at a busy regional hospital in South Africa.<sup>5</sup></p> <p>Variations in levels of care within a hospital provided to acute trauma patients.<sup>6</sup></p> <p>Establishing the feasibility of a nursing driven modified early warning system (MEWS) in a South African regional hospital.<sup>7</sup></p> <p>Understanding the reasons for delay to definitive surgical care of patients with acute appendicitis in rural South Africa.<sup>8</sup></p> <p>The accuracy of the Alvarado score in predicting acute appendicitis in the black South African population needs to be validated.<sup>9</sup></p> <p>What is the yield of routine chest radiography following tube thoracostomy for trauma?<sup>10</sup></p>	<p><b>Outcomes</b></p> <p>The implications of the patterns of error associated with acute trauma care in rural hospitals in South Africa for quality improvement programmes and trauma education.<sup>11</sup></p> <p>The spectrum and outcome of burns in a regional hospital in South Africa.<sup>12</sup></p> <p>Acute appendicitis in a developing country.<sup>13</sup></p> <p>The cost effectiveness of early management of acute appendicitis underlies the importance of curative surgical services to a primary health care programme.<sup>14</sup></p> <p>Quantifying the disparity in outcome between urban and rural patients with acute appendicitis in South Africa.<sup>15</sup></p> <p>The spectrum of visceral injuries secondary to misplaced intercostal chest drains: Experience from a high volume trauma service in South Africa.<sup>16</sup></p> <p>Selective conservatism for penetrating thoracic trauma is still appropriate in the current era.<sup>17</sup></p>	<p><i>Metrics Analysis</i></p>
<p><b>Synthesis and Implementation</b></p> <p>Generic quality improvement strategies.</p> <p>Increase resources</p> <p>Improve process</p>	<p>Surgical outreach in rural South Africa: are we managing to impart surgical skills?<sup>18</sup></p> <p>Using a structured morbidity and mortality meeting to understand the contribution of human error to adverse surgical events in a South African regional hospital.<sup>19</sup></p> <p>An educational programme for error awareness in acute trauma for junior doctors<sup>19</sup></p> <p>The design, construction and implementation of a computerised trauma registry in a developing South African metropolitan trauma service.<sup>20</sup></p> <p>Development, implementation and evaluation of a hybrid electronic medical record system specifically designed for a developing world surgical service.<sup>21</sup></p> <p>The design, construction and implementation of a computerized trauma registry in a developing South African metropolitan trauma service.<sup>22</sup></p>	<p>Tick-box admission forms improve the quality of documentation of surgical emergencies, but have limited impact on clinical behavior.<sup>23</sup></p> <p>The introduction of an acute physiological support service for surgical patients is an effective error-reduction strategy.<sup>24</sup></p> <p>Using a Hybrid Electronic Medical Record system for the surveillance of adverse surgical events and human error in a developing world surgical service.<sup>25</sup></p> <p>Challenges and merits of improving burn care in South Africa.<sup>26</sup></p>	<p>A multi-faceted quality improvement programme results in improved outcomes for the selective non-operative management of penetrating abdominal trauma in a developing world trauma centre.<sup>27</sup></p> <p>The spectrum and outcome of pregnant trauma patients in a metropolitan trauma service in South Africa.<sup>28</sup></p>	<p>Develop targeted Quality Improvement Programmes Metrics</p>
<b>Vision</b>	Quality metric	Quality metric	Quality metric	Metrics

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## Appendix A: Ethics approval



18 December 2012

Dr. DL Clarke  
Grey's Hospital  
Private Bag X9001  
Pietermaritzburg  
3200

Dear Dr Clarke

**PROTOCOL: Developing a multi-faceted approach to uplifting and improving trauma care in the periphery. REF: BF104/010**

The Biomedical Research Ethics Committee (BREC) has considered the abovementioned application.

The study was provisionally approved by a quorate meeting of BREC on 08 June 2010 pending appropriate responses to queries raised. Your responses dated 28 November 2012 to queries raised on 22 December 2010 have been noted by a sub-committee of the Biomedical Research Ethics Committee. The conditions have now been met and the study is given full ethics approval and may begin as from 18 December 2012.

This approval is valid for one year from **18 December 2012**. To ensure uninterrupted approval of this study beyond the approval expiry date, an application for recertification must be submitted to BREC on the appropriate BREC form 2-3 months before the expiry date.

Any amendments to this study, unless urgently required to ensure safety of participants, must be approved by BREC prior to implementation.

Your acceptance of this approval denotes your compliance with South African National Research Ethics Guidelines (2004), South African National Good Clinical Practice Guidelines (2006) (if applicable) and with UKZN BREC ethics requirements as contained in the UKZN BREC Terms of Reference and Standard Operating Procedures, all available at <http://research.ukzn.ac.za/Research-Ethics/Biomedical-Research-Ethics.aspx>. BREC is registered with the South African National Health Research Ethics Council (REC-290408-009). BREC has US Office for Human Research Protections (OHRP) Federal-wide Assurance (FWA 678).

Professor D Wassenaar (Chair)  
Biomedical Research Ethics Committee  
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ding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville



The following Committee members were present at the meeting that took place on 08 June 2010:

Professor D Wassenaar	Chair
Professor V Rambiritch	Pharmacology
Ms T Esterhuizen	Faculty of Medicine
Dr M A Sathar	Medicine
Dr Z Khumalo	KZN Health (External)
Mrs P Naidoo	External
Professor S Collings	Psychology
Ms J Hadingham	External
Prof R Bhimma	Paediatrics and Child Health
Prof L Puckree	Physiotherapy
Dr R Govender	Family Medicine
Dr S Paruk	Psychiatry
Dr T Hardcastle	Surgery – Trauma

We wish you well with this study. We would appreciate receiving copies of all publications arising out of this study.

Yours sincerely



**PROFESSOR D R WASSENAAR**  
Chair: Biomedical Research Ethics Committee



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Website: <http://research.ukzn.ac.za/ResearchEthics/BiomedicalResearchEthics.aspx>

19 September 2013

Dr. DL Clarke  
Grey's Hospital  
Private Bag X9001  
Pietermaritzburg  
3200

Dear Dr Clarke

**PROTOCOL: Developing a multi-faceted approach to uplifting and improving trauma care in the periphery. REF: BF104/010**

We wish to advise you that your letter dated 12 September 2013 in response to BREC letter dated 12 September 2013 has been noted and your letter dated 31 July 2013 requesting approval of Amendments for the above study has been approved by a sub-committee of the Biomedical Research Ethics Committee.

This approval will be ratified at a full committee meeting to be held on **08 October 2013**

Yours sincerely

A handwritten signature in blue ink, appearing to read 'D R Wasseenaar'.

**PROFESSOR D R WASSENAAR**  
Chair: Biomedical Research Ethics Committee

**health**

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Date: 02/10/2012  
Ref :2/6/3

Damian Clarke

**RE: PERMISSION TO CONDUCT RESEARCH AT DISTRICT /FACILITIES**

I have pleasure in forming you that permission has been granted to you by the Sisonke District Research Committee to conduct research on "A multifaceted approach to uplifting trauma care in the periphery."

Please note the following:

1. Please ensure that you adhere to all the policies, procedures, protocols and guidelines of the Department of health with regards to this research.
2. This research will only commence once this office has received confirmation from the Provincial Health Research Committee in the KZN, Département of Health.
3. Please ensure this office is informed before you commence your research.
4. The District office /Facility will not provide any resources for this research.
5. You will be expected to provide feedback on your findings to the District Research Committee and the District Management Team.

Thanking you

Regards

Mrs G.L.L. Zuma  
Sisonke Health District Research Committee Chairperson