A REVIEW OF FCRAD DIAG (SA) EXAMINATION RESULTS OVER TEN YEARS

By

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Declaration

I, Dr Vishnu Ramoorthy declare as follows:

1) The research reported in this dissertation, except where otherwise indicated, is my original work.
2) This dissertation has not been submitted to UKZN or any other institution for the purposes of an academic qualification, whether by myself or any other party.
3) That my contribution to the project is as follows:

   Principal author, literature review, data collation and synthesis.
4) That the contribution of others to the project are as follows:

   Dr V Du Plessis supervised the manuscript at all stages.
5) This dissertation does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.
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Overview

Over the past few decades, there have been major technological advancements in the field of diagnostic radiology, as imaging has become indispensible to patient diagnosis and management. Not only are multiple imaging modalities now available, but digital image capturing, storage, and transmission have resulted in a filmless modern hospital setting. Coupled with the ever-widening spectrum of disease, radiologists require a broader and more detailed knowledge base, while facing an increased workload.

Consequently, South African postgraduate radiology training programmes have had to adapt. Current radiological examination formats need to encompass multiple imaging modalities, a digital platform, a wider disease spectrum, and a more pressured work environment. In addition, continued research into the field of medical education has lead to several key role-players desiring an evaluation of the current examination format, as there is, to date, a profound lack of research on this topic in the South African context.

The purpose of this retrospective audit and historical study was to determine whether recent changes in the formats of the FCRadDiag (SA) examinations have impacted on candidate success rates, as well as determining which formats created the most impact on candidate success rates.

This was done by evaluating the candidate results for the Part I and II College of Radiology examinations over a ten-year period from September 2003 to March 2013, and comparing the success rates of candidates before and after several key changes in the examination format over this time period.

It is hoped that this information will serve as a useful guide to medical educators and radiology examiners in the College of Radiology in the development of a fair, valid and

reliable examination structure; as well as directing radiology examinees with the development of a blueprint of radiology examinations which could be used to guide training, learning and examination preparation.

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CHAPTER 1

Introduction

Internationally, principles around postgraduate medical training and outcome assessment are currently changing. Most of these changes are centered on maximizing learning and feedback opportunities in ever-expanding, time-constrained work environments.[1]

This is based on the need to find time and resource efficient examination techniques, which test contextual and practical knowledge while also assessing professionalism and patient interaction. Medical education is unique in this regard as structured clinical scenarios as well as theoretical examinations are equally important to assess overall competence in both formative and summative examination assessments.

Radiology is also unique in that recent technological advances in image acquisition as well as Picture Archiving and Communication Systems (PACS) and Radiology Information System (RIS) have resulted in several changes to both the working environment and workload of the modern radiologist. This has consequently impacted on radiology training, which needs to encompass the necessary skills, knowledge and attributes required to function appropriately in practice as a specialist in the field.[1]

Radiology trainees require perceptual and observational skills such as pattern recognition, image interpretation and deductive reasoning. In addition, they need practical proficiency to perform diagnostic and therapeutic procedures. Examinations thus need to accurately test these specific abilities in a reliable, valid and fair manner without effecting any changes in pre-determined set standards.[2,3]

References

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Literature Review

There has been a profound lack of research into different examination formats with regard to radiology in South Africa. The fundamental concept is that medical training must result in a standard of practice that provides the high quality of medical care expected by society. This dictates that the assessment of medical students and physicians must be of the highest standard and pre-determined methods of assessment should undergo rigorous evaluation to ensure testing methods are current while remaining as fair and valid as can be achieved[1].

During review of the literature it was found that there is a wealth of research surrounding the topic of assessment in medical education including formats, goals and methods. A review of several publications in the field of learning, assessment and education was undertaken to provide a broad and informative background of research into the topic. This background was vital in understanding the concepts related to assessment in medical education and formed the crux around which the proposal was designed.

Heath professions education is a unique discipline in that there are several different types of professions, each of which provide a wide variety of different services in differing settings. All these different medical disciplines require highly demanding courses of study designed to impart theoretical and clinical knowledge, as well as instilling professionalism, interpersonal skills and a code of ethics essential in delivering optimal patient care[4].

Assessment is defined by the *Standards for Education and Psychological Testing* (AERA (American Education Research association), APA (American Psychological Association), &NCME (National Council of Measurement in education), 1999, p.172) as ‘any systematic method of obtaining information from tests and other sources, used to draw inferences about characteristics peoples, objects or programmes.’ Assessment is entering every phase of

professional development and is a crucial step in the educational process. Good quality assessment not only evaluates candidates for potential advancement or accreditation but also drives the students learning'[3].

Extensive research has been done on commonly used and emerging methods of assessment, discussing the strengths and weaknesses of each method as well as outlining the challenges in assessment of medical professional competence particularly in the context of large scale standardized testing programmes[5].

The main role of examinations is to assess competence and provide insight into actual performance. Competence may be divided into six domains: medical knowledge, patient care, professionalism, communication and interpersonal skills, practice based learning and improvement and systems based practice[6]. Competence can be contextual or developmental. Contextual competence is dependant on the clinical setting, the patient and clinician's education level, as well as the local prevalence of disease, while developmental competence is gained through deliberate practice and reflection on experience[4]. Competence itself shows great variability across tasks and is therefore difficult to measure[5].

Assessment has three main goals: to optimize the capabilities of learners by directing future learning, to protect the public by identifying competent physicians, and to provide a base for choosing applicants suitable for advanced training[6].

There are two types of assessment: formative assessment guides future learning by providing feedback on student strengths and weaknesses with respect to learning objectives. This usually takes place during the course of study usually in the form of weekly short quizzes or shorter tests administered during a course or module. Summative assessment on the other hand, typically takes place at the end of the year or course of study and is an overall judgment about competence or fitness to practice. Feedback is one aspect of summative assessment but the main purpose is to determine what the student has learnt during the period of instruction. The type of assessment often guides the methods used to evaluate competence, which makes determination of the type of assessment important in structuring an assessment model[6].

Different assessment methods have been studied by various authors in terms of 5 criteria outlined by Van der Vleuten (1996)[7]. These criteria are: Validity (whether the assessment

measures what it claims to measure), reliability (the degree to which the measurement is accurate and reproducible), impact on future learning and practice; acceptability to learners and faculty; and costs (to the trainee, institution and society).

The understanding of validity, in particular, was found to be essential as it pertains to any and all forms of assessment techniques and is a ubiquitous principle in the discussion of education[8]. With regard to validity, there are several different types:

- External validity occurs when the causal relationship discovered can be generalized to other people, times and contexts.
- Internal validity is a measure which ensures that causal relationships can be determined (i.e. cause and effect).
- Construct validity is a type of validity that refers to a measure of the extent to which a test measures a hypothetical and unobservable variable or quality. This is an assessment of the quality of an instrument or experimental design. This can be sub-divided into convergent validity (where measures of constructs that are expected to correlate do so); and discriminate validity (where constructs that are expected not to relate do not).
- Content validity occurs when the test or experiment provides adequate coverage of the subject being studied. Or in other words it is a type of validation that refers to the relationship between a test and the instructional objectives and is thus related very closely to good test design.
- Criterion-related validity is a type of validation that refers to the extent to which scores from a test relate to theoretically similar measures. Criterion-related validity is related to external validity. This can be sub-divided into predictive validity, which measures the extent to which a future level of a variable can be predicted from a current measurement, and concurrent validity, which measures the relationship between measures, made with existing tests.
- Face validity occurs when something appears to be valid and is very dependant on the judgment of the observer. This type of validity alone is never sufficient and requires more solid validity to enable acceptable conclusions to be drawn.

It is important to note that validity can never be finally determined and is specific to each administration of the test.

Millers pyramid (1990) is often cited as a useful model of knowledge and skills with respect to assessment in health education, and represents an important framework within which assessment can occur[9]. At the base of the pyramid is the assurance that the candidate has the cognitive knowledge base required to carry out their professional functions effectively. This is the 'knows' level of factual knowledge on which more complex learning can begin and is the pre-requisite for all other types of learning. This is best measured by written objective tests.

It is also important that the candidate 'knows how' to acquire information from patient and laboratory sources, analyze and interpret these data and synthesize a rational diagnosis and management plan. This is a closer measure of functional adequacy than a pure reliance on simple factual knowledge and recall and indicates a student's ability to manipulate and apply knowledge.

This can also be assessed with carefully constructed written tests, oral exams or subjective observational methods. Examinations still however do not fully evaluate that a candidate knows what to do when faced with a patient or a real-life clinical scenario. It is thus essential that a candidate demonstrates or 'shows how' they will handle these situations. This is a demonstration of performance, which forms the third step on the ladder. All such performance exams are conducted in controlled conditions and use standardized patients/situations and check lists or ratings scales to assess students. These standardization procedures add to the measurement qualities of assessment but detract from authenticity of the assessment.

Finally the question of whether what is done during an artificial examination setting can predict what a candidate does in independent practice. This is the action component of professional behaviour which is the most difficult to measure. Miller's 'does' level is the highest level of assessment associated with free observations of the student's performance in the real world clinical setting. It is within this framework of expected goals that can be used as a guide for faculties and institutions to design instructional systems and evaluation procedures that fall within the upper reaches of the triangle.

Types of Assessment

No single assessment method can provide all the data required for judgement of an entity as complex as the delivery of professional services by a health professional. Downing and Yudkowsky in their book Assessment in Health Professions Education classify almost all assessments into one of four categories: Written tests, performance tests, clinical observation methods, and a broad miscellaneous category consisting of other types of assessment such as oral exams, portfolios, chart stimulated recall type assessments etc.[4]

Written Tests:

Most assessments include some form of written testing of which there are two main types: Constructed response tests and selected response tests. Constructed response tests include a variety of formats such as fill-in the blanks type questions as well as short and long essay questions, while multiple-choice questions (MCQ's) form the prototype for selected response questions. Alternative variations on the MCQ format include extended matching items, true-false and alternate choice items[10]. Questions can also either be content-rich or content–poor. Content rich questions allow more complex cognitive processes to be measured. MCQ's have been proven to be valid and are also ubiquitous in their use as they can provide a large number of questions which encompass as large amount of content and can be administered in a short period of time to a large number of examinees[10]. They can also be graded by computer, which eliminates subjective marking and thereby increases standardization.[6] Questions that ask the student to choose a single best answer from a list of possible answers are most commonly used.

MCQ's that are content- rich are difficult to write. They also create the situation where a student can answer questions by recognizing the correct option, but would not know the answer in the absence of options- an effect called cueing[10]. Extended matching items (several questions each with the same list of possible answers) and short answer questions can minimize cueing and are excellent tools to evaluate clinical reasoning. There is in fact a wealth of evidence that extending matching questions are the fairest format but that MCQ's should be used in conjunction with practical and written assessments.[11] Structured essay remain a widely used written assessment tool and allow for more complex cognitive processes and contextualized answers.

Observation of Clinical Performance:

Supervising clinician's observations and impressions of students over a specific period of time is a very common form of assessment in health professionals training, and encompasses a range of informal and formal observations of clinical performance. Typically these mostly rely on checklist and grading forms from multiple raters about the performance of a health professional student over a period of time. Educators rely heavily on observational assessments, which have been a tool used traditionally for health professional assessment. There are however shortcomings such as validity problems and issues with standardisation[4]. Another issue is direct observation of students while they are interacting with patients may occur too infrequently.

Performance Tests:

Health professions education has always relied upon the assessment of student performance such as oral examination or "vivas". Systematic performance testing was introduced in the late 1970's with the Objective Structured Clinical Examination (OSCE) and is used throughout all levels of medical education from undergraduate to post-graduate levels in both formative and summative assessments. Simulation refers to a testing method, which utilizes a representation of a real word task, and is often used for both teaching and assessment. Simulations thus cover a broad array of methods and modalities from structured oral exams to computer based clinical case simulations with some high technology simulations available[12]. Oral examinations are a good tool to assess knowledge base and clinical reasoning, while limitations include possible subjective, race and sex bias as well as their relatively time consuming nature as the examiners must be trained to ensure fairness and standardization.

Other Assessment Methods:

The miscellaneous category includes many different types of assessment used in health professions education such as bedside oral assessment, peer assessment, patient assessment, portfolios of student experiences as well as long and short case assessments. Most of these methods are non-standardized and the subjectivity to a large extent threatens validity. This makes tests of this nature poor tools to use especially in high stakes assessments such a postgraduate licensure examinations. Portfolios are widely used as a tool to assess all aspects of theoretical and clinical competence and are especially useful for practice-based learning. The limitation is that the student often selects the best-case material, which may provide a skewed view of overall competence, as well as the process being time consuming.

Reliability is another essential concept in medical education and is the degree to which an assessment tool produces stable and consistent results[13]. Joppe (2000) defines reliability as 'The extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered reliable'. [14] The key concept is replicability or repeatability. There are several types of reliability or ways in which reliability may be measured:

Test-retest reliability is a measure of reliability obtained by administering the same test twice over a period of time to a group of individuals. The scores from both tests can then be correlated in order to evaluate the test for stability over time. Joppe (2000) detects a problem with the test-retest method which can make the instrument to a degree unreliable. The test-retest method may sensitize the student to the subject matter, and hence influence the responses given.[14]

Parallel forms reliability is a measure of reliability obtained by administering different versions of an assessment tool to the same group of individuals. The tool must contain items that probe the same construct, skill or knowledge base. The scores form both tests can then be correlated in order to evaluate the consistency of results across alternate versions.

Inter-rater reliability is a measure of reliability used to assess the degree to which different judges or raters agree in their assessment decisions.

Internal consistency reliability is another measure of reliability used to evaluate the degree to which different test items that probe the same construct produce similar results.

A few studies have attempted to analyze different components of examinations by acquiring data on students as measures of individual performance. Hollingsworth et al; trialed a computer based format in conjunction with the traditional oral examination, with the aim of introducing a more objective and reliable format to augment and/or replace the current oral examination format of the paediatric radiology board exams in the United States.[1] Colletti (2008) also explored the idea of computer based formats as a potential way forward from the current oral examination component of the American Board of Radiology.[3]

There is much debate surrounding the issue of changing examination formats, which lends itself to radiology perhaps more than most other specialities. It is with these issues in mind that our research into the impact of instituted changes into the radiology examination was borne.

Problem statement

It is unclear whether recent changes to the FCRad Diag (SA)examinations have impacted on candidate success rates, and if there was an impact, whether this was positive (i.e. more successful candidates) or negative (i.e. fewer successful candidates).

Research Question

We aimed to determine whether recent changes with regard to the implementation of a digital platform for the long case component of the Part II examination and the addition of a different examination assessment method in the form of a digitized rapid reporting component of the Part II for the FCRad Diag (SA) examinations have impacted on candidate success rates.

We also aimed to establish whether changes in the eligibility criteria to participate in the Part I examinations for the FCRad Diag (SA) as well as the implementation of a digitized, image-oriented Anatomy examination and the removal of the oral examination for the Physics Part I examinations have impacted candidate success rates in these respective components of the examination.

CHAPTER 2

A REVIEW OF FCRAD DIAG (SA) EXAMINATION RESULTS OVER TEN YEARS

Prepared according to the Instructions for Authors of South African Journal of Radiology *(SAJR)*

A REVIEW OF REVIEW OF FCRAD DIAG (SA) EXAMINATION RESULTS OVER TEN YEARS

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Background. Over the past few decades, there have been major technological advancements in the field of diagnostic radiology, and imaging has become indispensible to patient diagnosis and management. Not only are multiple imaging modalities now available, but digital image capturing, storage, and transmission have resulted in a filmless modern hospital setting. Coupled with the ever-widening spectrum of disease, radiologists require a broader and more detailed knowledge base, and face an increased workload. Consequently, South African postgraduate radiology training programmes have had to adapt. Current radiological examination formats need to encompass multiple imaging modalities, a digital platform, a wider disease spectrum, and a more pressured work environment.

Objective. We aimed to determine whether recent changes in the formats of the FCRad Diag (SA) examinations specifically with regard to allowing all appropriately qualified medical professionals to participate in Part I examinations; the implementation of a digital platform for portions of the Part I and Part II examinations and the addition of a different examination assessment method in the form of a rapid reporting component, have impacted on candidate performance trends.

Method. Retrospective review of the examination results for Parts I and II of the Fellowship of the College of Diagnostic Radiologists of South Africa FCRad Diag (SA) from September 2003 to March 2013.

Results. Proportional analyses were performed of successful candidates versus the total number of participating candidates for each examination. There was enough evidence to

suggest that changes in the examination formats have had a statistically significant impact on candidate performance trends with fewer successful candidates after the format changes in components of both the Part I and Part II examinations.

Conclusion. Recent changes made to the FCRad Diag (SA) examination formats have altered candidate performance outcomes. The presence of confounding variables requires further analysis.

Introduction

Internationally, principles around postgraduate medical training and outcome assessment are currently changing. Most of these changes are centered on maximizing learning opportunities in ever-expanding, time-constrained work environments. There is also a need for changes in training to subscribe to current educational theory.[1]

Radiology is unique in that recent technological advances in image acquisition as well as PACS (Picture Archiving and Communication System) and RIS (Radiology Information System) have resulted in several changes to both the working environment and workload of the modern radiologist. This has consequently impacted on radiology training, which needs to encompass the necessary skills, knowledge and attributes required to function appropriately in practice as a specialist in the field.[1]

Radiology trainees require perceptual and observational skills such as pattern recognition, image interpretation and deductive reasoning. In addition, they need practical proficiency to perform diagnostic and therapeutic procedures. Examinations thus need to accurately test these specific abilities in a reliable, valid and fair manner without effecting any changes in pre-determined set standards.[2,3]

Validity is concerned with whether the assessment tool measures what it clams to measure, while reliability relates to the degree of accuracy and reproducibility of the measurement itself.[4] There are several types of validity which relate to causal relationships of the study, the extent to which a test measures a hypothetical or unobservable variable, and whether a test provides adequate coverage of the subject being studied.

The key concept of reliability is replicability or repeatability. There are several types of reliability or ways in which reliability may be measured including test-retest reliability where the same test is administered twice over a period of time to a group of individuals; parallel forms reliability- where a different version of the assessment tool is administered to a group of individuals; inter-rater reliability- where different judges or raters agree in their assessment decisions; or internal consistency reliability which evaluates the degree to which different test items that probe the same construct produce similar results.

There has also been a move to change film-viewing modalities to digital platforms which more accurately simulate the modern work environment. These also facilitate image manipulation where appropriate and can be used to examine more candidates in different centers to ensure improved standardisation.[1]

Background

In the South African context, there is a profound lack of research in the area of examination format changes. The FCRad Diag (SA) examinations are divided into Part I and Part II components. Traditionally, all Colleges affiliated to the Health Professionals Council of South Africa (HPCSA) have held examinations twice a year, during the first semester, from March-May and during the second semester, from August to October. Prior to 2007, entrance into an accredited radiology registrar training post was required to be eligible to write the Part I examination. Part I completion and 36 months of supervised training in an accredited programme was a pre-requisite for the Part II examination.

Since 2007, any candidate with the appropriate medical undergraduate qualifications and postgraduate training is deemed eligible to participate in the Part I examination. Candidates sitting the Part II examination need to have submitted a portfolio outlining the types and number of radiological examinations the candidate has completed and observed during the training period. Furthermore, the portfolio outlines the candidate's participation in academic programmes and attendance at conferences and skill-furthering workshops. This type of portfolio has become a widely used tool in medical education as it provides a continuous assessment and allows for appraisal by the trainee's direct supervisor during the course of training[1].

The FCRad Diag (SA) Part I examination format has traditionally comprised of Radiation Physics and Radiological Anatomy components. Prior to the second semester 2010, the Radiation Physics component consisted of written and oral examinations, with invitation to the oral examination predicated on passing the written component. The Radiological Anatomy component consisted of written, oral and spot test examinations, with invitation to the spot test and oral components predicated on passing the written component.

From the second semester 2010, the Radiation Physics component of the examination has been abridged to a written examination only, while the Radiological Anatomy component is in the format of a spot test, utilising digital images.

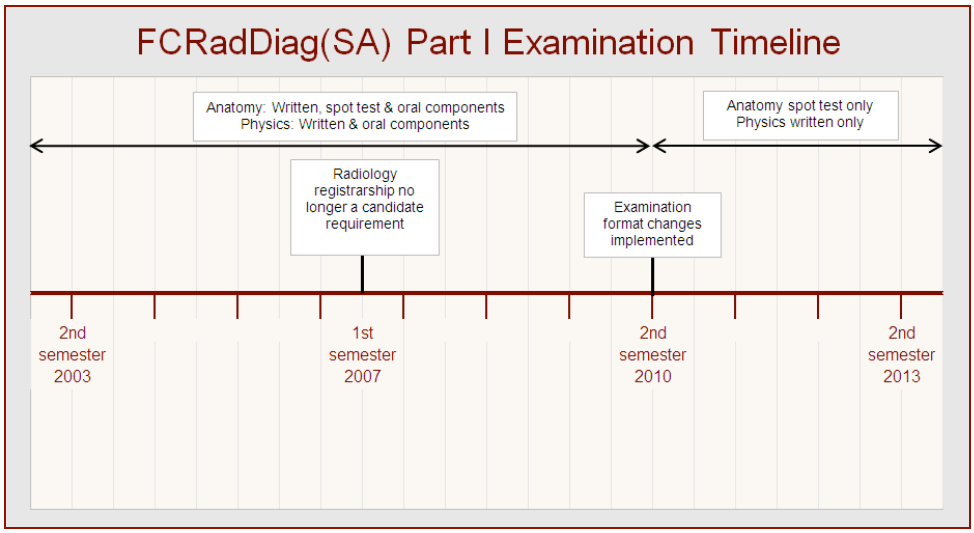

Figure 1: FCRad Diag (SA) Part I Examination Timeline

The FCRad Diag (SA) Part II examination, which traditionally consisted of written and oral components as well as a minimum of eight long cases, has also changed to include a rapid reporting session of typical emergency room imaging, which was instituted in the second semester of 2010 (with a 50% subminimum pass rate). A digital platform was introduced for the long cases since the first semester 2011. The digital platform was introduced with the view of implementing images of better quality that are more reflective of the modern day radiology cases encountered in practice.

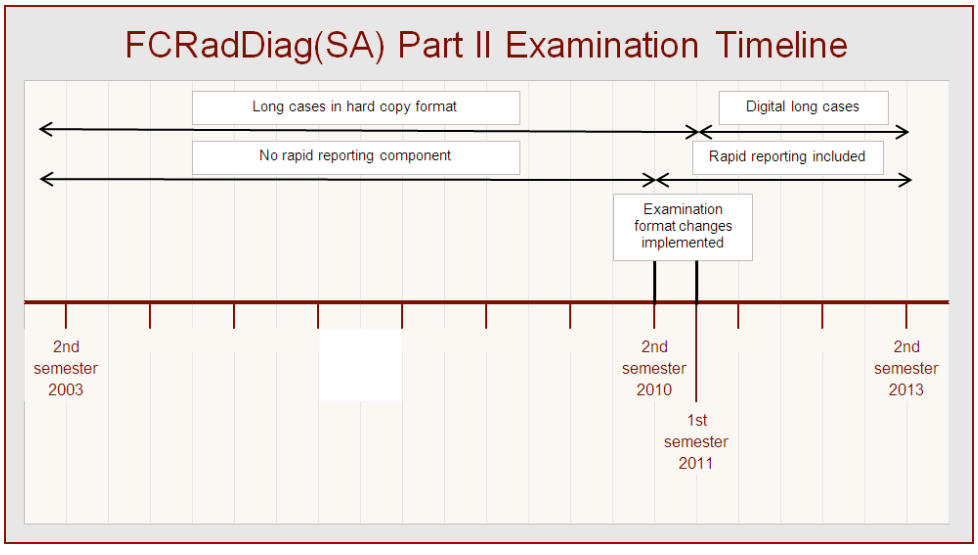

Figure 2: FCRad Diag (SA) Part II Examination Timeline

Method

We aimed to determine whether recent changes in the format of the FCRad Diag (SA) examinations have impacted on candidate success rates in terms of passes and failures. The Biomedical Research Ethics Committee at the University of Kwa-Zulu Natal approved the study in May 2015 (BREC 265/13).

We performed a retrospective audit of the results of all Part I and II candidates for the FCRad Diag (SA) from September 2003 (second semester 2003) to March 2013 (first semester 2013). The data set was received from the Academic Registrar at the Colleges of Medicine of South Africa. Anatomy oral and spot test results as well as Physics oral results were not provided in the source data for the first semester 2004 examination.

The following data were extracted:

- Candidate results for the Part I Physics and Anatomy including results from the written, oral and spotter components, where applicable.
- Candidate results for the Part II examination including results from the written, oral, long case and rapid reporting components, where applicable.

This yielded a sample size of 439 Part I results and 466 Part II results. The sample size is based on feasibility within the principal researcher's time-frame and encompasses all changes made to the examination formats.

Comparisons were performed by using *t* tests for unpaired data with unequal variances in the two groups. For the Part I results a *t* test for difference in sample means was conducted to determine if there was a difference between two test samples. The hypothesis was that there was no difference between the two means versus the alternative that the means were different. We subsequently performed a two-tail test to assess which mean values fell within the range of the Bell curve, indicating that there was no difference in the mean values; or whether the mean values fell outside the range of the Bell curve which indicated that there was a difference in the mean values. The test statistic used was as follows:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\left(\frac{(N_1-1)S_1^2 + (N_2-1)S_2^2}{N_1+N_2-2}\right)\left(\frac{1}{N_1}+\frac{1}{N_2}\right)}}$$

The test statistic was applied separately to the Physics written, Physics oral and the aggregate Physics marks as well as the Anatomy written, spot tests, oral and aggregate Anatomy marks. The time frames tested mean values for all the components of the Physics and Anatomy examinations was September 2003 to September 2007 versus March 2008 to September 2010. This time frame allowed for statistical comparison of the Physics and Anatomy component scores before and after the eligibility criteria to sit the examination were changed to include any candidate with the appropriate medical undergraduate qualifications and postgraduate training.

Further *t* tests were performed of the aggregate Physics marks from September 2003 to September 2010 versus March 2011 to March 2013, allowing for comparison before and after the format was changed from a written and oral examination to a written examination only. In addition *t* tests were performed of the mean values of the Physics written examination for the time frames from March 2007 to September 2010 versus March 2011 to March 2013. This was done to determine whether the mean values were different in the written examination when no changes in the specific format for the examination were effected. This was deemed an important test to evaluate if there were differences in the results due to the passage of time.

Tests of the mean values for the aggregate Anatomy marks was also performed from September 2003 to September 2010 versus March 2011 to March 2013 to allow for comparison before and after the Anatomy examination format was changed from a written, oral and spot test to a spot test only. As this time frame overlapped with the first format change in March 2007 where the eligibility criteria changed, further T tests of mean values were performed for both the Anatomy and Physics aggregate marks for the time frames of September 2003 to March 2007 versus September 2010 to March 2013 and March 2007 to September 2010 versus March 2011 to March 2013, to control for the initial format change. All tests were conducted with a 5% level of significance.

For the Part II examination *t* tests for the difference in sample means using the same test statistic were conducted for the long case component of the examination for the time frame September 2003 to March 2011 versus September 2011 to March 2013.This test allows for comparison of scores when the format for the long cases was changed from hard copies to a digital platform. Further tests were performed to evaluate the changes caused by the introduction of the rapid reporting component of the examination. This was done by using the same test statistic to determine the differences in the mean values of overall examination scores from September 2003 to March 2010, versus September 2010 to March 2013. As this time frame overlapped with the introduction of the digital platform in March 2011, further tests were performed of the overall examination scores for the time frame September 2003 to March 2010 versus September 2010 to March 2011 and September 2003 to March 2010 versus March 2011 to September 2013. This was done to control for the overlap of digitisation within the data set.

Further statistical analysis included the use of proportional analyses to obtain required data extrapolations. This was done to determine the percentage difference in overall results (passes versus failures) between the data sets analysed. Comparison was made between percentage of successful candidates overall in Part I from the second semester 2003 to the first semester 2010, and from the second semester 2010 to the first semester 2013 (i.e. before and after the examination formats were changed). Comparison was also made between the data subsets of Part I candidates prior to and after 2007 for both Physics and Anatomy (i.e. before and after candidates not enrolled in Radiology registrar programmes were eligible to sit the Part I examination).

For the Part II component, comparison was made between successful candidates overall from the second semester 2003 to the first semester 2010, and from the second semester 2010 to the first semester 2013 (i.e. before and after the examination format was changed - rapid reporting and digital long cases introduced).

The outcome variable of main interest is the change in the percentage of successful candidates in both Part I and Part II examinations after the implemented changes during the above time frames. A pooled proportion between the two formats was established. Z values were found for different populations and all results were tested at a 5% level of significance with a table value of 1.96.

Results

For the Part I examination, analysis of the *t* test results for the Anatomy oral and Anatomy written examinations for the time frames September 2003 to September 2007 versus March 2008 to September 2010 (before and after the eligibility criteria were changed) revealed that 96% of the tested mean values fell outside the expected range indicating that the results were different. Similarly for the Physics oral examination component of the Part I examination for the time frame of September 2003 to September 2007 versus March 2008 to March 2010 (before and after the eligibility criteria were changed) showed that 98% of the tested mean values fell outside of the expected range indicating that the results were different.

Analysis of the aggregate Anatomy and Physics overall results as well as the Physics written examinations from September 2003 to September 2007 versus March 2008 to March 2010 revealed that 100% of the tested mean values were different for both. This indicates the instituted change in the format of the Part I examination with the changing of the eligibility criteria did result in a change in the results for both the Anatomy and Physics components of the examination.

The *t* test results were then correlated with the pooled proportion analysis of the Part I pre-2007/post-2006 results yielded a statistically significant difference in proportions of passes in both Anatomy and Physics components, with there being more failures in the latter group (i.e. since radiology registrarship was not a candidate pre-requisite).

Separate analysis was then performed for the Anatomy and Physics overall results for the time frame of March 2007 to March 2010 versus September 2010 to March 2013 to establish if the elimination of the Physics oral and the Anatomy written and oral affected a change in the tested mean values. These tests also demonstrated that there was a difference in the tested mean values. Correlation with pooled proportional analysis for this time frame for the examinations confirmed a difference in proportions.

Before and after the format change in eligibility criteria, the proportions of passes for the various components of the Part I examination changed as follows:

- Physics written: 81.7% to 65.9%

- Physics oral: 83.3% to 81.3%
- Anatomy written: 74.6% to 47.3%
- Anatomy oral: 86.9% to 74.3%
- Anatomy spot: 87.6% to 77.3%

Before and after the change of eliminating the Anatomy written and oral components as well as the Physics oral component, the proportion of passes for the various components changed as follows:

- Physics written: 68.8% to 61%
- Anatomy aggregate: 89.9% to 82.5%

A further derivation from the above results, is that the Physics written examination results between September 2007 to March 2010 versus September 2010 to March 2013 changed from 65.9% to 68.8%. There was no change in this specific examination format over this time period and the difference in results is therefore a function of time.

For the Part II examination, *t* tests for the oral component and the overall results for the time frame of September 2003 to September 2011 versus March 2011 to March 2013 (i.e. before and after the introduction of the rapid reporting component) yielded a 91% and 100% difference in the test values respectively, indicating that the introduction of the rapid reporting component to the Part II examination did cause a change in the results over this time period. Similar *t* tests performed for the long cases marks for the time frame September 2003 to September 2010 versus March 2011 to March 2013 showed a 91% difference in the mean values indicating that the digitisation of the long cases did cause a change in the results for this component.

Correlation with the pooled proportion analysis for this time frame revealed that there has been an increase in Part II candidate failure rates since the first semester of 2011 which encompassed the introduction of the rapid reporting component in the second semester of 2010, with the digital platform following shortly afterwards in the first semester of 2011.

We subsequently analysed the Part II candidate long case results before and after the first semester of 2011 (inclusive) to ascertain whether there was significant statistical variation after the introduction of the digital platform for the long cases. The analysed data sets

revealed a significant statistical variation in proportions with an increased number of failures in the latter group (i.e. after the long cases were digitised).

For the overall Part II pass rates before and after the introduction of rapid reporting component the results changed from 86.5% (before) to 68.45 (after).

For the proportions of passes for the long case component of the Part II examination before and after digitization the proportion of passes changed from 78.9% to 73.3%.

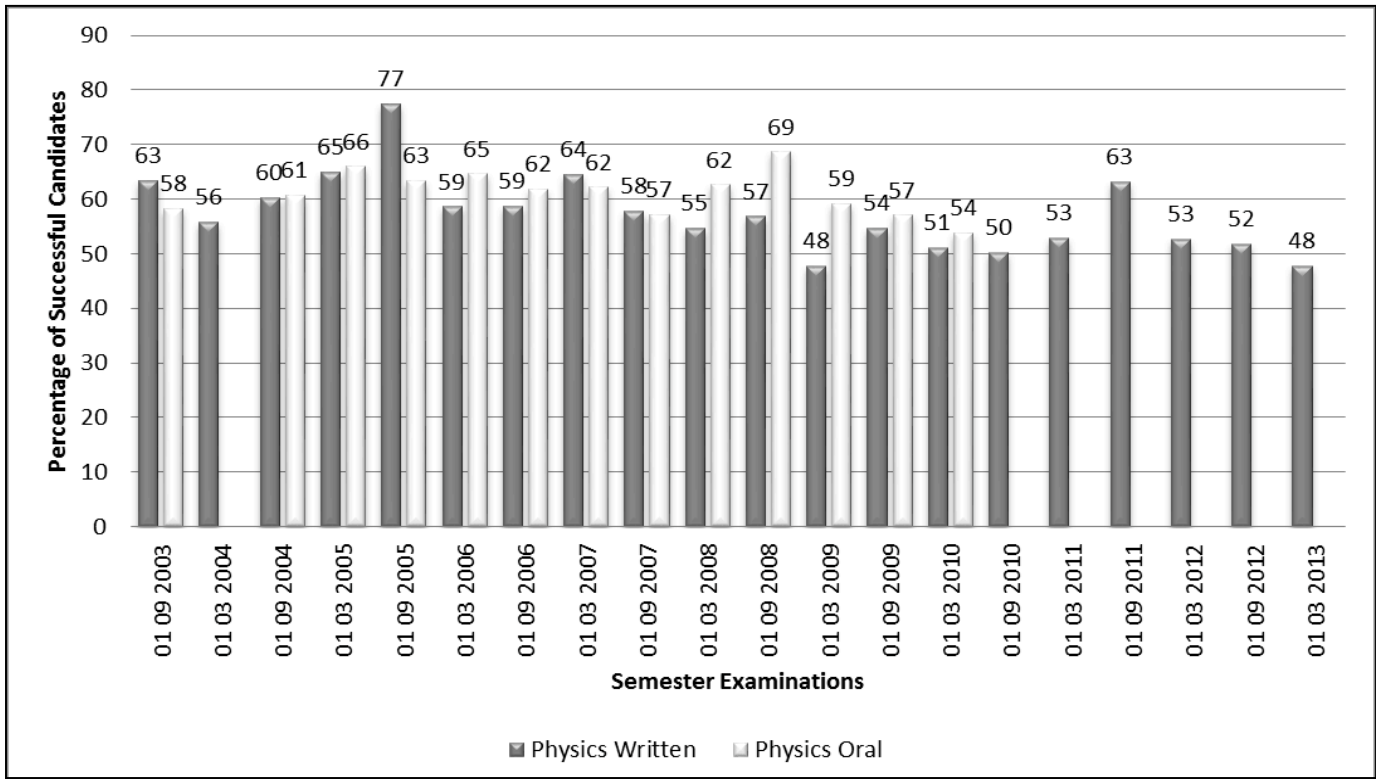

Figure 4: FCRadDiag(SA) Part I Physics results averages over 10 years

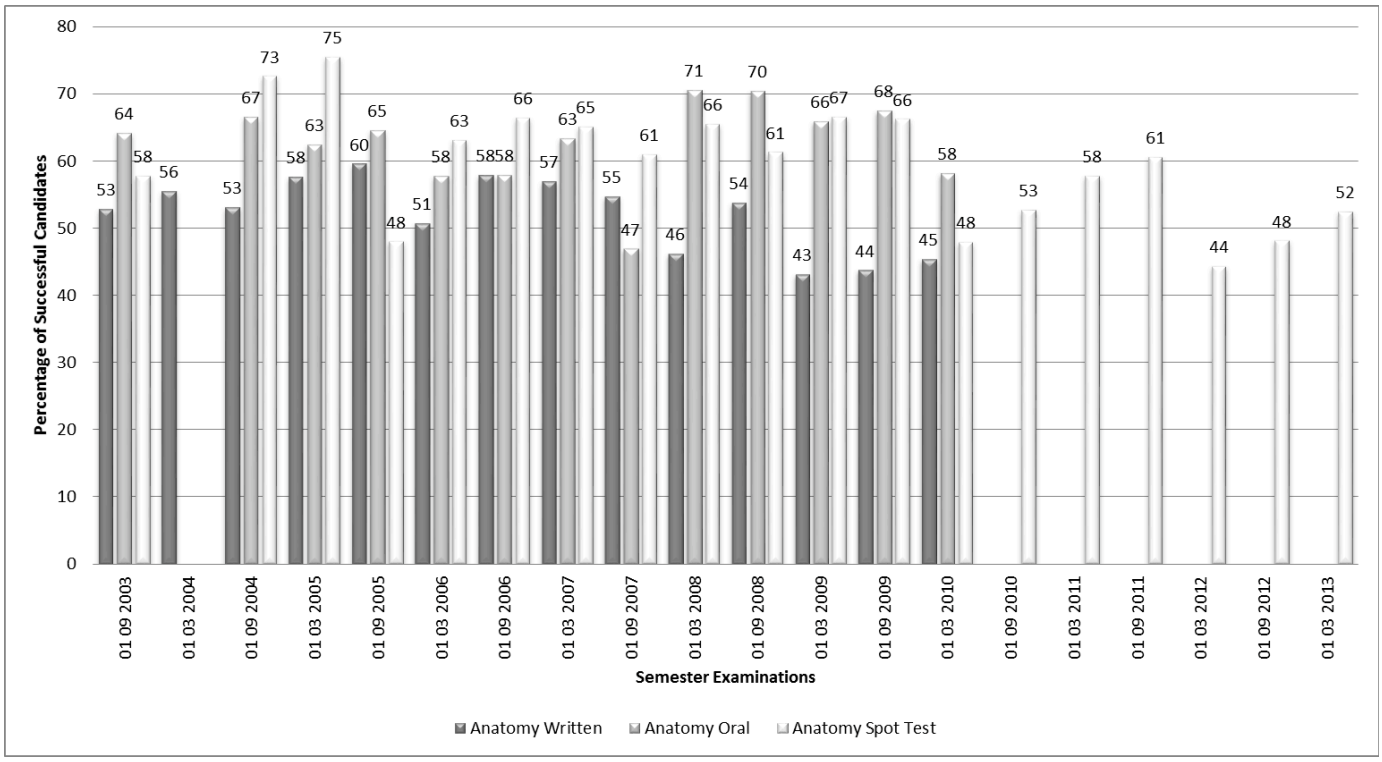

Figure 5: FCRad Diag (SA) Part I Anatomy results averages over 10 years

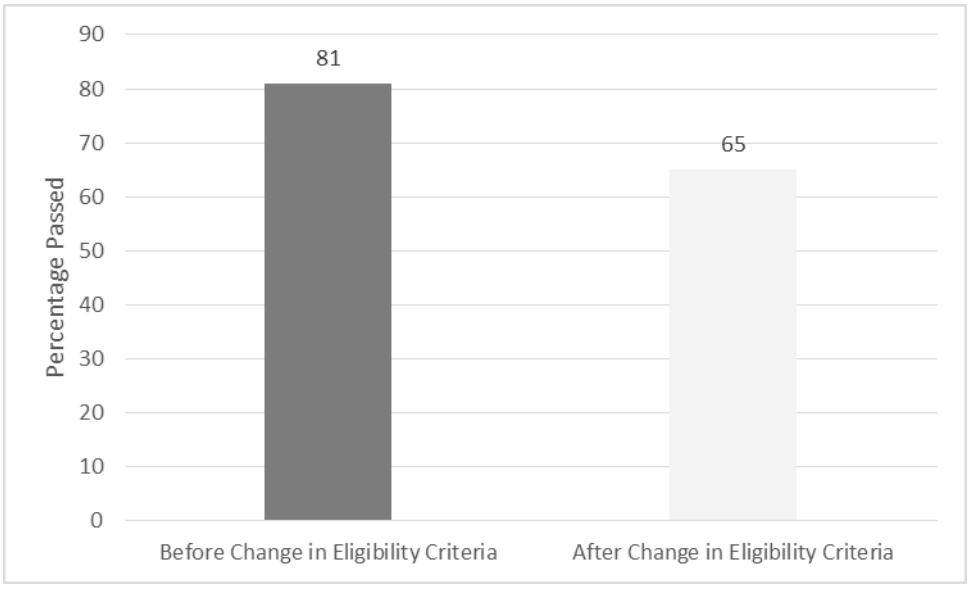

Figure 6: Physics written comparison

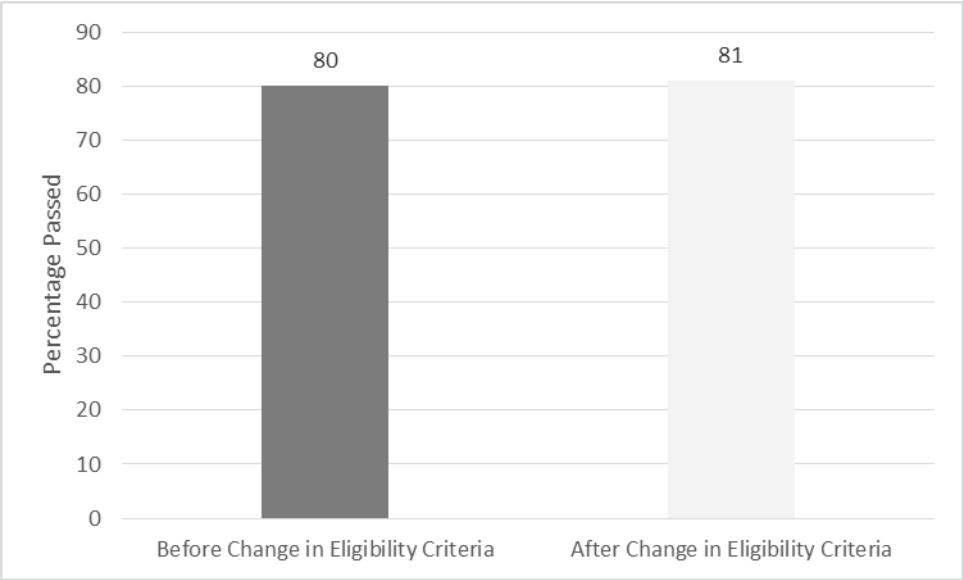

Figure 7: Physics oral comparison

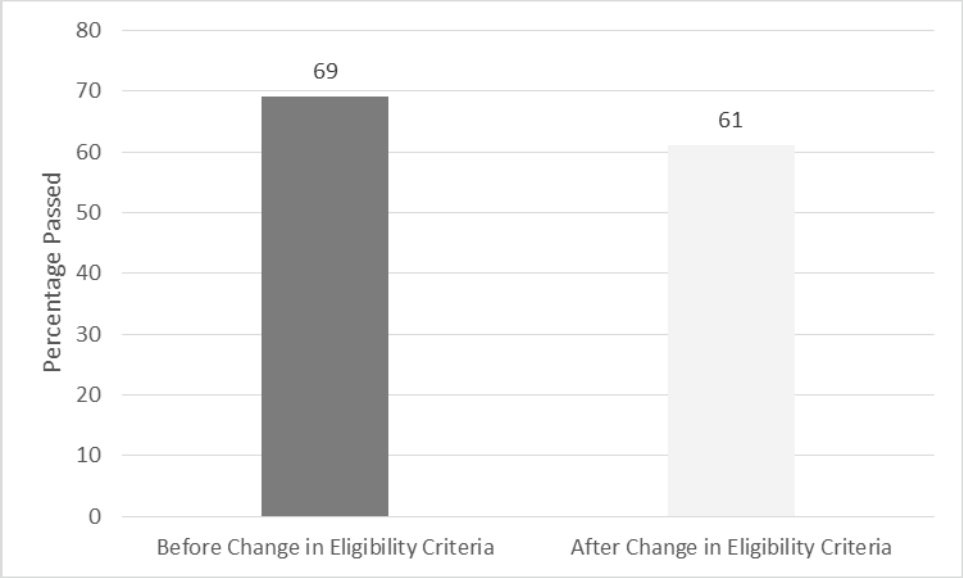

Figure 8: Physics written comparison after second change in format

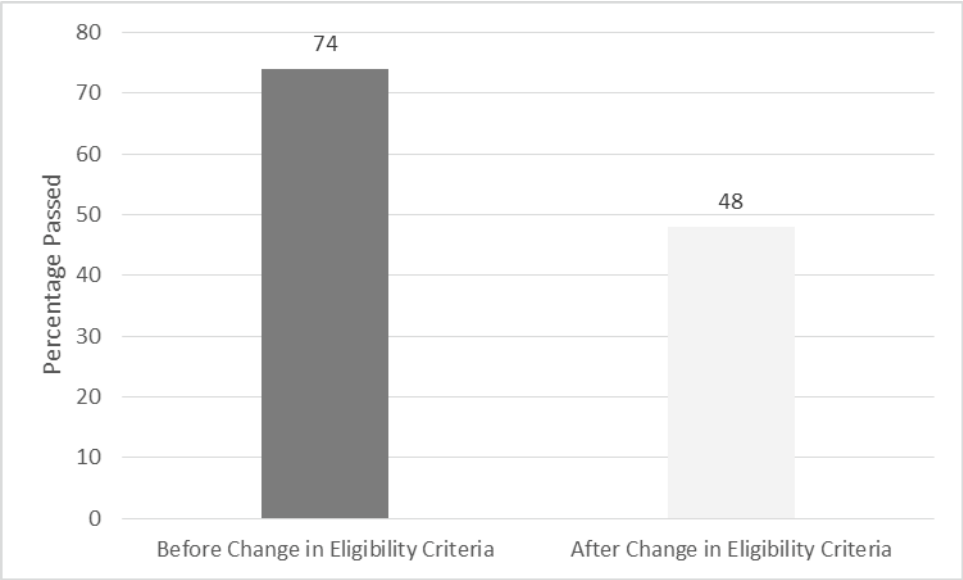

Figure 9: Anatomy written comparison after second format change

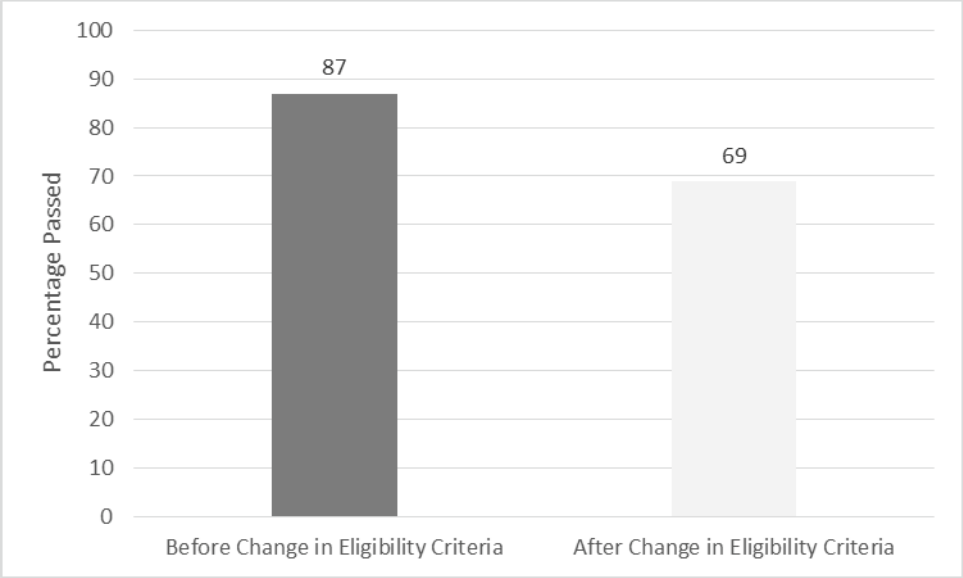

Figure 10: Overall Part II comparison

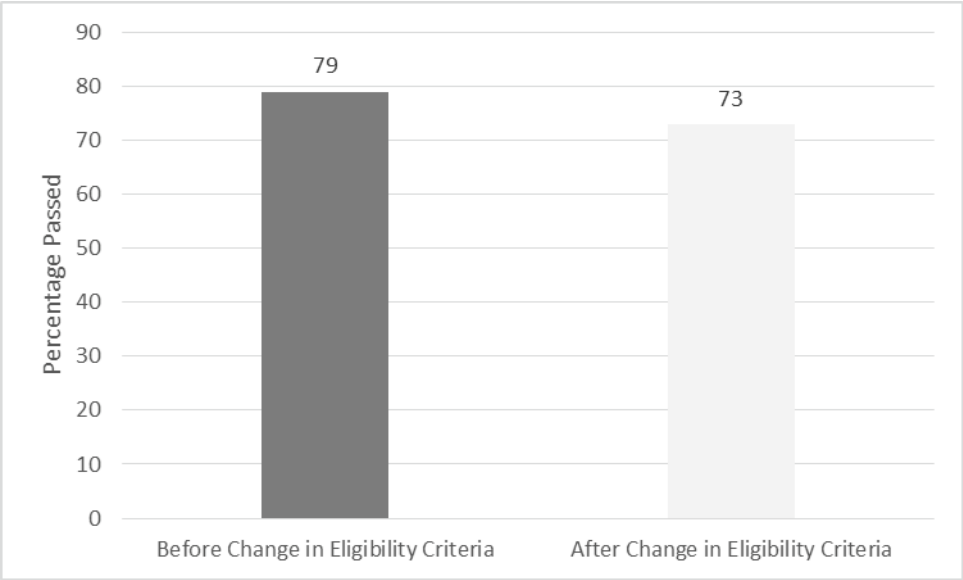

Figure 11: Long case comparison

Discussion

The format changes to the FCRad Diag (SA) Part I and II radiology examinations are consistent with current educational theory, and are designed to assess candidates in a fair, valid way with the aim of preparing them for a career in diagnostic radiology both locally and abroad.

With regard to the Part I examination, we hypothesised that candidate performance would be adversely affected by the inclusion of candidates not in radiology registrar posts (2007 onwards). Results proved that there was an increase in the percentage of candidate failures after this change in format, confirming our hypothesis. Likely reasons include a relative lack of practical experience and familiarity with course material amongst candidates not within a radiology training program. We were able to control for historical fluctuations in the candidate results by analyzing a component that did not change over a period of time.

We expected to find an improvement in candidate performance following the Part I examination format changes (removal of the seemingly more challenging oral Physics, and written and oral Anatomy components). In contradiction, an increased number of candidates failed Anatomy and Physics with a consequent decrease in the overall number of successful candidates.

With regard to the Part II examination, we hypothesised that candidate performance would be adversely affected, particularly in the short term, by the addition of the rapid reporting component and the digital imaging platform. There were an increased number of testing methods more likely to expose gaps in candidate knowledge. Possible explanations include time limitations (increased number of digital images per case in comparison to the previously used hard copies), candidate unfamiliarity with software packages, and on-site technical issues such as server instability.

Our results supported our hypothesis in that there was a demonstrable increase in candidate failures after the institution of format changes. Further research is needed to identify possible candidate factors regarding preparedness and examination technique that may impact performance levels.

Study Limitations

The limitations of the study include the retrospective study design and the small sample size. The sample size was limited by time constraints, but encompassed all format changes. Repeat candidates could not be identified as only examination numbers were provided with the core data in the interest of confidentiality, with different examination numbers issued at each sitting.

In addition, there has not and cannot be a review on examination content, and this variable has not been taken into account. This study can only comment on the delivery platform and different techniques of examination.

In addition, note was made of the presence of confounding variables. These include temporary but general, as well as specific characteristics related to the individual. Many of these characteristics such as memory fluctuations, stress and levels of preparedness could not be qualitatively or quantitatively assessed. Aggregating the data sets does however minimize these normal fluctuations.

Acknowledgements

The authors would like to thank Mr Jaco du Plessis and Mr Tyrone Rajah for assistance with data entry and statistical analysis respectively.

Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

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Appendix 1

Research Protocol

UNIVERSITY OF KWA-ZULU NATAL
NELSON R MANDELA SCHOOL OF MEDICINE

RESEARCH PROPOSAL

1. Title:
    - A review of FCRad Diag (SA)examination results: A new examination blueprint for the future
2. Aim:
    - To determine whether recent changes in the format of the FCRad Diag (SA) examinations have impacted on candidate performance trends.
    - To investigate the reproducibility and validity of the current testing methods

3. Background:

The changing face of Radiology

Over the last few decades, major technological advancements in image acquisition and storage have lead to a new approach to radiological investigations. Imaging has become indispensible to patient care and has thus become more commonplace. This has led to a steady rise in the work burden on radiologists. This, coupled with an ever-widening spectrum of disease has necessitated a larger required knowledge base for practising radiologists. Picture archiving and communication systems (PACS) and digital image capturing and storage have lead to film-less environments in the modern hospital setting[1].

Consequently the field of post-graduate medical training in radiology has needed to adapt to incorporate widespread digitalisation, *an ever-broadening knowledge base* and a heightened demand for imaging resources in all modalities. Similarly, it has become necessary to tailor the recent radiological examination formats to encompass multiple imaging modalities, *a wider spectrum of disease* and a more pressured work environment.

Radiology Fellowship examinations in South Africa

Radiology fellowship examinations in the country are divided into Part I and Part II components. Prior to 2007, entrance into an accredited radiology registrar training post was required to become eligible for the exam. Part I completion and 36 months of supervised training in an accredited programme was a pre-requisite for the Part II exam. Traditionally all colleges affiliated to the Health Professionals Council of South Africa have held examinations twice a year, in March/April and August/September.

Since 2007, any candidate with the appropriate medical undergraduate qualifications and postgraduate training was deemed eligible to participate in the part I examinations. Candidates sitting for part II examinations need to have submitted a portfolio outlining the number and types of radiological examinations the candidate has been exposed to during the training period. Furthermore the portfolio outlines, the candidates' participation in academic programmes and attendance at conferences and skill-furthering workshops. The portfolio has become a widely used tool in medical education as it provides a continuing assessment and allow for appraisal by the trainees direct supervisor during the course of training[2].

The radiology Part I exam format has traditionally comprised of Radiation Physics and Anatomy components. Prior to September 2010, the Radiation Physics component has comprised of a written and an oral examination, with invitation to the oral examination predicated on passing the written component. The anatomy component comprised of written, oral and spotter examinations, with invitation to the spotter and oral components predicated on passing the written component.

Since September 2010 the Radiation Physics component of the examination has been reduced to a written examination only. While the Anatomy component has been reduced to a spot test format exclusively utilising digital images.

Similarly the part II exam, which traditionally consisted of written and oral components, has also changed to include a rapid film reporting session. The examination also now exclusively utilises a pre-determined number of digital images throughout the oral and rapid reporting portions of the examination.

4. Literature Review

Principles around postgraduate medical training delivery and outcome assessment are currently changing.[1] Most of these changes are centered on maximising learning opportunities in ever-expanding, time-constrained work environments. There is also a need for changes in training to subscribe to current educational theory.[1]

Radiology is unique in that recent technological advances in the sphere of image acquisition as well as PACS (Picture Archiving and Communication System) and RIS (Radiology Information System) systems have resulted in several changes to both the working environment and workload of the modern radiologist. This has consequently impacted on radiology training, which needs to encompass the necessary skills, knowledge and attributes required to function appropriately in practice.[2]

Specific learning outcomes have taken on importance to provide a framework for expected skills and knowledge for trainees.[1]These outcomes need to be curriculum- based, which itself should reflect the skills, knowledge and attributes required of a specialist in the field.[3]

In addition, radiology training requires perceptual and observational skills such as pattern recognition, image interpretation and deductive reasoning. In addition they need practical skills to perform diagnostic and therapeutic procedures. Examinations thus need to accurately test these specific skills in a reliable, valid and fair way without effecting any changes in pre-determined set standards.[5]

There are several different assessment methods that can be used, depending on whether skill, knowledge or understanding needs to be assessed.

Multiple choice formats (MCQ), oral examinations, and several workplace based assessment methods such as mini-Clinical Evaluation Exercise (mini-CEX), Directly Observed Procedural Skills (DOPS) and Multi-source feedback (MSF); are aimed at measuring different important components of training, all while attempting to ensure the most reliable and valid outcomes.[2]

Research performed to compare different formats and their effect on candidate performance has yielded varying results.[2] Some studies demonstrate that multiple choice questions (MCQs) are better to evaluate factual information while many authors are adamant that, despite poor reliability, there is still a place for oral examinations in modern examination formats as they uniquely simulate day to day interactions between radiologist and clinician.[5,7] Oral examinations also allow examiners to assess the level of confidence a candidate has in the diagnosis provided.[6]

Similarly, there has been a move to change film-viewing modalities to digital platforms to more accurately simulate the work environment. They also facilitate image manipulation where appropriate and can be used to examine more candidates in different centers to ensure improved standardisation. Further benefits include elimination of examiner bias and ability to adjust examination difficulty based on candidates' current performance to provide more accurate assessment.[2]
There is a profound lack of research in the area of examination format changes in the South African context.

4. Study Design:
    - Retrospective audit
    - Descriptive study

5. Statistical Planning:

    Has the project been discussed with:

A professional statistician?	No
A person with a statistical background?	Yes

    Name of statistician: Mr T Rajah

6. Study Population:

    - All Part I and II candidates for the FCRad Diag (SA)from September 2003 to September 2012

7. Sample Size:

- 439 candidates sat Part I Physics
- 466 candidates sat Part I Anatomy

The sample size is based on feasibility within the principal researcher's time-frame and encompasses all changes made to the examination format. *Therefore no sample size calculations were done and the emphasis will not be placed on the p-value.*

8. Data Collection:

Data collection has been completed. The data was received from the *Academic Registrar* at the College of Radiology South Africa from which the following data was extracted:

- Candidate results in Part I Physics and Anatomy including results from the written, oral and spotter components where applicable.
- Candidate results for Part II examination including results from the written, oral and rapid reporting components where applicable.

9. Data Analysis:

Data analysis has been completed
Number of candidates passing the written Part I Physics examination
Number of candidates passing written Part I Anatomy examination
Number of candidates passing Part II written examination
Number of candidates passing Part II oral examination
Number of candidates passing Part II rapid reporting session
Comparison made between percentage of successful candidates overall in Part I from Sep 2003- march 2010, and from September 2010-September 2012
Compassion between successful Part II candidates overall from Sep 2003- march 2010, and from September 2010-September 2012

The outcome variable of main interest is the change in the percentage of successful candidates in both Part 1 and Part 2 examinations after the implemented changes during the above time-frames.

10. Statistical Analysis: included use t tests and proportional analysis to obtain required data extrapolations

11. Inclusions: All candidates sitting the Part I examination in Physics and Anatomy
All candidates sitting the Part II examination

Exclusions: *candidates who did not complete both examinations in one sitting due to failure to attend*

12. Ethical aspects:

A) Responsibility: *In respect of any litigation, which may result from this research:*

1. Are the pharmaceutical manufacturers prepared to take responsibility? N/A

2. Have you ensured that compensation to participants and investigators is in accordance with *Guidelines for Good Practice in the Conduct of Clinical Trials in Human Participants?*

No compensation involved

3. If this project is to be conducted at another institution, is additional ethical clearance approval required?

Not applicable

B) Incentives/ Reimbursement

1. List any undue incentives explicit and implicit that have been offered to study participants, either to recruit or to remain within the study. N/A

2. List reimbursement /compensation for participation in the study (e.g travel costs, out of pocket expenses, etc). N/A

C) Potential risk or discomfort:

Compared with participants with similar conditions indicate, for each study group, the potential additional

Risk: Nil

Discomfort: Nil

D) Health Service Utilisation:

Compared with participants with similar conditions indicate, for each study group, the likely additional:

Duration of hospital stay (days): N/A
Outpatient attendances (number): N/A
Laboratory services used: Nil
Extent of nursing involvement: N/A

E) Management:

In the case of participants drawn from patient populations, indicate, in respect of each sub-group, how management differs from that usually offered to patients with similar conditions.

Not Applicable

F) Community Consultation:
In the case of community-based studies, explain what consultation is planned within the community in the: N/A

1. Preparation
2. Implementation of the study and
3. Dissemination of the results thereafter

G) State the expected benefits arising from this study under the following headings:

1. Clinical care: Nil
2. Public health: Nil
3. Prospects of tested intervention being available to the study population if proven effective: N/A
4. Other (Specify)

Appendix 2

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

13 May 2015

Dr V Ramoorthy
Private Bag X9001
Pietermaritzburg
Vishnu.ramoorthy@gmail.com

Dear Dr Ramoorthy

PROTOCOL: A Review of FCRAD (DIAG) SA Results: A New Examination Blueprint for the Future. REF: BE265/13.

EXPEDITED APPLICATION

A sub-committee of the Biomedical Research Ethics Committee has considered and noted your application received on 05 July 2013.

The study was provisionally approved pending appropriate responses to queries raised. Your responses received on 16 February 2015 to queries raised on 19 March 2015 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.

This approval is valid for one year from **13 May 2015.** 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 (2015), 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).

The sub-committee's decision will be **RATIFIED** by a full Committee at its meeting taking place on **09 June 2015.**

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

Yours sincerely

Professor J Tsoka-Gwegweni
Chair: Biomedical Research Ethics Committee

Biomedical Research Ethics Committee
Professor J Tsoka-Gwegweni (Chair)
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Telephone: +27 (0) 31 260 2486 **Facsimile:** +27 (0) 31 260 4609 **Email:** brec@ukzn.ac.za
Website: http://research.ukzn.ac.za/Research-Ethics/Biomedical-Research-Ethics.aspx

Appendix 3

SUPERVISOR'S REPORT

PLEASE NOTE; This must essentially be a descriptive and non-evaluative report

1. **Candidate: ……VISHNU RAMOORTHY……Student no: 9831730**

2. **Registered title: A REVIEW OF FCRAD(DIAG)SA EXAMINATION RESULTS OVER TEN YEARS**

3. **Reference number: BE265/13**

4. **Approved by Postgraduate Education Committee: YES**

5. **Approved by Biomedical Research Ethics Committee: YES**

6. **Supervision history:** I supervised the whole process Yes _✓__ No ___
   1. If no, I took over from another supervisor : (date)
   2. Describe the stage at which the student was at that time:

7. **Schedule of supervision (describe):**
   Year 1 – Literature review and submission of research proposal
   Year 2 – Data collection and entry
   Year 3 – Statistical analysis and write-up

8. **Adherence of the candidate to the schedule (describe):**
   Excellent

   February 2013 - candidate began literature review
   July 2013 - submitted research proposal to BREC and UKZN post-graduate office
   August 2013 – provisional approval by BREC
   (2014 – candidate completed FCRadDiag(SA) Part II)
   February 2015 – post-grad approval
   May 2015 – BREC approval
   June 2015 – Data collection and entry
   September 2015 – Statistical analysis
   January 2016 – Final report completed

9. **Level of guidance or assistance given (mark appropriate column)**

Step	No assistance	Minimal assistance	Average assistance	Massive assistance
Formulation of research topic			✓	
Developing research proposal			✓	
Literature search		✓		

Defining theoretical basis			✓	
Choosing research design			✓	
Appropriate referencing			✓	
Data collection instruments			✓	
Conducting field work			✓	
Developing the argument			✓	
Solution of research problems			✓	
Data analysis		✓		
Expression, style and presentation			✓	

10. **Describe the response of the candidate to suggestions or recommendations** Open-minded and receptive.

11. **Describe any resource constraints which influenced the candidate**
    Time – no dedicated research time available in service delivery driven work schedule.

12. **Any further information which is relevant**
    -

13. **I saw/did not see the final version of the report that was handed in**

14. **I approve of/do not approve of the final version that was submitted** Needs amendments / revision of data analysis.

15. **I am satisfied that, to the best of my knowledge, there is no plagiarism in the report.**
    Yes__✓___ No _____

Supervisor: Dr Vicci du Plessis

Signature: _____ Date: 25 May 2016

Co-supervisor:_____

Signature: _____Date: _____