AN ANATOMICAL INVESTIGATION OF THE SYMPATHETIC AND PARASYMPATHETIC CONTRIBUTIONS TO THE CARDIAC PLEXUS

by
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So many times we think we cannot do something unless we take the small steps towards doing it. This has been made up of small steps of learning and hard times thus I give gratitude to God Almighty for giving me the strength to continue and complete this when I felt I cannot anymore.

I can do all things through Christ who strengthens me.

Philippians 4:13

ABSTRACT

The cardiac plexus is "formed by mixed autonomic nerves" that are "described in terms of superficial and deep components, with the superficial located below the aortic arch and anterior to the right pulmonary artery, and the deep located anterior to the tracheal bifurcation (above the division of the pulmonary trunk) and posterior to the aortic arch" (Standring *et al.*, 2008). This investigation aims to review and update the medial cardiac contributions of the cervical and thoracic sympathetic chains to the cardiac plexus and also the contributions from the vagus nerve and its counterpart, the recurrent laryngeal nerve. This study involved the macro and micro-dissection of 100 cadaveric sides of adult and fetal material.

The number of ganglia in a cervical sympathetic chain varied from 2 to 5 in this study. This study confirms previous reports on the location of the two components of the cardiac plexus. The origin of the sympathetic contributions to the cardiac plexus in this study were either ganglionic, interganglionic or from both the ganglion and interganglionic chain of the respective ganglia. The superior cervical cardiac nerve had an incidence of 92% while the middle cervical cardiac nerve had an incidence of 65% in the specimens studied. This study also records a vertebral cardiac nerve that arose from the vertebral ganglion in 39% of the cases. The inferior cervical and cervicothoracic cardiac nerves had incidences of 21%, respectively. This investigation records the thoracic caudal limit of the sympathetic contributions to the cardiac plexus as the T_5 ganglion.

The findings in this study indicate the importance of understanding the medial sympathetic contributions and their variations to the cardiac plexus as this may assist surgeons during minimal surgical procedures, sympathectomies, pericardiectomies and in the management of diseases like Reynaud’s Phenomenon and angina pectoris (Kalsey *et al*., 2000; Zhang *et al*., 2009).

PREFACE

This study represents work done by the author and has not be submitted in any other form to any other University. Where work done by others was used, it has been duly acknowledged in the text.

The research described in this dissertation was supervised by Professor K S Satyapal and Co-Supervised by the late Professor P. Partab and Mrs L Lazarus in the Discipline of Clinical Anatomy, College of Health Sciences, University of KwaZulu-Natal, in which this research was conducted.

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GLOSSARY OF TERMS

A	Adult
ANS	Autonomic nervous system
ARCH	Arch of aorta
AS	Ansa subclavia
BT	Brachiocephalic trunk
C	Cervical vertebra
C2, C3, C4	Second, third and fourth cervical ventral rami
CCA	Common carotid artery
CCN	Cervical cardiac nerves
CN III	Oculomotor nerve
CN IX	Glossopharyngeal nerve
CN X	Vagus nerve
CN V	Trigeminal nerve
CN VII	Facial nerve
CN VIII	Vestibulocochlear nerve
CNS	Central nervous system
CSC	Cervical sympathetic chain
CTCN	Cervicothoracic cardiac nerve
CTG	Cervicothoracic ganglion
DCP	Deep cardiac plexus
$_{D}$CTG	Dumbbell shaped cervicothoracic ganglion
F	Fetal
GSN	Greater splanchnic nerve
GRC	Gray rami communicantes
$_{H}$MCG	High type middle cervical ganglion
ICCN	Inferior cervical cardiac nerve
ICG	Inferior cervical ganglion
$_{I}$CTG	Invert "L" cervicothoracic ganglion
IG	Intermediate ganglia
IJV	Internal jugular vein
ITA	Inferior thyroid artery

IVCN	Inferior vagal cardiac nerve
L	Left
LCCA	Left common carotid artery
$_L$MCG	Low type middle cervical ganglion
LSA	Left subclavian artery
MCCN	Middle cervical cardiac nerve
MCG	Middle cervical ganglion
$_M$CSC	Multiple branches of cervical sympathetic chain
MVCN	Middle vagal cardiac nerve
$_N$MCG	Normal middle cervical ganglion
PNS	Peripheral nervous system
R	Right
RC	Rami communicantes
RCCA	Right common carotid artery
RLCN	Recurrent laryngeal cardiac nerve
RLN	Recurrent laryngeal nerve
RSA	Right subclavian artery
SA	Scalenus anterior
SCCN	Superior cervical cardiac nerve
SCG	Superior cervical ganglion
SCP	Superficial cardiac plexus
SVCN	Superior vagal cardiac nerve
T_1G	First thoracic ganglion
T_2G	Second thoracic ganglion
T_3G	Third thoracic ganglion
T_4G	Fourth thoracic ganglion
T_5G	Fifth thoracic ganglion
T_6G	Sixth thoracic ganglion
T_7G	Seventh thoracic ganglion
T_8G	Eighth thoracic ganglion
TCN_1	First thoracic cardiac nerve
TCN_2	Second thoracic cardiac nerve

TCN_3	Third thoracic cardiac nerve
TCN_4	Fourth thoracic cardiac nerve
TCN_5	Fifth thoracic cardiac nerve
TCN_6	Sixth thoracic cardiac nerve
TCN_7	Seventh thoracic cardiac nerve
TCN_8	Eighth thoracic cardiac nerve
TSC	Thoracic sympathetic chain
TVCN	Thoracic vagal cardiac nerve
VCN	Vertebral cardiac nerve
VG	Vertebral ganglion
WRC	White rami communicantes

CONTENTS

		Page No.
Abstract		iii
Preface		v
Acknowledgements		vi
Glossary of Terms		vii
Contents		x
List of Figures		xiv
List of Tables		xvii
List of Plates		xviii
CHAPTER 1	INTRODUCTION	1
CHAPTER 2	LITERATURE REVIEW	5
2.1	Embryology	12
2.1.1	Embryology of the peripheral nervous system	12
2.1.2	Embryology of the autonomic nervous system	14
2.1.3	Embryology of the sympathetic nervous system and ganglia	15
2.1.4	Embryology of the parasympathetic nervous system and ganglia	16
2.1.5	Development of the nerves to the heart	18
2.2	Autonomic nervous system	25
2.2.1	Anatomy of the sympathetic nervous system	27
2.2.1.1	Cervical sympathetic chain	29
2.2.1.2	Superior cervical ganglion	32
2.2.1.3	Middle cervical ganglion	33
2.2.1.4	Vertebral ganglion	36
2.2.1.5	Inferior cervical ganglion	37
2.2.1.6	Cervicothoracic ganglion	38
2.3	Thoracic sympathetic chain	40
2.3.1	Thoracic ganglia	42
2.4	Additional medial branches	43
2.5	The anatomy of parasympathetic nervous system to	44

	the heart	
2.6	Anatomy of the cardiac plexuses	47
2.6.1	Superficial cardiac plexus	50
2.6.2	Deep cardiac plexus	52
2.7.1	Cardiac nerves of the sympathetic chain	54
2.7.2	Cardiac nerves of the parasympathetic system	64
CHAPTER 3	MATERIALS AND METHODS	70
3.1	Materials	71
3.2	Methods	72
3.2.1	Gross anatomical dissection	72
3.2.1.1	Thoracic dissection	72
3.2.1.2	Cervical dissection	73
3.3	Nomenclature	74
CHAPTER 4	RESULTS	83
4.1	Sample size	84
4.2	Cervical sympathetic chain	84
4.2.1	Course and relations	84
4.3	Cervical ganglia	88
4.3.1	Superior cervical ganglion	90
4.3.2	Middle cervical ganglion	92
4.3.3	Vertebral ganglion.	96
4.3.4	Inferior cervical ganglion	98
4.3.5	Cervicothoracic ganglion	99
4.4	Thoracic sympathetic chain	101
4.4.1	Thoracic ganglia	101
4.5	Cardiac plexus	102
4.5.1	Superficial cardiac plexus	102
4.5.2	Deep cardiac plexus	105
4.6	Cervical sympathetic cardiac nerves	108
4.6.1	Superior cervical cardiac nerve	109
4.6.2	Middle cervical cardiac nerve	111

4.6.3	Vertebral cardiac nerve	114
4.6.4	Inferior cervical cardiac nerve	117
4.6.5	Cervicothoracic cardiac nerve	120
4.7	Thoracic cardiac nerves	123
4.7.1	TCN_1	123
4.7.2	TCN_2	125
4.7.3	TCN_3	128
4.7.4	TCN_4	131
4.7.5	TCN_5	134
4.7.6	TCN_6	136
4.7.7	TCN_7	138
4.7.8	TCN_8	140
4.8	Vagus nerve	141
4.8.1	Cervical vagal cardiac nerves	141
4.8.1.1	Superior cervical vagal cardiac nerve	143
4.8.1.2	Middle cervical vagal cardiac nerve	145
4.8.1.3	Inferior cervical vagal cardiac nerve	147
4.8.2	Thoracic vagal cardiac nerves	149
4.8.3	Recurrent laryngeal cardiac nerves	151
CHAPTER 5	DISCUSSION	153
5.1	Sample size	154
5.2	Cervical sympathetic chain	154
5.2.1	Course and relations	154
	Cervical ganglia	156
5.2.2	Superior cervical ganglion	157
5.2.3	Middle cervical ganglion	158
5.2.4	Vertebral ganglion	160
5.2.5	Inferior cervical ganglion	160
5.2.6	Cervicothoracic ganglion	160
5.3	Thoracic sympathetic chain	163
5.3.1	Course and relations	163
5.3.2	Thoracic ganglia	163

5.3.3	Additional medial branches	164
5.4	Cardiac plexus	164
5.4.1	Superficial cardiac plexus	165
5.4.2	Deep cardiac plexus	167
5.5	Cervical sympathetic cardiac nerves	168
5.5.1	Superior cervical cardiac nerve	169
5.5.2	Middle cervical cardiac nerve	171
5.5.3	Vertebral cardiac nerve	172
5.5.4	Inferior cervical cardiac nerve	172
5.5.5	Cervicothoracic cardiac nerve	173
5.6	Thoracic cardiac nerves	173
5.7	Vagus nerve	175
5.7.1	Cervical vagal cardiac nerves	175
5.7.2	Thoracic vagal cardiac nerves	175
5.7.3	Recurrent laryngeal cardiac nerve	176
CHAPTER 6	CONCLUSION	177
REFERENCES		181
APPENDICES		186
APPENDIX A		187
APPENDIX B		189
APPENDIX C		191
APPENDIX D		193
APPENDIX E		195
APPENDIX F		197

LIST OF FIGURES

Figure	Description	Page No.
Figure 1	Diagrammatic representation of the sympathetic cardiac nerves and their connections with higher centers.	7
Figure 2	Diagrammatic representation of the development of PNS	13
Figure 3	Diagrammatic representation of distribution of sensory ganglia to cranial nerves	14
Figure 4	Diagrammatic representation of reconstruction of: [A] antero-superior view of the heart after removal of atria; [B] dorsal view of heart showing nerves related to the heart	19
Figure 5	A section of the rich innervations of the sinus nodal region anterior to the superior caval inlet whereas the general myocardium is poorly innervated	20
Figure 6	Diagrammatic representation of dorsal view of the distribution of nerves in the embryonic heart after stage 31-40mm	21
Figure 7	Schematic representation of the origin and distribution of nerves to the heart	23
Figure 8	Diagrammatic representation of two parts of the autonomic nervous system and their ganglia.	25
Figure 9	Diagrammatic representation of two parts of the sympathetic nervous system and their ganglia.	27
Figure 10	An illustration of the relationship between spinal nerves and sympathetic ganglia	28
Figure 11	Sympathetic ganglia in the thorax	29
Figure 12	Cervical sympathetic chain and its ganglia	31
Figure 13	Superior cervical ganglion	32
Figure 14	The middle cervical ganglion	34
Figure 15	Varying loci of MCG	35
Figure 16	Diagram of the inferior cervical ganglion and its relations	37
Figure 17	Diagrammatic representation of the cervicothoracic ganglion	39
Figure 18	Thoracic sympathetic chain and its relations	41
Figure 19	Thoracic sympathetic chain and ganglia	42
Figure 20	Diagrammatic representation of the vagus nerve in the neck	44

Figure 21	Diagram illustrating the cardiac plexuses	48
Figure 22	Diagram showing superficial cardiac plexus	50
Figure 23	Diagram showing the deep cardiac plexus	53
Figure 24	Thoracic cardiac branches of the vagus nerve	67
Figure 25	Schematic diagram of single fetal CSC.	85
Figure 26	Schematic diagram of multiple CSC in a fetus.	87
Figure 27	Incidence of cervical ganglia	89
Figure 28	Schematic diagram of SCG in a fetus	91
Figure 29	Graphic representation of incidence of MCG	93
Figure 30	Schematic diagram of normal MCG in a fetus	93
Figure 31	Graphic representation of types of MCG	94
Figure 32	Schematic diagram of a left double MCG in a fetus	95
Figure 33	Schematic diagram of the left VG in a fetus	97
Figure 34	Schematic diagram of the right ICG in a fetus	98
Figure 35	Schematic diagram of the left inverted CTG in a fetus	100
Figure 36	Schematic diagram of SCP in a fetus	103
Figure 37	Schematic diagram of SCP on BT and arch of aorta in a fetus	104
Figure 38	Schematic diagram of the DCP in a fetus	106
Figure 39	Graphic representation of the incidence of cervical cardiac nerves	108
Figure 40	Schematic diagram of the right SCCN in a fetus	109
Figure 41	Incidence (%) of SCCN	111
Figure 42	Origin (%) of SCCN	111
Figure 43	Schematic diagram of the left MCCN showing ganglionic and interganglionic origins	111
Figure 44	Incidence (%) of MCCN	114
Figure 45	Origin (%) of MCCN	114
Figure 46	Schematic diagram of the right VCN in a fetus	115
Figure 47	Incidence (%) of VCN	116
Figure 48	Origin (%) of VCN	117
Figure 49	Schematic diagram of the right ICCN in a fetus	118
Figure 50	Incidence (%) of ICCN	119
Figure 51	Origin (%) of ICCN	120

Figure 52	Schematic diagram of the left CTCN in a fetus	121
Figure 53	Schematic diagram of the left TCN_1 contribution to DCP in a fetus	124
Figure 54	Schematic diagram of the left TCN_2 contribution to the DCP in a fetus	126
Figure 55	Schematic diagram of the left TCN_3 contribution to the DCP in a fetus	129
Figure 56	Schematic diagram of the left TCN_4 contribution to the DCP in a fetus	132
Figure 57	Schematic diagram of the left TCN_5 contribution to the DCP in a fetus	135
Figure 58	Schematic diagram of a contribution from the left T_6G to the GSN in a fetus	137
Figure 59	Schematic diagram of a contribution from the left T_7G to the GSN in a fetus	139
Figure 60	Schematic diagram of a contribution from the right cervical cardiac nerve of vagus nerve	142
Figure 61	Schematic diagram of the contribution from the SVCN to the DCP in a fetus.	144
Figure 62	Schematic diagram of the contribution from the left MVCN to the SCP in a fetus.	146
Figure 63	Schematic diagram of the contribution from the left IVCN to the SCP in a fetus.	148
Figure 64	Schematic diagram of the contribution from the right TVCN to the DCP in a fetus.	150
Figure 65	Schematic diagram of the contribution from the RLCN to the DCP in a fetus.	152

LIST OF TABLES

Table	Description	Page No.
Table 1	Varying thoracic roots of TCN to the DCP	64
Table 2	Sample distribution	84
Table 3	Branching patterns of CSC	86
Table 4	Distribution patterns of cervical ganglia	88
Table 5	Incidence of cervical ganglia	89
Table 6	Varying shapes of SCG	90
Table 7	Incidence of the middle cervical ganglia	92
Table 8	Incidence of types of MCG	94
Table 9	Percentage contributions to the SCP	105
Table 10	Percentage contributions to the DCP	107
Table 11	Incidence of cervical cardiac nerves	108
Table 12	Incidence and origin of SCCN	110
Table 13	Incidence and origin of MCCN	113
Table 14	Incidence and origin of VCN	116
Table 15	Incidence and origin of ICCN	119
Table 16	Incidence and origin of CTCN	122
Table 17	Incidence of TCN_1	125
Table 18	Incidence of TCN_2	127
Table 19	Incidence of TCN_3	130
Table 20	Incidence of TCN_4	133
Table 21	Incidence of TCN_5	136
Table 22	Reported incidence of cervical ganglia	156
Table 23	Comparison of incidence of different shapes of CTG	162
Table 24	Percentage contributions to the SCP	166
Table 25	Percentage contributions to the DCP	168
Table 26	Recorded thoracic limits of thoracic cardiac nerves	174

LIST OF PLATES

Plate	Description	Page No.
Plate 1	Antero-lateral view of a left single fetal cervical sympathetic chain with the vagus nerve and the common carotid artery removed.	85
Plate 2	Antero-lateral view of the right CSC dividing into multiple branches in a fetus	87
Plate 3	Antero-lateral view of the left SCG in a fetus	91
Plate 4	Antero-medial view of normal location of right MCG in a fetus	93
Plate 5	Antero-lateral view of double left MCG in a fetus	95
Plate 6	Antero-lateral view of the left VG in a fetus	97
Plate 7	Antero-lateral view of the right ICG in a fetus	98
Plate 8	Antero-lateral view of the left inverted CTG in a fetus	100
Plate 9	SCP in a fetal specimen	103
Plate 10	SCP on BT and arch of aorta in a fetus	104
Plate 11	DCP in a fetal specimen	106
Plate 12	Antero-medial view of the right SCCN in a fetus	109
Plate 13	Antero-medial view of the left MCCN in a fetus showing ganglionic and interganglionic origins	112
Plate 14	Antero-medial view of the right VCN in a fetus	115
Plate 15	Antero-medial view of the right ICCN in a fetus	118
Plate 16	Antero-medial view of left CTCN in a fetus	121
Plate 17	Antero-medial view of the left TCN_1 contribution to DCP in a fetus	124
Plate 18	Antero-medial view of the left TCN_2 contribution to the DCP in a fetus	126
Plate 19	Antero-medial view of the left TCN_3 contribution to the DCP in a fetus	129
Plate 20	Antero-medial view of the left TCN_4 contribution to DCP in a fetus	132
Plate 21	Anterior-medial view of the left TCN_5 contribution to the DCP in a fetus	135

Plate 22	Contribution from T_6G to GSN in a fetus	137
Plate 23	Contribution from T_7G to GSN in a fetus	139
Plate 24	Contribution of the left cervical cardiac nerve from vagus nerve	142
Plate 25	Contribution from the right superior vagal cardiac nerve to the SCP in a fetus	144
Plate 26	Contribution from the left middle vagal cardiac nerve to superficial cardiac plexus	146
Plate 27	Contribution from the left inferior cervical vagal cardiac nerve to the SCP in a fetus	148
Plate 28	Contribution from the right thoracic vagal cardiac nerve to the DCP in a fetus	150
Plate 29	Contribution from the right recurrent laryngeal cardiac nerve to the DCP in a fetus	152

CHAPTER 1

INTRODUCTION

The cardiac plexus is “formed by mixed autonomic nerves” that are “described in terms of superficial and deep components, with the superficial located below the aortic arch and anterior to the pulmonary artery, and the deep located posterior to the aortic arch and anterior to the tracheal bifurcation (above the division of the pulmonary trunk)” (Standring *et al*., 2008). In addition, these are further subdivided into “coronary, pulmonary, atrial and aortic” plexuses (Mizeres, 1972; Standring *et al*., 2008).

The cardiac sympathetic rami arise from the medial aspect of the cervical and upper thoracic parts of the sympathetic chain and contribute the majority of its branches to the cardiac plexus. The cervical cardiac nerves (arising from cervical ganglia) have contributed to the majority of the literature of the cardiac plexus (Kuntz and Morehouse 1930, Kalsey *et al.,* 2000; Pather *et al.,* 2003) compared to the contributions of the thoracic cardiac nerves (Kuntz and Morehouse, 1930; Groen *et al*., 1987).

The cervical cardiac sympathetic nerves arise from the superior, middle and inferior or cervicothoracic cervical ganglia, and the thoracic from the thoracic sympathetic chain. The superior cervical ganglion gives off a branch, the superior cervical cardiac nerve to the superficial cardiac plexus on the left side and to the deep cardiac plexus on the right side. The middle cervical ganglion sends the largest cardiac nerve to the deep cardiac plexus while the inferior cervical or cervicothoracic ganglion also contributes to the deep cardiac plexus (Standring *et al*., 2008; San Mauro *et al*., 2009).

According to standard anatomical textbooks, the thoracic sympathetic cardiac nerves arise from the upper four or five thoracic ganglia (Standring *et al*., 2008). However, other investigations have found the limit of these to vary from the cervicothoracic ganglion (Randall and Armour, 1977) to T2-T6 or T7 ganglia (Kuntz and Morehouse, 1930; Saccommano, 1943). It has been reported by several authors that the parasympathetic nerve supply to the cardiac plexus originates from the vagus nerve via its superior and inferior branches as well as from its counterpart, the recurrent laryngeal nerve (Mizeres, 1972; Kadowaki and Lewett, 1986; Kawashima, 2005, San Mauro *et al*., 2009). Variations in the sympathetic and parasympathetic contributions to the cardiac plexus have been previously reported by Kawashima (2005) and San Mauro *et al*. (2009).

Minimal invasive surgery has gained "popularity" in cardiac sympathetic denervation for intractable angina pectoris in patients unsuitable for conventional revascularization (Khogali *et al*., 1999). Khogali *et al*. (1999) was successful in interrupting the pain pathway in limited T2-T4 sympathectomy to relieve pain at rest in patients with intractable angina pectoris. This indicates the importance of understanding the medial sympathetic contributions and their variations to the cardiac plexus as this may assist surgeons during minimally invasive surgical procedures such as sympathectomies, pericardiectomies and in the management of diseases like Reynaud's Phenomenon and angina pectoris (Kalsey *et al*., 2000; Zhang *et al*., 2009).

This study aims to:

1) Examine the sympathetic contributions from the superior, middle and inferior or cervicothoracic sympathetic ganglia to the superficial and deep cardiac plexuses
2) Examine sympathetic contributions from TI-T8 thoracic sympathetic chain to the superficial and deep cardiac plexuses
3) Examine the parasympathetic contributions from the vagus nerve to the superficial and deep cardiac plexuses

CHAPTER 2

REVIEW OF LITERATURE

HISTORICAL BACKGROUND

AUTONOMIC NERVOUS SYTEM

The autonomic nervous system (ANS) was first studied by Galen (A.D. 130-200) in pigs where he described “the superior cervical, inferior, semilunar ganglia and rami communicantes” (Ackerknecht, 1974). Further studies by Eustachius in 1563 and Willis (1664) as reflected by Ackerknecht (1974) presented an enhanced understanding of this ANS. Eustachius (1524-1574) in 1563 regarded the vagus nerve and sympathetic nervous system as two different nerves but stated that the sympathetic nervous system was a continuation of the abducens nerve i.e. 6th cranial nerve (Ackerknecht, 1974). Willis in 1664 followed Eustachius‟ notion of two separate entities and referred to the vagus and the sympathetic nervous system as „intercostalis‟ and expressed that the voluntary and the involuntary motions were governed by the cerebrum and the cerebellum respectively (Ackerknecht, 1974).

In 1727 Du Petit (1664-1741) made “an outstanding contribution on the subsequent clinical outcomes viz. myosis, ptosis and enophthalmos” that occurred in “the excision of the superior cervical ganglion (SCG) in a dog”. Winslow (1669-1760) described and provided an extensive description of three sympathetic nerves viz. “small, middle and large sympathetic nerves” that are named today, viz. “facial nerve, vagus nerve and sympathetic chain”, respectively; and also the white and grey rami communicantes (Ackerknecht, 1974). Jackson (1873-1874) was the first to clearly state that visceral activities must be represented at varying levels in the central nervous system (CNS) (Mitchell, 1953).

The “turning point in the history of the ANS was reached in 1800” by Bichat (1771-1802) who described “the sympathetic trunk as not a nerve but a chain of little brains (i.e. ganglia) with new fibres” as quoted by Ackerknecht in 1974. Remak (1815-1865) discovered “the unmyelinated fibres in the sympathetic nervous system” and “explained the existence of white and grey rami communicantes” discovered by Winslow (1669-1760) (Ackerknecht, 1974). Remak (1815-1865) further discovered that “nerve fibres always arose from ganglion cells” (Ackerknecht, 1974). These findings were further established by Mitchell (1953) in that “the higher centers (i.e. hypothalamus, frontal cortex and brainstem) concerned with cardiovascular, respiratory and other autonomic activities (Figure 1) were linked via afferent and efferent pathways”.

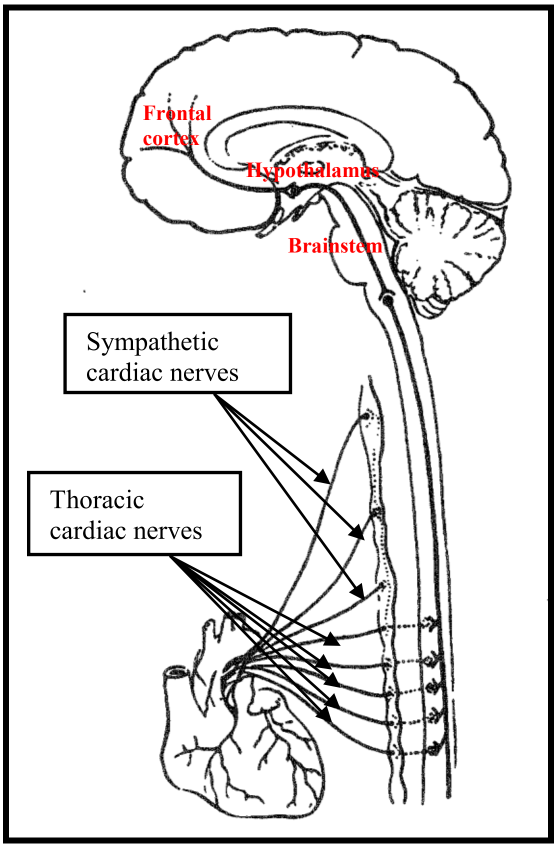


Figure 1: Diagrammatic representation of the sympathetic cardiac nerves and their connections with higher centers (Adapted from Mitchell, 1953).

Langley (1852-1925) gave the ANS its name and "developed the notion of antagonism between sympathetic and parasympathetic systems through experiments that demonstrated preganglionic and postganglionic neurons in the sympathetic nervous system" (Ackerknercht, 1974).

CARDIAC PLEXUS

Gabriello Fallopeo (Fallopius 1523-1562) was the pioneer in describing the nerves to the heart (Mizeres, 1972; Acierno, 1994). In 1749, Senae described the cardiac plexuses as consisting of "superficial and deep" or "superior and inferior" parts while Murray (1772) considered a "great cardiac plexus" between the aorta and the pulmonary trunk and a "superficial cardiac plexus" in relation to the arch of aorta (Mizeres, 1972).

In 1843, Valentin described a "superior" plexus around the brachiocephalic and carotid arteries and the arch of the aorta; and an "inferior" plexus within the pericardium related to the arterial and venous vessels of the heart. Perman (1924) portrayed the two parts of the cardiac plexus as passing anterior and posterior to the transverse pericardial sinus whereas Soulie (1904) described a "superficial" cardiac plexus located behind the aorta and pulmonary trunk and a "deep" plexus located behind the aorta and in front of the trachea (Mizeres, 1972).

Hovaloque (1927) decided to abandon the concept of superficial and deep cardiac plexuses and instead related the cardiac plexus to arterial and venous ends of the heart. This was also confirmed by Tinel (1937) although he followed Soulie"s description of the deep cardiac plexus (Mizeres, 1972). Licata (1954), in an account of the embryonic heart used the terms truncoconal cardiac plexus and sinoatrial cardiac plexus (Mizeres, 1972).

Thereafter, the cardiac plexus was described as the plexus in which the various vagal and sympathetic nerves ended and lost their individual entities (Mizeres, 1972). It was customarily described as consisting of superficial (anterior) and deep (posterior) parts and further subdivided into atrial, coronary and pulmonary plexuses (Mizeres, 1972). The superficial part was described as lying in the concavity of the aortic arch and received the left superior cervical sympathetic and inferior vagal cardiac nerves (Mitchell, 1953). Kuntz and Morehouse (1930) reported the cardiac plexuses and their intercommunications to be relatively simple in the foetus.

Arnulf (1950) described a more superficial part that lay anterior to the ascending aorta and termed it the pre-aortic plexus that is formed mainly by filaments from the left vagal and left sympathetic cardiac nerves which reached the anterior surface of the ascending aorta. Arnulf (1950) also stated that this pre-aortic plexus was reinforced by a few twigs from the corresponding nerve of the right side and several ganglia were found to be present in this plexus where vagal preganglionic fibres would relay. The largest of these ganglia is the ganglion of Wrisberg that lay below the aortic arch between the tracheal bifurcation and division of the pulmonary trunk (Mitchell, 1953).

The deep part was located posterior to the aortic arch, anterior to the tracheal bifurcation and received all the other vagal and sympathetic cardiac branches (Mitchell, 1953). The subdivisions were considered artificial as little difference existed between the two parts and as they interconnected freely with each other as a single unit. A tendency to separate these subdivisions into right and left halves was also noted (Mitchell, 1953).

SYMPATHETIC GANGLIA

In Axford‟s (1928) account on the cervical sympathetic ganglia, he described the superior and inferior cervical ganglia as ganglia either located high up and low down in the neck. He also reported that the middle cervical ganglion (MCG) was sometimes absent while Ionesco and Enachesco (1927) further stated that in a number of cases this MCG was represented by a number of small thickenings on the cervical sympathetic chain (Axford, 1928).

In a detailed account of the MCG, Axford (1928) illustrated two types of this ganglion viz. high and low types. The *high type* MCG was explained as the ganglion that was in close association with the inferior thyroid artery at the level of the 6^{th} cervical vertebra whilst the *low type* MCG was located anterior to the vertebral artery at the level of the 7^{th} cervical vertebra (Axford, 1928).

CARDIAC NERVES

Gaskel and Gadow (1885) reported three sympathetic cardiac nerves to be always present in man viz. “the superior, middle and inferior cardiac nerves”. In addition, they identified the middle cardiac nerve to be the “strongest” nerve as it enclosed the inferior cardiac nerve in its course to the heart (Gaskell and Gadow, 1885). Sympathetic fibres (myelinated and preganglionic) to the heart were depicted as axons of cells located in the lateral grey column of the upper four or five thoracic segments of the spinal cord leaving it via ventral roots of the corresponding spinal nerves. These entered white rami communicantes by passing to adjacent ganglia in the paravertebral sympathetic trunks, with some relaying in these ganglia while others ascended from these trunks to the cervical ganglia before forming synapses with efferent neurons. Postganglionic axons (unmyelinated) ran in various cardiac branches of the sympathetic trunks viz. the cardiac nerve of the SCG (Mitchell, 1953).

Afferent cardiac fibres in sympathetic nerves are peripheral processes of cells located in the dorsal root ganglia of the upper four and five thoracic spinal nerves and the central processes enter the spinal cord via their corresponding dorsal nerve roots. At this point synapses were formed with the posterior and lateral columns of grey matter (Mitchell, 1953). Cardiac branches were derived from cervical ganglia as three pairs and upper four or five thoracic ganglia; and named according to the respective ganglia or the sympathetic trunks below them or adjacent to them or closely related structures that they arose from (Mitchell, 1953). The thoracic cardiac nerves are the medial branches of the thoracic sympathetic chain that contributed to the cardiac plexus. In addition, they have varying thoracic limits (Kuntz and Morehouse, 1930) *(Table 1, page 63)*.

Parasympathetic cardiac fibers were carried in the vagi and in the cranial parts of the accessory nerves that join them. Preganglionic fibres (myelinated) originated in the dorsal vagal nucleus and the nucleus ambiguus located in the medulla oblongata (Mitchell, 1953). These myelinated fibres were conveyed to their destinations in the vagus nerves and their branches ended by forming synapses with postganglionic neurons in ganglia in the cardiac plexus or in the wall of the heart. The parasympathetic cardiac branches were found to be variable in size, number and distribution; and arose from the vagi both in the neck and thorax. The cardiac nerves were divided into three groups i.e. superior, middle and inferior, which interconnected with the sympathetic chain at various levels and sometimes with other nerves. These vagal cardiac nerves were named according to the levels of the neck at which they left the main vagus trunk or nerve. Any connections that existed between these and the sympathetic counterparts or other nerves were also documented (Mitchell, 1953).

2.1 EMBRYOLOGY

2.1.1 EMBRYOLOGY OF THE PERIPHERAL NERVOUS SYSTEM

The peripheral nervous system (PNS) consists of cranial, spinal and visceral nerves as well as cranial, spinal and autonomic ganglia. The PNS develops mostly from the neural crest cells. Sensory cells (i.e. somatic and visceral) of the PNS are derived from neural crest cells and their cell bodies are located outside the CNS. All these peripheral sensory cells are bipolar at first but the two processes unite to form a single process, the unipolar type of neuron. This unipolar neuron has a peripheral process that terminates in a sensory ending and a central process that enters the spinal cord or brain (Figure 2). (Moore and Persaud, 2008)

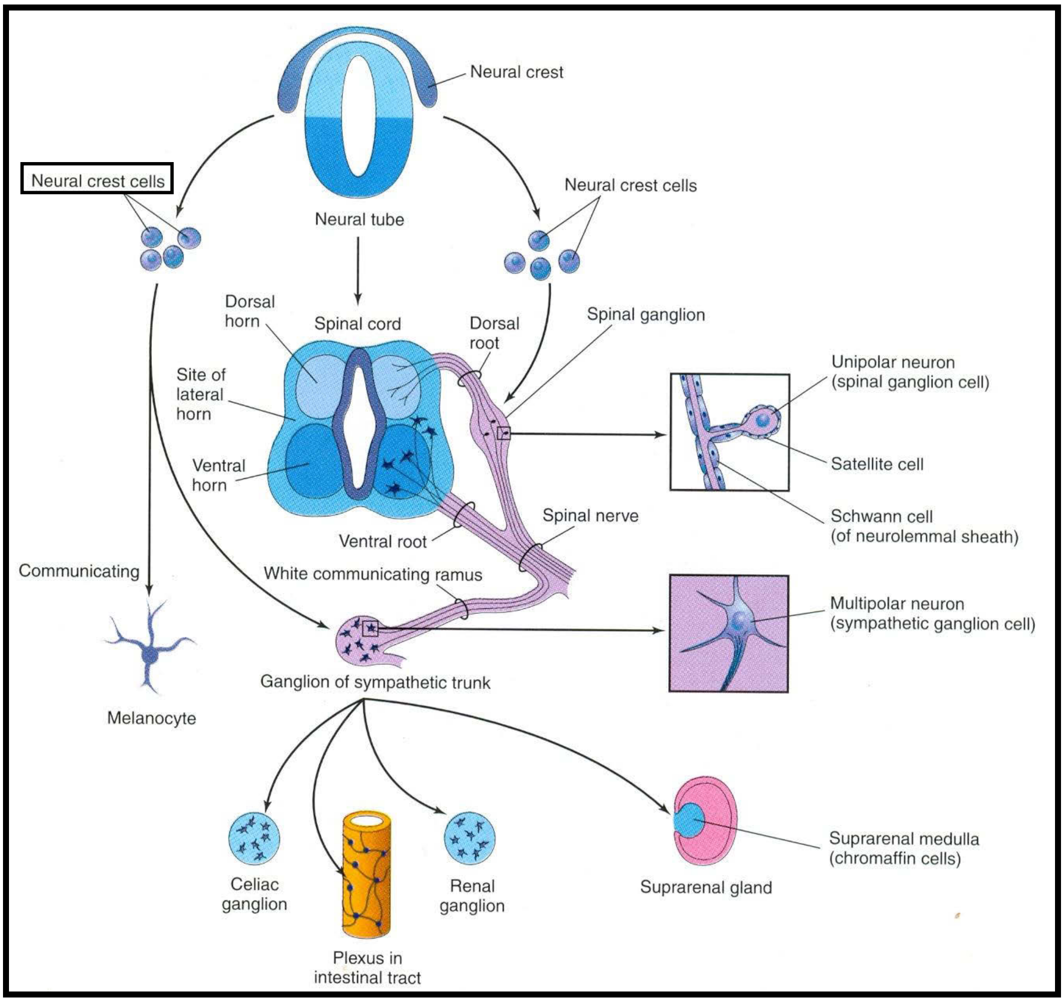


Figure 2: Diagrammatic representation of the development of PNS. (Adapted from Drake *et al*., 2009)

The neural crest cells in the developing brain migrate to form sensory ganglia in relation to the trigeminal (CN V), facial (CN VII), vestibulocochlear (CN VIII), glossopharyngeal (CN IX) and vagus nerves (CN X) (Figure 3). They differentiate into multipolar neurons of the autonomic ganglia (Figure 2) including ganglia of the sympathetic trunks that lie along the sides of the vertebral bodies i.e. prevertebral ganglia in plexuses of the thorax and abdomen (e.g. cardiac, celiac and mesenteric plexuses) and parasympathetic ganglia in or near the viscera (Moore and Persaud, 2008).

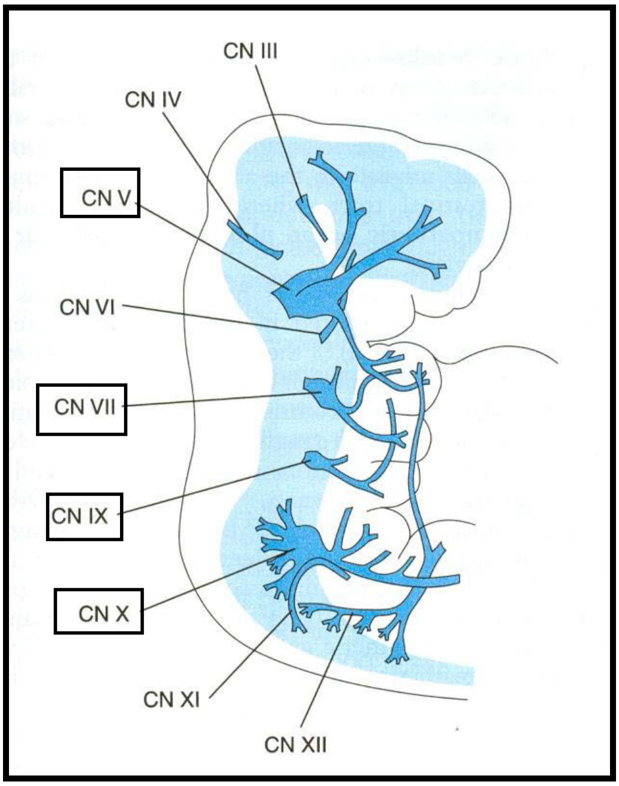


Figure 3: Diagrammatic representation of the distribution of sensory ganglia to cranial nerves.

(Adapted from Moore and Persaud, 2008)

2.1.2 EMBRYOLOGY OF THE AUTONOMIC NERVOUS SYSTEM

At neurulation in the trunk, "neural crest cells migrate to form the neural epithelium which lies transitorily on the fused neural tube" (Standring *et al*., 2008). They thereafter "migrate laterally and then ventrally to their respective destinations" (Standring *et al*., 2008) [Figure 2].

In the head, "the neural crest cells migrate prior to neural fusion, producing a vast mesenchymal population and autonomic neurons" as quoted by Standring *et al*. (2008). "The four major regions of neural crest cell distribution to the ANS are cranial, vagal, trunk and lumbosacral" (Standring *et al*., 2008). "The cranial neural crest gives rise to the cranial parasympathetic ganglia" while "the vagal neural crest gives rise to the thoracic parasympathetic ganglia" (Standring *et al*., 2008). "The trunk neural crest gives rise to the sympathetic ganglia i.e. mainly the paravertebral ganglia and supramedullary cells" (Standring *et al*., 2008). This "is often referred to as the sympathoadrenal lineage" (Standring *et al*., 2008). The lumbosacral neural crest is reported to "form components of the pelvic plexus" (Standring *et al*., 2008).

2.1.3 EMBRYOLOGY OF THE SYMPATHETIC NERVOUS SYSTEM AND GANGLIA

Sympathetic nervous system

Moore and Persaud (2008) stated that "during the fifth week of development, the neural crest cells in the thoracic region migrate along each side of the spinal cord where they form paired cellular ganglia dorsolateral to the aorta" (Moore and Persaud, 2008). "These segmentally arranged sympathetic ganglia were connected in a bilateral chain by longitudinal nerve fibers i.e. sympathetic trunks located on each side of the vertebral bodies" (Moore and Persaud, 2008). "Some of these neural crest cells migrated ventral to the aorta to form preaortic ganglia such as the celiac and mesenteric ganglia while the other neural crest cells migrated to the area of the heart, lungs and gastrointestinal tract where they formed terminal ganglia in sympathetic organ plexuses" (Moore and Persaud, 2008).

Sympathetic ganglia

Ganglion cells of the sympathetic nervous system are derived from neural crest cells (Moore and Persaud, 2008). "Neural crest cells migrate from the body segments to penetrate the underlying somites and continue to the region of the future paravertebral and prevertebral plexuses, forming the sympathetic chain of ganglia and major ganglia around the ventral visceral branches of the abdominal aorta" and "cell specific recognition of postganglionic and growth cones of sympathetic preganglionic neurons occurs and they meet during their growth, which might be important in guidance to their appropriate target" (Standring *et al*., 2008).

"The position of the postganglionic neurons and their exit point from the spinal cord of preganglionic neurons may influence the types of synaptic connections made and affinity for postganglionic neurons" and "when the postganglionic neuroblast is in place it extends axons (and dendrites) and synaptogenesis occurs" (Standring *et al*., 2008). Earliest axonal outgrowths from the SCG occur at about stage 14 (Standring *et al*., 2008).

2.1.4 EMBRYOLOGY OF PARASYMPATHETIC NERVOUS SYSTEM AND GANGLIA

"The preganglionic parasympathetic fibers arise from neurons in nuclei of the brainstem and in the sacral region of the spinal cord" and "these fibers leave the brainstem through oculomotor (CN III), facial (CN VII), glossopharyngeal (CN IX) and vagus nerves (CN X)" (Moore and Persaud, 2008). "The postganglionic neurons are located in peripheral ganglia or in plexuses near or within the structures being innervated" (Moore and Persaud, 2008).

"Neural crest cells migrate from the region of the mesencephalon and rhombencephalon prior to closure of the neural tube" (Standring *et al*., 2008). "From rostral to caudal, three populations of neural crest are noted: cranial, cardiac and vagal; the cranial neural crest give rise to the cranial parasympathetic ganglia, while the vagal neural crest give rise to the thoracic parasympathetic ganglia" (Standring *et al*., 2008).

"The neural crest cells from the caudal third of the mesencephalon and rostral metencephalon migrate along or close to the ophthalmic branch of the trigeminal nerve (CNV) and gives rise to the ciliary ganglion which can also receive cells migrating from the oculomotor nerve (CNIII)" (Standring *et al*., 2008). "Preotic mylencephalic neural crest cells give rise to the pterygopalatine ganglion which may also receive contributions from ganglia of the trigeminal (CNV) and facial (CNVII) nerves" (Standring *et al*., 2008). "The otic and submandibular ganglia are also derived from the mylencephalic neural crest and may receive contributions from the glossopharyngeal (CNIX) and facial (CNVII) cranial nerves, respectively" (Standring *et al*., 2008).

The cardiac neural crest is the crest from the region located between the otic placode and the caudal limit of somite 3 (Standring *et al*., 2008). "Cells derived from these levels migrate through pharyngeal arches 3, 4 and 6 where they provide support for embryonic aortic arch arteries, cells of the aorticopulmonary septum and truncus arteriosus" and "some of these also differentiate into the neural anlage of the parasympathetic ganglia of the heart" (Standring *et al*., 2008). The "sensory innervation to the heart is from the inferior ganglion of the vagus nerve; this is derived from the nodose placodes" (Standring *et al*., 2008). "Neural crest cells migrating from the level of somites 1-7 are collectively termed the vagal neural crest; they migrate to the gut along with sacral neural crest" (Standring *et al*., 2008).

"The vagus nerve is formed by fusion of the fourth and sixth pharyngeal arches" (Moore and Persaud, 2008). "It has large efferent and afferent visceral components that are distributed to the heart, foregut (and its derivatives) and to a large part of the midgut" (Moore and Persaud, 2008). The nerves of the vagus from the fourth and sixth pharyngeal arches become the superior laryngeal and the recurrent laryngeal nerves (RLN), respectively (Moore and Persaud, 2008).

2.1.5 DEVELOPMENT OF THE NERVES TO THE HEART

Navaratnam (1965) stated that the 11-mm embryonic stage is the earliest stage at which nerve fibres to the heart were identified which preceded the 7.5-mm embryonic stage of the differentiation of the atrio-ventricular bundle. At this stage, the heart is found to lie between the levels of the dorsal root ganglia of the fifth cervical and second thoracic spinal nerves with vagal and sympathetic nerve fibres running towards the truncus arteriosus to form a plexus at the dorsal extremity of the pulmonary arch artery.

During the 11-13mm embryonic stage, no nerve fibres are found in the interventricular septum or in the walls of the ventricles. In the 13-20mm embryonic stage (Figure 4 A and B), the nerve fibres accompanying the pulmonary arch artery entered the arterial mesocardium by piercing the aortic-pulmonary spur of extracardiac mesoderm. These nerves from the right and left sides remained in their separate groups within this mesocardium although both give off twigs around the aorta and pulmonary trunk (Navaratnam, 1965).

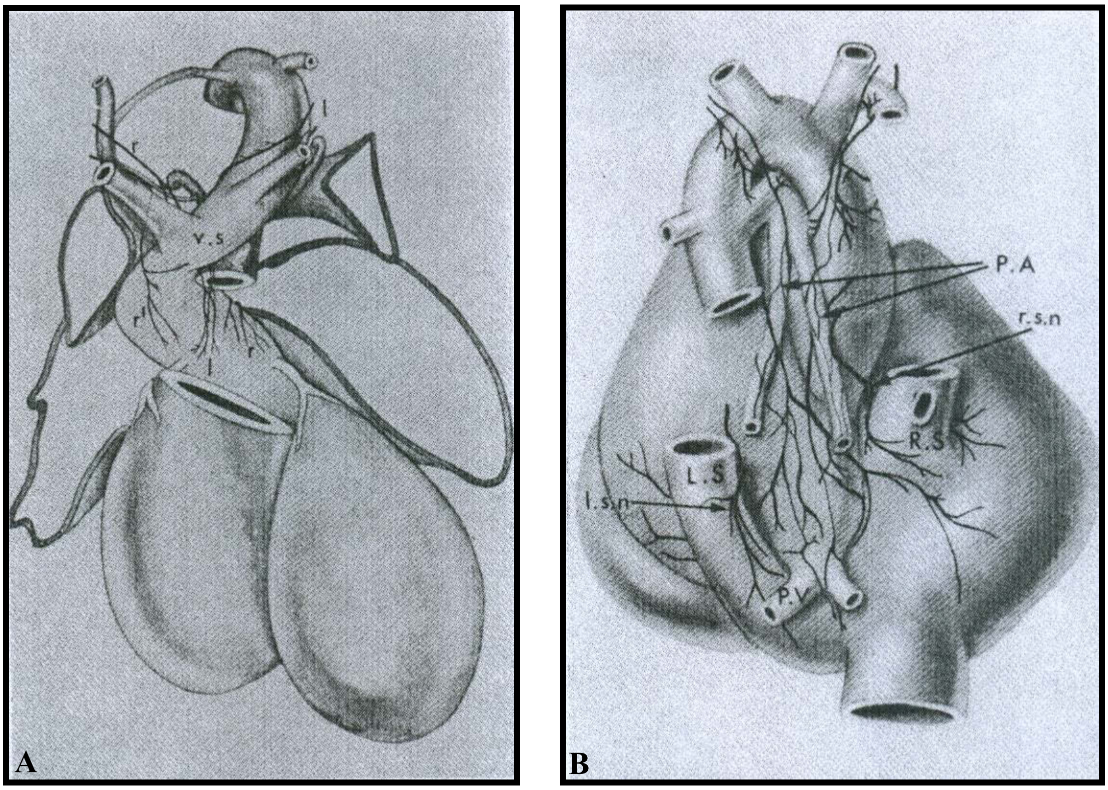


Figure 4: Diagrammatic representation of reconstruction of: [A] antero-superio view of the heart after removal of atria; [B] dorsal view of heart showing nerves related to the heart (Adapted from Navaratnam, 1965).

Key: r-right cardiac nerves, v.s.-ventral aortic sac, P.A.-pulmonary arteries, R.S.-right sinus horn, L.S.-left sinus horn, r.s.n.-right sinus nerve, PV-pulmonary veins, l.s.n-left sinus nerve, l-left cardiac nerves, r'-right cardiac nerves to the right side.

In addition, Navaratnam (1965) described another group of nerves traversing the venous mesocardium which were more numerous than those of the arterial mesocardium that maintained a similar distribution to that of the 11mm embryonic stage. These right and left sinus nerves reached the sinus horns after being accompanied by sympathetic twigs. These two groups i.e. arterial and venous mesocardia connected together posterior to the transverse pericardiac sinus along the pulmonary arteries. In the 21-30mm embryonic stage, the nerves of the arterial mesocardium formed plexuses that accompanied the coronary arteries for a short distance (Figure 5) but not the coronary arteries that penetrated the myocardium. It was noted that at the 28mm embryonic stage, these two sets of nerves joined and formed a single plexus on the right side of the ductus arteriosus which contained many developing ganglion nerve cells. Further development in this stage included the differentiation of the cardiac ganglia (Navaratnam, 1965).

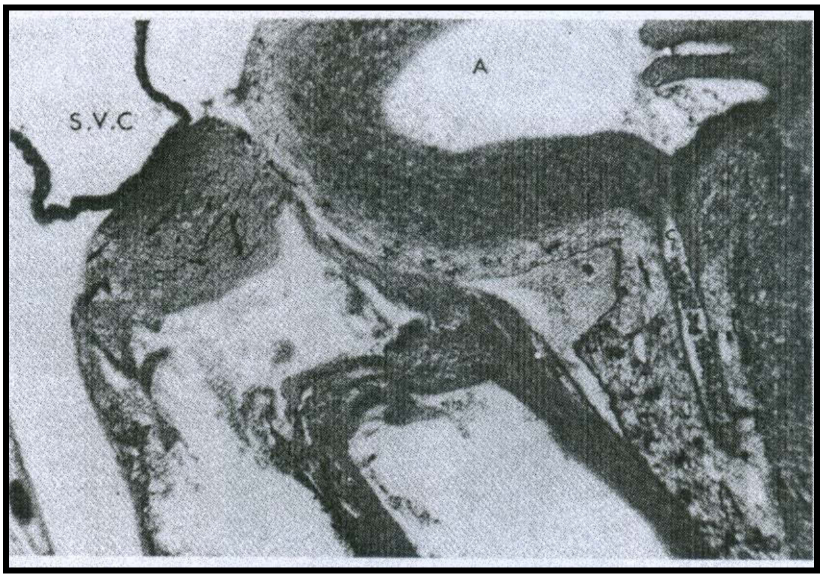


Figure 5: A section of the rich innervations of the sinus nodal region anterior to the superior caval inlet whereas the general myocardium is poorly innervated. (Adapted from Navaratnam, 1965).

Key: A-ascending aorta, c-Right coronary artery SVC-superior vena cava opening.

In the 31-40mm fetal stage, "the heart has descended to lie at the levels of the fifth to eighth thoracic segments (a position that it will maintain throughout development and postnatal life)" (Navaratnam, 1965). At this stage the group of cardiac nerves form 3 plexuses:

(1) “a plexus lying on the dorsal end of the ductus arteriosus formed by cervical cardiac nerves from the left side, this plexus corresponds to the superficial cardiac plexus in the adult;

(2) an arterial plexus on the right side of the ductus arteriosus formed by nerves from plexus (1) above i.e. cervical cardiac nerves from the right side and many thoracic cardiac nerves;

(3) The venous plexus of nerves which lie in relation to the venous mesorcadium” as quoted from Navaratnam (1965).

By the 40mm fetal stage, the venous mesocardium is closely related to the arterial mesocardium such that plexuses 2 and 3 unite to form a single plexus extending from the arterial mesocardium to the back of the atria, “this plexus corresponds to the definitive deep cardiac plexus” (Navaratnam, 1965) (Figure 6 A and B).

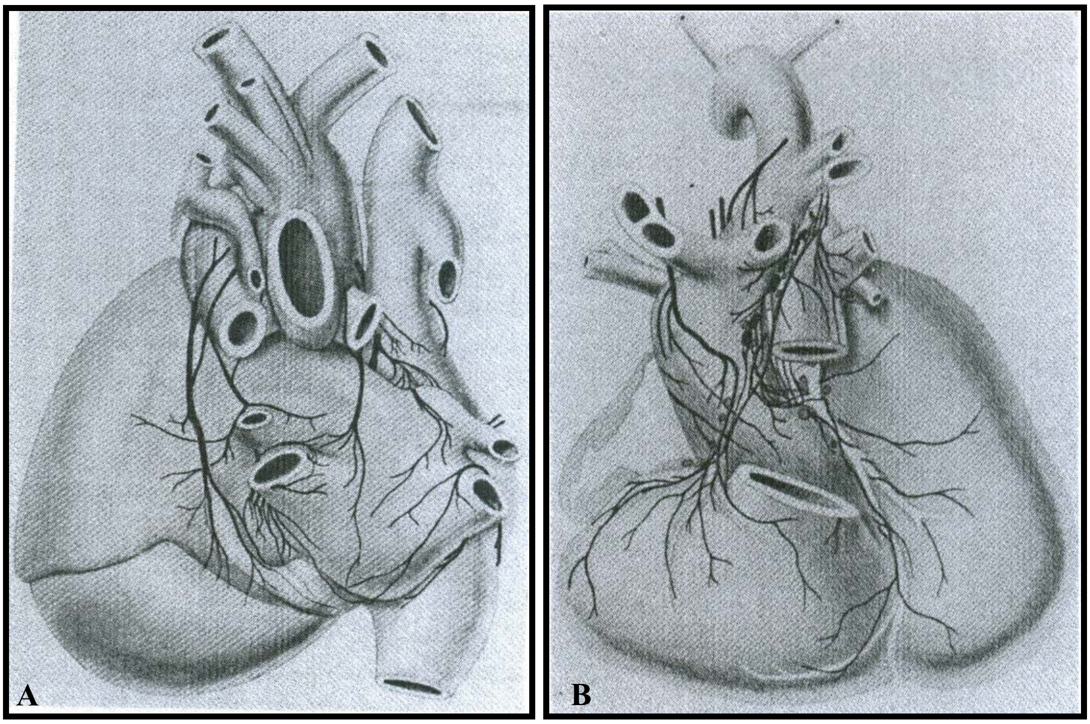


Figure 6: Diagrammatic representation of dorsal view of the distribution of nerves A: to the atrial region and B: to coronary plexuses.in the embryonic heart after stage 31-40mm (Adapted from Navaratnam, 1965).

According to Gardner and O'Rahilly (1976), the nerve supply on the right side arose from several cervical vagal and sympathetic filaments that were interconnected and ganglionated thus losing their separate entities; they regarded these as vagosympathetic and afferent nerves. They described two filaments that arose from the level of origin of the recurrent laryngeal nerve (RLN) that formed a branch which entered the aorticopulmonary ganglion which had a potential widespread distribution to arterial and venous structures (ductus arteriosus, pulmonary trunk, ascending aorta, coronary arteries and pulmonary vein). The nerve filaments below the origin of the RLN formed a right sinal nerve that gave filaments that entered the sinu-atrial node. No cardiac branches were noted to arise from the right sympathetic ganglia or the trunk below the level of the ansa subclavia (Figure 7) (Gardner and O'' Rahilly, 1976).

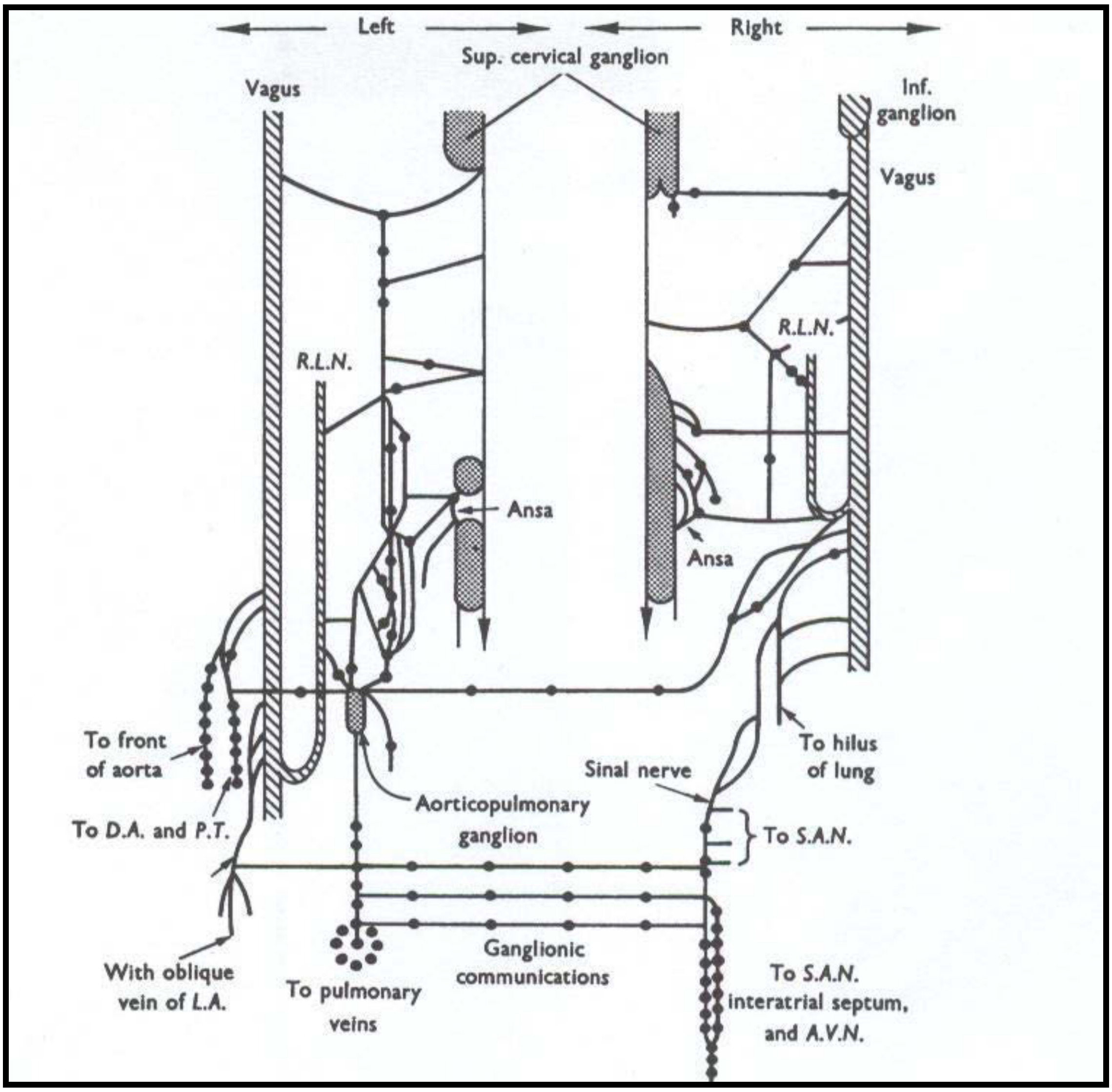


Figure 7: Schematic representation of the origin and distribution of nerves to the heart (Adapted from Gardner and O'Rahilly, 1976).

Key: AVN-Atrioventricular node, DA-Ductus arteriosus, LA-Left atrium, PT-Pulmonary trunk, SAN-Sino-atrial node

On the left side, "the nerve supply arose from several cervical sympathetic ganglionated filaments, and several thoracic vagal filaments" (Gardner and O" Rahilly, 1976). These filaments "including several from the RLN were directed chiefly towards the aorticopulmonary ganglion" (Gardner and O'Rahilly, 1976); which were distributed to the pulmonary trunk, ductus arteriosus, ascending aorta and pulmonary veins. "The two uppermost thoracic cardiac branches of the vagus descended to the left of the arch of the aorta" to supply "the arterial end of the heart" (Gardner and O'Rahilly, 1976) while the other thoracic filaments arose below the level of origin of RLN; united and formed the left sinal nerve with a filament from the aorticopulmonary ganglion (Gardner and O'Rahilly, 1976). The left sinal nerve "ended in groups of ganglion cells which were closely related to pulmonary veins as they entered the left atrium" (Gardner and O'Rahilly, 1976). No cardiac branches were also noted from the left sympathetic ganglia or trunk below the level of ansa subclavia (Gardner and O'Rahilly, 1976) (Figure 7).

Gordon *et al*. (1993) stated that progressive development of the general cardiac innervation was observed from the 7th week to the 24th week of gestation where the nerves and ganglia are localized by the 7th-10th week of gestation in the atrial epicardium, adventitia of the aorta and the pulmonary trunk. At the 9th week of gestation, the ventricles receive their innervations later than the atria. At 12-14 weeks of gestation, nerve fibres and fascicles are reported to be increasingly distributed throughout the atrial myocardium and endocardium and also around the intramyocardial blood vessels. At this stage of development, the perivascular plexus of ventricular coronary arteries extended with the vessels from the epicardium into the myocardium. The density of innervations increased up to the 24th week of gestation in order to resemble the pattern observed in the adult (Gordon *et al.,* 1993).

2.2 AUTONOMIC NERVOUS SYSTEM

The ANS is divided into three major parts i.e. sympathetic, parasympathetic and enteric. These differ in organization and structure but are functionally integrated. Structures innervated by the ANS receive both sympathetic and parasympathetic fibres (Figure 8) whilst the enteric nervous system supplies the network of neurones intrinsic to the wall of the gastrointestinal tract (Standring *et al*., 2008).

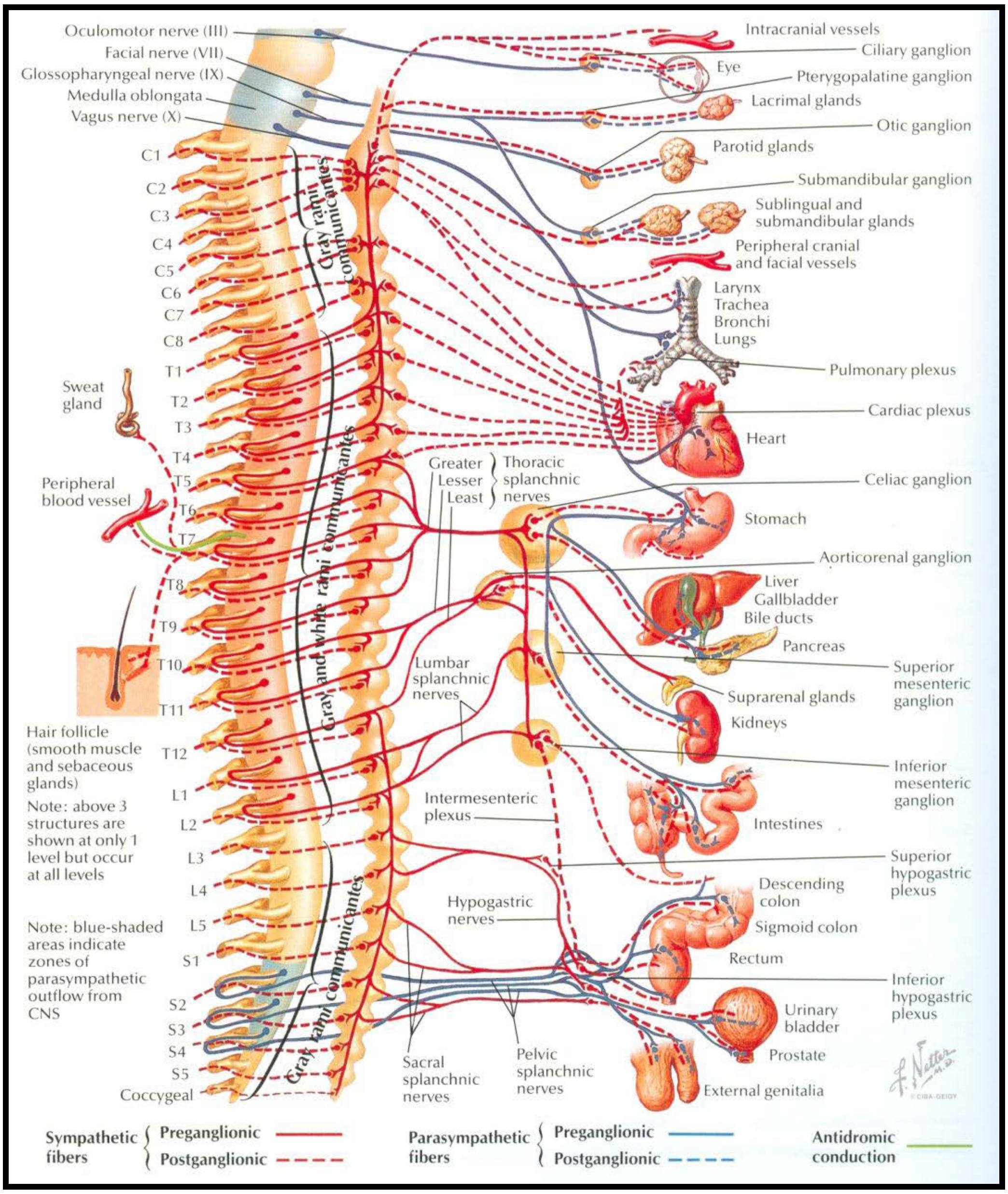


Figure 8: Diagrammatic representation of two parts of the autonomic nervous system and their ganglia. (Adapted from Netter, 1990)

The ANS represents the visceral component of the nervous system and consists of neurones located in both the CNS and PNS. The CNS and PNS are concerned with the control of the internal environment (i.e. innervations of secretory glands, cardiac and smooth muscle) by functions that are closely incorporated within the somatic nervous system (Standring *et al*., 2008).

According to Standring *et al*. (2008), "the visceral afferent pathway resembles the somatic afferent pathways in many ways". "Their cell bodies are unipolar neurones located in either cranial sensory or dorsal root ganglia" and "their peripheral processes are distributed through autonomic ganglia or plexuses, or possibly through somatic nerves" (Standring *et al*., 2008). "Their central processes (axons) accompany somatic afferent fibres through cranial nerves or dorsal spinal roots into the CNS where they establish connections that mediate autonomic reflexes and visceral sensation" (Standring *et al*., 2008).

"The visceral efferent pathways differ from their somatic equivalents in that the former are interrupted by peripheral synapses, there being a sequence of at least two neurones between the CNS and the target structure" (Figure 8) (Standring *et al*., 2008). "These are referred to as preganglionic and postganglionic neurones" (Standring *et al*., 2008). "The somata of preganglionic neurones are located in visceral efferent nuclei of the brain stem and in the lateral grey columns of the spinal cord" and "their axons exit from the CNS in certain cranial and spinal nerves and then pass to peripheral ganglia, where they synapse with the postganglionic neurones" (Standring *et al*., 2008). "The axons of postganglionic neurones are usually myelinated" and "are more numerous than the preganglionic ones which permit the wide diffusion of many postganglionic effects" (Standring *et al*., 2008)

2.2.1 ANATOMY OF THE SYMPATHETIC NERVOUS SYSTEM

The sympathetic trunks are two ganglionated nerve cords that extend on either side of the vertebral column from the upper cervical region (Romanes, 1968) or cranial base (McMinn, 1994, Standring *et al*., 2008) to the coccyx (Figure 9).

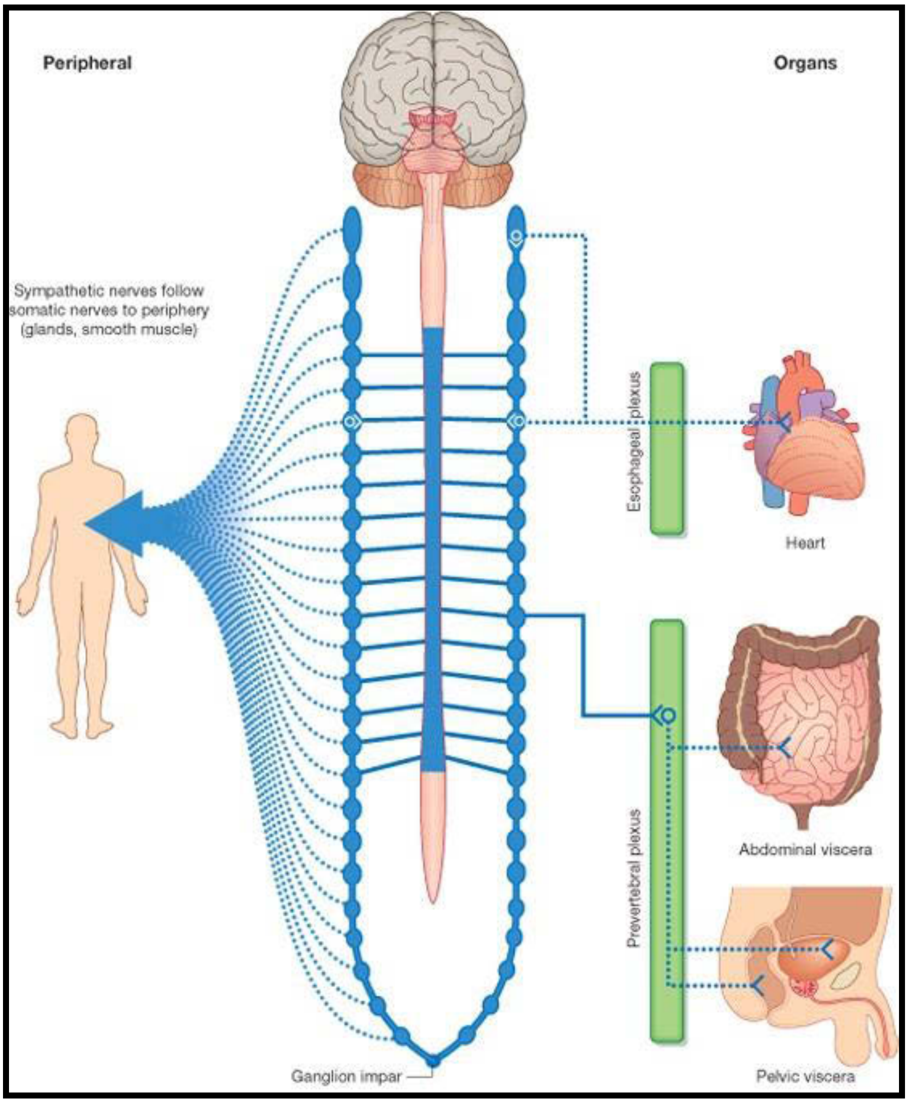


Figure 9: Diagrammatic representation of two parts of the sympathetic nervous system and their ganglia (Adapted from Drake *et al*., 2009)

The sympathetic ganglia are joined to spinal nerves by short connecting nerves called white and grey rami communicantes. Preganglionic axons join the sympathetic trunk through white rami communicantes (WRC) while postganglionic axons leave the trunk in the grey rami communicantes (GRC) (Figure 10) (Standring *et al*., 2008).

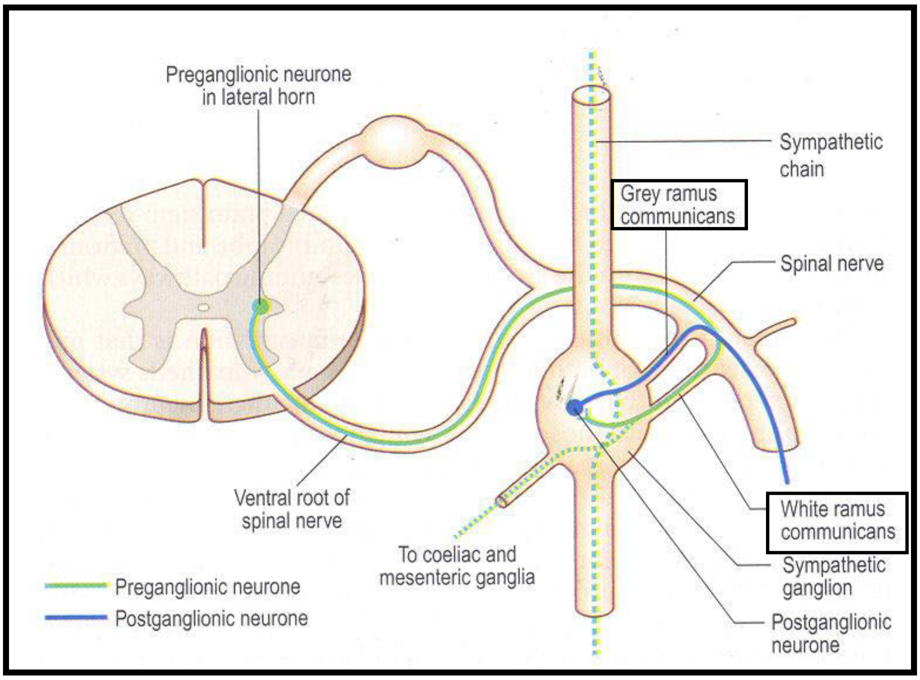


Figure 10: An illustration of the relationship between spinal nerves and sympathetic ganglia.

(Adapted from Standring *et al*., 2008)

In the neck, the sympathetic trunks lie posterior to the carotid sheath and anterior to transverse processes of cervical vertebrae (Standring *et al*., 2008). In the thorax the sympathetic trunks lie anterior to the heads of the ribs (Figure 11) while in the abdomen, they are located anterolateral to the bodies of the lumbar vertebrae (Standring *et al.,* 2008).

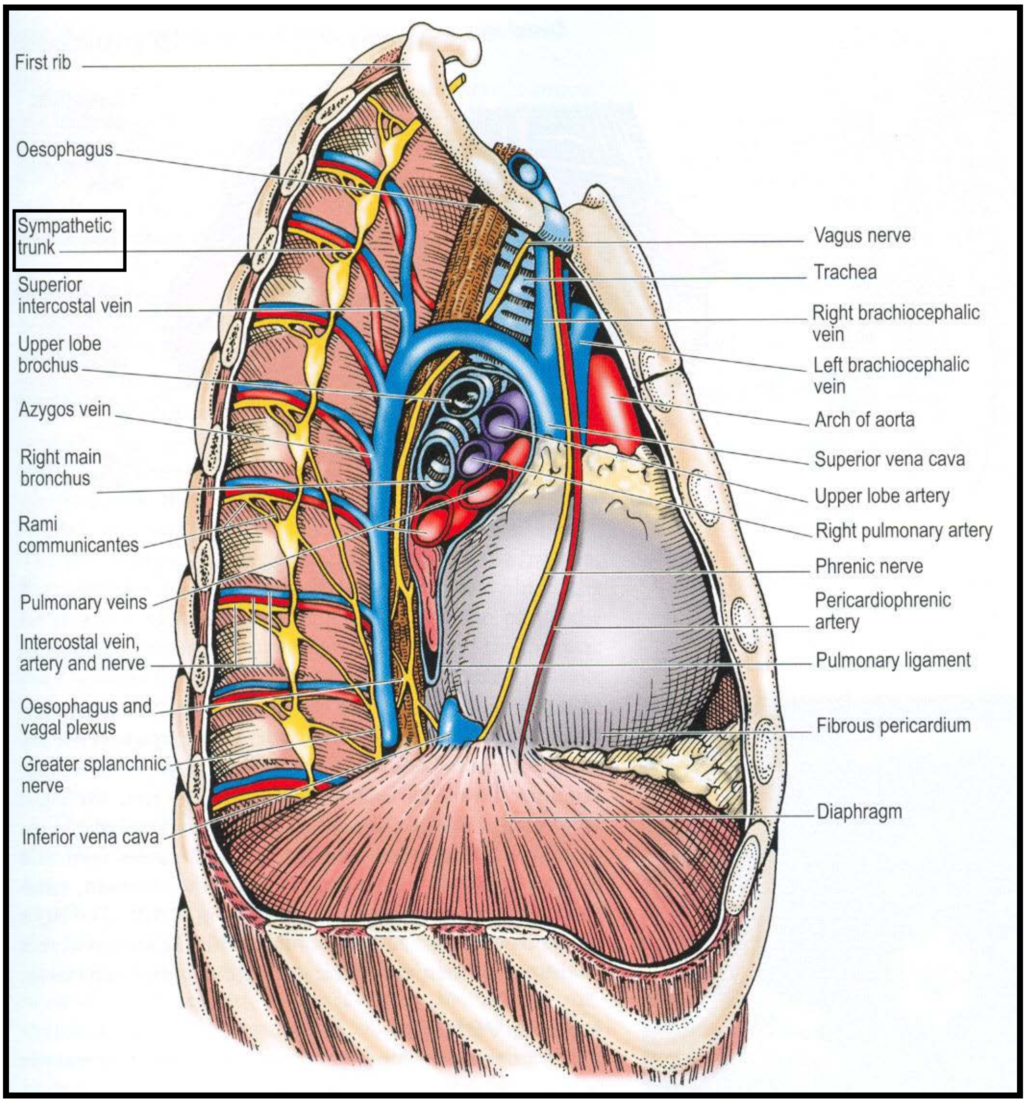


Figure 11: Sympathetic ganglia in the thorax (Adapted from Snell, 2008).

2.2.1.1 CERVICAL SYMPATHETIC CHAIN

COURSE AND RELATIONS

Standard anatomical textbooks describe the cervical sympathetic chain (CSC) as lying on the prevertebral fascia behind the carotid sheath (McMinn, 1994; Standring *et al.*, 2008) while Lyons and Mills (1998) reported it as lying within this sheath in two cases of their study. Kadowaki and Levett (1986) stated that the CSC consists of a series of ganglia that are variable in number and position.

Reports show that it contains three interconnected ganglia viz. superior cervical ganglion (SCG), middle cervical ganglion (MCG) and inferior cervical ganglion (ICG) [or cervicothoracic (CTG) if fused with T1 ganglion] (McMinn. 1994; Standring *et al.,* 2008) (Figure 12). Ellison and Williams (1969) and Bhatnagar *et al*. (2003) suggested that occasionally there may be two or four ganglia present. In addition, a fourth ganglion termed the vertebral ganglion (VG) (due to its relationship with the vertebral artery) may be present (Becker and Grunt, 1957; Wrete, 1959) (Figure 12). Saccomanno (1943) described the cervical portion of the sympathetic trunk as consisting of two or three ganglia above the inferior or stellate (i.e. CTG) ganglion.

The interconnecting chain is usually single but it has been reported to be sometimes double by Mitchell (1953) and Kalsey *et al*. (2000). In the study by Kalsey *et al*. (2000) it was described as a single interconnecting chain below SCG in 83% of their dissections and a duplicated chain in 17% of the lower part of SCG near MCG; they found no duplicated cord proximal to SCG. Kadowaki and Levett (1986) observed this double strand termed "ansa subclavian" (AS) as a loop around the subclavian arteries while Ellison and Williams (1969) observed it around the inferior thyroid artery.

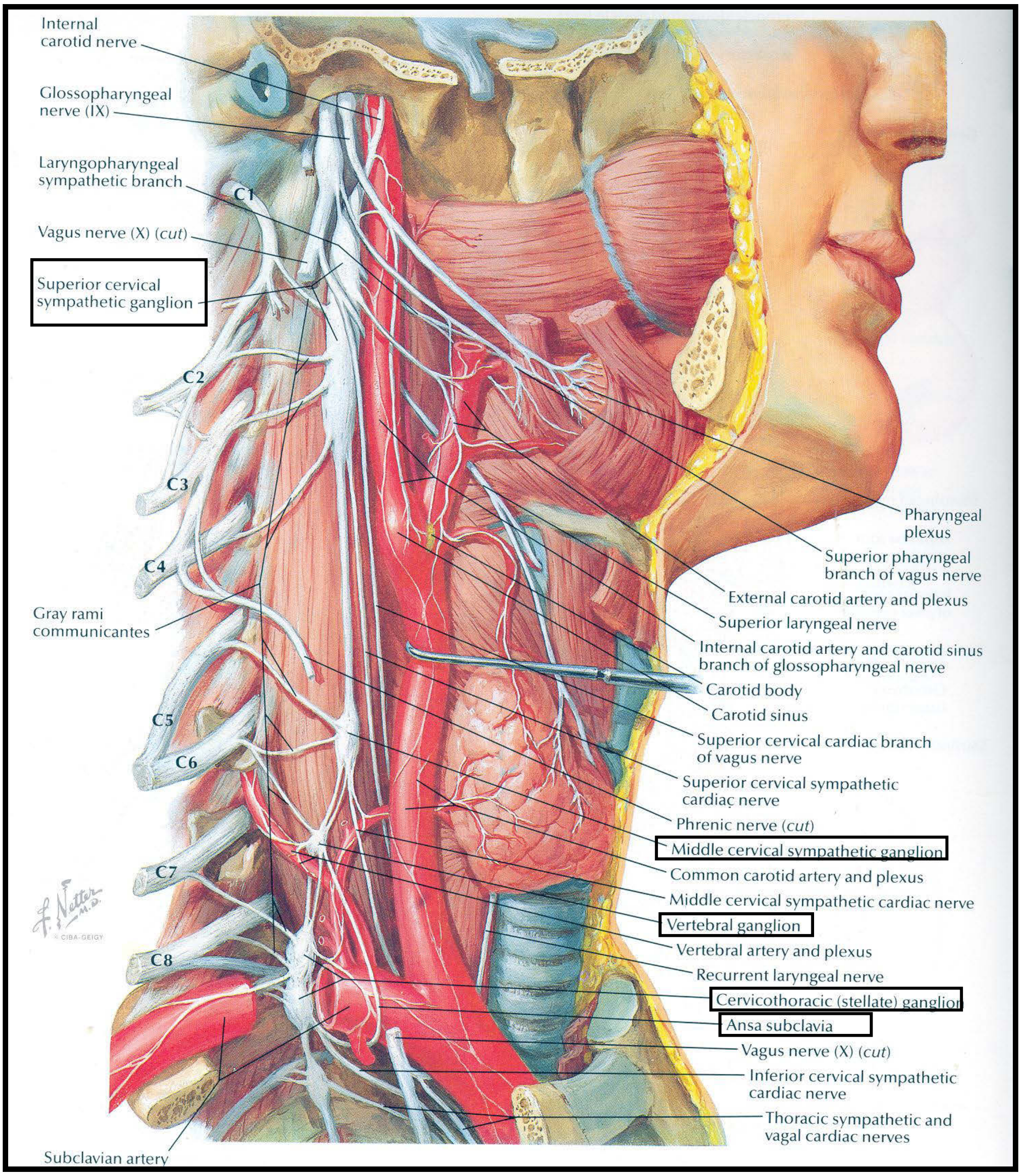


Figure 12: Cervical sympathetic chain and its ganglia (Adapted from Netter, 1990)

2.2.1.2 SUPERIOR CERVICAL GANGLION (SCG)

The SCG is the largest of the three cervical ganglia (Figure 13) (Standring *et al*., 2008). Wrete (1959) described the SCG as the most cranial ganglion consisting of the most cranial segments of the cervical sympathetic trunk. Ellison and Williams (1969) described it as having a constant presence. Kawashima (2005) described this ganglion as being consistently located behind the bifurcation of the common carotid artery while Standring *et al*. (2008) stated that it is related to the internal carotid artery anteriorly (which lies within the carotid sheath) and the longus capitis muscle posteriorly.

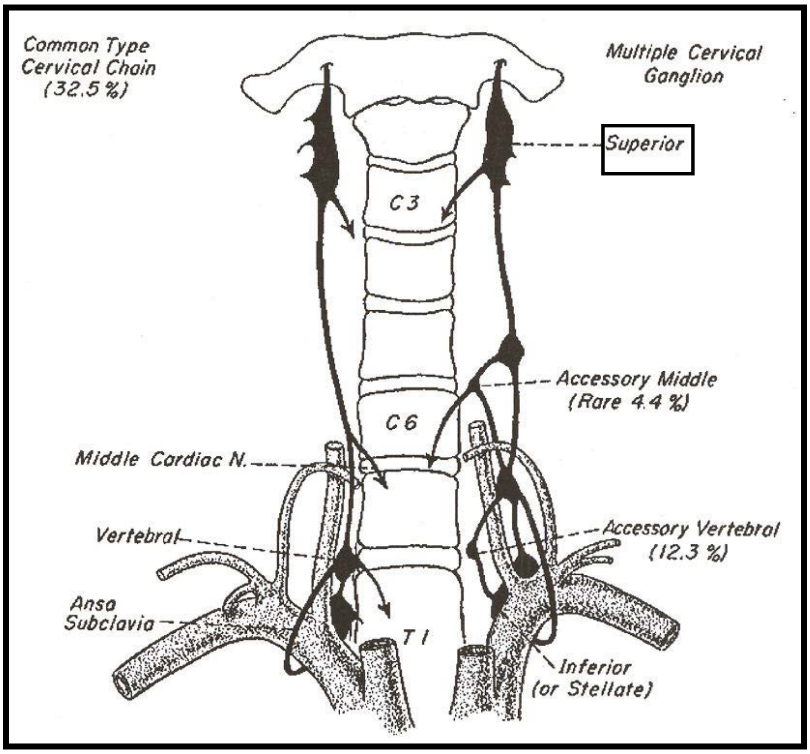


Figure 13: Superior cervical ganglion (Adapted from Becker and Grunt, 1957).

The SCG was found to be proportionately small in fetuses with varying shapes, viz. fusiform (77%), elongated (7%) and round, oval or club (2%) in a study conducted by Kasley *et al*. (2000). Furthermore, it communicated with cranial nerves viz. glossopharyngeal, vagus and hypoglossal (Kalsey *et al*., 2000). It might also communicate with the accessory nerve and through a communicating branch with the superior laryngeal nerve (Kalsey *et al*., 2000).

Lyons and Mills (1998) stated that the appearance of SCG varied from a discoid to a fusiform shape, located anterior to the transverse processes and consistent with the highest cervical vertebra. Bhatnagar *et al*. (2003) reported a large oblong fusiform SCG located anterior to the prevertebral fascia at the level of bifurcation of the common carotid artery bilaterally.

2.2.1.3 MIDDLE CERVICAL GANGLION (MCG)

The MCG is described as the smallest of the three cervical ganglia (Elias, 2000; Standring *et al*., 2008) and is occasionally absent and replaced by minute ganglia in the sympathetic trunk (Standring *et al*., 2008). It has also been reported to have a double occurrence or was sometimes represented by a tiny or medium sized knot (Pick and Sheehan, 1946). In addition, the MCG is usually located anterior or just superior to the inferior thyroid artery (ITA) or may connect to ICG (Figure 14) (Kalsey *et al*., 2000). Elias (2000) stated that it is located anterior to the longus colli muscle.

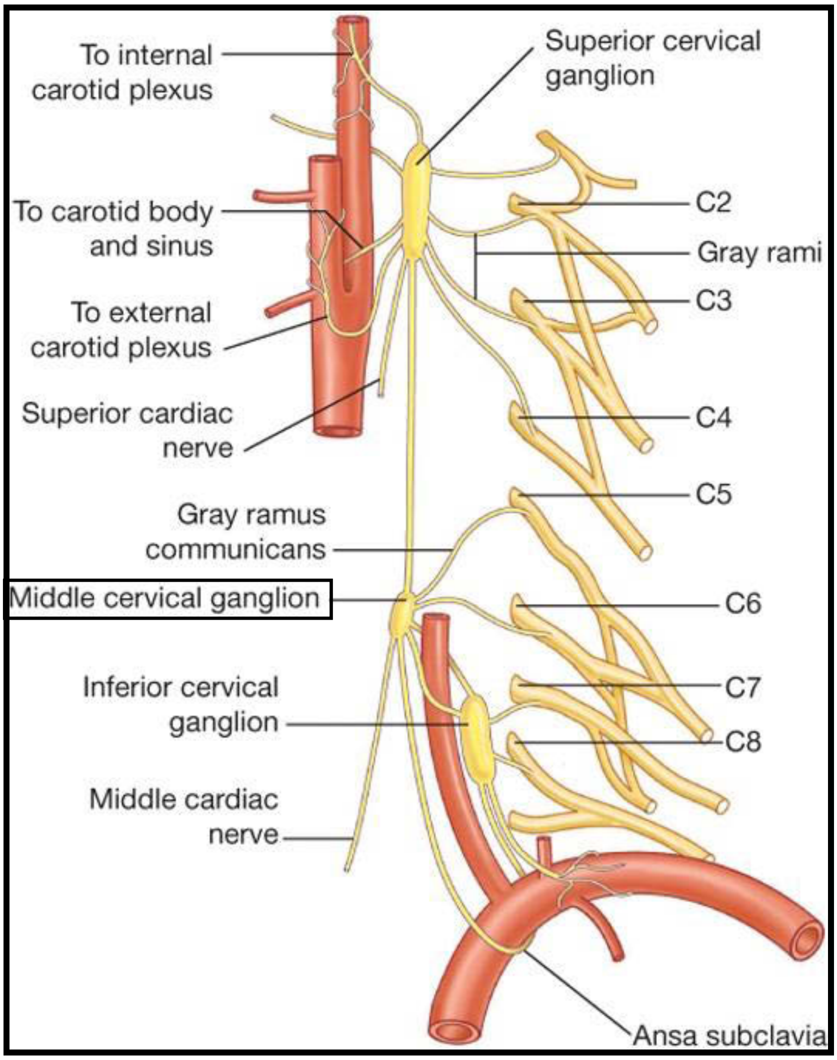


Figure 14: The middle cervical ganglion (Adapted from Drake *et al*., 2009).

In a study conducted by Axford (1928), he described the MCG as a definite thickening of the cervical sympathetic chain. He described two types of ganglia:

(a) ***High type***: here the ganglion was in close relation to the arch of the ITA at about the level of the sixth cervical vertebra

(b) ***Low type***: in this type the ganglion was on the anterior or antero-medial aspect of the vertebral artery at about the level of the seventh cervical vertebra.

In his study, he described the low type MCG as occurring more frequently than the high type MCG (Axford 1928).

Becker and Grunt, in 1957, found 82% of the MCG to be located on the arch of the ITA and they described a more constant ganglion at the level of C7 vertebra, anterior to or lateral to the vertebral artery below the level of the arch of the ITA: this was termed the vertebral ganglion. This vertebral ganglion had been termed the "low type middle cervical ganglion", "middle" and an "intermediate" ganglion in the past by authors Axford (1928), Mitchell (1953) and Wrete (1959).

The low type MCG described by Axford (1928) is also referred to as the "intermediate" ganglion by some researchers (Mizeres, 1972; Elias, 2000; Kasley *et al*., 2000). Pather *et al*. (2001) stated that an individual low MCG may be found in a single CSC, this was recorded in 2 cases in their study. In the study by Becker and Grunt (1957) they provided varying loci of the MCG (Figure 15). Randall and Armour (1977) described the MCG as large and multilobuled and reported that it may be fused to other ganglia near the ITA and called it the "thyroid cervical ganglion".

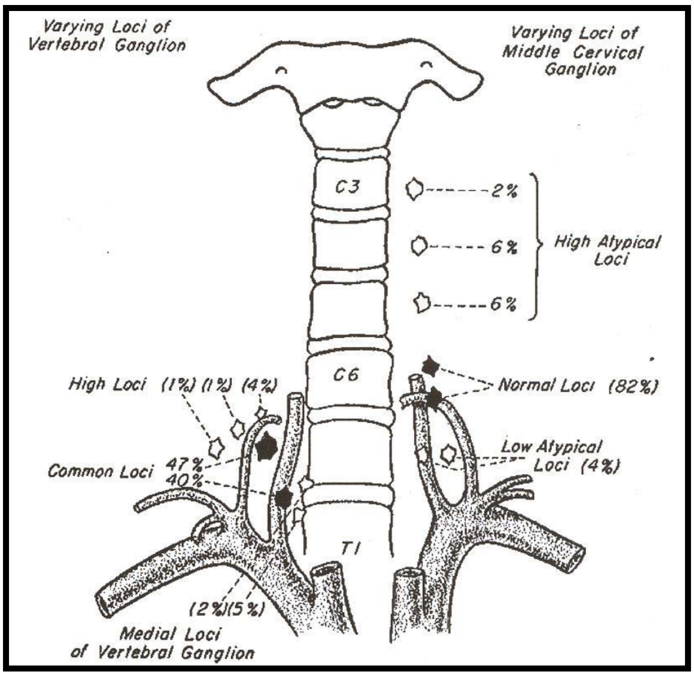


Figure 15: Varying loci of MCG (Adapted from Becker and Grunt, 1957).

Kalsey *et al*. (2000) described the MCG to be present in all specimens in their study and found a duplicated ganglion in 5 cases. With regards to MCG relations to ITA, it was found in the same study that it varied from being anterior or posterior and superior or inferior (Kalsey *et al*., 2000).

The MCG connects to the ICG by two or more variable cords: the posterior cord divides to enclose the vertebral artery; the anterior cord loops down anterior to and below the first part of the subclavian artery, medial to the origin of the internal thoracic artery and supplies rami to it. This loop called the ansa subclavius (AS) (Figure 14) is frequently multiple, and is located in close contact with the cervical pleura and also connects to the phrenic and vagus nerves (Standring *et al.,* 2008).

Saccomanno (1943) described the MCG as located medial to the vertebral artery. He further stated that the MCG is connected to the CTG by a large ramus passing posterior to the vertebral artery and by another one anterior to the same artery (Saccomanno, 1943). In addition, the MCG was found to be absent in a high percentage of cases by Saccomanno (1943) whilst Axford (1928) found the MCG to be constantly present.

2.2.1.4 VERTEBRAL GANGLION

Ionesco and Enachesco (1927) described a fourth ganglion in the CSC which they termed the intermediate ganglion situated ventro-medial to the vertebral artery; which could occur in the presence or absence of the MCG (Axford, 1928). In the study conducted by Kalsey *et al*. (2000), they also described the vertebral ganglion as an intermediate ganglion but negated the notion that it was a detached form of the MCG. The literature reviewed described the vertebral ganglion as the ganglion that is located between the middle and inferior cervical ganglia (Mitchell, 1953; Mizeres, 1972; Ellison and Williams, 1969; Randall and Armour, 1977). Mitchell (1953) emphasized that the term "vertebral ganglion" is preferable to "intermediate ganglion" as this was closely related to the vertebral artery. Axford (1928) described the ganglion located anterior or anteromedial to the vertebral artery as "the low type of middle cervical ganglion".

2.2.1.5 INFERIOR CERVICAL GANGLION

The inferior cervical ganglion (ICG) is situated at the base of the transverse process of the seventh cervical vertebra and the neck of the first rib, medial to the costocervical artery (Standring *et al*., 2008) (Figure 16).

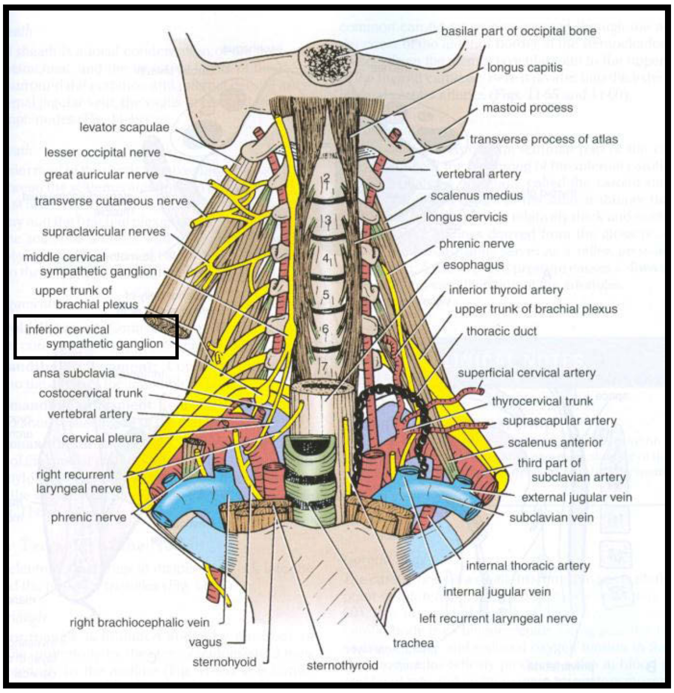


Figure 16: Diagram of the inferior cervical ganglion and its relations. (Adapted from Snell, 2008)

If ICG is highly arched, then it is located at the level of disc space between the seventh cervical and first thoracic vertebrae (Ellis and Feldman, 1993).

The ICG is irregular in form, larger than the MCG and is frequently fused with the first thoracic ganglion (termed CTG or stellate ganglion) probably due to the coalescence of two ganglia which correspond to the seventh and eighth cervical nerves (Standring *et al*., 2008).

The ICG is connected to the MCG by two or more loops; one of which forms a loop named AS i.e. around the subclavian artery and supplies small branches to it (Standring *et al*., 2008). In addition, it gives off a cardiac branch, branches to nearby blood vessels and sometimes a branch to the vagus nerve" (Standring *et al.,* 2008).

2.2.1.6 CERVICOTHORACIC GANGLION (CTG)

The CTG (previously named the stellate ganglion) is much larger than the MCG (Standring *et al*., 2008) and is formed by the fusion of the ICG and the first thoracic ganglion (Zhang *et al*., 2009) (Figure 17). Occasionally it is formed by fusion of the second, third and fourth thoracic segmental ganglia (Pather *et al.,* 2006; Standring *et al.,* 2008). In cases where the ganglia are not fused, the ganglion is called the inferior cervical ganglion (Kuntz and Morehouse, 1930; Saccomanno, 1943; Pick and Sheehan, 1946; Ellison and Williams, 1969; Kalsey *et al*., 2000; Pather *et al.,* 2006). There are irregular, spindle, dumbbell and inverted types of CTG (Pather, 2001).

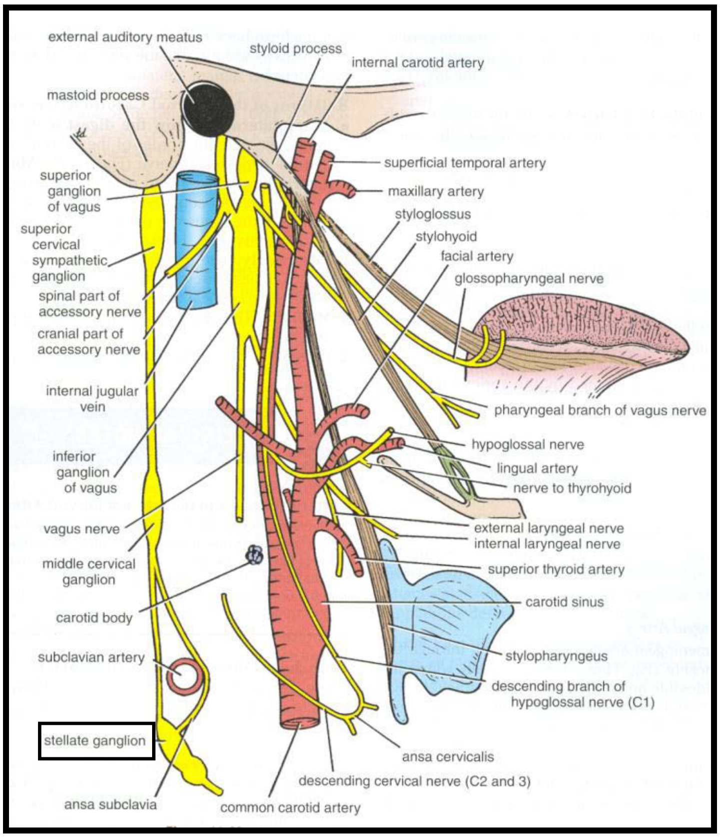


Figure 17: Diagrammatic representation of the cervicothoracic ganglion (Adapted from Snell, 2008)

The location of the long axis of CTG is described as "anteroposterior, lying on or lateral to the lateral border of the longus colli muscle" (Standring *et al*., 2008) and between "the base of the transverse processes of the seventh cervical vertebra" (Kawashima, 2005) and "neck of the first rib) (these are posterior to it) (Standring *et al*., 2008). Janes *et al*. (1986) described its location as "over the heads of the first and second ribs" and as "an enlargement at the superior ends of the thoracic sympathetic chains which can be composed of one or more swellings". The vertebral artery and its associated veins are located anterior to CTG. CTG is separated inferiorly from the posterior aspect of the cervical pleura by the suprapleural membrane; lateral to it is the costocervical trunk of the subclavian artery (Standring *et al*., 2008).

2.3. THORACIC SYMPATHETIC CHAIN

COURSE AND RELATIONS

The thoracic sympathetic chain (TSC) begins at the first thoracic ganglion which is usually fused with the ICG to form the CTG and "passes dorsal to the medial arcuate ligament (or through the crus of diaphragm) to become continuous with the lumbar sympathetic chain" (Standring *et al*., 2008). "The number of thoracic segments is twelve" (Groen *et al*., 1987) and they can overlap with each other as "rami communicantes cross each other in their course to different spinal nerves" (Groen *et al*., 1987). This overlapping is common at the level of sympathetic segments T1 and T2 (Groen *et al*., 1987). "Two or more rami communicantes, white and grey, connect each ganglion with its corresponding spinal nerve; the white rami joining the spinal nerve farther distally than the grey" (Standring *et al*., 2008). "Sometimes a grey and white rami communicantes may be fused to form a „mixed" ramus (Standring *et al*., 2008). Janes *et al*. (1986) stated that these "are flat, band-like structures with indistinct enlargements along their lengths". "The thoracic sympathetic trunk is connected to the 12 thoracic spinal nerves, to the 6th -8th cervical spinal nerves and to various perivascular nerve plexuses" (Groen *et al*., 1987).

The thoracic component of the sympathetic chain "contains a series of ganglia, which usually correspond approximately in number to that of the thoracic spinal nerves, but their number is variable" (Standring *et al*., 2008). The total number of these ganglia "is 11 in more than 70% of the population, occasionally 12 and rarely 10 or 13" (Figure 18) (Standring *et al*., 2008). Hollinshead (1974) stated that the thoracic part of the sympathetic chain "is of a particular importance because its paired trunks receive the majority of the preganglionic fibres that leave the spinal cord" which supply the head and neck, thorax, upper limb and abdomen. They are "symmetrical and consist of a series of ganglia connected by interganglionic branches formed by nerve fibers" (Hollinshead, 1974).

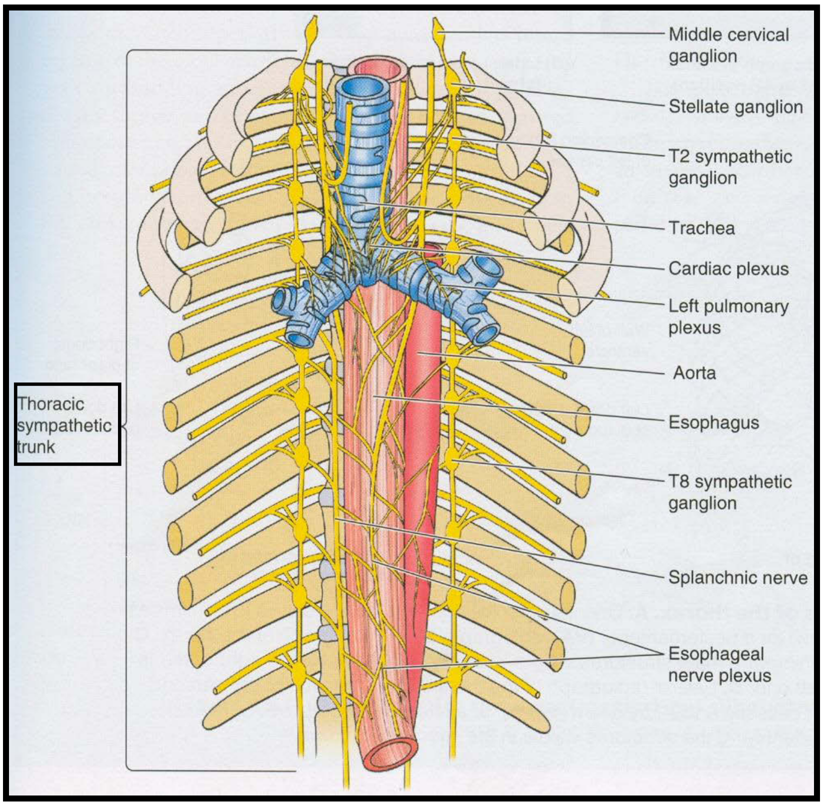


Figure 18: Thoracic sympathetic chain and its relations. (Adapted from Drake *et al*., 2009)

The upper trunks lie mostly lateral to the vertebral column, anterior to the necks of ribs and the lower trunks incline forward on the sides of the vertebra to become continuous with the lumbar trunks when they penetrate the diaphragm; here "they are situated more anteriorly than laterally" (Hollinshead, 1974). "There are usually 11 rather than the expected 12 thoracic ganglia on each side, and the last one usually communicates with both the 11^{th} and 12^{th} thoracic nerves" (Hollinshead, 1974).

2.3.1 THORACIC GANGLIA

The first thoracic ganglion is located at the base of the neck and "is very frequently fused with the lowest or ICG to form the CTG" (Hollinshead, 1974). "The second thoracic ganglion may be larger than the others, which tend to be smaller than the similar ganglia in the abdomen" (Hollinshead, 1974) (Figure 19).

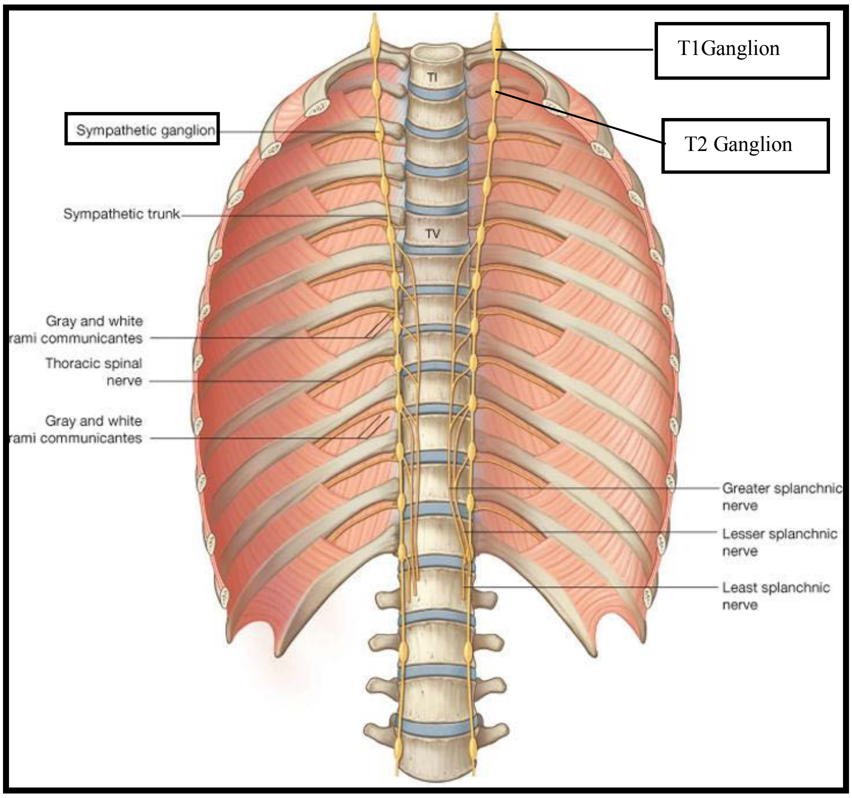


Figure 19: Thoracic sympathetic chain and ganglia (Adapted from Drake *et al*., 2009)

The remaining thoracic ganglia (aside from the two that have been mentioned and the last two or three) "rest against the heads of the ribs, and are posterior to the costal pleura" (Standring *et al*., 2008) [Figure 19]. "The last two or three thoracic ganglia are placed on the sides of the bodies of the corresponding vertebrae" (Standring *et al*., 2008) [Figure 19].

In a study by Zhang *et al*. (2009), "the 2nd to the 4th thoracic sympathetic ganglia were commonly located in the corresponding intercostal spaces having an incidence of 92%, 68% and 50%, respectively". In a study conducted by Groen *et al*. (1987), the number of thoracic sympathetic ganglia was found to vary between 8 and 10. "Furthermore, variations exist concerning the position of the ganglia in the sympathetic trunk and their size" (Groen *et al*., 1987). At various levels, ganglia were found to be fused (viz. sixth and seventh thoracic ganglia) in all of their specimens (Groen *et al*., 1987).

2.4 ADDITIONAL MEDIAL BRANCHES

These are branches from the lower seven ganglia (Standring *et al*., 2008). They "are large; they contribute filaments to the aorta and unite to form the greater, lesser and lower splanchnic nerves" (Standring *et al.,* 2008).

The greater splanchnic nerve (GSN) has "myelinated, preganglionic and visceral efferent fibres" (Standring *et al.,* 2008). It "is formed by branches from the fifth to ninth (Romanes, 1968) or including "tenth thoracic ganglia" (Standring *et al*., 2008); "fibres in the higher branches may be traced upwards in the sympathetic trunk as far as the first or second thoracic ganglion" (Standring *et al.,* 2008). Groen *et al*. (1987) reported this origin to be at the eighth and ninth thoracic sympathetic segments: the highest level being the sixth and the lowest level being the eleventh thoracic sympathetic segments. The GSN descended obliquely on the bodies of the thoracic vertebra to supply branches to the oesophagus (Romanes, 1968) and the descending aorta; thereafter it pierced "the crus of the diaphragm to end mainly on the celiac ganglion but partly in the aorticorenal ganglion and suprarenal gland" (Standring *et al.,* 2008) (Figure 19). "A splanchnic ganglion exists on this nerve opposite the eleventh or twelfth thoracic vertebra" (Standring *et al.,* 2008) or "the twelfth thoracic vertebrae" (Romanes, 1968).

The lesser thoracic splanchnic nerve originated from the tenth and eleventh thoracic sympathetic segments while the least splanchnic nerve originated "exclusively from the last thoracic sympathetic segment" (Groen *et al*., 1987).

2.5. THE ANATOMY OF THE PARASYMPATHETIC NERVOUS SYSTEM TO THE HEART

The parasympathetic innervation of the heart is via preganglionic fibres from the vagus nerve (CN X) (Kadowaki and Levett, 1986; Kawashima, 2005) (Figure 20).

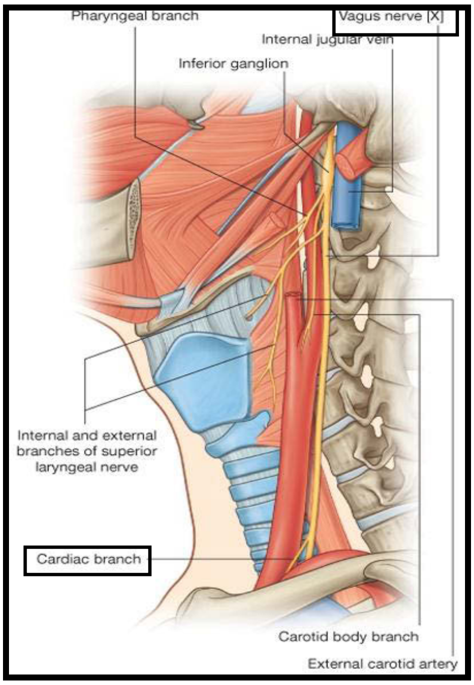


Figure 20: Diagrammatic representation of the vagus nerve in the neck

(Adapted from Drake *et al*., 2009)

“The vagus nerve is a large mixed nerve” and “it has a more extensive course and distribution than any other cranial nerve, and traverses the neck and the abdomen” (Standring *et al*., 2008). “The vagus descends vertically in the neck in the carotid sheath, between the internal jugular vein and the internal carotid artery to the upper border of the thyroid cartilage, and then passes between the vein and the common carotid artery to the root of the neck” (Standring *et al*., 2008). “The right vagus descends posterior to the internal jugular vein to cross the first part of the subclavian artery and enter the thorax” while “the left vagus enters the thorax between the left common carotid and subclavian arteries and behind the brachiocephalic vein” (Standring *et al*., 2008).

The “efferent fibres travel in the vagus nerve and its pulmonary, cardiac, oesophageal, gastric, intestinal and other branches” and “they synapse in minute ganglia in the visceral walls” (Standring *et al*., 2008). San Mauro *et al*. (2009) reported that “there are two types of fibers” that are “poorly differentiated” and are described as: “(i) the superior cardiac nerves: from one up to three nerves are born in the origin of the superior and inferior laryngeals; (ii) the inferior cardiac nerves: they are born under the origin of the recurrent.” (San Mauro *et al*., 2009). The “cardiac branches, which act to slow the cardiac cycle, join the cardiac plexus and the fibres relay in ganglia distributed over both atria” (Standring *et al*., 2008). The “pulmonary branches contain fibres which relay in ganglia of the pulmonary plexuses” (Standring *et al*., 2008)

Randall and Armour (1977) described the vagus nerve giving off cardiac vagal branches; termed recurrent cardiac, thoracic craniovagal cardiac nerve and thoracic caudovagal cardiac nerves on the right side. In addition, they noted that “the majority of vagal branching occured at or below the left recurrent laryngeal nerve" (Randall and Armour, 1977).

Mizeres (1972) described these in terms of cervical, cervicothoracic and thoracic cardiac branches. "The cervical branches arise from any part of the cervical part of the vagus nerve as far inferiorly as the lower border of the sixth cervical vertebra" while "the right cervicothoracic cardiac branches arise from the right RLN near its origin and from vagal trunk at the level of the seventh cervical and first thoracic vertebrae" (Mizeres, 1972). "The left cervicothoracic cardiac branches, one or two in number, arise from the left vagal trunk at the level of seventh cervical and first thoracic vertebrae" (Mizeres, 1972). "The right thoracic cardiac branches arise from the thoracic vagal trunk between the level of the lower border of the first thoracic vertebra and the pulmonary hilus" and "vary from two to four in number" (Mizeres, 1972)."The left thoracic cardiac branches arise from the left RLN and from the vagal trunk just below the origin of the left recurrent nerve" (Mizeres, 1972).

Kawashima (2005) described the vagal cardiac contributions in terms of superior, inferior and thoracic cardiac branches with the superior cardiac branch arising "from the vagus nerve at the level of the upper (proximal) portion of the RLN (Kawashima, 2005). "The inferior cardiac branch arose from the RLN" while "the thoracic cardiac branch arose from the vagus nerve at the level of the lower (distal) portion of the RLN (Kawashima, 2005).

Standring *et al*. (2008) further states that the RLN, the counterpart of the vagus nerve differed in its course on both sides. On the right, it arose from the vagus nerve anterior to the first part of subclavian artery while on the left side it arose from the vagus nerve on the left of the aortic arch (Standring *et al*., 2008). They further stated that the left RLN gave off cardiac branches to the deep cardiac plexus (Standring *et al*., 2008).

2.6 THE ANATOMY OF THE CARDIAC PLEXUSES

Romanes (1968) described the cardiac plexuses as being “situated on the bifurcation of the trachea” and made up of two kinds of fibres i.e. (i) sympathetic fibres that arise from “the ganglion cells of the cervical and upper thoracic ganglia of the sympathetic trunk” (Romanes, 1968); (ii) parasympathetic fibres that “arise in the ganglion cells of the cardiac plexuses and scattered ganglia along blood vessels of the heart” (Romanes, 1968).

Gardner *et al*. (1975) reported that the heart is innervated by autonomic and sensory nerve fibres from the vagus nerves and sympathetic trunks. Hollinshead (1974) stated that “the immediate innervation of the heart is from the cardiac plexus, which receives the sympathetic and vagal branches”. “The cardiac plexus gives off two coronary plexuses that follow the coronary arteries and are distributed to these vessels and to the interior of the heart, and two atrial plexuses” (Hollinshead, 1974).

Mizeres (1972) described the cardiac plexus as lying on the anterior and posterior walls of the bifurcation of the pulmonary trunk, consisting of subsidiary subplexuses to the great vessels and walls of the heart. “These subsidiary subplexuses may be named the right and left pulmonary, the right and left atrial, the right and left coronary and the plexus on the arch of aorta” (Figure 21) (Mizeres, 1972).

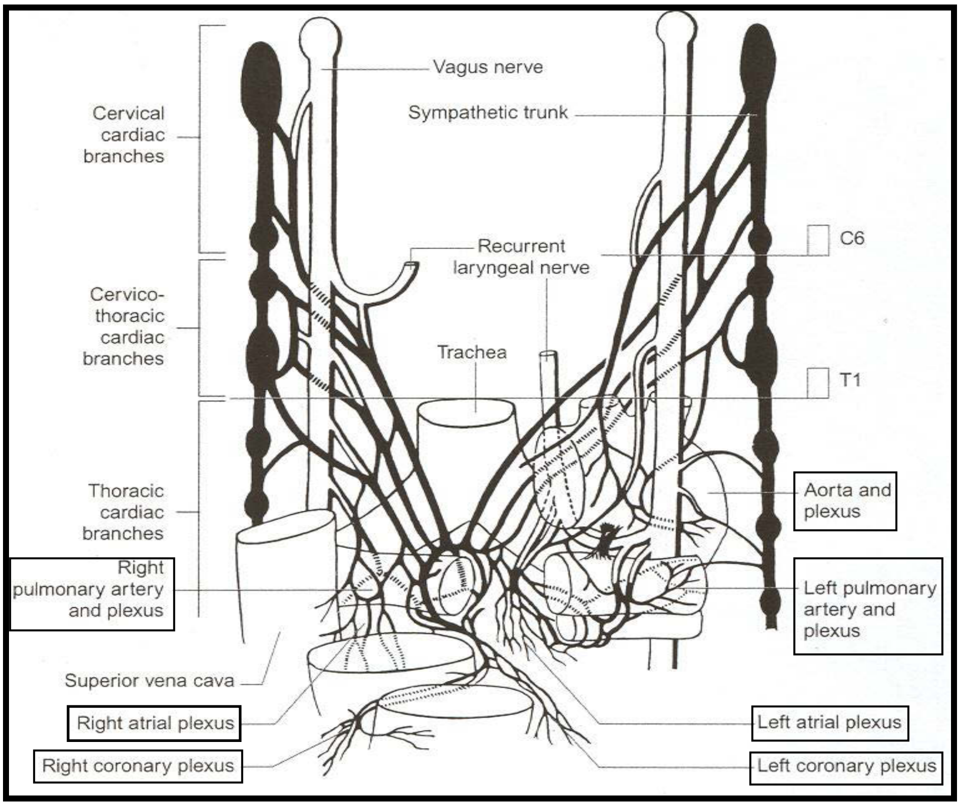


Figure 21: Diagram illustrating the cardiac plexus (Adapted from Mizeres, 1972).

McMinn (1990) suggested that "the cardiac plexus consists of various sympathetic, parasympathetic and afferent fibers and is divided into superficial and deep parts" whilst Standring *et al*. (2008) described the cardiac plexus as divided into superficial and deep parts that are closely connected and consisted of several small ganglia. San Mauro *et al*. (2009) described a wide network that included sympathetic and parasympathetic branches situated at the base of the heart which divided into superficial and deep portions although this division is not shown in an anatomical dissection. Randall and Armour (1977) stated that "the vagal and sympathetic cardiac nerves are anatomically separate".

Janes *et al*. (1986) reported cardiopulmonary nerves from the CTG and the caudal halves of the cervical sympathetic chain that collectively form two cardiopulmonary plexuses with nerves from RLN or the vagus nerves directly. “These plexuses contain distinct nerves that unite to form 3 major nerves at the base of the heart” and “other small cardiac nerves arise from the plexuses as well as from the thoracic vagi posterior to the pulmonary hila” (Janes *et al*., 1986).

Kawashima (2005) described the cardiac plexus as being “composed of complex bifurcations and anastomoses of cardiac nerves and branches”. He referred to a right cardiac plexus surrounding the brachiocephalic trunk and a left cardiac plexus surrounding the aortic arch (Kawashima, 2005). He also stated that the positions of the mixed nerves between the sympathetic cardiac nerves and vagal cardiac branches varied from each side. The highest position of the right cardiac plexus was located at the level of the cervical part of the common carotid artery (CCA) instead of the brachiocephalic trunk (Kawashima, 2005). The highest position of the left cardiac plexus was located at the level of the cervical part of the CCA instead of the aortic arch (Kawashima, 2005). “Furthermore, the cardiac plexus surrounding the great vessels on both sides was made from a larger cardiac plexus between the aortic arch and pulmonary arterial trunk through the ventral/dorsal aspect of the aortic arch” (Kawashima, 2005).

2.6.1 SUPERFICIAL CARDIAC PLEXUS

Romanes (1968) described the superficial cardiac plexus (SCP) as “the anterior extremity of a complicated plexus of nerve fibres and cells which extend from the bifurcation of the trachea to the concavity of the arch of aorta”. It received a superior cervical cardiac branch from the left sympathetic trunk and an inferior cervical cardiac branch from the left vagus nerve (Romanes, 1968). Furthermore, he stated that this superficial part sent branches to the heart on the pulmonary trunk and to the left pulmonary plexus (Romanes, 1968).

Hollinshead (1974) described the SCP location as “antero-inferior to the arch, somewhat between it and the pulmonary trunk and to the right side of the ligamentum arteriosum continuous below the arch with the remainder” (Figure 22). It “is usually joined by two small twigs from the left side, one the superior sympathetic cardiac nerve (from SCG) and the other an inferior cardiac nerve from the left vagus nerve in the neck.

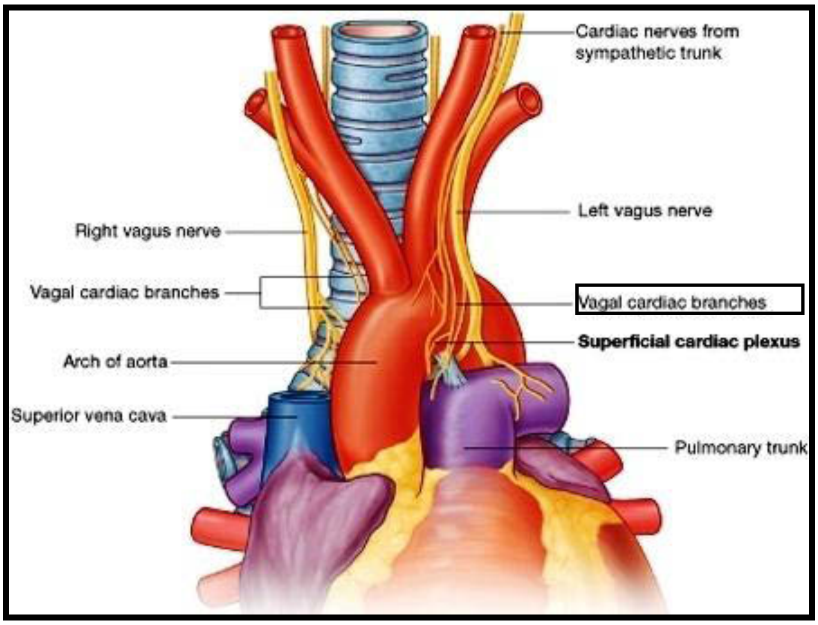


Figure 22: Diagram showing superficial cardiac plexus (Adapted from Drake *et al*., 2009)

McMinn (1990) portrayed the SCP as lying “in front of the ligamentum arteriosum and becomes continuous with the deep part” (McMinn, 1990). The SCP was formed by “the union of the inferior cervical cardiac branch of the left vagus nerve and the cardiac branch of the left cervical sympathetic ganglion” (McMinn, 1990).

Gardner *et al*. (1975) described the cervical cardiac nerves that arose from the cervical sympathetic trunk, the cervical ganglia, or from both, and were usually joined by cervical cardiac branches from the vagus nerve. These “descended in front of, or behind, the arch of the aorta and entered the cardiac plexus” (Gardner *et al*., 1975). Several nerves arose from the CTG and ansa subclavia, and were usually joined to the cervicothoracic cardiac branches of the vagus nerve. These conjoined nerves ran anterior or posterior to the arch of the aorta to the cardiac plexus (Gardner *et al*., 1975). Thoracic nerves were described as those that arose from the upper four or five thoracic sympathetic ganglia and together with the thoracic branches of the vagus and left RLN, innervated the cardiac plexus, especially to the posterior wall of the atria (Gardner *et al*., 1975).

Standring *et al*. (2008) and San Mauro *et al*. (2009) described this superficial part of the cardiac plexus as the part situated below the arch of aorta and anterior to the right pulmonary artery. Standring *et al*. (2008) stated that it is formed by the left superior sympathetic cardiac nerve and two cardiac branches of the vagus nerve while San Mauro *et al*. (2009) stated that it is formed by left sympathetic cardiac branches and two cardiac branches of the cardiac vagus. Standring *et al*. (2008) stated further that it connected with the deep cardiac, right coronary and the left pulmonary plexuses while

San Mauro *et al*. (2009) stipulated that it sent branches to "the deep portion of the cardiac plexus, right cardiac plexus and anterior left pulmonary plexus".

2.6.2 DEEP CARDIAC PLEXUS

The deep cardiac plexus (DCP) is located "in front of or below the lower end of the trachea behind the arch of the aorta" (Romanes, 1968; Hollinshead, 1974).

In the description by Romanes (1968) "the DCP is continuous with the SCP on the ligamentum arteriosum" and "consists of interlacing nerve fibres from the parasympathetic (vagus) and sympathetic systems, together with a few groups of ganglion cells most of which belong to the parasympathetic system" (Romanes, 1968). The "nerve fibres that reach it are: (1) through all the cervical cardiac branches of the sympathetic trunks (except the left superior) and cardiac branches of the 2^{nd}, 3^{rd} and 4^{th} thoracic ganglia of both sympathetic trunks, and (2) through cervical cardiac branches of both vagi (except the inferior left), the thoracic cardiac branch of thoracic vagus, and cardiac branches of both the recurrent laryngeal nerves" (Romanes, 1968). The two parts of the cardiac plexus together send efferent fibres to "(1) atria directly, and to the rest of the heart through the coronary plexuses, and (2) to the lungs over the anterior surfaces of the lung roots (anterior part of the pulmonary plexus)" (Romanes, 1968).

Hollinshead (1974) stated that the DCP was formed by the rest of the nerves whether sympathetic or vagal, passing behind the arch of aorta on the left side and the right subclavian and brachiocephalic arteries or the arch of aorta on the right side. McMinn

(1990) described the deep part as lying “to the right of the ligamentum arteriosum, infront of the left bronchus at the bifurcation of the pulmonary trunk”. It “receives contributions from the right vagus nerve by its upper and lower cervical cardiac branches, from the left vagus nerve by its superior cervical cardiac branch, and a branch from each RLN, and also sympathetic fibres from the remaining five cervical sympathetic ganglia (the middle and inferior on the left and all three from the right), and from the upper five or six thoracic sympathetic ganglia of both sides” (McMinn, 1990).

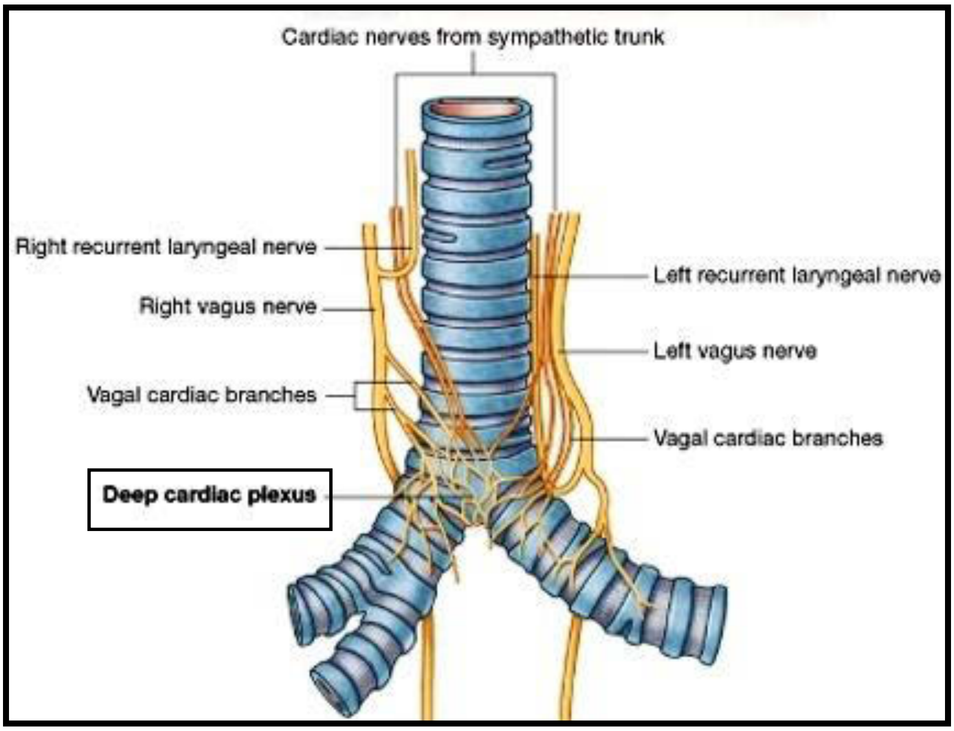


Figure 23: Diagram showing the deep cardiac plexus (Adapted from Drake *et al*., 2009)

The deep part as described by Standring *et al*. (2008) and San Mauro *et al*. (2009) is that part of the plexus that is situated “anterior to the bifurcation of the trachea, above the point of division of the pulmonary trunk and posterior to the aortic arch” (Figure 23). They further stated that “it is formed by cardiac branches of the cervical and upper thoracic sympathetic ganglia and of the vagus and the recurrent laryngeal nerves" (Standring *et al*., 2008).

San Mauro *et al*. (2009) stated that "it is formed by sympathetic branches of the cervical ganglions and branches of the vagus and recurrent". Furthermore, they considered two parts i.e. "(i) a half right: it sends branches to the pulmonary right branch and to the right auricles", (ii) "half left: it sends branches to the left pulmonary and left atrium, and continues ahead to constitute the left cardiac plexus" (San Mauro *et al*., 2009). In addition, they reported that these two parts joined to distribute fibres to "(a) a plexus which follows the territory of the right coronary artery, (b) a plexus which follows the territory of the left coronary artery, (c) a plexus that continues in the posterior face between the cava‟s venous pedicles and the pulmonary" (San Mauro *et al*., 2009).

2.7 DESCRIPTION OF CARDIAC NERVES

2.7.1 CARDIAC NERVES OF THE SYMPATHETIC CHAIN

[A] BRANCHES FROM THE CERVICAL SYMPATHETIC CHAIN & GANGLIA

Saccomanno (1943) stated that "the cervical portion of the sympathetic trunk regularly gives rise to a superior, middle and an inferior cardiac nerve". Mizeres (1972) reported that "the cervical cardiac branches which vary from one to three in number arise from any part of the cervical sympathetic trunk, including the superior and middle cervical ganglia, down through the level of the lower border of the sixth cervical vertebra". It is also possible that all three cardiac nerves passed posterior to the subclavian artery individually to reach the superficial and deep cardiac plexuses (Saccomanno, 1943). Kawashima (2005) regarded cardiac nerves "as nerves with direct connections or connections via the cardiac plexus".

CARDIAC BRANCHES FROM THE CERVICAL SYMPATHETIC CHAIN OR TRUNK

The branches from the right sympathetic trunk joined and coursed posterior to the CCA; these conjoined nerves fused with "one or two cervicothoracic cardiac branches and with the cervical and at least one of the cervicothoracic branches of the vagus nerve" (Figure 23) (Mizeres, 1972). "As a single or double nerve, it courses between the aorta and the right bronchus" (Mizeres, 1972); forming a major part of both the pulmonary plexuses upon reaching the adventitia of the right pulmonary artery (Mizeres, 1972). "Sometimes a right cervical cardiac branch, after uniting with a cervical cardiac branch of the vagus, may course anterior to the arch of aorta to join the pulmonary and coronary plexuses directly" (Mizeres, 1972).

The branches from "the left sympathetic trunks are usually interconnected before descending behind the left common carotid artery" (Mizeres, 1972). These branches "course between the aorta and the left bronchus to enter the left and right pulmonary plexuses" (Mizeres, 1972). "A cervical branch fuses with the left cervical cardiac branch of the vagus and as a single nerve courses anterior to the aorta, contributing to a plexus on the aorta and sending a contribution to the coronary plexus" (Mizeres, 1972). Janes *et al*. (1986) described these as "cardiopulmonary nerves" that arose "from the stellate ganglia and the caudal halves of the cervical sympathetic trunks and, together with nerves which arise from the recurrent laryngeal nerves or the vagi immediately distal to them, form 2 cardiopulmonary plexuses".

CARDIAC BRANCHES OF THE SUPERIOR CERVICAL GANGLION

The superior cervical cardiac nerve (SCCN) arose "by two or more filaments" (Standring *et al*., 2008) from "the inferior sector" of the SCG (San Mauro *et al*., 2009) and "the sympathetic trunk between the superior and the middle cervical ganglia" (Kawashima, 2005). This branch "descends behind the common carotid artery, in front of the longus colli, and crosses anterior to the inferior thyroid artery and recurrent laryngeal nerve" (Standring *et al*., 2008). The course of this branch differs on both sides (Standring *et al.,* 2008).

"The right cardiac branch usually passes behind, but sometimes in front of the subclavian artery and runs posterolateral to the brachiocephalic trunk to join the deep (dorsal) part of the cardiac plexus behind the aortic arch" (Standring *et al*., 2008). "It has other sympathetic connections", at the middle of the neck "it receives filaments from the external laryngeal nerve; inferiorly, one or two vagal cardiac branches join it; as it enters the thorax it is joined by a filament from the recurrent laryngeal nerve" (Standring *et al*., 2008). Filaments from this nerve also communicated with the thyroid branches of the MCG (Standring *et al.,* 2008). Randall and Armour (1977) stated that in their findings "there was no discreet right superior cervical cardiac nerve".

“The left cardiac branch, in the thorax, is anterior to the left common carotid artery and crosses in front of the left side of the aortic arch to reach the superficial (ventral) part of the cardiac plexus” (Standring *et al*., 2008). “Sometimes it descends on the right of the aorta to end in the deep (dorsal) part of the cardiac plexus (Standring *et al*., 2008). It communicated with cardiac branches of the MCG and CTG and “sometimes with the inferior cervical cardiac branches of the left vagus, and branches from these mixed nerves form a plexus on the ascending aorta” (Standring *et al.,* 2008). No left SCCN was reported in the study by Randall and Armour (1977).

Saccomanno (1943) reported that the SCCN “commonly arises from the inferior portion of the superior cervical ganglion” while Mitchell (1953) stated that it “originates on each side from the lower part of the superior cervical ganglion or from the sympathetic trunk below it”. It usually united with vagal cardiac branches and communicated with other branches (viz. pharyngeal, laryngeal, carotid, thyroid branches and RLNs) via slender rami or as a conjoined nerve (Mitchell, 1953). The right SCCN descended posterolateral to the subclavian artery and aortic arch to reach the cardiac plexus, while on the left side it is closely related with the common carotid artery and curves on the left side of the aortic arch to reach the cardiac plexus (Mitchell, 1953). Mitchell (1953) stated that SCCN always communicated with the middle and inferior cervical cardiac nerves “and occasionally united with them or corresponding vagal groups of cardiac nerves” (Mitchell, 1953).

Kalsey *et al*. (2000) depicted that the SCCN “arose from superior cervical ganglion or interganglionic cord (betwixt superior and middle cervical ganglia) or both in percentage frequency of 40%, 33.3% and 26.7% respectively” and varied from 1-2 in most cases (Kalsey *et al*., 2000). In one case, three branches were noted to arise from an elongated SCG and in another case there were three branches which arose from the interganglionic cord without having an origin from the SCG (Kalsey *et al*., 2000). Furthermore, Kalsey *et al*. (2000) reported that "these branches proceeded to thorax as such or by communicating with each other or with similar branches of middle or inferior cervical ganglion".

CARDIAC BRANCHES OF THE MIDDLE CERVICAL GANGLION

The middle cervical cardiac nerve (MCCN) commonly "arose from the (accessory) middle cervical, the vertebral ganglia, and the sympathetic trunk between the middle and inferior cervical ganglia, including the ansa subclavia" (Kawashima, 2005). Ellison and Williams (1969) stated that this nerve "springs from the middle cervical ganglion, from the adjacent part of the trunk or from the vertebral ganglion". The MCCN "commonly arises by the union of a root derived from the middle cervical ganglion or sympathetic trunk at the corresponding level and one derived from intermediate cervical ganglion" (Saccomano, 1943). Randall and Armour (1977) noted branches from the MCG naming them the thoracic dorsomedial and dorsolateral cardiac nerves. In addition, Randall and Armour (1977) stated that a major connecting nerve from this ganglion to the vagus nerve may occur on the right side.

In a study conducted by Kalsey *et al*. (2000) they reported MCCN as varying from 1-3 in number with the maximum being 1, 2 and 3 in 60%, 33.3% and 3.7% of cases, respectively. In addition, MCCN was found to be thicker when it was single and communicated with branches from the superior and inferior ganglia forming "a plexus which proceeded to the thorax posterior to the subclavian artery" (Kalsey *et al*., 2000). They found that in 2 cases the MCCN communicated with the RLN (Kalsey *et al*., 2000).

Standring *et al*. (2008) described MCCN as "the largest sympathetic cardiac nerve", occasionally arising directly from the ganglion or frequently on "the sympathetic trunk caudally or cranially to it" (Standring *et al*., 2008). On the right side, the MCCN "descends behind the common carotid artery, in front of or behind the subclavian artery to the trachea where it receives a few filaments from the recurrent laryngeal nerve before joining the right half of the deep (dorsal) part of the cardiac plexus (Standring *et al*., 2008). In the neck it joined the superior cardiac and the RLNs (Standring *et al*., 2008). "On the left side, it enters the thorax between the left common carotid and subclavian arteries to join the left deep (dorsal) part of the cardiac plexus" (Standring *et al*., 2008).

CARDIAC BRANCHES FROM THE ICG

The inferior cervical cardiac nerve (ICCN) arose directly from the AS, comprising fibres that originated from the ICG or CTG (Saccomanno, 1943) or originated from the medial aspect of the CTG and AS to course along the subclavian artery to reach the cardiac plexus (Elias, 2000). Kawashima (2005) suggested that the ICCN originates from the ICG or CTG. San Mauro *et al*. (2009) reported that the ICCN descended posterior to the subclavian artery to converge with the RLN along the trachea to reach the deep cardiac plexus.

CARDIAC BRANCHES FROM THE CTG

Randall and Armour (1977) termed the cardiac nerves arising from the CTG as cervicothoracic cardiac nerves. Kalsey *et al*. (2000) stated that the CTCN "gave off 2 to 4 branches" which "formed plexus with similar branches from the superior and middle cervical ganglia before proceeding to heart". "The right cervicothoracic cardiac nerves, two or three in number, arise from the seventh, eight and first thoracic levels of the sympathetic trunk, in relation to the seventh cervical and first thoracic vertebrae" (Mizeres, 1972). These usually arise from AS and CTG, and occasionally from the VG; and may be fused with the other cervical sympathetic nerves and cervicothoracic branches of the vagus nerve before reaching the right bronchus (Mizeres, 1972). CTCN contributes to the right pulmonary plexus and occasionally "directly to the right coronary plexus" (Mizeres, 1972). In addition, CTCN sends "filaments which fuse with the trunk of the thoracic vagus" (Mizeres, 1972).

The left CTCN arose "from the corresponding vertebral levels of the left sympathetic trunk" and "course between the arch of aorta and left bronchus and contribute to the left pulmonary plexus" (Mizeres, 1972). Mizeres (1972) also suggested that the left CTCN "usually do not join any of the cervicothoracic branches of the vagus nerve".

The CTCN "descends behind the subclavian artery and along the front of the trachea to the deep cardiac plexus" (Standring *et al*., 2008). The branches from CTG to blood vessels formed plexuses on the subclavian artery and its branches (Standring *et al.,* 2008). Pather *et al*. (2006) described the CTCN in "all cases with a direct ganglionic origin in 83.7%" of which 97.9% of these had two rami that arose from this ganglion "presumably representing the inferior cervical cardiac ramus and the first thoracic ramus" (Pather *et al*., 2006). CTCN contributed to the plexus posterior to the arch of aorta i.e. the DCP (Pather *et al*., 2006).

[B] BRANCHES FROM THE THORACIC SYMPATHETIC SYSTEM

Previous investigations on the thoracic cardiac nerves stated that no nerves arose below the level of the ICG (Randall and Armour, 1977; Janes *et al*., 1986) although Valentin (1843) and Perman (1924) had described thoracic cardiac nerves arising from the second thoracic ganglion (Kuntz and Morehouse, 1930). Ionesco and Enachescu (1928) described that "these nerves arise mainly from ganglions or intervening portions of the sympathetic trunk in the second to the fifth thoracic segments" (Kuntz and Morehouse, 1930); and the former authors reported that these "commonly anastomose with each other and with the inferior cervical sympathetic cardiac nerve and cardiac branches of the vagus". Kuntz and Morehouse (1930) described nerves that were "traced from the medial aspect of both the second and the third thoracic ganglion of the sympathetic trunk below the inferior cervical ganglion or from the interganglionic portions of the sympathetic trunk in the second and third thoracic segments". These nerves united and formed a single trunk which gave rise to smaller branches that joined the cervical sympathetic nerves and branches of the vagus nerve; other branches entered the DCP or joined the SCP (Kuntz and Morehouse, 1930). In addition, they reported that cardiac nerves can be identified from the thoracic ganglia or sympathetic trunk from below the ICG to as far as the fifth thoracic ganglia on both sides (Table 1) (Kuntz and Morehouse, 1930).

Saccomano (1943) stated that “the thoracic cardiac nerves are more abundant” and “in some cases fifteen to twenty could be traced into the cardiac plexuses on either side”; with the exact number of these nerves varying bilaterally while the arrangement and number varied unilaterally (Saccomano, 1943). He stated further that “nearly all thoracic cardiac nerves arise from the upper six thoracic segments of the sympathetic trunks” and “the larger ones usually arise from the ganglia; the smaller ones from the internodes” (Saccomano, 1943).

These extended medially in close association with the intercostal vessels, lying between the intercostal artery and the vein and within the same tissue” (Saccomano, 1943). Numerous branches of these nerves terminated in relation to the intercostal vessels (Saccomano, 1943). In his study, Saccomanno (1943) reported that “the thoracic cardiac nerves arising from the upper six or seven thoracic segments of the sympathetic trunk could be traced to the cardiac plexuses” and that “the nerves which reach the cardiac plexuses are more abundant in the third, fourth and fifth segments than in the upper three” (Saccomano, 1943).

“The right thoracic cardiac branches arise from the sympathetic trunk below the level of the lower border of first thoracic vertebra and above the levels of the fourth or fifth vertebrae” (Mizeres, 1972). These varied from one to three and fused with one of the CTCN and with one thoracic cardiac branch of the vagus nerve, contributing to the right pulmonary and atrial plexuses (Mizeres, 1972). “The left thoracic cardiac branches arise from the corresponding vertebral levels of the sympathetic trunk” and “they do not fuse immediately with other cardiac branches” (Mizeres, 1972). These varied from two to four and sent “filaments to the plexus on the arch of aorta, directly into the thoracic vagal trunk, and also to the left pulmonary and atrial plexuses" (Mizeres, 1972).

Randall and Armour (1977) stated that the right thoracic sympathetic chain ended in the thoracic inlet by a large swelling viz. the right CTG. In their study, "no nerves arising from the chain below this level coursed medially into the pretracheal and cardiac regions" (Randall and Armour, 1977). This was corroborated by a study conducted by Janes *et al*. in 1986.

Standring *et al*. (2008) stated that "the medial branches from the upper five ganglia are very small" and "they supply filaments to the thoracic aorta and its branches". These formed a delicate plexus on the aorta together with filaments from the greater splanchnic nerve (Standring *et al*., 2008). "Twigs from the second to fifth or sixth ganglia enter the posterior pulmonary plexus; others, from the second, third, fourth and fifth ganglia, pass to the deep (dorsal) part of the cardiac plexus" (Standring *et al*., 2008) (Table 1). The other small branches from the pulmonary and cardiac nerves passed to the oesophagus and trachea (Standring *et al*., 2008)

TABLE 1: VARYING THORACIC ROOTS OF TCN TO THE DCP

Author	Year	Composition	Lowest root
Perman	1924	Adults	T2
Ionesco and Enachescu	1928	Fetuses and adults	T5
Kuntz and Morehouse	1930	Adult, young cadavers and fetuses	T5
Saccomanno	1943	Adults	T6/T7
Mitchell	1953	Adults	T4
Ellison and Williams	1969	Fetuses	T5
Mizeres	1972	Adults	T4
Fukuyama	1982	Not reported	T4-T5
Kawashima	2005	Adults	T7
San Mauro *et al.*	2009	Adults	T4-T5

2.7.2 CARDIAC NERVES OF THE PARASYMPATHETIC NERVOUS SYSTEM

The vagus nerves give rise to the parasympathetic cardiac nerves that have varying courses on either side (Kawashima, 2005). “The right vagus nerve descends posterior to the internal jugular vein (IJV) to cross the first part of subclavian artery and enter the thorax” (Standring *et al.*, 2008). “The left vagus enters the thorax between the left common carotid artery (LCCA) and subclavian arteries and behind the left brachiocephalic vein” (Standring *et al.*, 2008). Kawashima (2005) described these as the vagal cardiac branches with direct connections or connections via the cardiac plexus.

Preganglionic parasympathetic fibres in the vagus nerve are carried by cervical and thoracic branches of the vagus nerves to ganglion cells in the heart (Gardner *et al*., 1975).

CERVICAL CARDIAC BRANCHES

These cervical cardiac branches "arise from any part of the cervical part of the vagus as far inferiorly as the lower border of the sixth cervical vertebra" (Mizeres, 1972). The vagus nerve mostly gave off a single branch which is usually fused with the cervical cardiac branches of the cervical sympathetic trunk (Mizeres, 1972). Kawashima (2005) described a superior cardiac branch "which arose from the vagus nerve at the level of the upper portion of the recurrent laryngeal nerve". "The right cervical cardiac branch of the vagus nerve usually fuses with the right cervical cardiac branch of the sympathetic trunk, coursing posterior to the aorta and entering the pulmonary plexuses" (Mizeres, 1972).

The left cervical cardiac branch of vagus nerve received a contribution from the left cervical cardiac branch of the sympathetic trunk and these descended as a single filament anterior to the carotid sheath and to the arch of aorta (Mizeres, 1972). It contributed to the plexus of the arch of aorta and coronary plexuses; this description is what is referred to as the superficial cardiac plexus by other authors (McMinn, 1990; Standring *et al*., 2008). "Sometimes, both the right and left cervical branches course anterior to the arch of aorta, contributing to the plexus on the arch of aorta and to the coronary plexus" (Mizeres, 1972). San Mauro *et al*. (2009) described superior cardiac nerves that vary from one to three which originated from the superior and inferior laryngeal nerves while Janes *et al*. (1986) described no cardiopulmonary nerves arising from the right cervical vagus nerve although the left cervical vagus nerve had the cranial and caudal cardiopulmonary nerves originating from it.

THE CERVICOTHORACIC BRANCHES

"The right cervicothoracic cardiac branches arise from the right recurrent laryngeal nerve near its origin and from the vagal trunk at the levels of the seventh cervical and the first thoracic vertebrae" (Mizeres, 1972). At this point they are usually joined by the right cervical and CTCN of the sympathetic trunk to course as conjoined nerves before reaching the pulmonary plexus (Mizeres, 1972). The left branches are one or two in number and arose at the same level as the right branches coursing anterior to the arch of aorta; thus contributing to the plexus on the arch of aorta and the left atrial plexus (Mizeres, 1972). San Mauro *et al*. (2009) termed this group of nerves the inferior cardiac nerves and stated that they terminated in front of the aortic arch. Kawashima (2005) referred to these as an inferior cardiac branch which arose from the RLN.

THORACIC BRANCHES

The right vagal thoracic branches vary from two to four in number arising from the thoracic vagal trunk between the level of the lower border of the first thoracic vertebra and the pulmonary hilum (Mizeres, 1972). The thoracic branches "join the cervicothoracic or thoracic cardiac branches of the sympathetic trunk before coursing anterior to the right bronchus" (Mizeres, 1972). After reaching the right pulmonary plexus, filaments could be followed into the right atrial plexus (Mizeres, 1972).

There are two groups of the left thoracic cardiac branches that arise from left RLN and vagal trunk, below the origin of RLN (Figure 24) (Mizeres, 1972). One group from the left RLN coursed posterior to the arch of aorta to join the left atrial plexus directly (Mizeres, 1972). The second group coursed anteriorly to join the left pulmonary plexus and then coursed posteriorly to reach the left atrial plexus (Mizeres, 1972). "Although no sympathetic cardiac branches join the left thoracic cardiac branches, these nerves may conceivably carry sympathetic fibres since the left thoracic cardiac branches of the sympathetic trunk send filaments directly into the trunk of the thoracic vagus" (Mizeres, 1972). In a study by Kawashima (2005), the thoracic cardiac branch arose from the vagus nerve at the level of the lower portion of RLN.

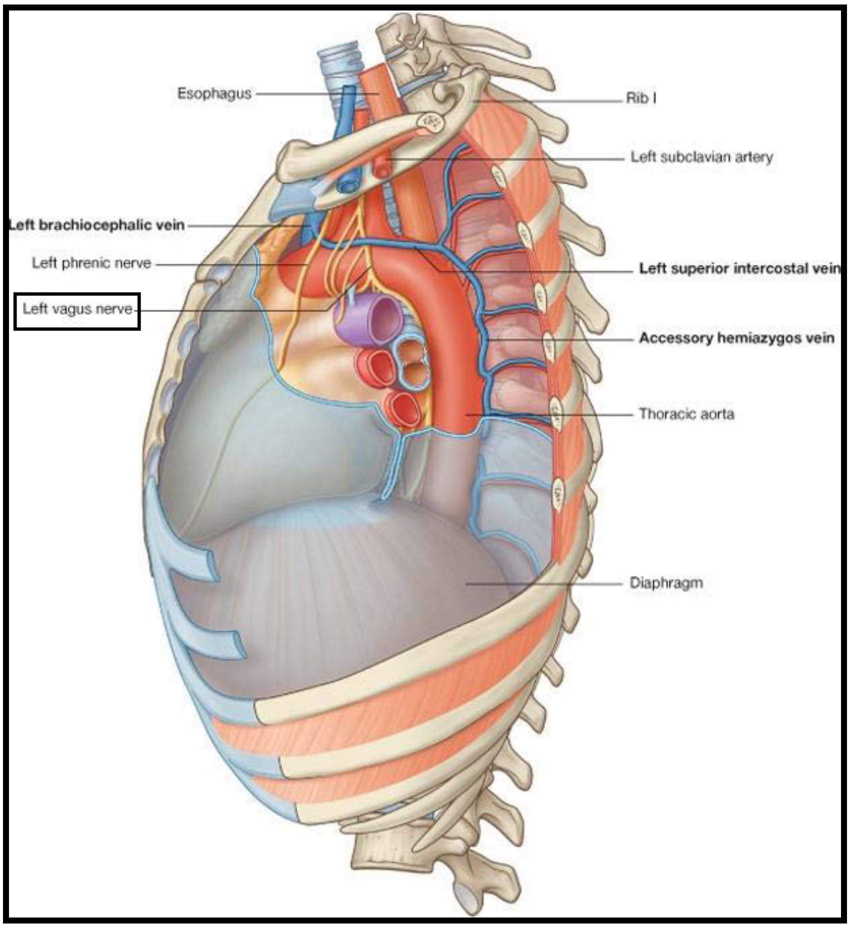


Figure 24: Thoracic cardiac branches of the vagus nerve (Adapted from Drake *et al*., 2009)

According to Randall and Armour (1977) in describing branches from the right side, the vagus nerve gives a few cardiac vagal branches in a zone where it gives off the RLN, with the major branch being the recurrent cardiac branch. "Near the origin of the recurrent laryngeal nerve another major branch arises, cranial or caudal to the recurrent, from the thoracic vagus-the thoracic craniovagal cardiac nerve" and "lower down the vagus gives off branches to the heart, a large one is usually present and is designated as the thoracic caudovagal cardiac nerve" (Randall and Armour, 1977). In addition, Randall and Armour (1977) reported that a major interconnecting nerve between the MCG and the vagus nerve may occur. On the left side, a few major interconnecting branches were noted by Randall and Armour (1977). "At the level of the nodose ganglion a thin filament was present in one cadaver between that ganglion and the superior cervical ganglion" (Randall and Armour, 1977). A small branch was also noted from the vagus in the mid cervical region to the left atrium in one specimen (Randall and Armour, 1977). Most branching occurred at or below the left RLN (Randall and Armour, 1977).

CLINICAL RELEVANCE

Mitchell (1953) stated that "efferent accelerator and some afferent fibres from the heart and great vessels pass through the cervical and thoracic sympathetic cardiac nerves due to their importance in the treatment of angina pectoris". The use of sympathectomy for the relief of angina pectoris was first proposed by Francois-Franck in 1899 and reported as an operative procedure by Ionnesco in 1920 (Kadowaki and Levett, 1986). Sympathectomy was thought to interrupt the efferent sensory fibers that carried pain stimuli from the heart and aorta and provided symptomatic relief (Kadowaki and Levett, 1986). Kadowaki and Levett (1986) further stated that sympathectomy was effective in the treatment of angina but was no longer indicated for patients.

Sympathectomy was further indicated for treatment of Prinzmetal‟s angina, atrial and ventricular tachycardia (Kadowaki and Levett, 1986). The clinical studies reviewed by Kadowaki and Levett (1986) showed that Prinzmetal‟s angina and atrial tachycardia were not effectively treated by sympathectomy while long-term relief was possible in ventricular tachycardia. They concluded that sympathectomy seemed most effective when carried out bilaterally and extended to lower thoracic segments (Kadowaki and Levett, 1986).

Minimal invasive surgery has gained "popularity" in cardiac sympathetic denervation for intractable angina pectoris in patients unsuitable for conventional revascularization (Khogali *et al*., 1999). Khogali *et al*. (1999) was successful in interrupting the pain pathway in limited T2-T4 sympathectomy to relieve pain at rest in patients with intractable angina pectoris.

The upper thoracic sympathetic chain is approached for the treatment of a group of medical condition: upper limb hyperhidrosis, complex regional pain syndrome and Raynaud‟s phenomenon (Zhang *et al*., 2009). The anatomical variations that exist have been proposed as the potential cause of failed sympathectomy and thus their study documented knowledge of anatomical structures in the upper thoracic sympathetic trunk and intercostals nerves (Zhang *et al*., 2009).

CHAPTER 3

MATERIALS AND METHODS

GENERAL

Specimens for this study were obtained from the Discipline of Clinical Anatomy at the University of KwaZulu-Natal (Westville and Nelson R Mandela School of Medicine campuses).

The research was conducted at the above mentioned departments (in accordance with the Human Tissue Act 51 of 1989, and the National Health Act, 2003) with clearance from the Biomedical Research and Ethics Committee of the University of KwaZulu-Natal (Ethical clearance number: BF 152/07).

3.1 MATERIALS

The study comprised 40 fetuses (n=80 sides) with normal necks and trunks (gestational ages: 16-30 weeks) and 10 (n=20 sides) adult cadavers. The total sample size comprised 100 sides [50 right; 50 left].

The dissections were conducted at both macro and microscopic levels. In the macroscopic dissection, surgical loupes were used to examine contributions from the sympathetic chain and its ganglia. During micro-dissection of the fetuses, micro-dissecting instruments were used and specimens were examined under a stereomicroscope, Stemi DV4 (Carl Zeiss Inc., Germany). A Canon digital camera was used to photograph the dissected specimens and all findings were subsequently recorded.

The following parameters were investigated in all specimens:

- Incidence of cervical ganglia (superior, middle, vertebral and inferior cervical or cervicothoracic) and their cardiac contributions.
- The first to the eighth thoracic ganglia and the incidence of their cardiac contributions.
- The vagus nerve and the incidence of its cardiac contributions.
- The formation of the superficial cardiac plexus.
- The formation of the deep cardiac plexus.

3.2 METHODS

GROSS ANATOMICAL DISSECTION

3.2.1 THORACIC DISSECTION

The thoracic dissection was performed prior to the cervical dissection. In both adults and fetuses, a midline vertical skin incision was made from the jugular notch (at the level of T2-T3 vertebrae) to the xiphisternal junction (at the level of T10-T11 vertebrae). Two transverse incisions were then made viz.

i) From jugular notch along the clavicle to the acromion of the scapula, continuing to a point that is halfway to the arm;

ii) From the xiphoid process along the costal margin to the midaxillary line.

Another incision around the anterior and posterior surfaces of the arm was made to meet the incision along the midaxillary line.

The skin was then reflected from medial to lateral and detached at the midaxillary line. All muscles i.e. serratus anterior and pectoral muscles that were attached on the anterior thoracic wall were detached from the rib cage by removal or reflection. The clavicle was cut at its mid-length and a transverse cut across the sternum and costal cartilages at the level of the 5^{th} intercostal space, using a saw, was made taking care not to damage the underlying structures.

The intervening intercostal muscles and vessels were then cut using a scalpel and ribs were cut using a rib cutter. The anterior thoracic wall was detached from the parietal pleura and internal thoracic vessels were reflected superiorly and removed. The lungs were removed by excision of the pulmonary vessels and the bronchi at the hilum. All surrounding tissue and the supra-pleural membrane overlying the sympathetic chain were carefully removed from the first rib to the costo-diaphragmatic recess (T10-T11). The medial branches of the sympathetic chain were traced using surgical loupes (MABM27, 2.75x) in adults and under a stereomicroscope (Stemi DV4, Carl Zeiss) in fetuses.

3.2.2. CERVICAL DISSECTION

In both adults and fetuses, a midline vertical incision from the mental protuberance to the jugular notch (at level of T2-T3 vertebrae) was made and a lateral incision from the angle of the mandible (at the level of C2 vertebra) along the anterior border of the trapezius to the first transverse incision of the thoracic dissection was also made. The skin and fascia were reflected from medial to lateral to the 2^{nd} vertical incision. The sternocleidomastoid and strap muscles of the neck were detached from their attachments and removed to view the carotid sheath and its contents. Major venous structures *viz*. subclavian and brachiocephalic veins were removed to expose the brachiocephalic trunks and subclavian arteries. The cervical sympathetic trunk and ganglia were then followed upward from the thoracic inlet to the base of the skull to identify medial branches to the cardiac plexus. The brachiocephalic trunk and subclavian artery on the right were further excised to view ganglia and contributions to the cardiac plexus while the common carotid artery and the subclavian artery were further excised on the left to view the same.

3.3 NOMENCLATURE

3.3.1. IDENTIFICATION OF THE CERVICAL SYMPATHETIC CHAIN

The cervical sympathetic chain was identified as the sympathetic chain located between the superior cervical ganglion and the inferior cervical or cervicothoracic ganglion. Its course and relations, number of chains, number of ganglia and medial contributions to the cardiac plexus were observed and recorded in each of the cervical sympathetic chains.

3.3.2 CERVICAL GANGLIA

The incidences of cervical ganglia in the cervical sympathetic chains were recorded in both foetuses and adults. The cervical ganglia were described as ganglia residing on the CSC located between the bases of the skull cranially and the thoracic inlet caudally.

3.3.2.1 SUPERIOR CERVICAL GANGLION

In this study the superior cervical ganglion was described as the ganglion located posterior to the common carotid artery (Kawashima, 2005).

3.3.2.2 MIDDLE CERVICAL GANGLION

The middle cervical ganglion was described as the ganglion that is located in the CSC between the SCG and the ICG or CTG. The location and description of the MCG was based on Becker and Grunt's (1957) classification which described the MCG in relation to the ITA viz.

Type I: *a MCG lying above the ITA (above ITA)-'high'* MCG;

Type II: *a MCG lying on the ITA (at ITA)-'normal' MCG;*

Type III: *a MCG lying below ITA (below ITA)-'low' MCG*

3.3.2.3 VERTEBRAL GANGLION

The vertebral ganglion (VG) was described as the ganglion located on the anterior surface of the vertebral artery (Kawashima, 2005). Its incidence and medial distribution to the cardiac plexus was recorded.

3.3.2.4 INFERIOR CERVICAL GANGLION

The inferior cervical ganglion was described as the ganglion located medial to the costocervical artery; the incidence and medial distribution to the cardiac plexus was recorded.

3.3.2.5 CERVICOTHORACIC GANGLION

The cervicothoracic ganglion was described as the fused inferior cervical and first thoracic ganglion located posterior to the subclavian arteries. Its incidences, shapes and medial distribution to the cardiac plexus were recorded.

3.3.3 THORACIC SYMPATHETIC CHAIN

The thoracic sympathetic chain was described as that part of the sympathetic chain that is located below the thoracic inlet. Its course and relations, and medial contributions to the cardiac plexus were observed and recorded.

3.3.4 CARDIAC PLEXUS

In this study the cardiac plexus is described according to Standring *et al*. (2008) as consisting of superficial and deep parts.

3.3.4.1 SUPERFICIAL CARDIAC PLEXUS

The superficial part was identified as the cardiac plexus located anterior to arch of aorta and the right pulmonary artery and closely related to the brachiocephalic trunk and ascending aorta. The medial contributions from the cervical sympathetic ganglia and chain and from the cervical vagus nerve were observed and recorded.

3.3.4.2 DEEP CARDIAC PLEXUS

The deep cardiac plexus was identified as the part located posterior to the arch of aorta and anterior to the tracheal bifurcation. The medial contributions from cervical and thoracic sympathetic ganglia and chains as well as from the cervical and thoracic vagus and recurrent laryngeal nerves were observed and recorded.

3.3.5 CERVICAL SYMPATHETIC CARDIAC NERVES

In this study cervical sympathetic cardiac nerves were described according to the cervical ganglia that they originated from e.g. the superior cervical cardiac nerve as the cervical cardiac nerve arising from the SCG (*Represented by G in respective tables*). The nerves that originated from the CSC (i.e. interganglionic chain) were described together with the ganglia located superior to them (*Represented by IG in respective tables*). In some cases the cervical sympathetic cardiac nerves arose from both the ganglion and the interganglionic chain (*Represented by G+IG in the respective tables*).

3.3.5.1 SUPERIOR CERVICAL CARDIAC NERVE

The superior cervical cardiac nerve is described as the nerve arising from the SCG or the interganglionic chain below it or both reaching any of the two parts of the cardiac plexus. The incidence was observed and recorded.

3.3.5.2 MIDDLE CERVICAL CARDIAC NERVE

The middle cervical cardiac nerve is described as the nerve arising from the MCG or the interganglionic chain below it or both reaching any of the two parts of the cardiac plexus. The incidence was observed and recorded.

3.3.5.3 VERTEBRAL CARDIAC NERVE

The vertebral cardiac nerve is described as the nerve arising from the VG to any part of the cardiac plexus. The incidence was observed and recorded.

3.3.5.4 INFERIOR CERVICAL CARDIAC NERVE

The inferior cervical cardiac nerve is described as the nerve arising from the ICG or the interganglionic chain below it or both that reaches any part of the cardiac plexus. The incidence was observed and recorded.

3.3.5.5 CERVICOTHORACIC CARDIAC NERVE

The cervicothoracic cardiac nerve is described as the nerve arising from the CTG to reach any part of the cardiac plexus. The incidence was observed and recorded.

3.3.6 THORACIC CARDIAC NERVES

In this study the thoracic cardiac nerves were described according to the thoracic ganglia that they arose from or the interganglionic chain or both. (*Represented by G, IG and G+IG in the respective tables in the results section*).

3.3.6.1 TCN_1

The first thoracic cardiac nerve is described as the nerve arising from the first thoracic ganglion that reaches the deep part of the cardiac plexus. The incidence of this nerve was observed and recorded.

3.3.6.2 TCN_2

The second thoracic cardiac nerve is described as the nerve arising from the second thoracic ganglion or the interganglionic chain below it, to reach the deep cardiac plexus. The incidence of this nerve was observed and recorded.

3.3.6.3 TCN_3

The third thoracic cardiac nerve is described as the nerve arising from the third thoracic ganglion to reach the deep cardiac plexus. The incidence of this nerve was observed and recorded.

3.3.6.4 TCN_4

The fourth thoracic cardiac nerve is described as the nerve arising from the fourth thoracic ganglion or the interganglionic chain below it, to the deep cardiac plexus. The incidence of this nerve was observed and recorded.

3.3.6.5 TCN_5

The fifth thoracic cardiac nerve is described as the nerve arising from the fifth thoracic ganglion to reach the deep cardiac plexus. The incidence of this nerve was observed and recorded.

3.3.6.6 TCN_6

The sixth thoracic cardiac nerve is described as the nerve arising from the sixth thoracic ganglion or the interganglionic chain below it or both, to reach the deep cardiac plexus. The incidence of this nerve was observed and recorded.

3.3.6.7 TCN_7

The seventh thoracic cardiac nerve is described as the nerve arising from the seventh thoracic ganglion or the interganglionic chain below it or both, to reach the deep cardiac plexus. The incidence of this nerve was observed and recorded.

3.3.6.8 TCN_8

The eighth thoracic cardiac nerve is described as the nerve arising from the eighth thoracic ganglion or the interganglionic chain below it or both, to reach the deep cardiac plexus. The incidence of this nerve was observed and recorded.

3.3.7 VAGUS NERVE

3.3.7.1 CERVICAL VAGAL CARDIAC NERVES

These nerves were identified as superior, middle and inferior cervical cardiac nerves according to their level of origin from the vagus nerve (Mitchell, 1953).

3.3.7.1.1 SUPERIOR CERVICAL VAGAL CARDIAC NERVE

The superior branch was described as the branch that left the vagus nerve in the upper part of the neck to reach any part of the cardiac plexus; its incidence was observed and recorded.

3.3.7.1.2 MIDDLE CERVICAL VAGAL CARDIAC NERVE

The middle branch was described as the branch that arose from the lower third of the vagus nerve in the neck that reached any part of the cardiac plexus; its incidence was observed and recorded.

3.3.7.1.3 INFERIOR CERVICAL VAGAL CARDIAC NERVE

The inferior branch was described as the branch that arose from the vagus nerve at the cervicothoracic inlet or within the upper thorax to reach any part of the cardiac plexus; its incidence was observed and recorded.

3.3.7.2 THORACIC VAGAL CARDIAC NERVES

The thoracic vagal cardiac nerves were described as the branches that arose from the vagus nerve below the cervicothoracic inlet to reach the deep part of the cardiac plexus. Their incidence was observed and recorded.

3.3.7.3 RECURRENT LARYNGEAL CARDIAC NERVES

The recurrent laryngeal cardiac nerves were described as the nerves that arose from any part of the recurrent laryngeal nerve to reach the deep cardiac plexus. Their incidence was observed and recorded.

CHAPTER 4

RESULTS

4.1. SAMPLE

Forty fetuses and ten adults were included in this study with a total of one hundred sides (n=100: right, 50 and left, 50) [*Table 2*].

TABLE 2: *SAMPLE DISTRIBUTION*

MATERIAL	RIGHT	LEFT	TOTAL
FETUSES	40	40	80
ADULTS	10	10	20
TOTAL	50	50	100

4.2. CERVICAL SYMPATHETIC CHAIN

4.2.1. COURSE AND RELATIONS

The cervical part of the sympathetic chain was located anterior to the prevertebral fascia [*Plate 1* and *Figure 25*]. It was located posterior to the carotid sheath and medial to the vagus nerve in all of the fetuses and adults.

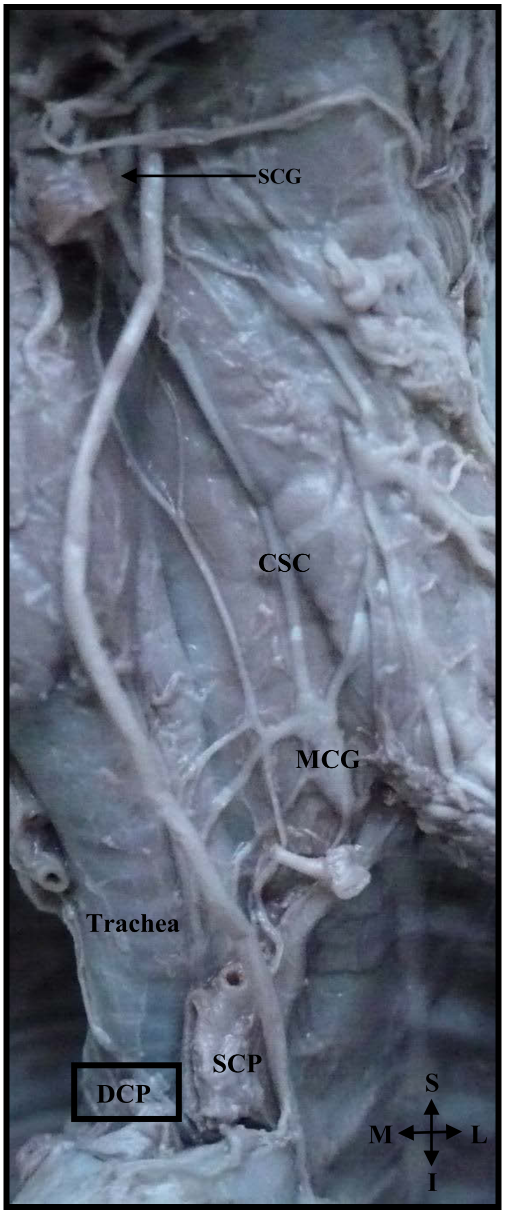


Plate 1: *Antero-lateral view of a left single fetal CSC with the vagus nerve and the common carotid artery removed. (x4.0)*

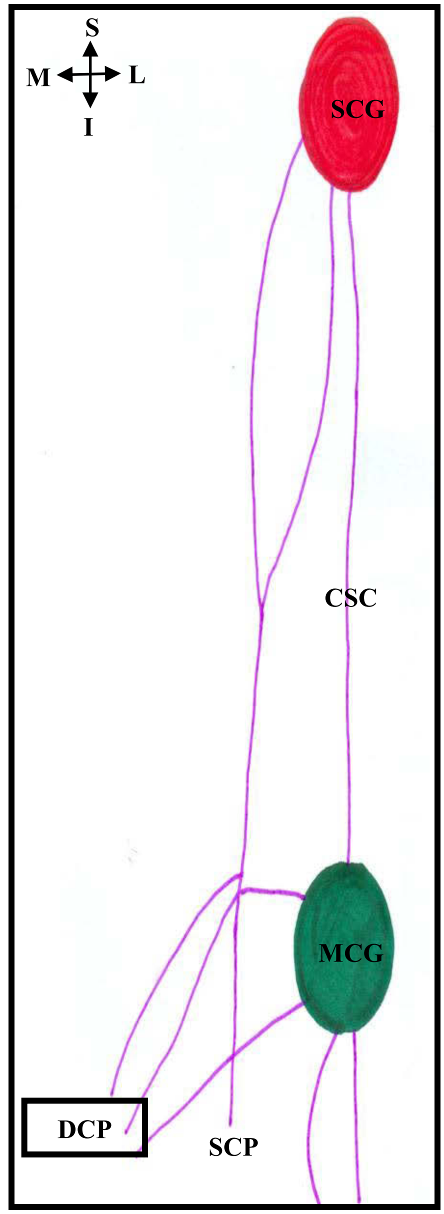


Figure 25: *Schematic diagram of single fetal CSC.*

Key: ***CSC****-Cervical sympathetic chain,* ***DCP****-Deep cardiac plexus,* ***I****-Inferior,* ***L****-Lateral,* ***M****-Medial,* ***MCG****-Middle cervical ganglion,* ***SCG****-Superior cervical ganglion,* ***SCP****-Superficial cardiac plexus,* ***S****-Superior*

4.2.2. INCIDENCE

OVERALL INCIDENCE OF CERVICAL SYMPATHETIC CHAIN

Single CSC was present in 99% ($^{99}/_{100}$) while a CSC formed by multiple branches was present in 1% ($^{1}/_{100}$) of the specimens examined [*Table 3*]. The adult specimens had a single CSC in 100% of the specimens while the fetal specimens had a CSC represented by multiple branches in 1% of the specimens (Plate 2, Figure 26).

TABLE 3: *BRANCHING PATTERNS OF CSC*

CHAINS	SINGLE (n=99)				MULTIPLE (n=1)			
MATERIAL	A		F		A		F	
SIDES	R	L	R	L	R	L	R	L
INCIDENCE	10	10	39	40	0	0	1	0
TOTAL	20		79		0		1	

Key: ***A***-*Adult,* ***F***-*Fetal,* ***L***-*Left,* ***R***-*Right*

FETAL INCIDENCE

The single CSC was present in 99% ($^{79}/_{80}$) of the specimens. The incidence of single was present in 98% ($^{39}/_{40}$) on the right side and in 100% ($^{40}/_{40}$) on the left side of these specimens [*Table 3*] [*Plate 1* and *Figure 25]*. Furthermore, a right CSC formed by multiple branches was present in 1% ($^{1}/_{80}$) of these specimens [*Table 3*] [*Plate 2* and *Figure 26*].

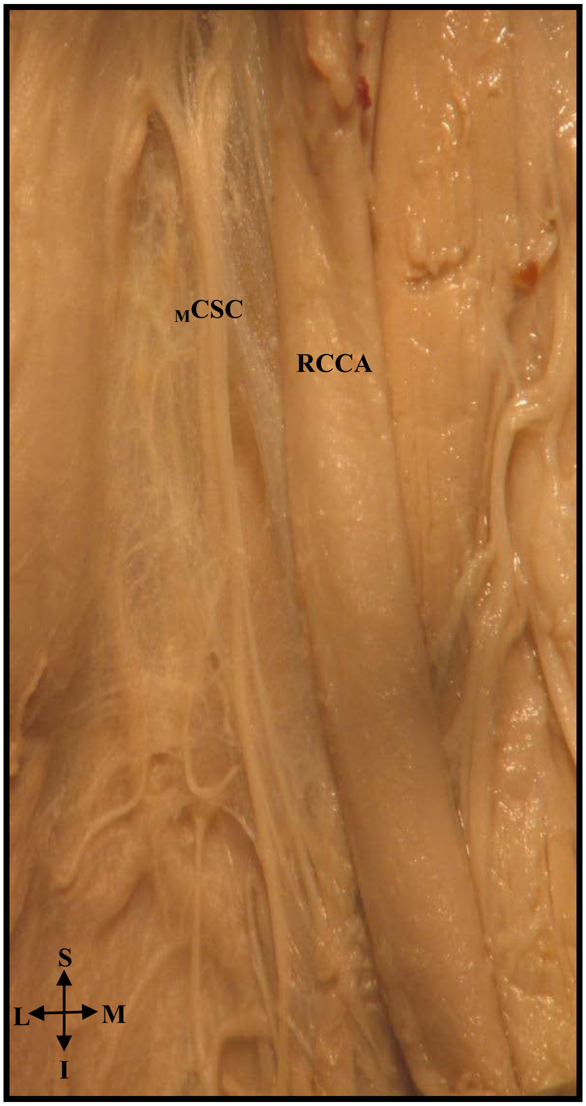


Plate 2: *Antero-lateral view of the right CSC dividing into multiple branches in a fetus. (x4.0)*

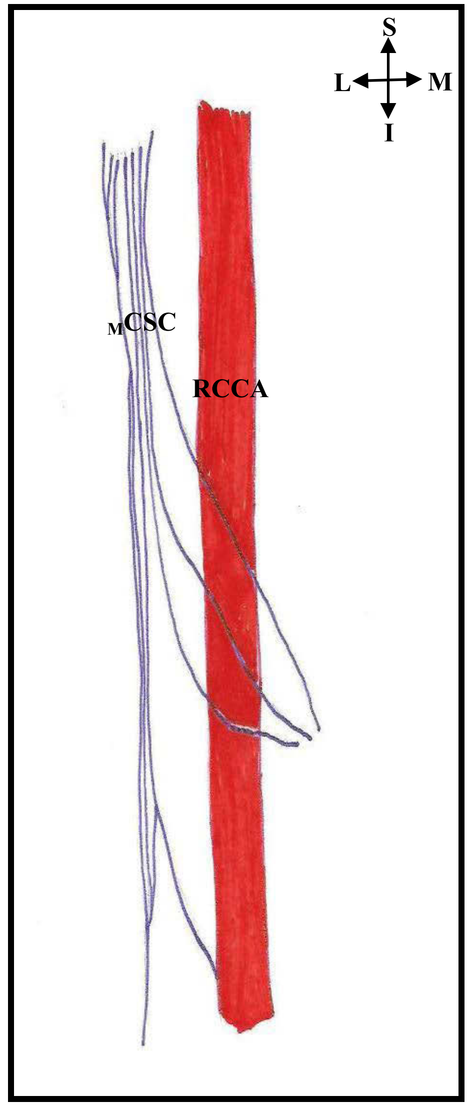


Figure 26: *Schematic diagram of multiple CSC in a fetus.*

Key: ***I***-*Inferior*, **L-***Lateral*, ***M***-*Medial*, $_{M}$***CSC***- *Multiple branches of cervical sympathetic chain*, ***RCCA***-*Right common carotid artery*, ***S***-*Superior.*

ADULT INCIDENCE

The single CSC was present in 100% ($^{20}/_{20}$) of the specimens. The incidence of single CSC was present in 100% ($^{10}/_{10}$) on both right and left sides of the specimens [*Table 3*].

4.3. CERVICAL GANGLIA

The numbers of cervical ganglia of the cervical sympathetic chains were noted to vary from two to five [*Table 4*] in both fetuses and adults. The ganglia residing on the CSC between SCG and ICG/CTG were named MCG and VG. The MCG was found to be the most variable cervical ganglion while VG was found to have a variable incidence in all the specimens. The incidences of the cervical ganglia were as follows [*Table 5* and *Figure 27*]:

- Two ganglia: 13 specimens (13%)
- Three ganglia: 58 specimens (58%)
- Four ganglia: 28 specimens (26%)
- Five ganglia: 2 specimens (2%)

TABLE 4: *DISTRIBUTION PATTERNS OF CERVICAL GANGLIA*

PATTERN	TOTAL (n=100)	RIGHT (n=50)		LEFT (n=50)	
		A	F	A	F
SCG, CTG	4	1	0	3	0
SCG, ICG	6	1	2	2	1
SCG, MCG	2	0	2	0	0
SCG, MCG, CTG	17	1	8	0	8
SCG, MCG, ICG	21	3	8	2	8
SCG, MCG, VG	2	0	2	0	0
SCG, MCG, VG, CTG	17	1	5	1	10
SCG, MCG, VG, ICG	11	0	5	0	6
SCG, VG	1	0	0	0	1
SCG, VG, CTG	11	3	4	1	3
SCG, VG, ICG	7	0	4	1	2

Key: ***A***-*Adult,* ***CTG***-*Cervicothoracic ganglion,* ***F***-*Fetus,* ***ICG***-*Inferior cervical ganglion,* ***MCG***-*Middle cervical ganglion,* ***SCG***-*Superior cervical ganglion,* ***VG***-*Vertebral ganglion.*

TABLE 5: *INCIDENCE OF CERVICAL GANGLIA*

GANGLION	RIGHT (n=50)			LEFT (n=50)			TOTAL (n=100)
	F	A	Abs	F	A	Abs	
SCG	40	10	0	40	10	0	100
MCG	30	5	15	33	3	14	100
VG	19	4	27	22	3	25	100
ICG	18	4	28	18	5	27	100
CTG	17	6	27	21	4	25	100

Key: ***A***-*Adult,* ***CTG***-*Cervicothoracic ganglion,* ***F***-*Fetus,* ***ICG***-*Inferior cervical ganglion,* ***MCG***-*Middle cervical ganglion,* ***SCG***-*Superior cervical ganglion,* ***VG***-*Vertebral ganglion.*

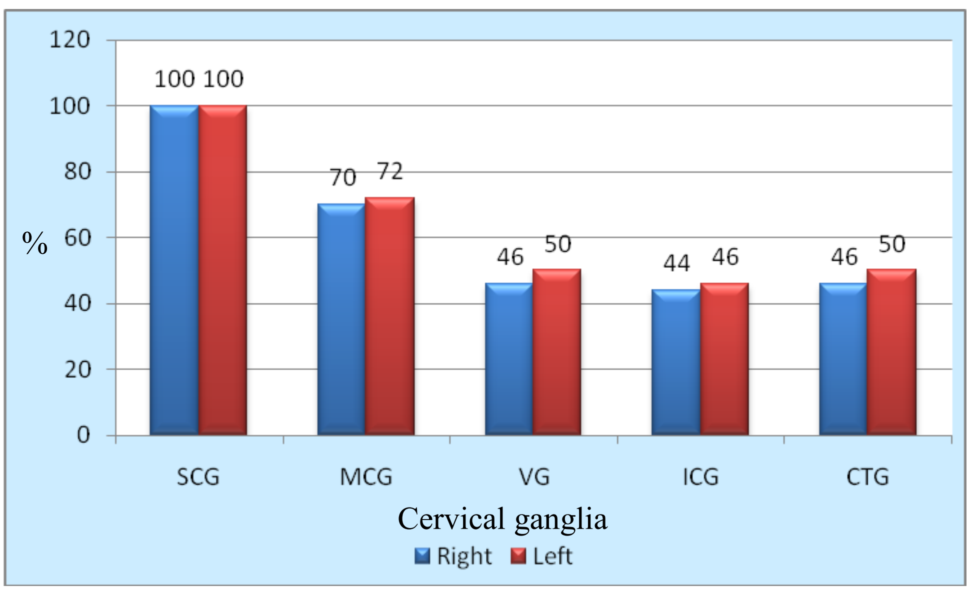


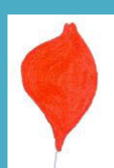
Figure 27: *Incidence (%) of cervical ganglia*

4.3.1 SUPERIOR CERVICAL GANGLION

[I] OVERALL INCIDENCE OF SUPERIOR CERVICAL GANGLION

The SCG was present in 100% ($^{50}/_{50}$) [right: 50; left: 50] on both right and left sides of the specimens studied with varying shapes such as fusiform in 61% ($^{61}/_{100}$), oval-rounded in 30% ($^{30}/_{100}$), elongated in 6% ($^{6}/_{100}$) and irregular in 3% ($^{3}/_{100}$) [*Table 6*]. There were no significant differences in the incidence of SCG in both adult and fetal specimens.

TABLE 6: *VARYING SHAPES OF SCG*

SCHEMATIC	SHAPE	RIGHT (n=50)		LEFT (n=50)	
	FUSIFORM	10	21	10	20
	OVAL-ROUNDED	0	14	0	16
	ELONGATED	0	3	0	3
	IRREGULAR	0	2	0	1

FETAL INCIDENCE

The superior cervical ganglion was present in 100% ($^{80}/_{80}$) of the specimens. This ganglion was located posterior to the bifurcation of the common carotid arteries with the vagus nerve situated laterally at all times (*Plate 3* and *Figure 28*). The numbers of varying shapes of SCG are reflected in *Table 6* above.

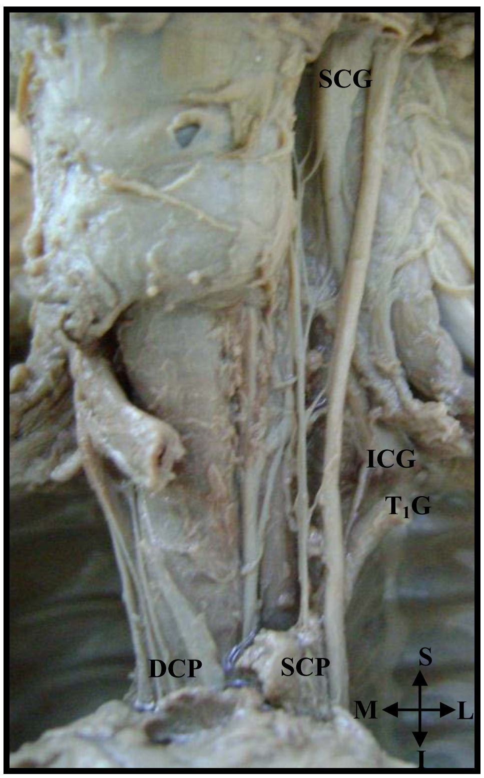


Plate 3: *Antero-lateral view of the left SCG in a fetus. (x4.0)*

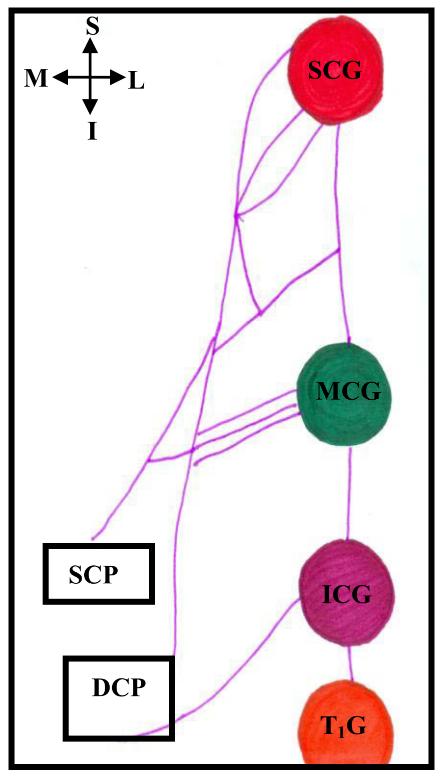


Figure 28: *Schematic diagram of SCG in a fetus*

Key: ***DCP***- *Deep cardiac plexus,* ***ICG***-*Inferior cervical ganglion,* ***I***-*Inferior,* ***L***-*Lateral,* ***M***-*Medial,* ***SCG***-*Superior cervical ganglion,* ***SCP***-*Superficial cardiac plexus,* ***S***-*Superior,* ***T_1G***-*First thoracic ganglion*

ADULT INCIDENCE

The superior cervical ganglion was present in 100% ($^{20}/_{20}$) of the specimens. This ganglion was located above the bifurcation of the common carotid arteries and closely related to the internal carotid artery in 100% of the specimens. This ganglion had a fusiform shape in 100% of the specimens.

4.3.2. MIDDLE CERVICAL GANGLION

I. OVERALL INCIDENCE OF THE MIDDLE CERVICAL GANGLION

The middle cervical ganglion was present in 71% ($^{71}/_{100}$) of the specimens [*Table 7* and *Figure 29*]. The incidence of MCG was 70% ($^{35}/_{50}$) on the right side and 72% ($^{36}/_{50}$) on the left side. Of the 71 MCG that were present, a single MCG was present in 68% ($^{68}/_{100}$) while a double MCG was present in 3% ($^{3}/_{100}$) of the specimens. The MCG was absent in 29% of the specimens examined. The fetal specimens had a higher incidence of MCG compared to the adult specimens (79% vs. 40%).

TABLE 7: *INCIDENCE OF THE MIDDLE CERVICAL GANGLIA*

MCG	RIGHT (n=50)			LEFT (n=50)			TOTAL (n=100)
	F	A	Total	F	A	Total	
Present	30	5	35	33	3	36	71
Absent	10	5	15	7	7	14	29
Single	28	5	33	32	3	35	68
Double	2	0	2	1	0	1	3

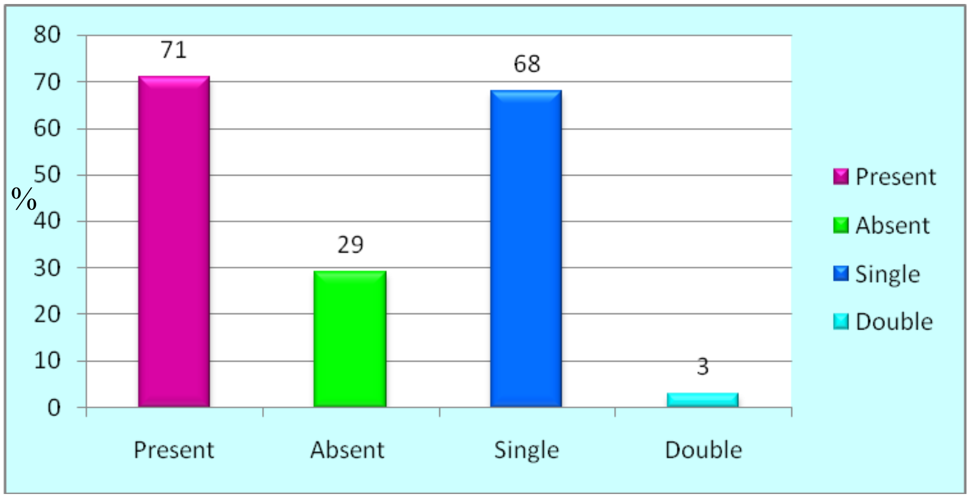


Figure 29: *Graphic representation of incidence of MCG.*

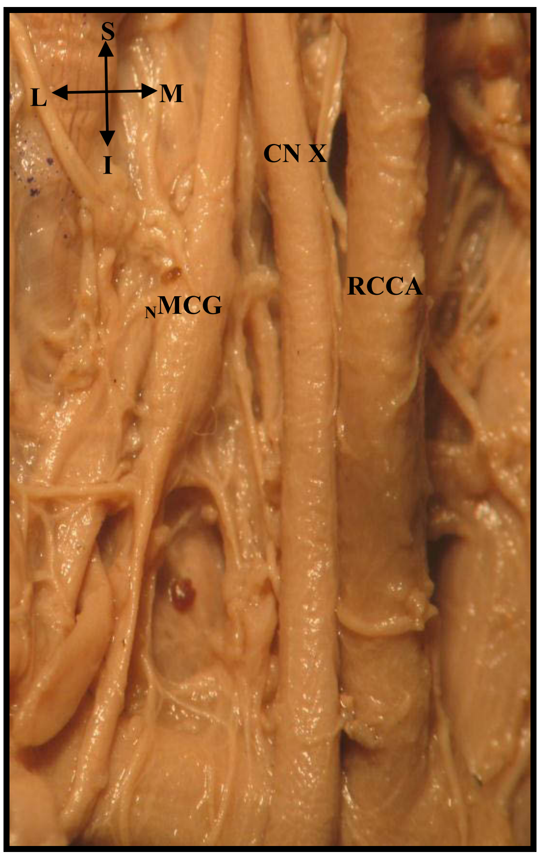


Plate 4: *Antero-medial view of normal location of right MCG in a fetus.* (x4.0)

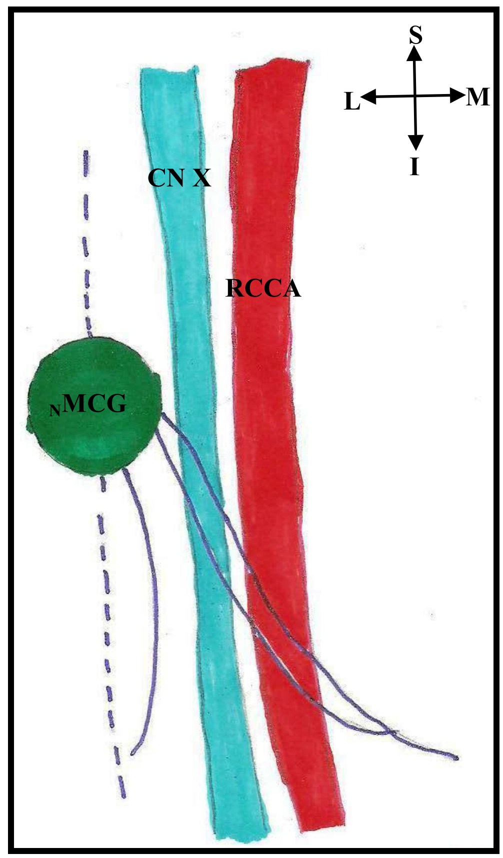


Figure 30: *Schematic diagram of normal MCG in a fetus*

Key: ***CN X****-Vagus nerve,* $_N$***MCG****-normal MCG,* **I**-*Inferior,* **M**-*Medial,* **L**-*Lateral,* ***RCCA****-Right common carotid artery,* **S**-*Superior*

II. TYPES OF MCG

The location and description of the MCG is based on Becker and Grunt's (1957) classification [*Table 8 and Figure 31*] which comprised of three types of MCG as follows:

Type I: *MCG lying above the ITA -„high‟*MCG;

Type II: *MCG lying on the ITA -„normal‟MCG;*

Type III: *MCG lying below ITA -„low‟ MCG*

TABLE 8: *INCIDENCE OF TYPES OF MCG*

LEVEL	RIGHT (n=50)			LEFT (n=50)			TOTAL (n=100)
MATERIAL	F	A	Total	F	A	Total	
Above ITA-high	2	1	3	4	0	4	7
At ITA-normal	12	4	16	16	3	19	35
Below ITA-low	17	0	17	14	0	14	31

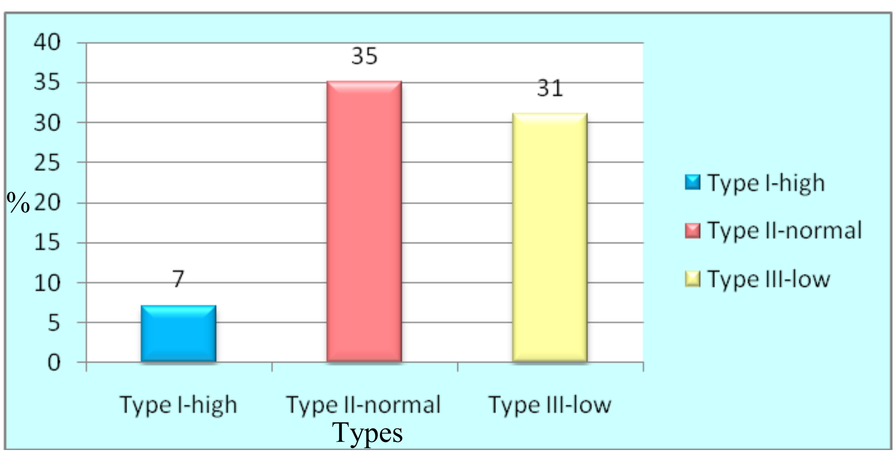


Figure 31: *Graphic representation of percentage incidence of types of MCG.*

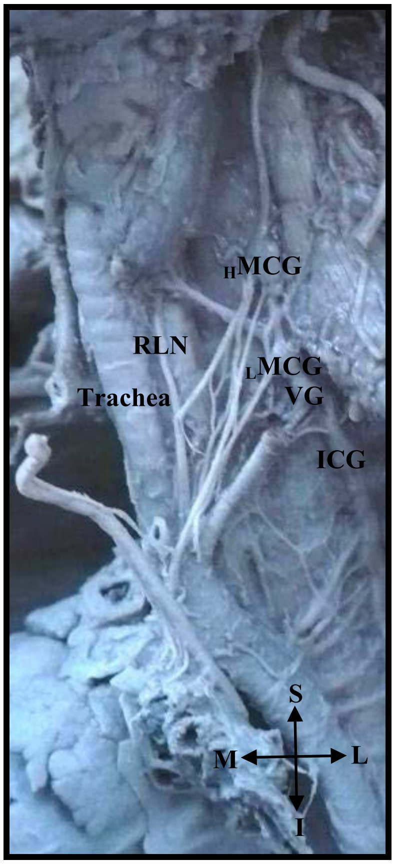


Plate 5: *Antero-lateral view of double left MCG in a fetus.* (x4.0)

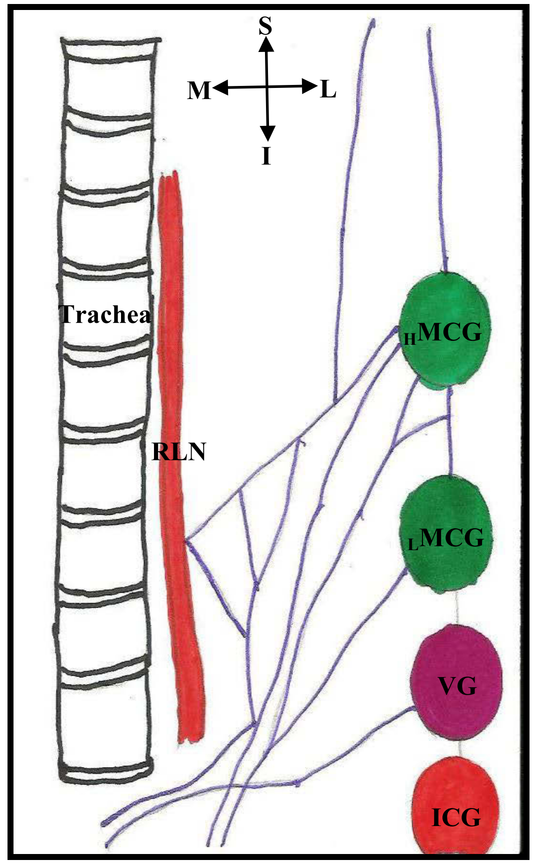


Figure 32: *Schematic diagram of a double left MCG in a fetus.*

Key: ***ICG****-Inferior cervical ganglion,* **I**-*Inferior,* **M**-*Medial,* ***$_H$MCG****-High MCG,* ***$_L$MCG****-Low MCG,* **L**-*Lateral,* ***RLN****-Recurrent laryngeal nerve,* ***S****-Superior,* ***VG****-Vertebral ganglion*

FETAL INCIDENCE

The incidence of MCG was 79% ($^{63}/_{80}$ sides) in the specimens examined. It was present in 75% ($^{30}/_{40}$) on the right and 83% ($^{33}/_{40}$) on the left side. A total number of 60 MCG were single. A total number of 3 sides [n=3: right, 2; left, 1] had double MCG and were high (Type I: 33%), low (Type III: 33%) [*Plate 5* and *Figure 32*] and normal (Type II: 33%) [*Plate 4* and *Figure 30*] [*Table 7*]. The MCG was absent in 21% ($^{17}/_{80}$) specimens.

ADULT INCIDENCE

The incidence of MCG was 40% ($^{8}/_{20}$) [n=8: right, 5; left, 3] in the specimens examined. These were described as normal MCG in 88% ($^{7}/_{8}$) and a high MCG in 12% ($^{1}/_{8}$). The MCG was absent in 60% ($^{12}/_{20}$) of the specimens.

4.3.3. VERTEBRAL GANGLION

OVERALL INCIDENCE OF VERTEBRAL GANGLION

The VG was present in 48% ($^{48}/_{100}$). The incidence of VG was 46% ($^{23}/_{50}$) on the right side and 50% ($^{25}/_{50}$) on the left side in the specimens examined. The VG was absent in 52% ($^{52}/_{100}$) of the specimens. The incidence of the VG between the fetal and adult specimens compared favourably with each other.

FETAL INCIDENCE

The incidence of VG was present in 51% ($^{41}/_{80}$) of specimens [*Table 5*]. It was constantly closely related to the vertebral arteries. The incidence of VG was 48% ($^{19}/_{40}$) on the right side and 55% ($^{22}/_{40}$) on the left side in the specimens examined [*Plate 6* and *Figure 33*]. The VG was absent in 49% ($^{39}/_{80}$) specimens.

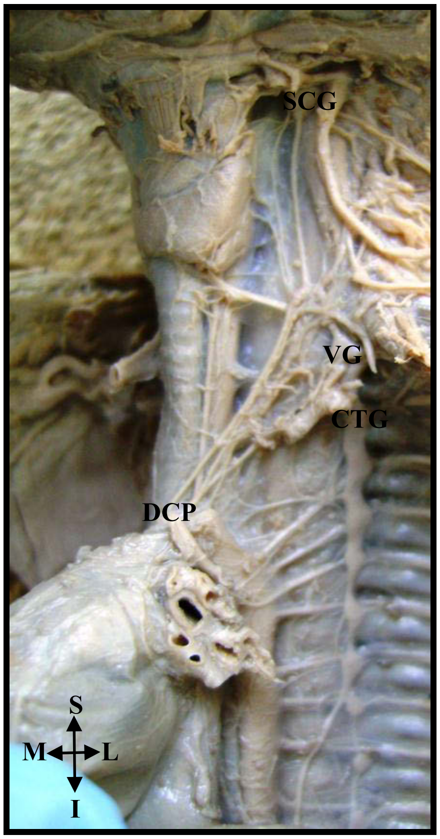


Plate 6: *Antero-lateral view of the left VG in a fetus.* (x4.0)

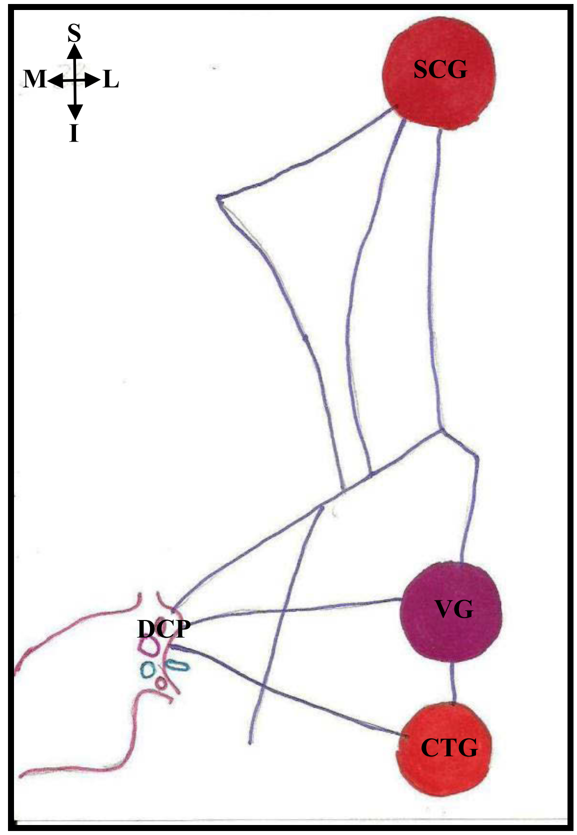


Figure 33: *Schematic diagram of the left VG in a fetus.*

Key: ***DCP***-*Deep cardiac plexus,* ***CTG***-*Cervicothoracic ganglion,* ***I***-*Inferior***,** ***L***-*Lateral***,** ***M***-*Medial***,** ***S***-*Superior,* ***SCG***-*Superior cervical ganglion,* ***VG***-*Vertebral ganglion.*

ADULT INCIDENCE

The incidence of VG was 35% ($^{7}/_{20}$) in the specimens examined [*Table 5*]. It was closely related to the vertebral artery in 100% of these specimens. The VG was present on the right and left sides in 20% ($^{4}/_{20}$) and 15% ($^{3}/_{20}$) of the specimens, respectively. The VG was absent in 65% ($^{13}/_{20}$) of the specimens.

4.3.4. INFERIOR CERVICAL GANGLION

OVERALL INCIDENCE OF INFERIOR CERVICAL GANGLION

The inferior cervical ganglion was present in 45% ($^{45}/_{100}$) [*Table 5*] of the specimens examined. The incidence of ICG was 44% ($^{22}/_{50}$) on the right and 46% ($^{23}/_{50}$) on the left side. This ganglion was absent in 55% ($^{55}/_{100}$) of the specimens. There were no differences between the incidence of the ICG in both the fetal and adult specimens.

FETAL INCIDENCE

The incidence of ICG was present in 45% ($^{36}/_{80}$) of specimens [*Plate 7* and *Figure 34*] [*Table 5*]. The incidence of ICG was present in 45% ($^{18}/_{40}$) of the specimens bilaterally. The ICG was absent in 55% ($^{44}/_{80}$) of these specimens.

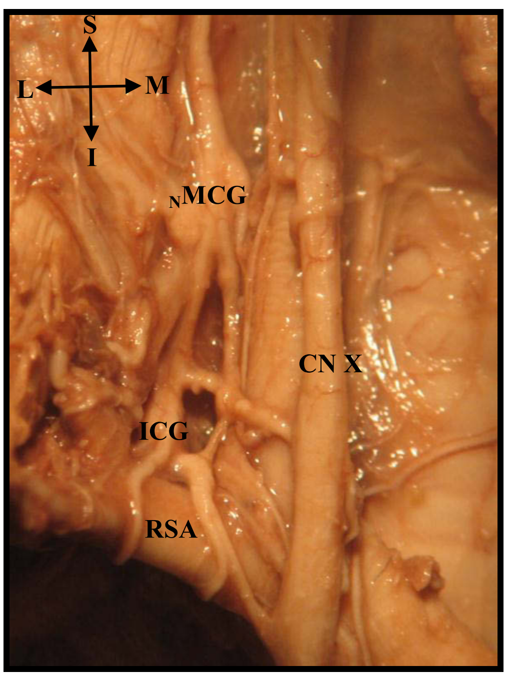


Plate 7: *Antero-lateral view of the right ICG in a fetus.* (x4.0)

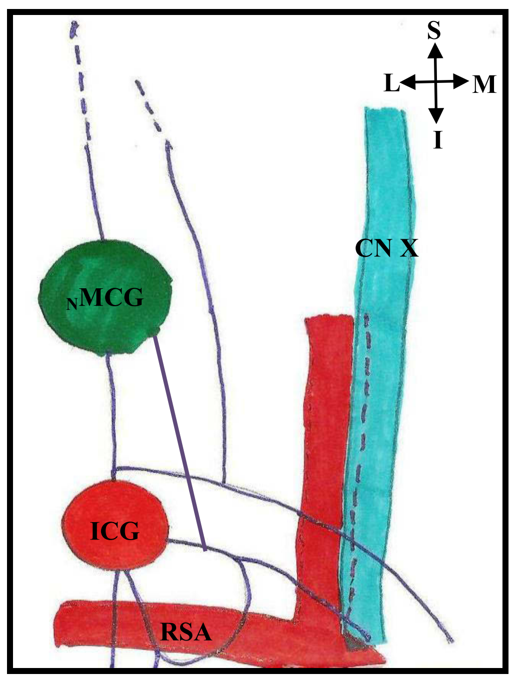


Figure 34: *Schematic diagram of the right ICG in a fetus*

Key: ***CN X****-Vagus nerve,* ***I****-Inferior,* ***ICG****-Inferior cervical ganglion,* $_{N}$***MCG****-Middle cervical ganglion,* ***M****-Medial,* ***L****-Lateral,* ***S****-Superior,* ***RSA****-Right subclavian artery*

ADULT INCIDENCE

The incidence of ICG was recorded in 45% ($^{9}/_{20}$) of the specimens examined [*Table 5*] in which it was located superior to the subclavian artery in all the specimens. The ICG was present in 40% ($^{4}/_{10}$) on the right and in 50% ($^{5}/_{10}$) on the left side. It was absent in 55% ($^{11}/_{20}$) of the specimens.

4.3.5. CERVICOTHORACIC GANGLION

OVERALL INCIDENCE OF CTG

The cervicothoracic ganglion was present in 48% ($^{48}/_{100}$) [*Table 5*] of the specimens examined. The incidence of CTG was 46% ($^{23}/_{50}$) on the right and 50% ($^{25}/_{50}$) on the left side in the specimens examined. It was found to have the following varying shapes by visual discrimination: spindle 36% ($^{36}/_{100}$), dumbbell 4% ($^{4}/_{100}$) and inverted 8% ($^{8}/_{100}$). The CTG was absent in 52% ($^{52}/_{100}$) of the specimens examined. There was no significant difference between the fetal and adult incidence of CTG.

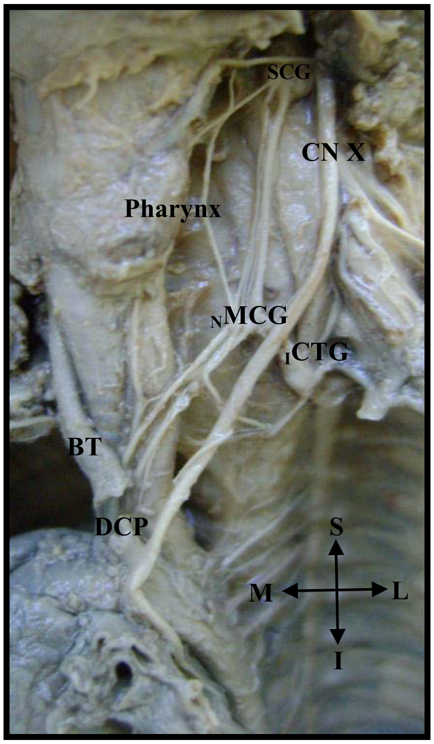


Plate 8: *Antero-lateral view of the left inverted CTG in a fetus.* (x4.0)

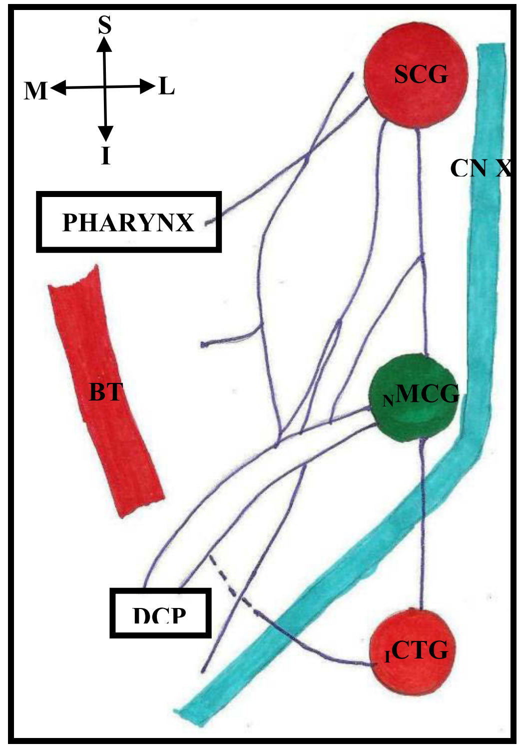


Figure 35: *Schematic diagram of the left inverted CTG in a fetus*

Key: ***BT****-Brachiocephalic trunk,* ***CN X****-Vagus nerve,* ***DCP****-Deep cardiac plexus,* $_I$***CTG****-Inverted "L" cervicothoracic ganglion,* $_N$***MCG****-Normal MCG,* ***SCG****-Superior cervical ganglion.*

FETAL INCIDENCE

The incidence of CTG was present in 48% ($^{38}/_{80}$) of specimens [Table 3]. It had three varying shapes in its appearance viz. spindle 33% ($^{26}/_{80}$), dumbbell 5% ($^{4}/_{80}$) and inverted 10% ($^{8}/_{80}$) [*Plate 8* and *Figure 35*].

ADULT INCIDENCE

The incidence of CTG was present in 50% ($^{10}/_{20}$) of specimens [Table 3]. All specimens were spindle shaped.

4.4. THORACIC SYMPATHETIC CHAIN

The thoracic sympathetic chain was examined in 50 ($^{100}/_{100}$) specimens. The location and the number of ganglia were examined to describe the medial contributions from this chain to the cardiac plexus.

COURSE AND RELATIONS

The thoracic sympathetic chain commenced below the ICG or CTG. It was found to lie posterior to the costal pleura with the azygos vein medial to it on the right side and the hemiazygos vein medial to it on the left side. It consisted of medial branches that comprised of visceral, cardiac and aortic branches.

The location of the upper thoracic chain (up to 6th thoracic vertebra) was on the neck of the ribs and their intervening intercostal spaces. The thoracic chain (from the 7th thoracic vertebra) lay close to the vertebral bodies and the intervening spaces.

4.4.1 THORACIC GANGLIA

The first thoracic ganglion was constantly present in 100% of the specimens. It was fused to the ICG in 48% of the specimens to form CTG. It was located at the base of the neck at all times. The second to the eighth thoracic ganglia were also present in 100% of the specimens and connected together by intervening portions of the trunk. These rested on the heads of their corresponding ribs and intercostals spaces and posterior to costal pleura. At some levels, the ganglia were fused viz. CTG to T_2 in 7%; T_1 and T_2 in 4%; T_3 and T_4 in 11%; T_4 and T_5 in 7%; T_5 and T_6 in 5%; T_6 and T_7 in 4%; T_6,$T_7$and T_8 in 1%.

4.5. CARDIAC PLEXUSES

The incidence of the cardiac plexuses was demonstrated in 100% ($^{100}/_{100}$) of the specimens studied. The cardiac plexuses were described according to superficial and deep parts. The superficial cardiac plexus was located on the arch of aorta and the pulmonary artery in 80% of the specimens. The SCP was also found in relation to the brachiocephalic trunk and ascending aorta on the right side in 20% of the specimens. The deep cardiac plexus located posterior to the arch of aorta and anterior to the tracheal bifurcation in 100% of the specimens.

4.5.1. SUPERFICIAL CARDIAC PLEXUS

OVERALL INCIDENCE

There were 100 superficial cardiac plexuses demonstrated in the specimens studied (right: 50; left: 50) [*Plate 9* and *Figure 36*]. The overall incidence on the right and left sides were 20% ($^{20}/_{100}$) and 80% ($^{80}/_{100}$), respectively. The left SCP was found in relation to the arch of aorta in the 80% ($^{80}/_{100}$) [*Plate 9* and *Figure 36*] of the specimens while the right SCP was found in relation to the brachiocephalic trunk and ascending aorta in 20% ($^{20}/_{100}$) [*Plate 10* and *Figure 37*]. Contributions to this CP are shown in *Table 9*. There were no significant differences between the adult and fetal incidences of the SCP.

FETAL INCIDENCE

The incidence of superficial cardiac plexuses was 100% in the specimens studied (right: 40; left: 40). The overall incidence on the right and left sides were 21% ($^{17}/_{80}$) and 79% ($^{63}/_{80}$), respectively. The left SCP was found inferior to the arch of aorta and above the right pulmonary artery [*Plate 9* and *Figure 36*] whilst the right SCP was located in relation to the brachiocephalic trunk [*Plate 10* and *Figure 37*].

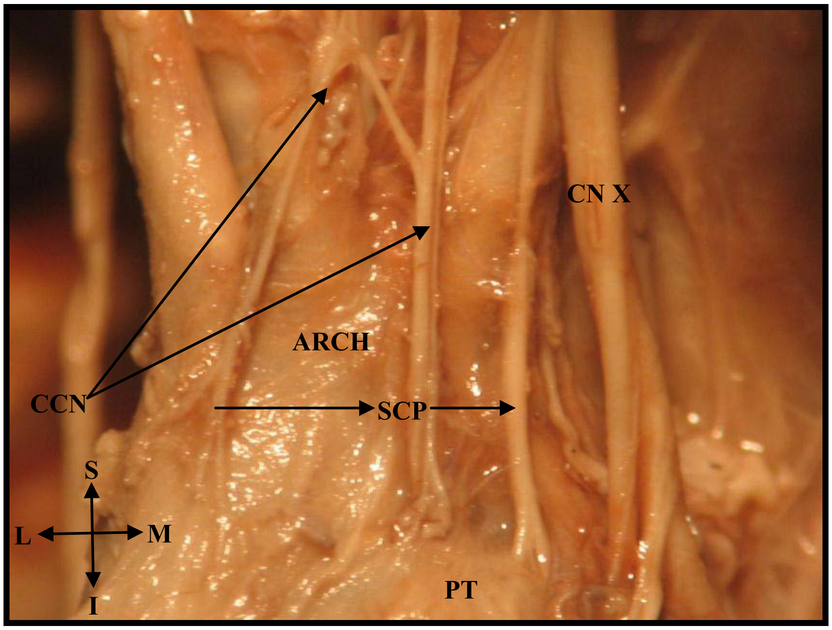


Plate 9: *SCP in a fetal specimen. (x4.0)*

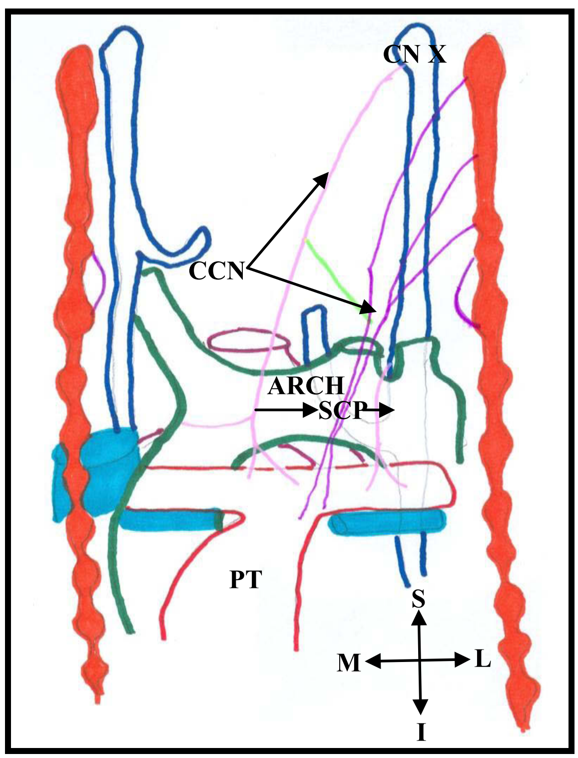


Figure 36: *Schematic diagram of SCP in a fetus.*

Key: Arch-*Arch of aorta***, *CCN***-*cervical cardiac nerves,* ***PT***-*Pulmonary trunk,* ***SCP***-*Superior cardiac plexus,* ***CN X***-*Vagus nerve.*

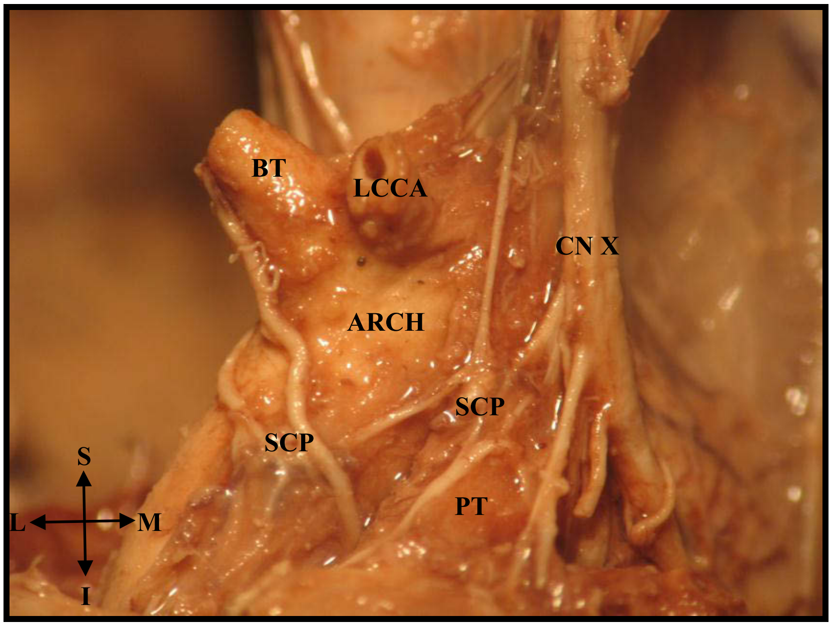


Plate 10: *SCP on BT and arch of aorta in a fetus. (x4.0)*

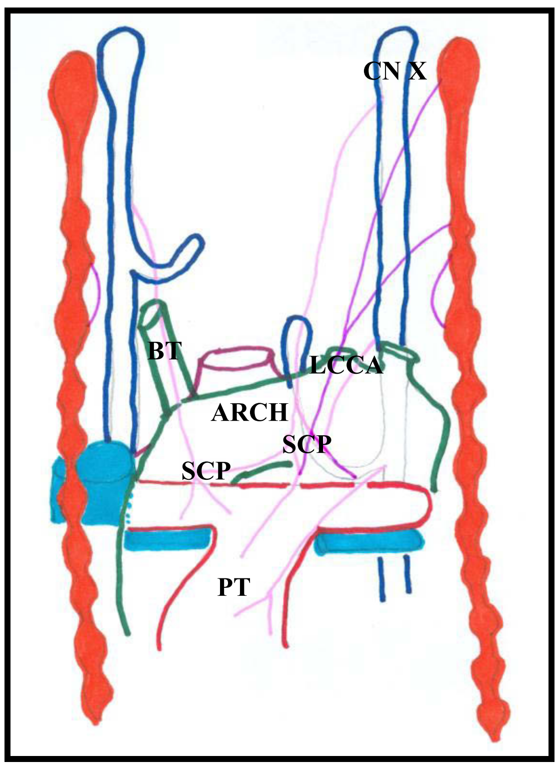


Figure 37: *Schematic diagram of SCP on BT and arch of aorta in a fetus*

Key: ***Arch****-Arch of aorta,* ***BT****-Brachiocephalic trunk,* ***LCCA****-left common carotid artery, PT-Pulmonary trunk,* ***CN X****-Vagus nerve*

ADULT INCIDENCE

The incidence of superficial cardiac plexuses was 100% in the specimens studied (right: 10; left: 10). The overall incidence on the right and left sides was 15% ($^{3}/_{20}$) and 85% ($^{17}/_{20}$), respectively. The left SCP was found in relation to the arch of aorta while the right SCP was in relation to the brachiocephalic trunk.

TABLE 9: *PERCENTAGE CONTRIBUTIONS TO THE LEFT SCP*

SIDES	SCCN	MCCN	VCN	ICCN	CTCN	VN
RIGHT (n=50)	4	4	6	0	0	5
LEFT (n=50)	76	30	8	0	4	55

4.5.2. DEEP CARDIAC PLEXUS

OVERALL INCIDENCE

There were 100 deep cardiac plexuses demonstrated in the specimens studied (right: 50; left: 50) [*Plate 11* and *Figure 38*]. The overall incidence bilaterally was 100%. The DCP was located in relation to the bifurcation of the trachea and the right pulmonary artery in 100% of these specimens. Contributions to this CP are shown in *Table 10*. There were no significant differences in the location of the DCP between fetal and adult specimens.

FETAL INCIDENCE

The incidence of deep cardiac plexus was 100% in the specimens studied (right: 40; left: 40). The overall incidence bilaterally was 100%. The DCP was found in relation to the bifurcation of the trachea and the right pulmonary artery in 100% of these specimens [*Plate 11* and *Figure 38*].

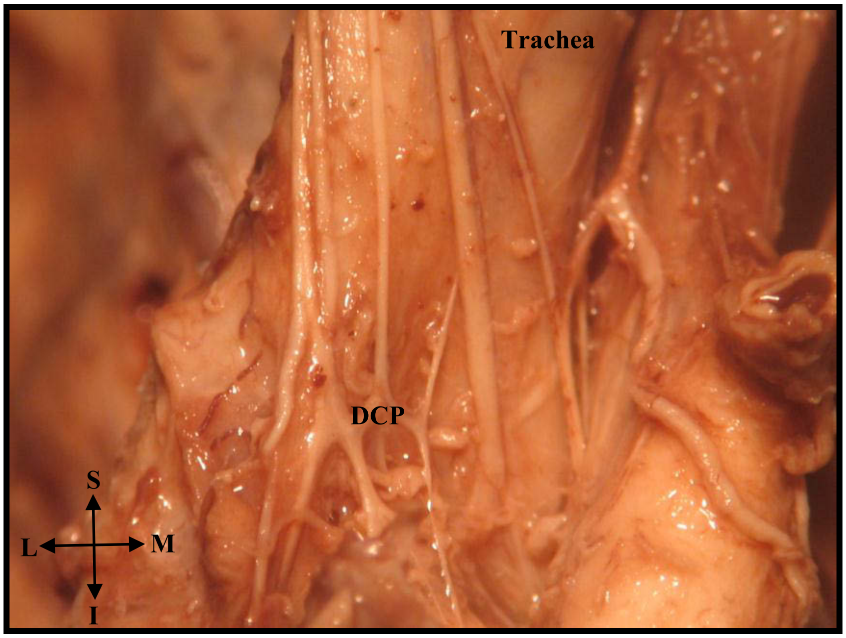


Plate 11: *DCP in a fetal specimen.* (x4.0)

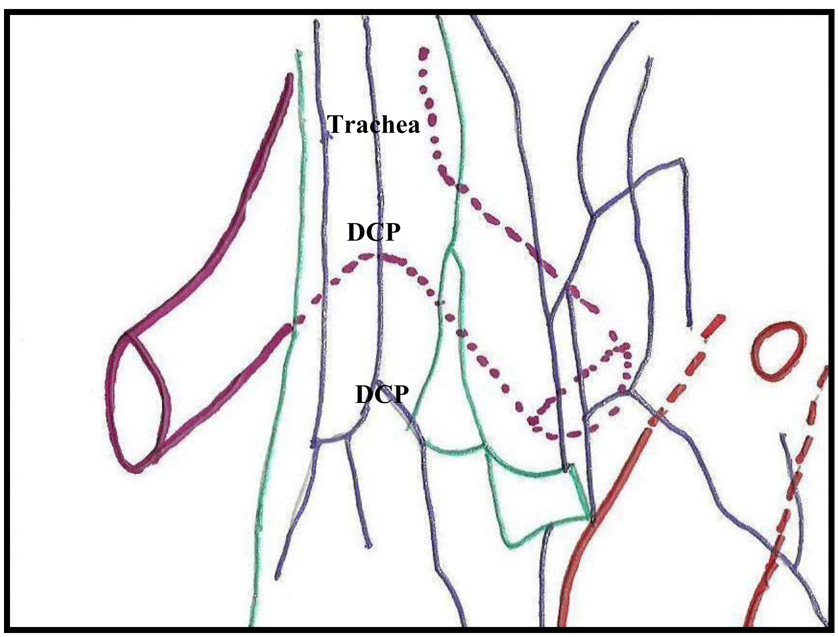


Figure 38: *Schematic diagram of the DCP in a fetus*

Key: ***DCP****-Deep cardiac plexus.*

ADULT INCIDENCE

The incidence of deep cardiac plexus was 100% in the specimens studied (right: 10; left: 10). The overall incidence on both the right and left sides was 100%. The DCP was found in relation to the bifurcation of the trachea and the right pulmonary artery in 100% of these specimens.

TABLE 10: *OVERALL PERCENTAGE CONTRIBUTIONS TO THE DCP*

ORIGIN OF CONTRIBUTION	CONTRIBUTIONS	RIGHT (n=50)	LEFT (n=50)
SCG	**SCCN**	88	56
MCG	**MCCN**	58	68
VG	**VCN**	26	38
ICG	**ICCN**	20	22
CTG	**CTCN**	12	26
T_1G	**TCN_1**	22	50
T_2G	**TCN_2**	14	32
T_3G	**TCN_3**	14	20
T_4G	**TCN_4**	10	14
T_5G	**TCN_5**	6	0
VN	**VN_S**	16	4
VN	**VN_M**	26	4
VN	**VN_I**	74	6
VN	**VN_T**	96	0
RLN	**RLN**	50	6

4.6. CERVICAL SYMPATHETIC CARDIAC NERVES (CSCN)

The overall incidences of cervical sympathetic cardiac nerves in the specimens studied for superior (SCCN), middle (MCCN), vertebral (VCN), inferior (ICCN), and cervicothoracic (CTCN) cervical cardiac nerves were 92%, 65%, 39%, 21% and 21%, respectively [*Table 11* and *Figure 39*].

TABLE 11: *INCIDENCE OF CERVICAL CARDIAC NERVES*

Cervical cardiac nerve	RIGHT (n=50)			LEFT (n=50)			TOTAL (n=100)
	F	A	Abs	F	A	Abs	
SCCN	38	7	5	38	9	3	100
MCCN	26	4	20	32	3	15	100
VCN	14	3	33	19	3	28	100
ICCN	8	2	40	9	2	39	100
CTCN	6	0	44	13	2	35	100

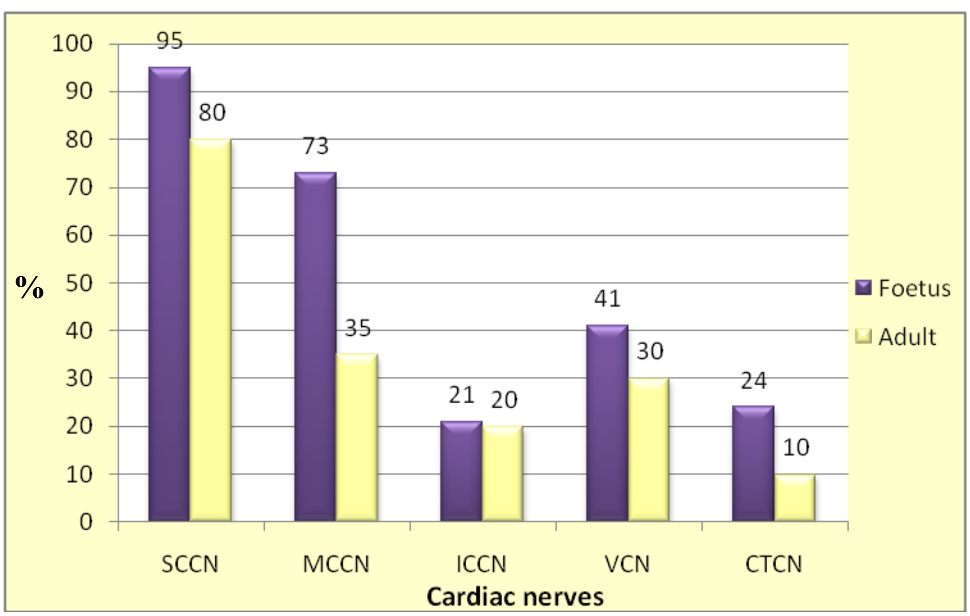


Figure 39: *Graphic representation of the incidence (%) of cervical cardiac nerves*

Key: ICCN-Inferior cervical cardiac nerve, **CTCN**-Cervicothoracic cardiac nerve, **MCCN**-Middle cervical cardiac nerve, **SCCN**-Superior cervical cardiac nerve, **VCN**-Vertebral cardiac nerve.

4.6.1. SUPERIOR CERVICAL CARDIAC NERVE (SCCN)

OVERALL INCIDENCE OF SUPERIOR CERVICAL CARDIAC NERVE

There were 92 superior cervical cardiac nerves [*Plate 12* and *Figure 40*] in the specimens studied. The overall incidence of the SCCN on the right and left sides were 90% ($^{45}/_{50}$) and 94% ($^{47}/_{50}$) [*Table 12; Figure 41*], respectively. The SCCN had ganglionic, interganglionic and both origins in 35% ($^{35}/_{100}$), 16% ($^{16}/_{100}$) and 41% ($^{41}/_{100}$) [*Figure 42*], respectively. It was absent in 8% ($^{8}/_{100}$) of the specimens. There were no significant differences between the fetal and adult specimens on the incidence of the SCCN.

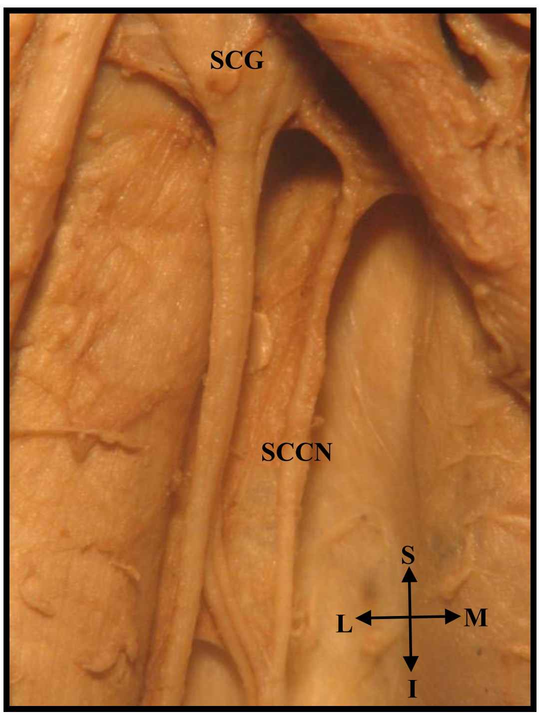


Plate 12: *Antero-medial view of the right SCCN in a fetus.* (x4.0)

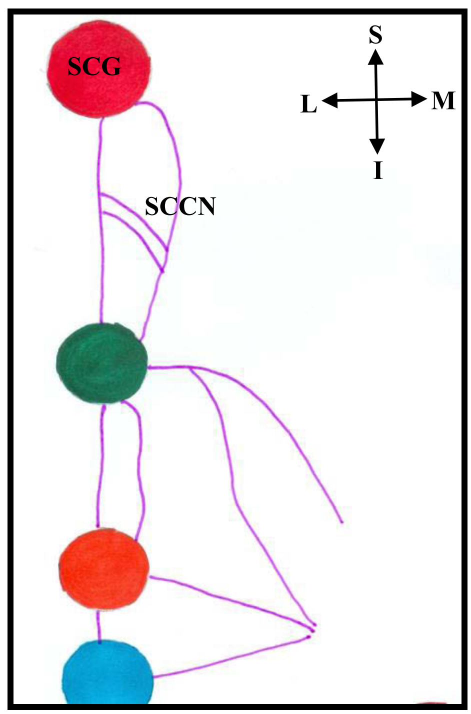


Figure 40: *Schematic diagram of the right SCCN in a fetus*

Key: ***SCG****-Superior cervical ganglion;* ***SCCN****-Superior cervical cardiac nerve,* ***I****-Inferior,* ***M****-Medial,* ***L****-Lateral,* ***S****-Superior.*

FETAL INCIDENCE

The superior cervical cardiac nerve was present in 95% ($^{76}/_{80}$) of the specimens [*Plate 12* and *Figure 40*]. The incidence of the superior cervical cardiac nerve was 95% ($^{38}/_{40}$) bilaterally [*Table 12*]. The SCCN had ganglionic, interganglionic and both origins in 36% ($^{29}/_{80}$), 14% ($^{11}/_{80}$) and 45% ($^{36}/_{80}$) [*Table 12*], respectively. The SCCN was absent in 5% ($^{4}/_{80}$).

ADULT INCIDENCE

The superior cervical cardiac nerve was present in 80% ($^{16}/_{20}$) of the specimens. The incidence of the superior cervical nerve was 70% ($^{7}/_{10}$) on the right and 90% ($^{9}/_{10}$) on the left side [*Table 12*]. The SCCN had ganglionic, interganglionic and both origins in 35% ($^{6}/_{20}$), 25% ($^{5}/_{20}$) and 25% ($^{5}/_{20}$) [*Table 12*], respectively. The SCCN was absent in 20% ($^{4}/_{20}$) of the specimens.

TABLE 12: *INCIDENCE AND ORIGIN OF SCCN*

SIDES	RIGHT (n=50)				LEFT (n=50)				TOTAL (n=100)
ORIGIN	G	IG	G+IG	Abs	G	IG	G+IG	Abs	
FETAL	16	8	14	2	13	3	22	2	80
ADULT	3	1	3	3	3	4	2	1	20
TOTAL	19	9	17	5	16	7	24	3	100

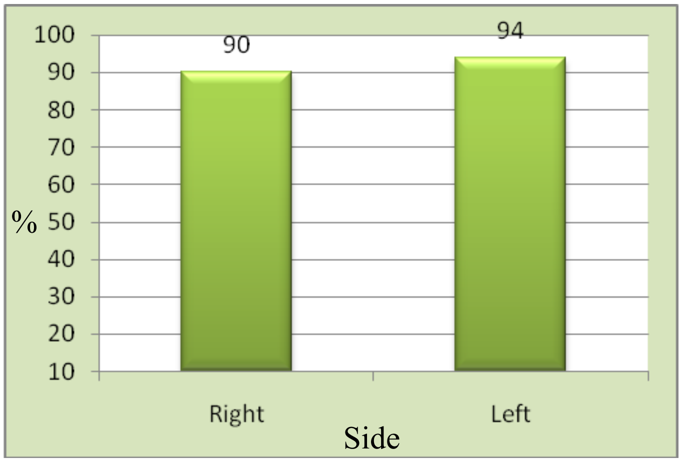


Figure 41: *Incidence (%) of SCCN*

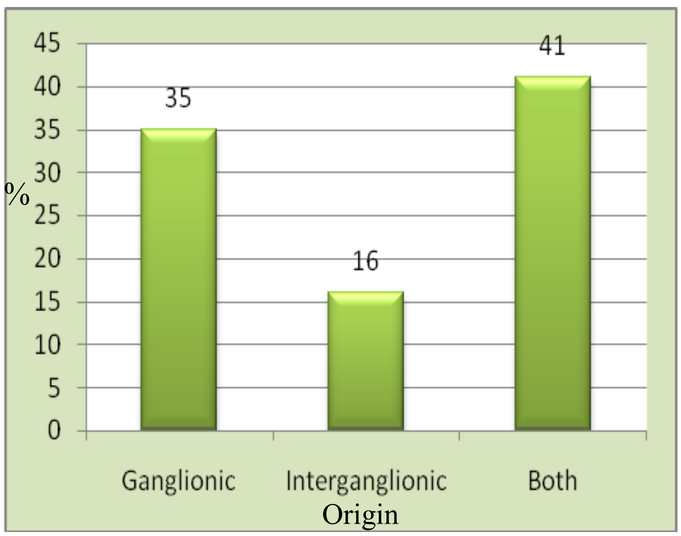


Figure 42: *Origin (%) of SCCN*

4.6.2 MIDDLE CERVICAL CARDIAC NERVE

OVERALL INCIDENCE OF MIDDLE CERVICAL CARDIAC NERVE

There were 65 middle cervical cardiac nerves [*Plate 13 and Figure 43*] in the specimens studied. The overall incidence of the MCCN on the right and left sides were 60% ($^{30}/_{50}$) and 70% ($^{35}/_{50}$) respectively [*Table 13; Figure 44*]. The MCCN had ganglionic, interganglionic and both origins in 56% ($^{56}/_{100}$), 1% ($^{1}/_{100}$) and 8% ($^{8}/_{100}$) [*Figure 45*], respectively. It was absent in 35% ($^{35}/_{100}$) of the specimens.

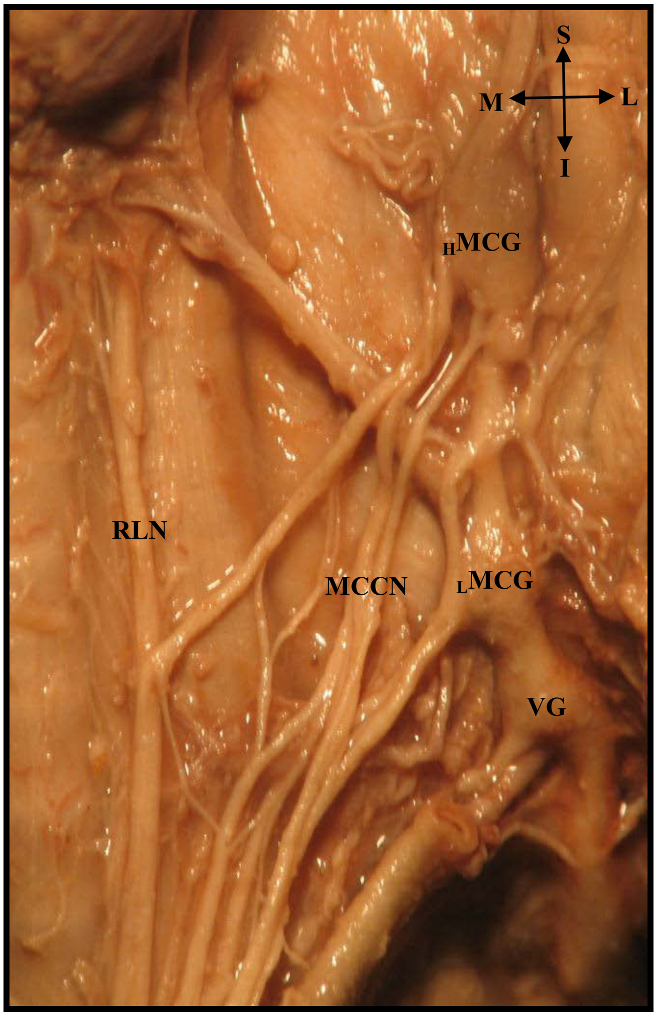


Plate 13: *Antero-medial view of the left MCCN in a fetus showing G and IG origins.* (x4.0)

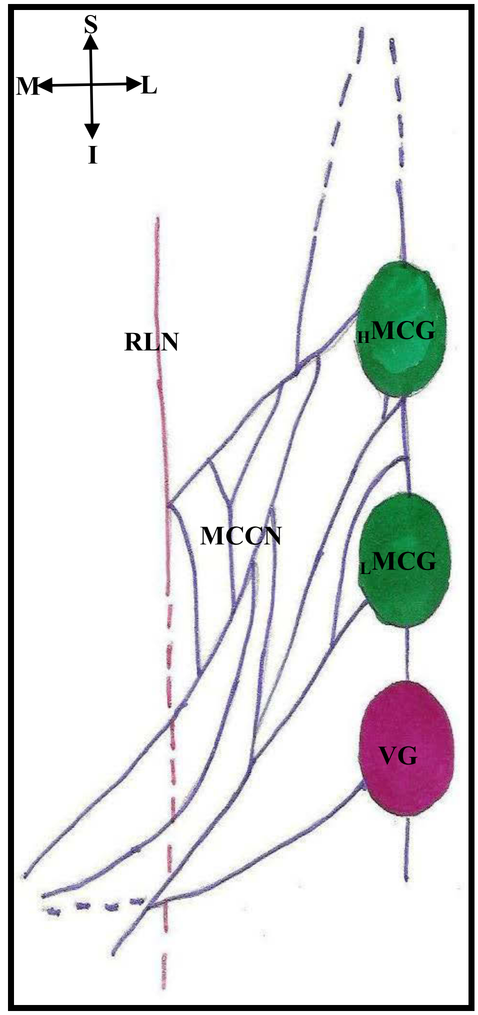


Figure 43: *Schematic diagram of the left MCCN in a fetus showing G and IG origins*

Key: ***$_H$MCG****-High type middle cervical ganglion,* ***$_L$MCG****-Low type middle cervical ganglion,* ***VG****-Vertebral ganglion,* ***MCCN****-Middle cervical cardiac nerve,* ***RLN****-Recurrent laryngeal nerve,* ***I****-Inferior,* ***L****-Lateral,* ***M****-Medial,* ***S****-Superior.*

FETAL INCIDENCE

The middle cervical cardiac nerve was present in 73% ($^{58}/_{80}$) of the specimens. The incidence of the middle cervical cardiac nerve on the right and left side was 65% ($^{26}/_{40}$) and 80% ($^{32}/_{40}$), respectively [*Table 13*]. The MCCN had ganglionic, interganglionic and both origins in 61% ($^{49}/_{80}$), 1% ($^{1}/_{80}$) and 10% ($^{8}/_{80}$) [*Table 13*], respectively. The MCCN was absent in 27% ($^{22}/_{80}$) of the specimens.

ADULT INCIDENCE

The middle cervical cardiac nerve was present in 35% ($^{7}/_{20}$) of the specimens. The incidence of the middle cervical nerve was 40% ($^{4}/_{10}$) on the right and 30% ($^{3}/_{10}$) on the left side, respectively [*Table 13*]. The MCCN had a ganglionic origin only in 36% ($^{7}/_{20}$) [*Table 13*]. The MCCN was absent in 65% ($^{13}/_{20}$) of the specimens.

TABLE 13: *INCIDENCE AND ORIGIN OF MCCN*

SIDES	RIGHT (n=50)				LEFT (n=50)				TOTAL (n=100)
ORIGIN	G	IG	G+IG	Abs	G	IG	G+IG	Abs	
FETAL	22	0	4	14	27	1	4	8	80
ADULT	4	0	0	6	3	0	0	7	20
TOTAL	26	0	4	20	30	1	4	15	100

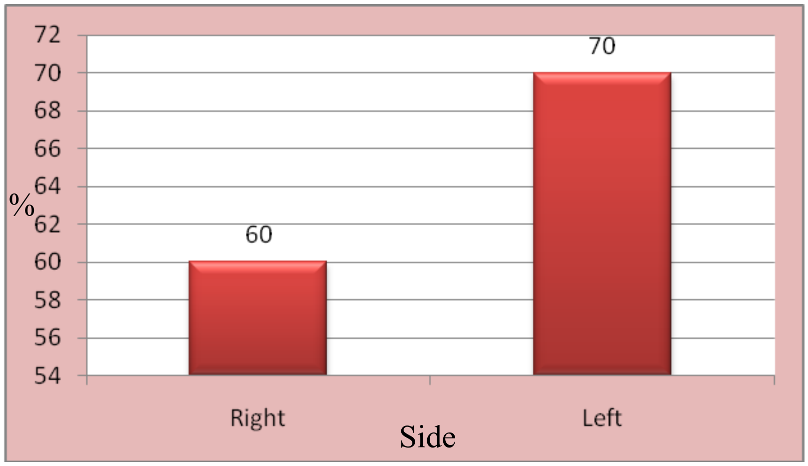


Figure 44: *Incidences (%) of MCCN*

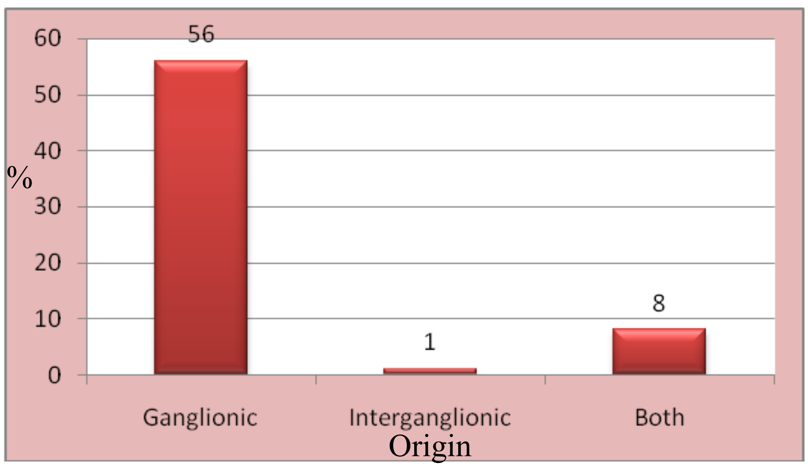


Figure 45: *Origin (%) of MCCN*

4.6.3. VERTEBRAL CARDIAC NERVE (VCN)

OVERALL INCIDENCE OF VERTEBRAL CARDIAC NERVE

There were 39 vertebral cardiac nerves (VCN) demonstrated in the specimens studied. The overall incidence of the VCN on the right and left side were 34% ($^{17}/_{50}$) and 44% ($^{22}/_{50}$), respectively [*Table 14; Figure 47*]. The VCN had a ganglionic origin only in 39% ($^{39}/_{100}$) [*Figure 48*] of the specimens. It was absent in 61% ($^{61}/_{100}$) of the specimens.

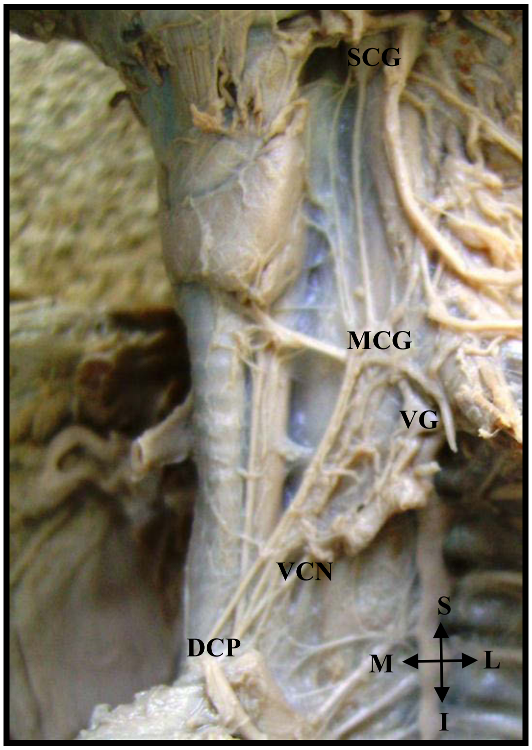


Plate 14: *Antero-medial view of the right VCN in a fetus.* (x4.0)

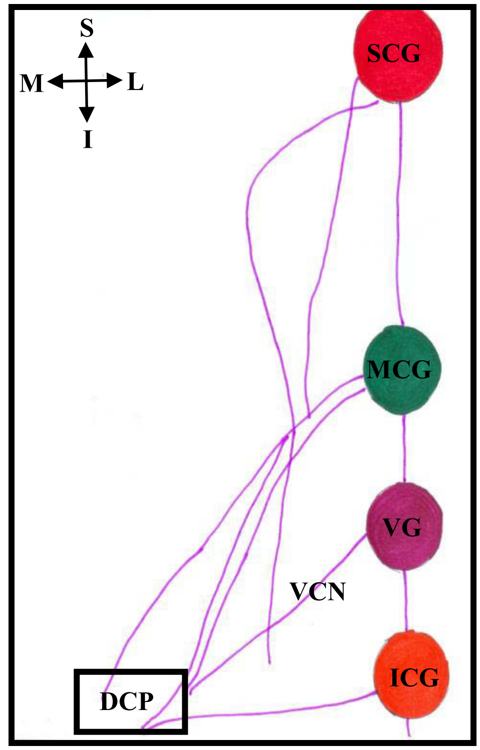


Figure 46: *Schematic diagram of the right VCN in a fetus*

Key: ***VCN****-Vertebral cardiac nerve,* ***VG****-Vertebral ganglion,* ***VN****-vagus nerve,* ***SCG****-Superior cervical ganglion,* ***MCG****-Middle cervical ganglion,* ***ICG****-Inferior cervical ganglion,* ***DCP****-Deep cardiac plexus,* ***SCP****-Superficial cardiac plexus,* ***I****-Inferior,* ***L****-Lateral,* ***M****-Medial,* ***S****-Superior.*

FETAL INCIDENCE

The VCN [*Plate 14* and *Figure 46*] was present in 41% ($^{33}/_{80}$) of the specimens. The incidence of the VCN on the right and left side were 35% ($^{14}/_{40}$) and 48% ($^{19}/_{40}$) [*Table 14*], respectively. The VCN had a ganglionic origin only in 41% ($^{33}/_{80}$) of the specimens [*Table 14*]. The VCN was absent in 59% ($^{47}/_{80}$) of these specimens.

ADULT INCIDENCE

The VCN was present in 30% ($^{6}/_{20}$) of the specimens. The incidence of the VCN was 20% ($^{3}/_{10}$) on both the right and left sides [*Table 14*]. The VCN had a ganglionic origin only in 30% ($^{6}/_{20}$) [*Table 14*] of the specimens. It was absent in 70% ($^{14}/_{20}$) of the specimens.

TABLE 14: *INCIDENCE AND ORIGIN OF VCN*

SIDES	RIGHT (n=50)				LEFT (n=50)				TOTAL (n=100)
ORIGIN	G	IG	G+IG	Abs	G	IG	G+IG	Abs	
FETAL	14	0	0	26	19	0	0	21	80
ADULT	3	0	0	7	3	0	0	7	20
TOTAL	17	0	0	33	22	0	0	28	100

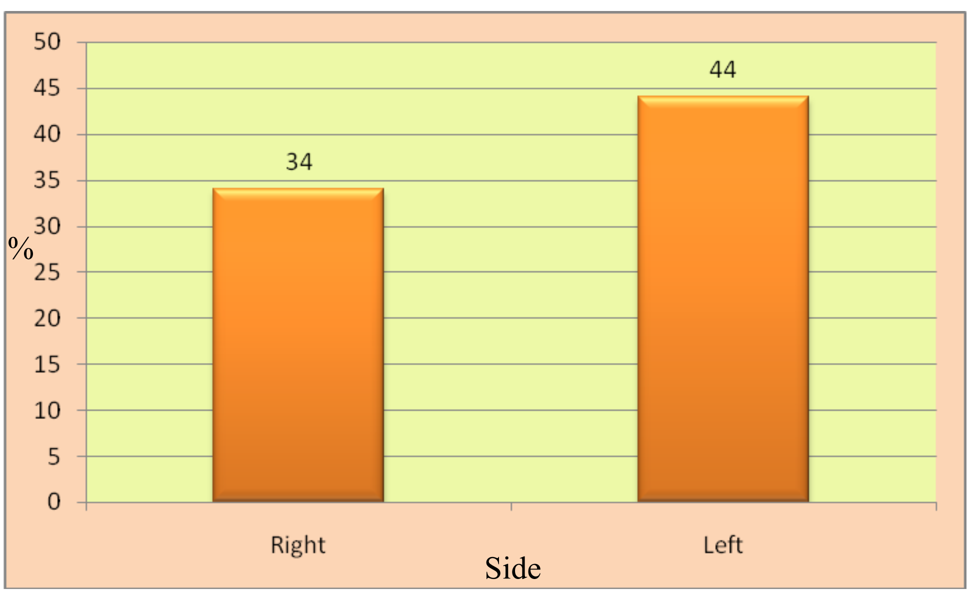


Figure 47: *Incidence (%) of VCN*

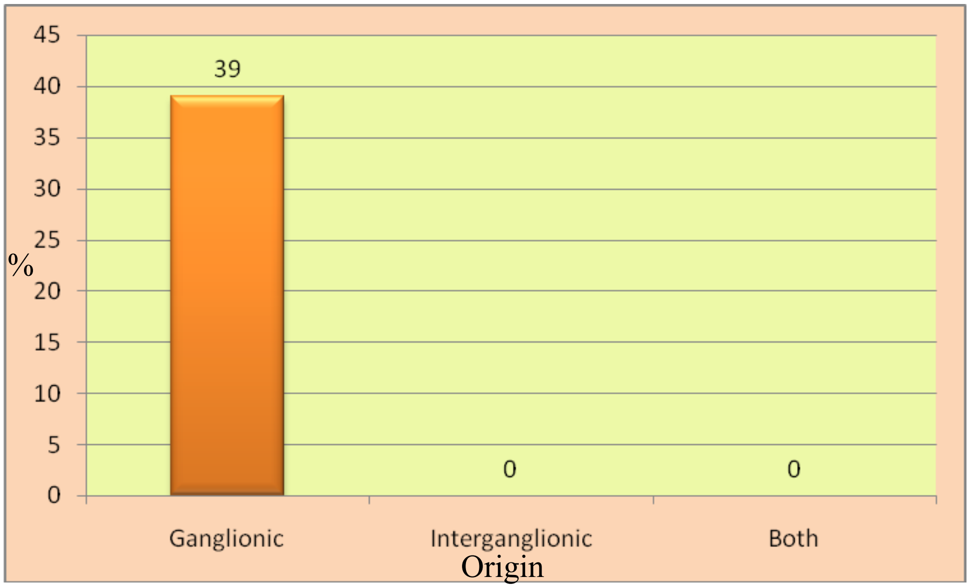


Figure 48: *Origin (%) of VCN*

4.6.4. INFERIOR CERVICAL CARDIAC NERVE (ICCN)

OVERALL INCIDENCE OF INFERIOR CERVICAL CARDIAC NERVE

There were 21 inferior cervical cardiac nerves demonstrated in the specimens studied. The overall incidence of the ICCN on the right and left sides were 20% ($^{10}/_{50}$) and 22% ($^{11}/_{50}$), respectively [*Table 15; Figure 50*]. The ICCN had ganglionic, interganglionic and both origins in 56% ($^{19}/_{100}$), 1% ($^{1}/_{100}$) and 1% ($^{1}/_{100}$) [*Figure 51*], respectively. It was absent in 79% ($^{79}/_{100}$) of the specimens.

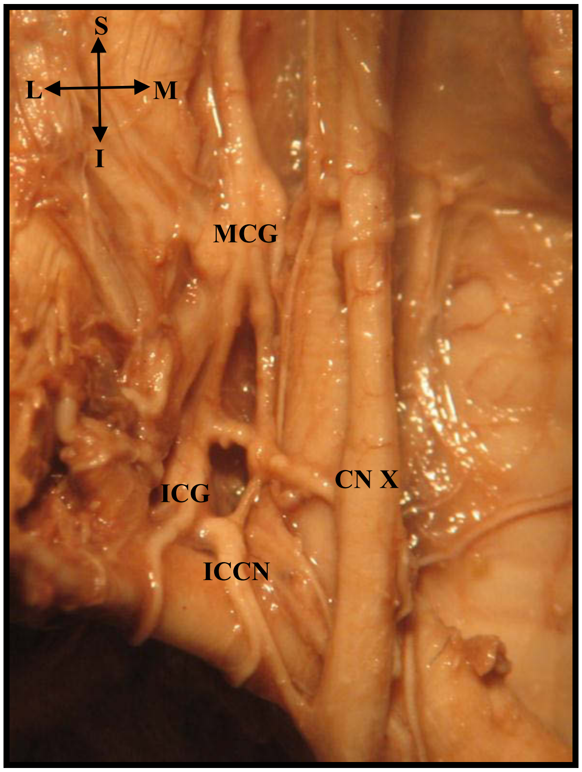


Plate 15: *Antero-medial view of the right ICCN in a fetus.* (x4.0)

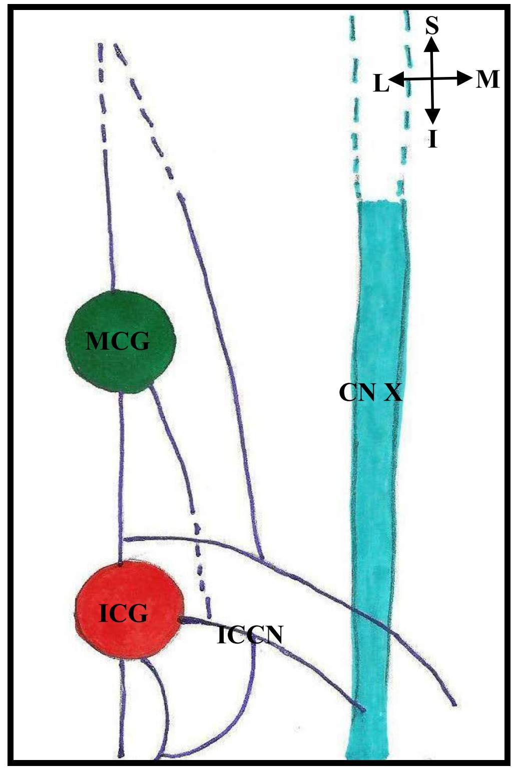


Figure 49: *Schematic diagram of the right ICCN in a fetus*

Key: ***ICG****-inferior cervical ganglion,* ***ICCN****-inferior cervical cardiac nerve,* ***MCG****-middle cervical ganglion,* ***I****-Inferior,* ***L****-Lateral,* ***M****-Medial,* ***S****-Superior*

FETAL INCIDENCE

The ICCN [*Plate 15* and *Figure 51*] was present in 21% ($^{17}/_{80}$) of the specimens. The incidence of the ICCN on the right and left sides was 20% ($^{8}/_{40}$) and 23% ($^{9}/_{40}$) [*Table 15*], respectively. The ICCN had a ganglionic origin only in 21% ($^{17}/_{80}$) [*Table 15*] of these specimens. The ICCN was absent in 79% ($^{63}/_{80}$) of the specimens.

ADULT INCIDENCE

The ICCN was present in 20% ($^4/_{20}$) of the specimens. The incidence of the ICCN was 20% ($^2/_{10}$) [*Table 15*] bilaterally. The ICCN had ganglionic, interganglionic and both origins in 10% ($^2/_{20}$), 5% ($^1/_{20}$) and 5% ($^1/_{20}$) [*Table 15*], respectively. The ICCN was absent in 80% ($^{16}/_{20}$) of these specimens.

TABLE 15: *INCIDENCE AND ORIGIN OF ICCN*

SIDES	RIGHT (n=50)				LEFT (n=50)				TOTAL (n=100)
ORIGIN	G	IG	G+IG	Abs	G	IG	G+IG	Abs	
FETAL	8	0	0	32	9	0	0	31	80
ADULT	0	1	1	8	2	0	0	8	20
TOTAL	8	1	1	40	11	0	0	39	100

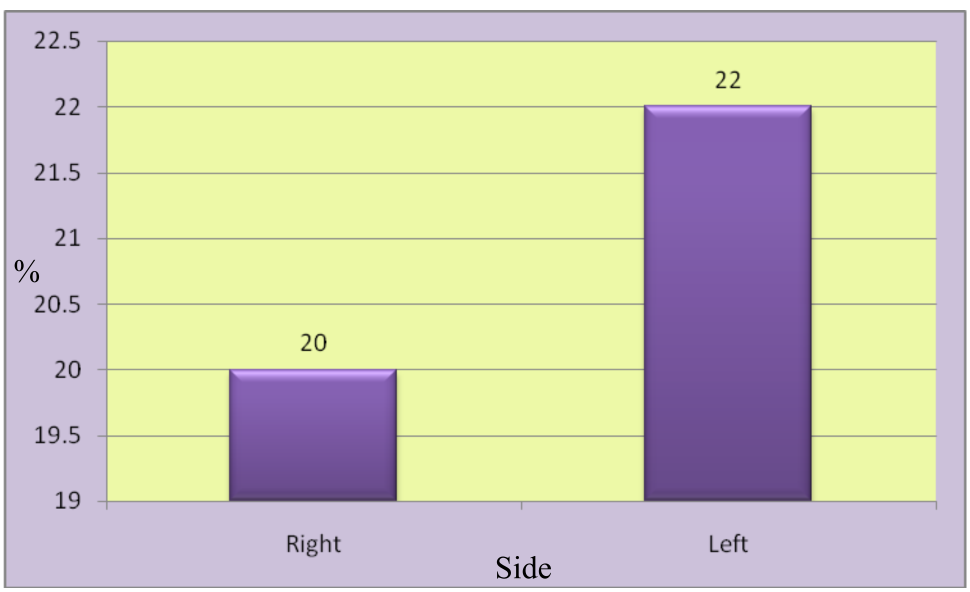


Figure 50: *Incidence (%) of ICCN*

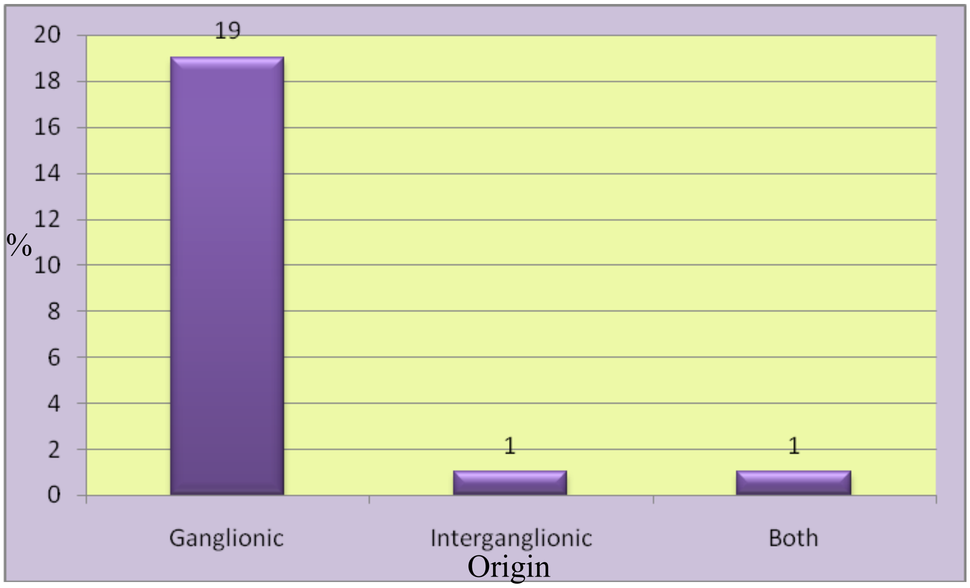


Figure 51: *Origin (%) of ICCN*

4.6.5. CERVICOTHORACIC CARDIAC NERVE (CTCN)

OVERALL INCIDENCE OF CERVICOTHORACIC CARDIAC NERVE

There were 21 cervicothoracic cardiac nerves (CTCN) demonstrated in the specimens studied. The overall incidence of the CTCN on the right and left sides were 12% ($^{6}/_{50}$) and 30% ($^{15}/_{50}$), respectively [*Table 16*]. The CTCN had a ganglionic origin only in 21% ($^{21}/_{100}$) [*Table 16*] of the specimens. It was absent in 79% ($^{79}/_{100}$) of the specimens.

FETAL INCIDENCE

The CTCN [*Plate 16* and *Figure 52*] was present in 24% ($^{19}/_{80}$) of the specimens. The incidence of the CTCN on the right and left sides was 15% ($^{6}/_{40}$) and 33% ($^{13}/_{40}$), respectively [*Table 16*]. The CTCN had a ganglionic origin only in 24% ($^{19}/_{80}$) [*Table 16*] of the specimens. It was absent in 76% ($^{61}/_{80}$) of the specimens.

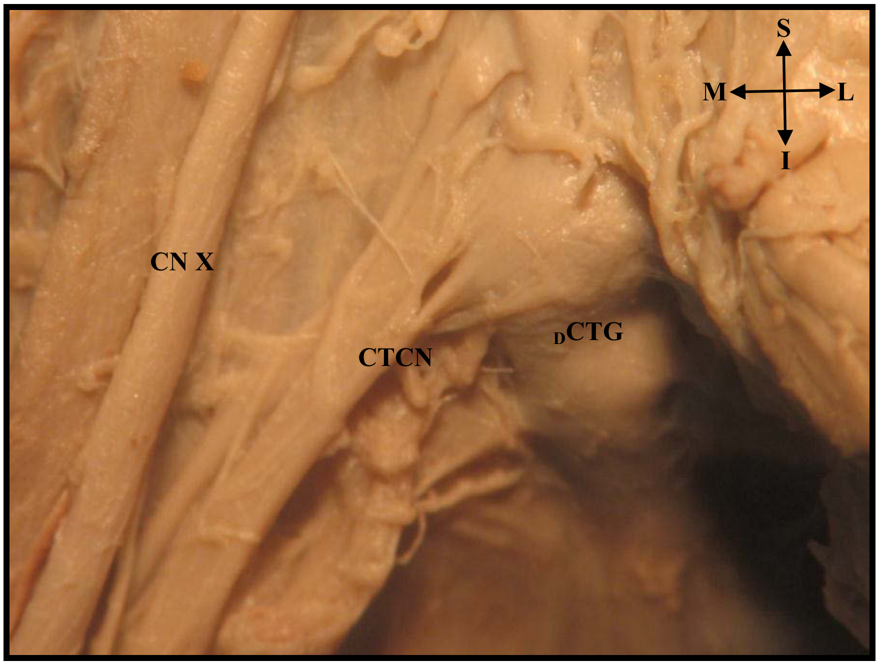


Plate 16: *Antero-medial view of left CTCN in a fetus*

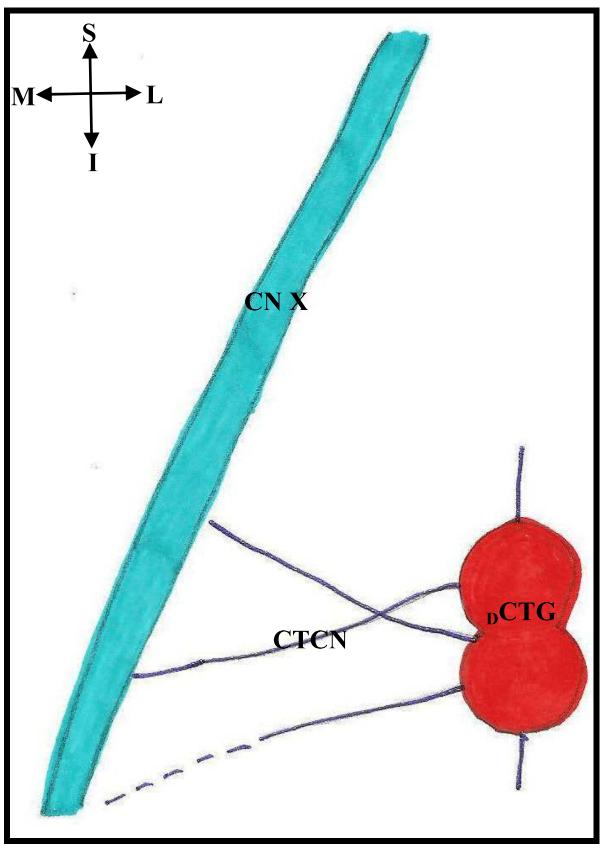


Figure 52: *Schematic diagram of the left CTCN in a fetus*

Key: ***$_D$CTG***-*Dumbbell shaped cervicothoracic ganglion,* ***CTCN***-*cervicothoracic cardiac nerve,* ***CN X***-*Vagus nerve,* ***I***-*Inferior,* ***L***-*Lateral,* ***M***-*Medial,* ***S***-*Superior*

ADULT INCIDENCE

The CTCN was present in 10% ($^{2}/_{20}$) of these specimens. There were no CTCN on the right side. However, there was an incidence of 20% ($^{2}/_{10}$) on the left side [*Table 16*]. The CTCN had a ganglionic origin only in 10% ($^{2}/_{20}$) [*Table 16*] of the specimens. The CTCN was absent in 90% ($^{18}/_{20}$) of the specimens.

TABLE 16: *INCIDENCE AND ORIGIN OF CTCN*

SIDES	RIGHT (n=50)				LEFT (n=50)				TOTAL (n=100)
ORIGIN	G	IG	G+IG	Abs	G	IG	G+IG	Abs	
FETAL	6	0	0	34	13	0	0	27	80
ADULT	0	0	0	10	2	0	0	8	20
TOTAL	6	0	0	44	15	0	0	35	100

4.7. THORACIC CARDIAC NERVES

4.7.1 First thoracic cardiac nerve ($TCN_{1)}$

OVERALL INCIDENCE OF TCN_1

A total of 36 thoracic cardiac nerves originated from the T_1 ganglion in the specimens studied [*Plate 17* and *Figure 53*]. The overall incidence of TCN_1 on the right and left sides were 22% ($^{11}/_{50}$) and 50% ($^{25}/_{50}$), respectively [*Table 17*]. The TCN_1 had a ganglionic origin only in 36% ($^{36}/_{100}$) [*Table 17*] of the specimens. It was absent in 64% ($^{64}/_{100}$) of the specimens. In the 64 cases that TCN_1 was absent, the medial branches terminated on the thoracic aorta 14% ($^{14}/_{100}$), oesophagus 4% ($^{4}/_{100}$), thoracic viscera 20% ($^{20}/_{100}$), trachea 2% ($^{2}/_{100}$), prevertebral muscles 1% ($^{1}/_{100}$), right subclavian artery 1% ($^{1}/_{100}$) and T_1 ganglion 2% ($^{2}/_{100}$). The T_1 ganglion had no medial contributions to the CP in 20% ($^{20}/_{100}$) of the specimens.

FETAL INCIDENCE

The TCN_1 was present in 40% ($^{32}/_{80}$) of the specimens (*Plate 17* and *Figure 53*). The incidence of TCN_1 on the right and left sides were 25% ($^{10}/_{40}$) and 55% ($^{22}/_{40}$), respectively. The TCN_1 had a ganglionic origin only in 40% ($^{32}/_{80}$) [*Table 17*] of the specimens. It was absent in 60% ($^{48}/_{80}$) of the specimens. In the 48 cases that TCN_1 was absent, the medial branches terminated on the thoracic aorta 8% ($^{7}/_{80}$), oesophagus 5% ($^{4}/_{80}$), thoracic viscera 14% ($^{11}/_{80}$), trachea 3% ($^{2}/_{80}$), prevertebral muscles 1% ($^{1}/_{80}$), right subclavian artery 1% ($^{1}/_{80}$) and T_1 ganglion 3% ($^{2}/_{80}$). The T_1 ganglion had no medial contributions to the CP in 25% ($^{20}/_{80}$) of the specimens.

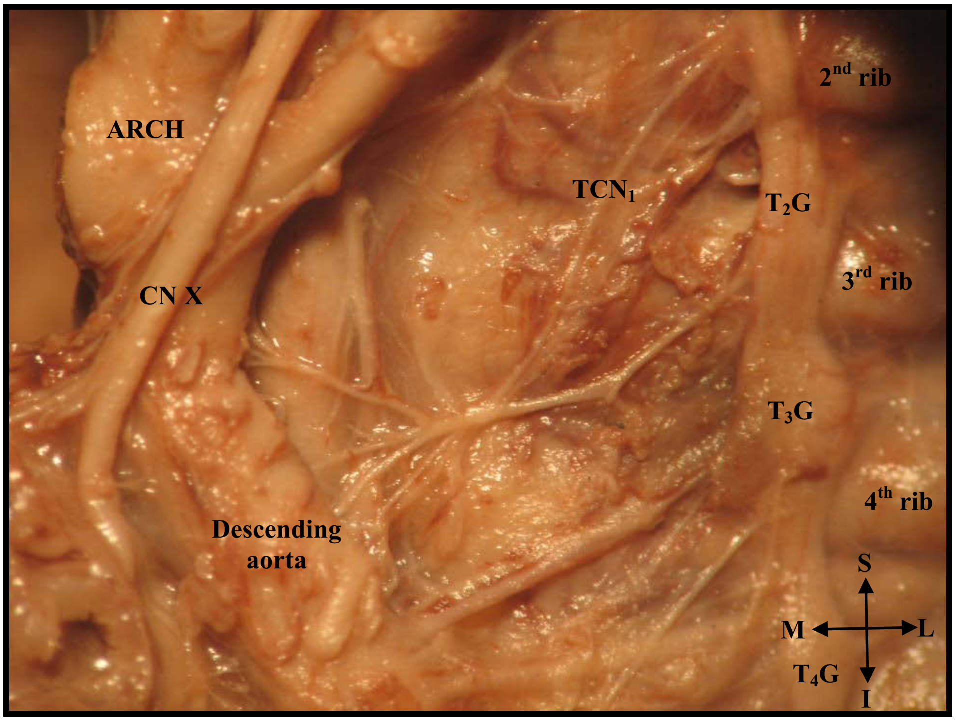


Plate 17: *Antero-medial view of the left TCN_1 contribution to DCP in a fetus.* (x4.0)

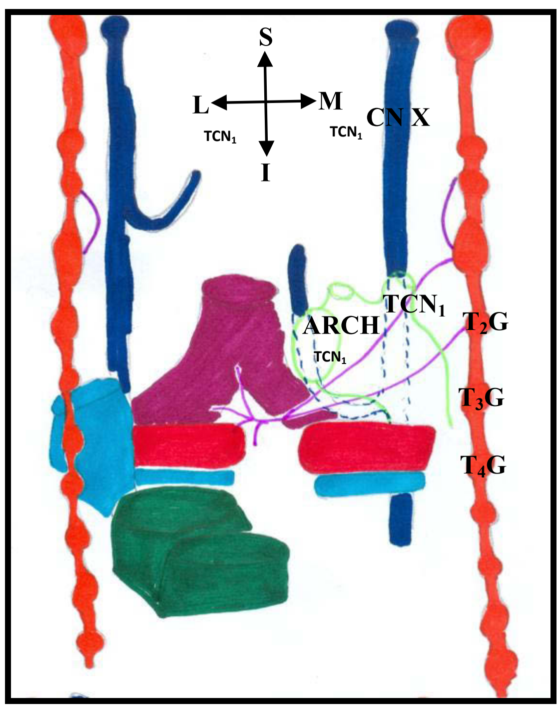


Figure 53: *Schematic diagram of the left TCN_1 contribution to DCP in a fetus*

Key: ***ARCH***-*Arch of aorta,* ***CN X***-*Vagus nerve,* ***TCN_1***-*First thoracic cardiac nerve,* ***T_2G***-*Second thoracic ganglion,* ***T_3G***-*Third thoracic ganglion,* ***T_4G***-*Fourth Thoracic ganglion,* ***I***-*Inferior,* ***M***-*Medial,* ***L***-*Lateral,* ***S***-*Superior.*

ADULT INCIDENCE

The TCN_1 was present in 20% ($^4/_{20}$) of the specimens. The incidence of TCN_1 was 10% ($^1/_{10}$) on the right and 30% ($^3/_{10}$) on the left side. The TCN_1 had a ganglionic origin only in 20% ($^4/_{20}$) [*Table 17*] of the specimens. It was absent in 80% ($^{16}/_{20}$) of the specimens. In the 16 cases that TCN_1 was absent, the medial branches terminated on the thoracic aorta 35% ($^7/_{20}$) and thoracic viscera 45% ($^9/_{20}$).

***TABLE 17**: INCIDENCE OF TCN_1*

SIDES	RIGHT (n=50)				LEFT (n=50)				TOTAL (n=100)
ORIGIN	G	IG	G+IG	Abs	G	IG	G+IG	Abs	
FETAL	10	0	0	30	22	0	0	18	80
ADULT	1	0	0	9	3	0	0	7	20
TOTAL	11	0	0	39	25	0	0	25	100

4.7.2. Second thoracic cardiac nerve (TCN_2)

OVERALL INCIDENCE OF TCN_2

A total of 24 thoracic cardiac nerves originated from the T_2 ganglion in the specimens studied [*Plate 18* and *Figure 54*]. The overall incidence of TCN_2 on the right and left sides were 14% ($^7/_{50}$) and 34% ($^{17}/_{50}$), respectively [*Table 18*]. The TCN_2 had ganglionic and interganglionic origins in 22% ($^{22}/_{100}$) and 2% ($^2/_{100}$) [*Table 18*], respectively. It was absent in 76% ($^{76}/_{100}$) of the specimens. In the 76 cases that TCN_2 was absent, the medial branches terminated on the thoracic aorta 24% ($^{24}/_{100}$), oesophagus 8% ($^8/_{100}$), thoracic viscera 28% ($^{28}/_{100}$) and trachea 3% ($^3/_{100}$). The T_2 ganglion was found to have no medial contributions to the CP in 13% ($^{13}/_{100}$) of the specimens.

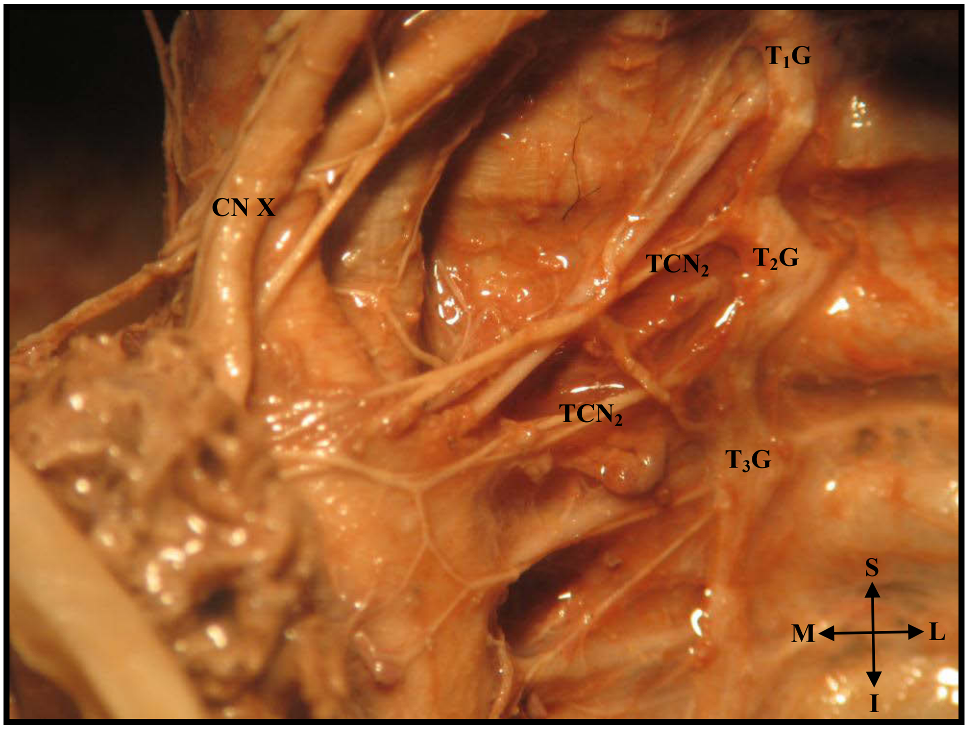


Plate 18: *Antero-medial view of the left TCN$_2$ contribution to the DCP in a fetus* (x4.0)

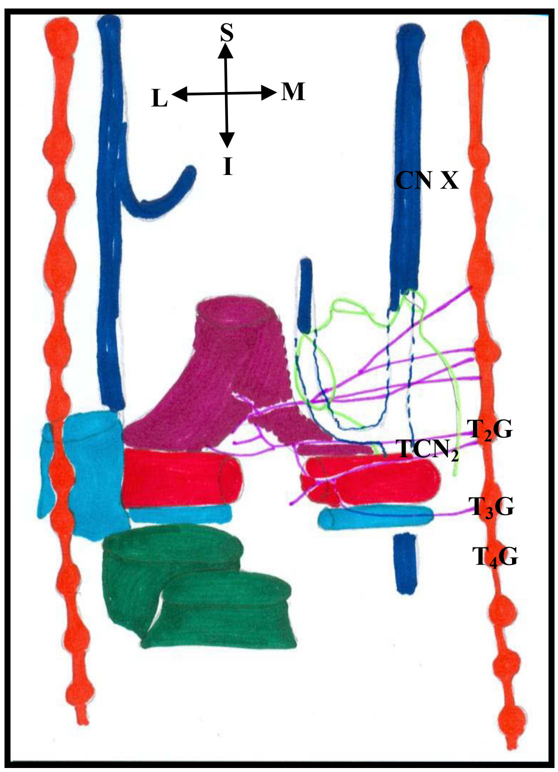


Figure 54: *Schematic diagram of the left TCN$_2$ contribution to the DCP in a fetus*

Key: ***T$_2$G***-*Second thoracic ganglion,* ***T$_3$G***-*Third thoracic ganglion,* ***T$_4$G***-*Fourth thoracic ganglion,* ***CN X***-*Vagus nerve,* ***TCN$_2$***-*Second thoracic cardiac nerve,* ***I***-*Inferior,* ***M***-*Medial,* ***L***-*Lateral,* ***S***-*Superior.*

FETAL INCIDENCE

The TCN_2 was present in 28% ($^{22}/_{80}$) of the specimens [*Plate 18* and *Figure 54*]. The incidence of TCN_2 on the right and left sides were 18% ($^{7}/_{40}$) and 38% ($^{15}/_{40}$), respectively. The TCN_2 had ganglionic and interganglionic origins in 25% ($^{20}/_{80}$) and 3% ($^{2}/_{80}$) [*Table 18*], respectively. It was absent in 73% ($^{58}/_{80}$) of the specimens. In the 58 cases that TCN_2 was absent, the medial branches terminated on the thoracic aorta 20% ($^{16}/_{80}$), oesophagus 10% ($^{8}/_{80}$), thoracic viscera 23% ($^{18}/_{80}$) and trachea 3% ($^{3}/_{80}$). The T_2 ganglion was found to have no medial contributions to the CP in 16% ($^{13}/_{80}$) of the specimens.

ADULT INCIDENCE

The TCN_2 was present in 10% ($^{2}/_{20}$) of the specimens. The incidence of TCN_2 was 20% ($^{2}/_{10}$) on the left sides. TCN_2 was absent on the right side. The TCN_2 had a ganglionic origin only in 10% ($^{2}/_{20}$) [*Table 18*] of the specimens. It was absent in 90% ($^{18}/_{20}$) of the specimens. In the 18 cases that TCN_2 was absent, the medial branches terminated on the thoracic aorta 40% ($^{8}/_{20}$) and thoracic viscera 50% ($^{10}/_{20}$).

TABLE 18: *INCIDENCE OF* TCN_2

SIDES	RIGHT (n=50)				LEFT (n=50)				TOTAL (n=100)
ORIGIN	G	IG	G+IG	Abs	G	IG	G+IG	Abs	
FETAL	6	1	0	33	14	1	0	25	80
ADULT	0	0	0	10	2	0	0	8	20
TOTAL	6	1	0	43	16	1	0	33	100

4.7.3. Third thoracic cardiac nerve (TCN_3)

OVERALL INCIDENCE OF TCN_3

A total of 17 thoracic cardiac nerves originated from the T_3 ganglion in the specimens studied [*Plate 19* and *Figure 55*]. The overall incidence of TCN_3 on the right and left sides were 14% ($^{7}/_{50}$) and 20% ($^{10}/_{50}$); respectively [*Table 19*]. The TCN_3 had a ganglionic origin only in 17% ($^{17}/_{100}$) of the specimens. It was absent in 83% ($^{83}/_{100}$) of the specimens. In the 83 cases that TCN_3 was absent, the medial branches terminated on the thoracic aorta 33% ($^{33}/_{100}$), oesophagus 10% ($^{10}/_{100}$), thoracic viscera 26% ($^{26}/_{100}$), and trachea 4% ($^{4}/_{100}$). The T_3 ganglion had no medial contributions to the CP in 10% ($^{10}/_{100}$) of the specimens.

FETAL INCIDENCE

The TCN_3 was present in 19% ($^{15}/_{80}$) of the specimens [*Plate 19* and *Figure 55*]. The incidence of TCN_3 on the right and left sides were 15% ($^{6}/_{40}$) and 23% ($^{9}/_{40}$), respectively. The TCN_3 had a ganglionic origin only in 19% ($^{15}/_{80}$) [*Table 19*] of the specimens. It was absent in 81% ($^{65}/_{80}$) of the specimens. In the 65 cases that TCN_3 was absent, the medial branches terminated on the thoracic aorta 30% ($^{24}/_{80}$), oesophagus 13% ($^{10}/_{80}$), thoracic viscera 21% ($^{17}/_{80}$), trachea 5% ($^{4}/_{80}$). The T_3 ganglion had no medial contributions to the CP in 12% ($^{10}/_{80}$) of the specimens.

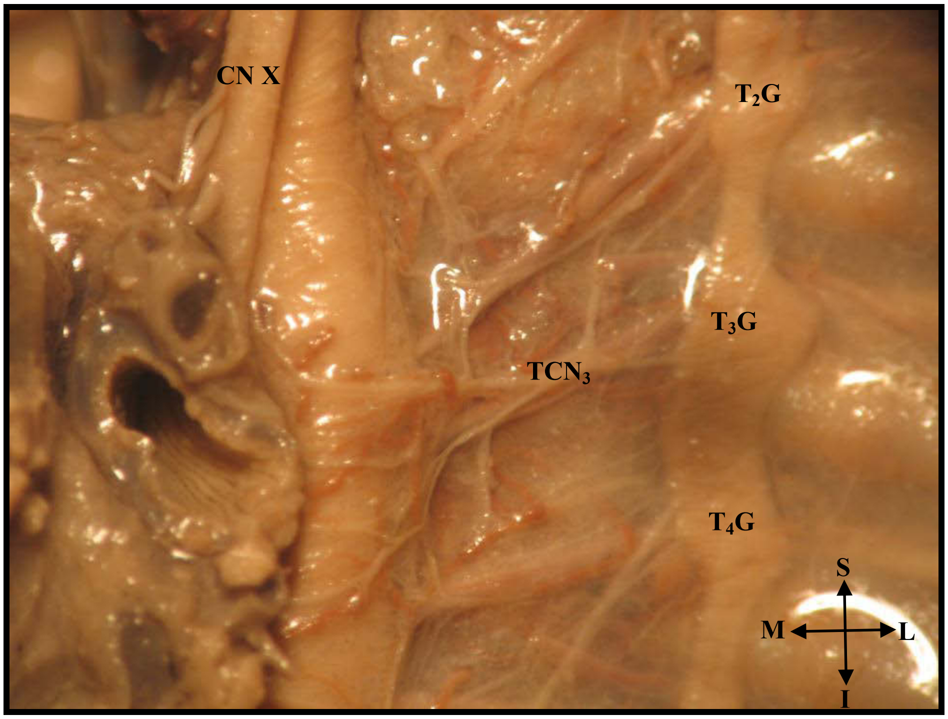


Plate 19: *Antero-medial view of the left TCN$_3$ contribution to the DCP in a fetus.* (x4.0)

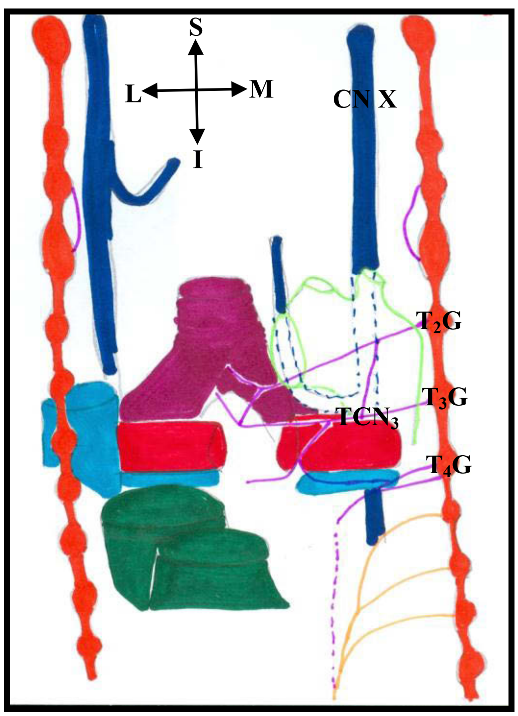


Figure 55: *Schematic diagram of the left TCN$_3$ contribution to the DCP in a fetus*

Key: ***TCN$_3$***-*Third thoracic cardiac nerve,* ***T$_2$G***-*Second thoracic ganglion,* ***T$_3$G***-*Third thoracic ganglion,* ***T$_4$G***-*Fourth thoracic ganglion,* ***CN X***-*Vagus nerve,* ***I***-*Inferior,* ***L***-*Lateral,* ***M***-*Medial,* ***S***-*Superior.*

TABLE 19: INCIDENCE OF TCN$_3$

SIDES	RIGHT (n=50)				LEFT (n=50)				TOTAL (n=100)
ORIGIN	G	IG	G+IG	Abs	G	IG	G+IG	Abs	
FETAL	6	0	0	34	9	0	0	31	80
ADULT	1	0	0	9	1	0	0	9	20
TOTAL	7	0	0	43	10	0	0	40	100

ADULT INCIDENCE

The TCN$_3$ was present in 10% ($^2/_{20}$) of the specimens. The incidence of TCN$_3$ was 10% bilaterally ($^1/_{10}$). The TCN$_3$ had a ganglionic origin in 10% ($^2/_{20}$) [*Table 19*] of the specimens. It was absent in 90% ($^{18}/_{20}$) of the specimens. In the 18 cases that TCN$_3$ was absent, the medial branches terminated on the thoracic aorta 45% ($^9/_{20}$) and thoracic viscera 45% ($^9/_{20}$).

4.7.4. Fourth thoracic cardiac nerve (TCN_4)

OVERALL INCIDENCE OF TCN_4

A total of 12 thoracic cardiac nerves originated from the T_4 ganglion in the specimens studied [*Plate 20* and *Figure 56*]. The overall incidence of TCN_4 on the right and left sides were 10% ($^{5}/_{50}$) and 14% ($^{7}/_{50}$), respectively [*Table 20*]. The TCN_4 had ganglionic and interganglionic origins in 11% ($^{11}/_{100}$) and 1% ($^{1}/_{100}$), respectively. It was absent in 88% ($^{88}/_{100}$) of the specimens. In the 88 cases that TCN_4 was absent, the medial branches terminated on the aorta 31% ($^{31}/_{100}$), oesophagus 11% ($^{11}/_{100}$), thoracic viscera 33% ($^{33}/_{100}$), trachea 1% ($^{1}/_{100}$), greater splanchnic nerve (GSN) 5% ($^{5}/_{100}$) and lung hilum 1% ($^{1}/_{100}$). The T_4 ganglion had no medial contributions to the CP in 6% ($^{6}/_{100}$) of the specimens.

FETAL INCIDENCE

The TCN_4 was present in 11% ($^{9}/_{80}$) of the specimens [*Plate 20* and *Figure 56*]. The incidence of TCN_4 on the right and left sides were 8% ($^{3}/_{40}$) and 15% ($^{6}/_{40}$), respectively. The TCN_4 had ganglionic and interganglionic origins in 10% ($^{8}/_{80}$) and 1% ($^{1}/_{80}$) [*Table 20*] of the specimens. It was absent in 89% ($^{71}/_{80}$) of the specimens. In the 71 cases that TCN_4 was absent, the medial branches terminated on the thoracic aorta 29% ($^{23}/_{80}$), oesophagus 14% ($^{11}/_{80}$), thoracic viscera 31% ($^{25}/_{80}$), trachea 1% ($^{1}/_{80}$), greater splanchnic nerve (GSN) 5% ($^{4}/_{80}$) and lung hilum 1% ($^{1}/_{80}$). The T_4 ganglion had no medial contributions to the CP in 8% ($^{6}/_{80}$) of the specimens.

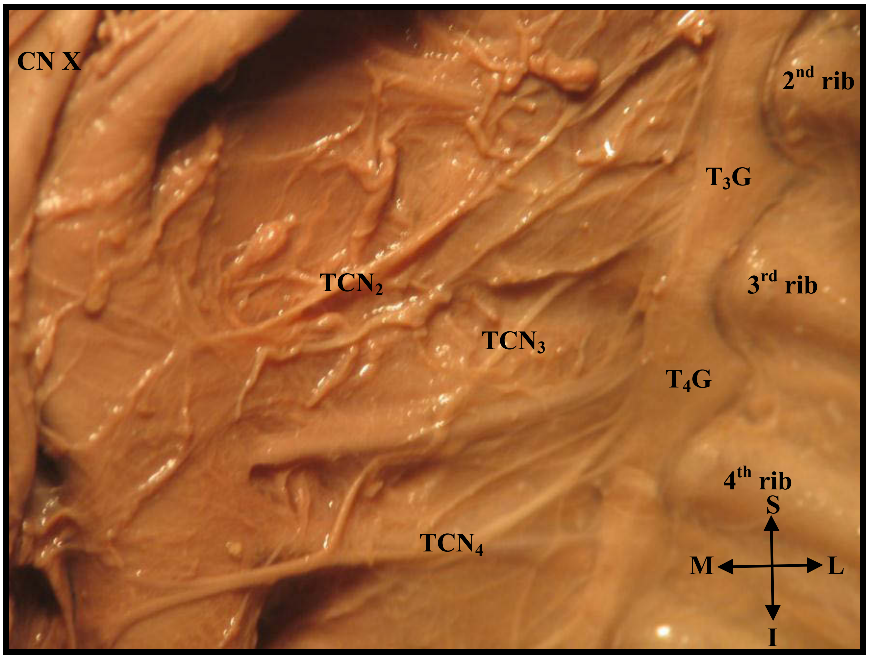


Plate 20: *Antero-medial view of the left TCN_4 contribution to DCP in a fetus.* (x4.0)

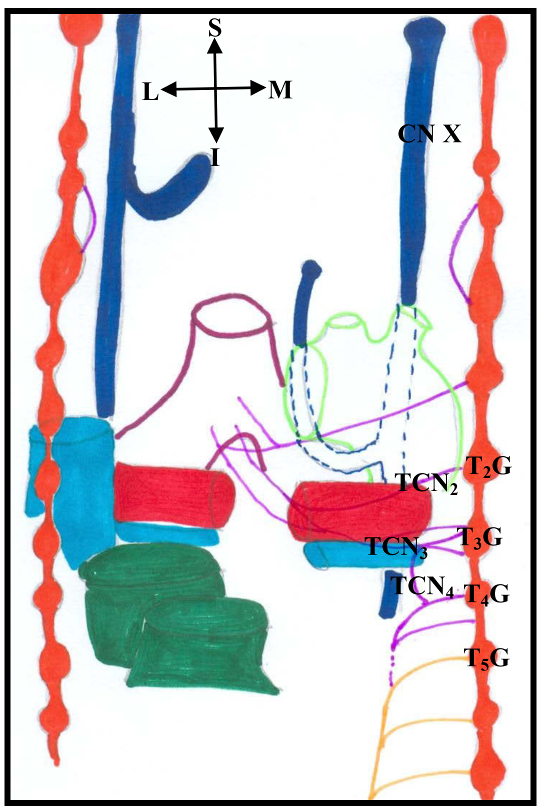


Figure 56: *Schematic diagram of the left TCN_4 contribution to DCP in a fetus*

Key: ***T_2G***-*Second thoracic ganglion,* ***T_3G***-*Third thoracic ganglion,* ***T_4G***-*Fourth thoracic ganglion,* ***T_5G***-*Fifth thoracic ganglion,* ***CN X***-*Vagus nerve,* ***TCN_2***-*Second thoracic ganglion,* ***TCN_3***-*third thoracic cardiac nerve,* ***TCN_4***–*Fourth thoracic cardiac nerve,* ***I***-*Inferior,* ***L***-*Lateral,* ***M***-*Medial,* ***S***-*Superior.*

TABLE 20: *INCIDENCE OF TCN_4*

SIDES	RIGHT (n=50)				LEFT (n=50)				TOTAL (n=100)
ORIGIN	G	IG	G+IG	Abs	G	IG	G+IG	Abs	
FETAL	3	0	0	37	5	1	0	34	80
ADULT	2	0	0	8	1	0	0	9	20
TOTAL	5	0	0	45	6	1	0	43	100

ADULT INCIDENCE

The TCN_4 was present in 15% ($^3/_{20}$) of the specimens. The incidence of TCN_4 on the right and left sides were 20% ($^2/_{10}$) and 10% ($^1/_{10}$), respectively. The TCN_4 had a ganglionic origin only in 15% ($^3/_{20}$) [*Table 20*] of the specimens. It was absent in 85% ($^{17}/_{20}$) of the specimens. In the 17 cases that TCN_4 was absent, the medial branches terminated on the thoracic aorta 40% ($^8/_{20}$), greater splanchnic nerve (GSN) 5% ($^1/_{20}$) and thoracic viscera 40% ($^8/_{20}$).

4.7.5. Fifth thoracic cardiac nerve (TCN_5)

OVERALL INCIDENCE OF TCN_5

A total of 3 thoracic cardiac nerves originated from the T_5 ganglion in the specimens studied [*Plate 21* and *Figure 57*]. The overall incidence of TCN_5 on the right side was 6% ($^3/_{50}$) [*Table 21*]. No TCN_5 were present on the left side. The TCN_5 had a ganglionic origin only in 3% ($^3/_{100}$) of the specimens. It was absent in 97% ($^{97}/_{100}$) of the specimens. In the 97 cases that TCN_5 was absent, the medial branches terminated on the aorta in 16% ($^{16}/_{100}$), oesophagus 3% ($^3/_{100}$), thoracic viscera 14% ($^{14}/_{100}$) and GSN 46% ($^{46}/_{100}$). The T_5 ganglion had no medial contributions in 18% ($^{18}/_{100}$) of the specimens.

FETAL INCIDENCE

The TCN_5 was present in 4% ($^3/_{80}$) of the specimens; these were found on the right side of these specimens only. The TCN5 had a ganglionic origin only in 4% ($^3/_{80}$) [*Table 21*] of the specimens. In the 77 cases that TCN_5 was absent, the medial branches terminated on the greater splanchnic nerve in 49% ($^{39}/_{80}$), thoracic viscera in 18% ($^{14}/_{80}$), thoracic aorta in 11% ($^9/_{80}$), oesophagus in 3% ($^3/_{80}$) of the specimens. The T_5 ganglion was found to have no medial contributions in 15% ($^{12}/_{80}$) of the specimens.

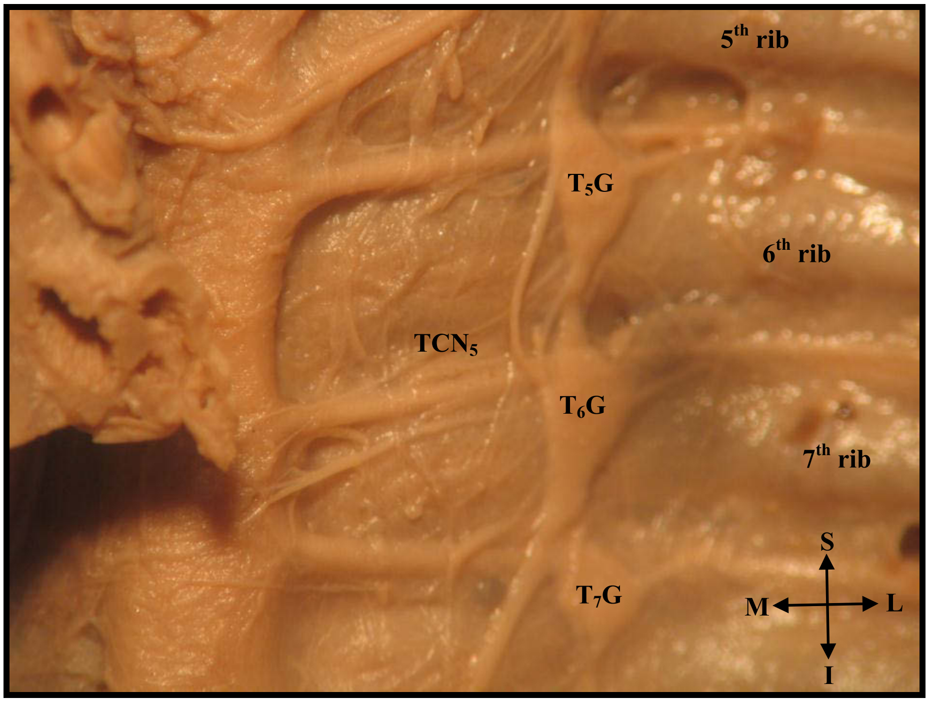


Plate 21: *Anterior-medial view of the left TCN_5 contribution to the DCP in a fetus* (x4.0)

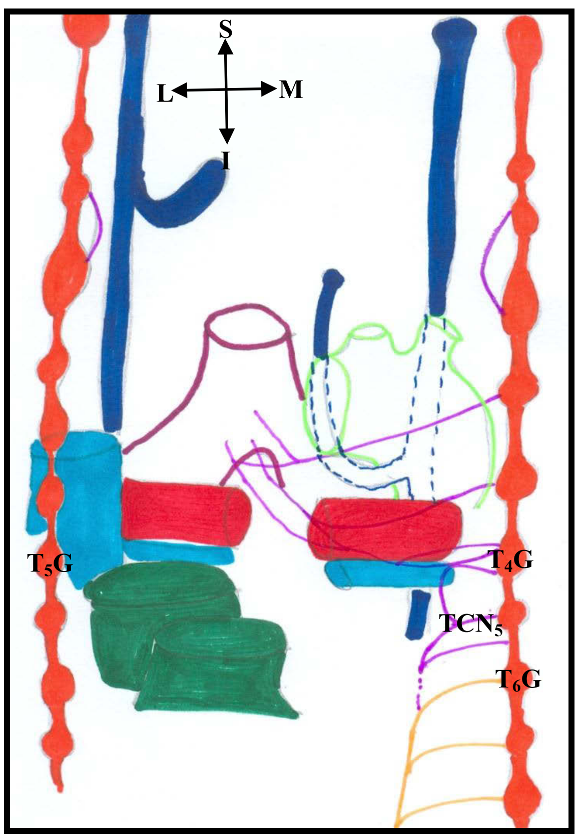


Figure 57: *Schematic diagram of the left TCN_5 contribution to the DCP in a fetus*

Key: ***LPA***-*Left pulmonary artery,* ***PT***-*Pulmonary trunk,* ***RPA***-*Right pulmonary artery,* ***T_4G***-*Fourth thoracic ganglion,* ***TCN_5***-*Fifth thoracic cardiac nerve,* ***I***-*Inferior,* ***M***-*Medial,* ***L***-*Lateral,* ***S***-*Superior.*

TABLE 21: *INCIDENCE OF TCN_5*

SIDES	RIGHT (n=50)				LEFT (n=50)				TOTAL (n=100)
ORIGIN	G	IG	G+IG	Abs	G	IG	G+IG	Abs	
FETAL	3	0	0	37	0	0	0	40	80
ADULT	0	0	0	10	0	0	0	10	20
TOTAL	3	0	0	47	0	0	0	50	100

ADULT INCIDENCE

The TCN_5 was found to be absent [*Table 21*] in all the specimens studied. In the 100 cases that TCN_5 was found to be absent, the medial branches terminated on the greater splanchnic nerve in 89% ($^{89}/_{100}$) of the specimens. The T_5 ganglion was found to have no medial contributions in 11% ($^{11}/_{100}$) of the specimens.

4.7.6. Sixth thoracic cardiac nerve (TCN_6)

OVERALL INCIDENCE OF TCN_6

There were no thoracic cardiac nerves that originated from the T_6 ganglion in the specimens studied [*Plate 22* and *Figure 58*]. It was found to be absent in 100% ($^{100}/_{100}$) of the specimens. In the 100 cases that TCN_6 was found to be absent, the medial branches terminated on the GSN in 65% ($^{65}/_{100}$), aorta in 2% ($^{2}/_{100}$), viscera in 4% ($^{4}/_{100}$) and intercostal vein in 1% ($^{1}/_{100}$). The T_6 ganglion had no medial contributions in 28% ($^{28}/_{100}$) of the specimens.

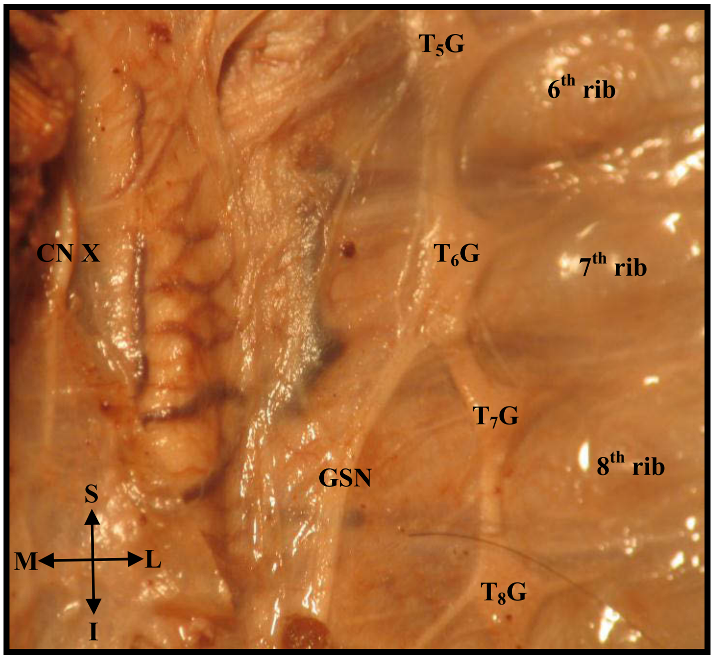


Plate 22: *Contribution from T_6G to GSN in a fetus* (x4.0)

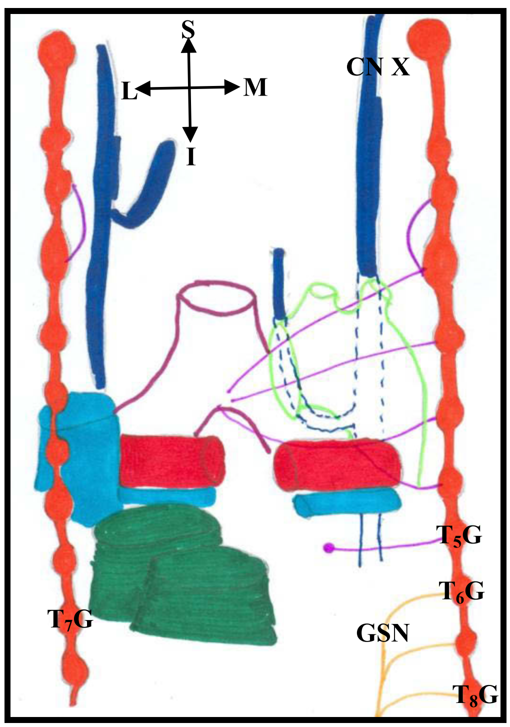


Figure 58: *Schematic diagram of a contribution from the left T_6G to GSN in a fetus.*

Key: ***CN X***-*Vagus nerve,* ***GSN***-*Greater splanchnic nerve,* ***T_5G***-*Fifth thoracic ganglion,* ***T_6G***-*Sixth thoracic ganglion,* ***T_7G***-*Seventh thoracic ganglion,* ***T_8G***-*Eighth thoracic ganglion,* ***I***-*Inferior,* ***L***-*Lateral,* ***M***-*Medial,* ***S***-*Superior*

FETAL INCIDENCE

The TCN_6 was absent in all the specimens studied. In the 100 cases that the TCN_6 was absent, the medial branches terminated on the GSN in 64% ($^{51}/_{80}$), on the aorta in 3% ($^{2}/_{80}$), on the viscera in 5% ($^{4}/_{80}$) and on the intercostal vein in 1% ($^{1}/_{80}$) of the specimens. The T_6 ganglion had no medial contributions in 29% ($^{23}/_{80}$) of the specimens.

ADULT INCIDENCE

The TCN_6 was absent in all the specimens studied. In the 100 cases that TCN_6 was absent, the medial branches terminated on the GSN in 55% ($^{11}/_{20}$) of the specimens. The T_6 ganglion had no medial contributions in 45% ($^{9}/_{20}$) of the specimens.

4.7.7. Seventh thoracic cardiac nerve (TCN_7)

OVERALL INCIDENCE OF TCN_7

There were no thoracic cardiac nerves that originated from the T_7 ganglion in the specimens studied [*Plate 23* and *Figure 59*]. It was absent in 100% ($^{100}/_{100}$) of the specimens. In these specimens, the medial branches terminated on the GSN in 80% ($^{80}/_{100}$) and viscera in 3% ($^{3}/_{100}$) of the specimens. The T_7 ganglion had no medial contributions in 17% ($^{17}/_{100}$) of the specimens.

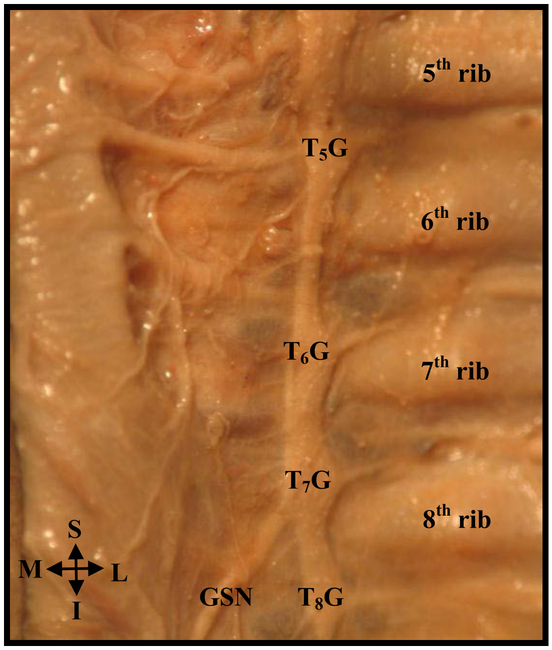


Plate 23: *Contribution from T_7G to GSN in a fetus* (x4.0)

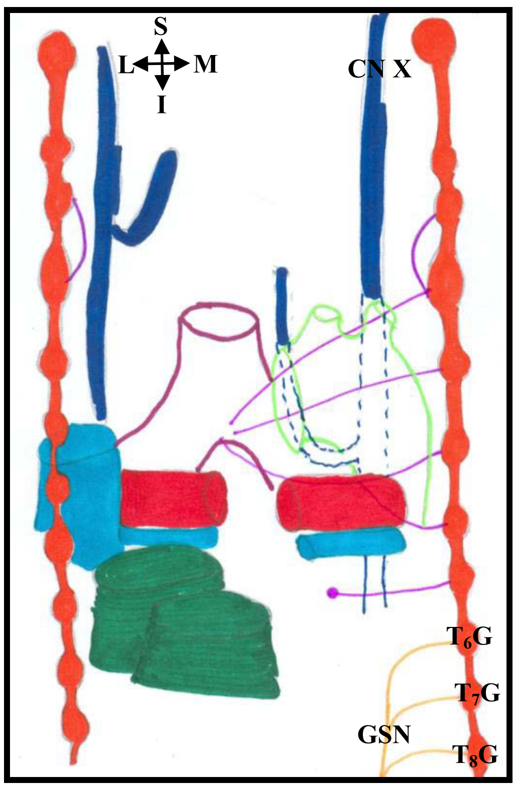


Figure 59: *Schematic diagram of a contribution from the left T_7G to GSN in a fetus*

Key: ***GSN***-*Greater splanchnic nerve,* ***T_5G***-*Fifth thoracic ganglion,* ***T_6G***-*Sixth thoracic ganglion,* ***TCN_7***-*Seventh thoracic cardiac nerve,* ***T_8G***-*Eighth thoracic ganglion,* ***CN X***-*Vagus nerve,* ***I***-*Inferior,* ***L***-*Lateral,* ***M***-*Medial,* ***S***-*Superior.*

FETAL INCIDENCE

The TCN_7 was absent in all of the specimens studied. In the 100 cases that TCN_7 was absent, the medial branches terminated on the GSN in 75% ($^{60}/_{80}$) and on the viscera in 4% ($^{3}/_{80}$) of the specimens. The T_7 ganglion had no medial contributions in 21% ($^{17}/_{80}$) of the specimens.

ADULT INCIDENCE

The TCN_7 was absent in all the specimens studied. In the 100 cases that TCN_7 was absent, the medial branches terminated on the GSN in 100% ($^{20}/_{20}$) of the specimens.

4.7.8 Eighth thoracic cardiac nerve (TCN_8)

OVERALL INCIDENCE OF TCN_8

There were no thoracic cardiac nerves that originated from the T_8 ganglion in the specimens studied. It was absent in 100% ($^{100}/_{100}$) of the specimens. In these specimens, the medial branches terminated on the GSN in 89% ($^{89}/_{100}$) of the specimens. The T_8 ganglion had no medial contributions in 11% ($^{11}/_{100}$) of the specimens.

FETAL INCIDENCE

The TCN_8 was absent in all of the specimens studied. In the 100 cases that TCN_8 was absent, the medial branches terminated on the GSN in 86% ($^{69}/_{80}$) of the specimens. The T_8 ganglion had no medial contributions in 14% ($^{11}/_{80}$) of the specimens.

ADULT INCIDENCE

The TCN_8 was absent in all the specimens studied. In the 100 cases that TCN_8 was absent, the medial branches terminated on the GSN in 100% ($^{20}/_{20}$) of the specimens.

4.8. VAGUS NERVE

4.8.1 CERVICAL VAGAL CARDIAC NERVES

OVERALL INCIDENCE

A total of 86 cervical vagal cardiac nerves (CVCN) originated from the cervical part of the vagus nerve in the specimens studied [*Plate 24* and *Figure 60*]. The overall incidence of the CVCN on the right and left sides were 88% ($^{44}/_{50}$) and 84% ($^{42}/_{50}$), respectively. These were absent in 14% ($^{14}/_{100}$) of the specimens.

FETAL INCIDENCE

The CVCN was present in 90% ($^{72}/_{80}$) of the specimens [*Plate 24* and *Figure 60*]. The incidence of the CVCN on the right and left sides were 93% ($^{37}/_{40}$) and 88% ($^{35}/_{40}$), respectively. These were absent in 10% ($^{8}/_{80}$) of the specimens.

ADULT INCIDENCE

The CVCN was present in 70% ($^{14}/_{20}$) of the specimens. The incidence of the CVCN was 70% ($^{7}/_{10}$) bilaterally. These were absent in 30% ($^{6}/_{20}$) of the specimens.

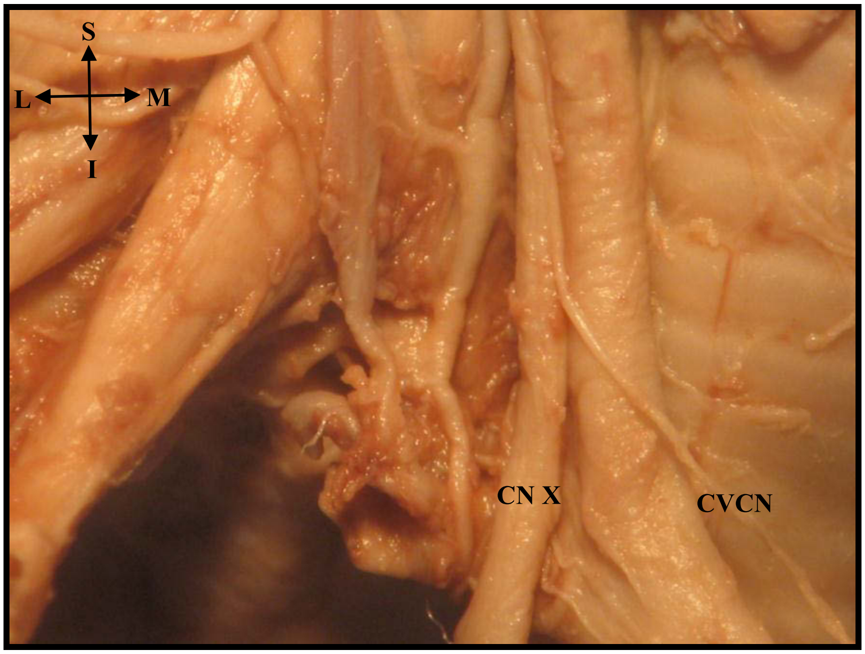


Plate 24*: Contribution of the left CVCN from vagus nerve.* (x4.0)

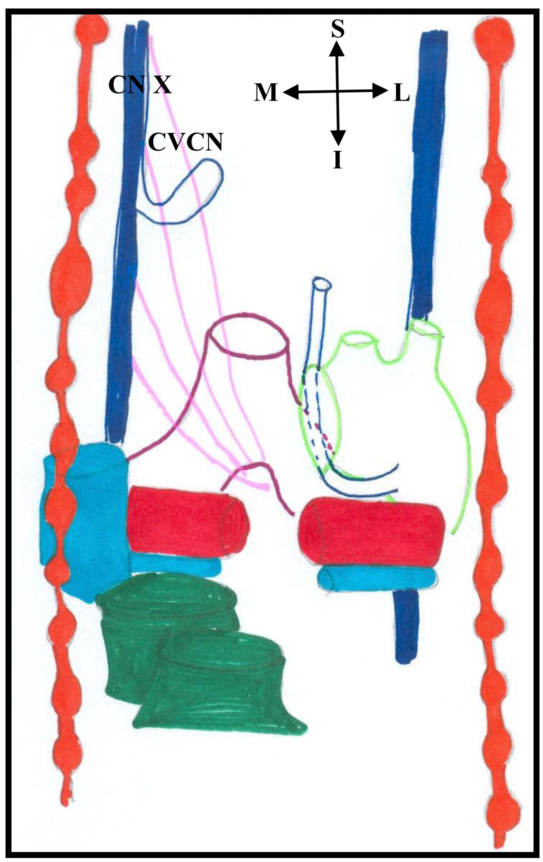


Figure 60: *Schematic diagram of a contribution from the right CVCN of vagus nerve*

Key: ***CN X****-Vagus nerve,* ***CVCN****-cervical vagal cardiac nerve,* ***S****-Superior,* ***I****-Inferior,* ***L****-Lateral,* ***M****-Medial.*

4.8.1.1 SUPERIOR CERVICAL VAGAL CARDIAC NERVE

OVERALL INCIDENCE

A total of 19 superior vagal cardiac nerves (SCVCN) demonstrated in the specimens studied [*Plate 25* and *Figure 61*]. The overall incidence of the SCVCN on the right and left sides were 16% ($^{8}/_{50}$) and 22% ($^{11}/_{50}$), respectively. These were absent in 81% ($^{81}/_{100}$) of the specimens.

FETAL INCIDENCE

The SCVCN was present in 24% ($^{19}/_{80}$) of the specimens. The incidence of the SCVCN on the right and left sides were 20% ($^{8}/_{40}$) and 28% ($^{11}/_{40}$), respectively. These were absent in 76% ($^{61}/_{80}$) of the specimens.

ADULT INCIDENCE

The SCVCN was absent in 100% ($^{20}/_{20}$) of the specimens.

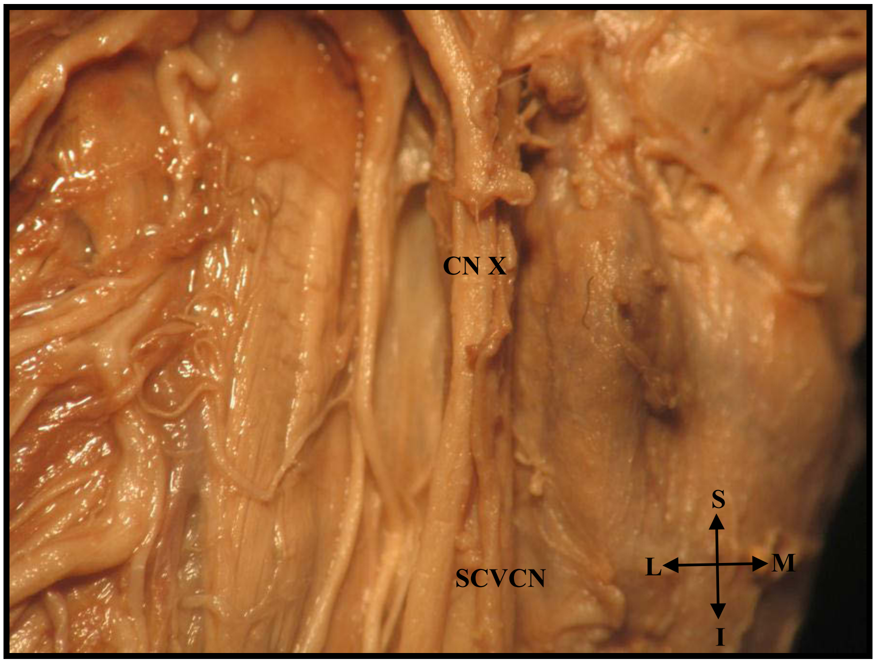


Plate 25: *Contribution from the right SCVCN to the DCP in a fetus* (x4.0)

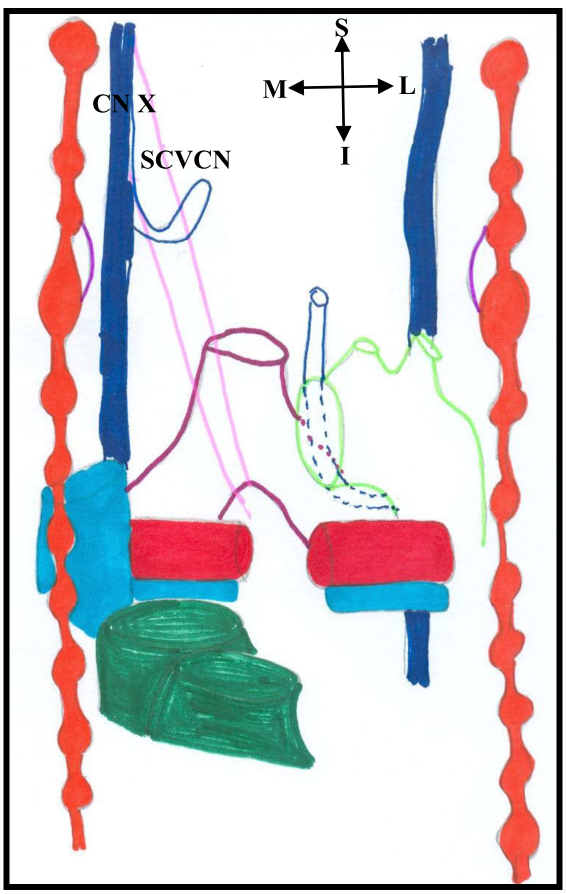


Figure 61: *Schematic diagram of the contribution from the SCVCN to the DCP in a fetus.*

Key: ***CN X***-*Vagus nerve,* ***SCVCN***-*superior cervical vagal cardiac nerve,* ***I***-*Inferior,* ***L***-*Lateral,* ***M***-*Medial,* ***S***-*Superior.*

4.8.1.2 MIDDLE CERVICAL VAGAL CARDIAC NERVE

OVERALL INCIDENCE

A total of 34 middle vagal cardiac nerves (MCVCN) demonstrated in the specimens studied [*Plate 26* and *Figure 62*]. The overall incidence of the MCVCN on the right and left sides were 32% (${}^{16}/_{50}$) and 36% (${}^{18}/_{50}$), respectively. These were absent in 66% (${}^{66}/_{100}$) of the specimens.

FETAL INCIDENCE

The MCVCN was present in 36% (${}^{29}/_{80}$) of the specimens. The incidence of the MCVCN on the right and left sides were 35% (${}^{14}/_{40}$) and 38% (${}^{15}/_{40}$), respectively. These were absent in 64% (${}^{51}/_{80}$) of the specimens.

ADULT INCIDENCE

The MCVCN was present in 25% (${}^{5}/_{20}$) of the specimens. The incidence of the MCVCN on the right and left sides were 20% (${}^{2}/_{10}$) and 30% (${}^{3}/_{10}$), respectively. These were absent in 75% (${}^{15}/_{20}$) of the specimens.

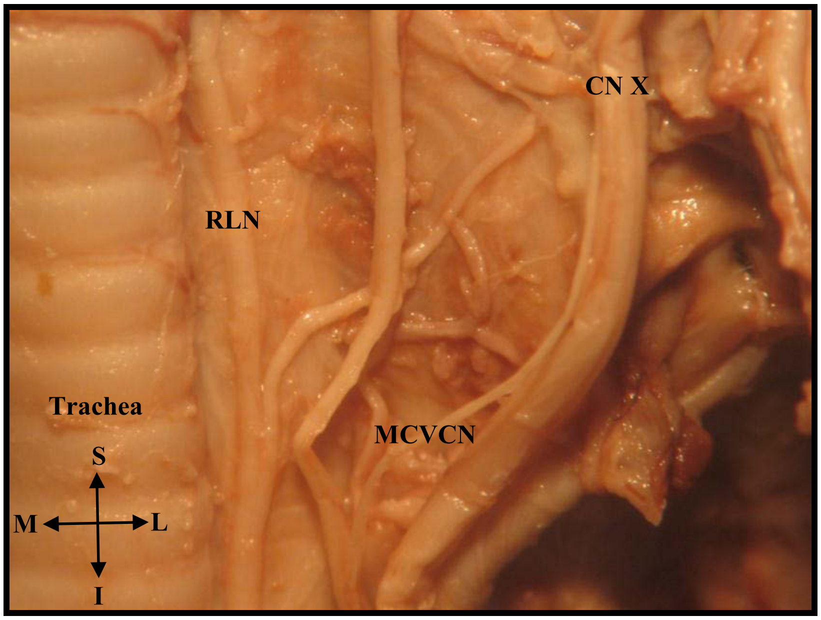


Plate 26: *Contribution from the left MCVCN to superficial cardiac plexus* (x4.0)

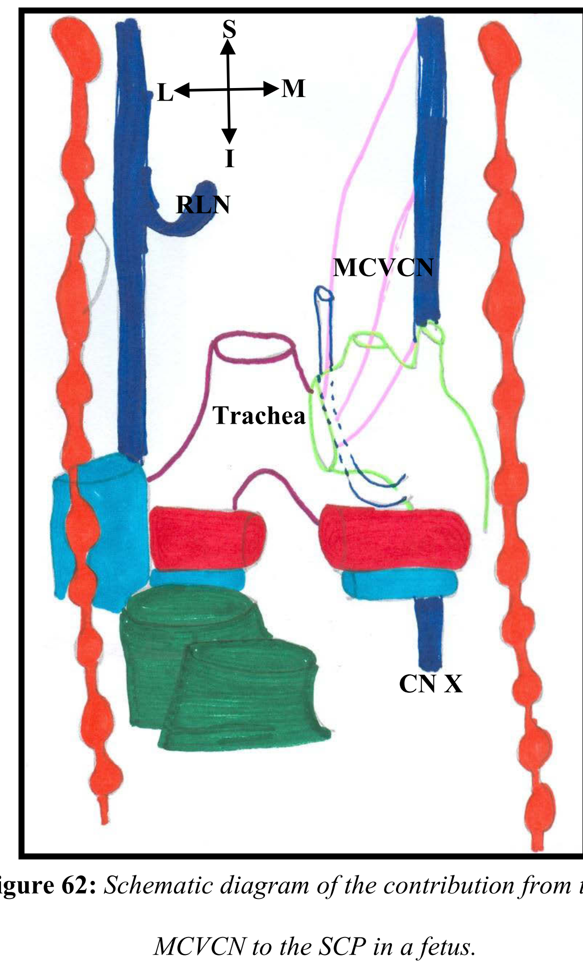


Figure 62: *Schematic diagram of the contribution from the left MCVCN to the SCP in a fetus.*

***Key: RLN**-Recurrent laryngeal nerve, **CN X**-Vagus nerve, **MCVCN**-Middle cervical vagal cardiac nerve, **I**-Inferior, **L**-Lateral, **M**-Medial, **S**-Superior.*

4.8.1.3 INFERIOR CERVICAL VAGAL CARDIAC NERVE

OVERALL INCIDENCE

A total of 69 inferior vagal cardiac nerves (ICVCN) were demonstrated in the specimens studied [*Plate 27* and *Figure 63*]. The overall incidence of the ICVCN on the right and left sides were 74% ($^{37}/_{50}$) and 64% ($^{32}/_{50}$), respectively. These were absent in 31% ($^{31}/_{100}$) of the specimens.

FETAL INCIDENCE

The ICVCN was present in 70% ($^{56}/_{80}$) of the specimens. The incidence of the ICVCN on the right and left sides was 78% ($^{31}/_{40}$) and 63% ($^{25}/_{40}$), respectively. These were absent in 30% ($^{24}/_{80}$) of the specimens.

ADULT INCIDENCE

The ICVCN was present in 65% ($^{13}/_{20}$) of the specimens. The incidence of the ICVCN on the right and left sides were 60% ($^{6}/_{10}$) and 70% ($^{7}/_{10}$), respectively. These were absent in 35% ($^{7}/_{20}$) of the specimens.

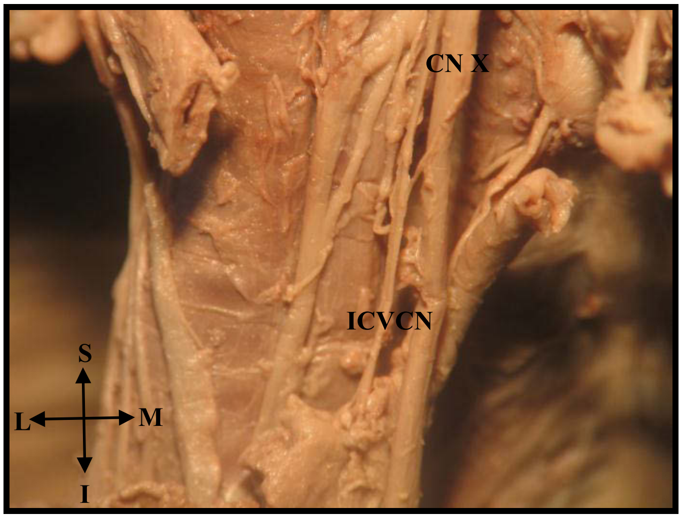


Plate 27: *Contribution from the left ICVCN to the SCP in a fetus* (x4.0)

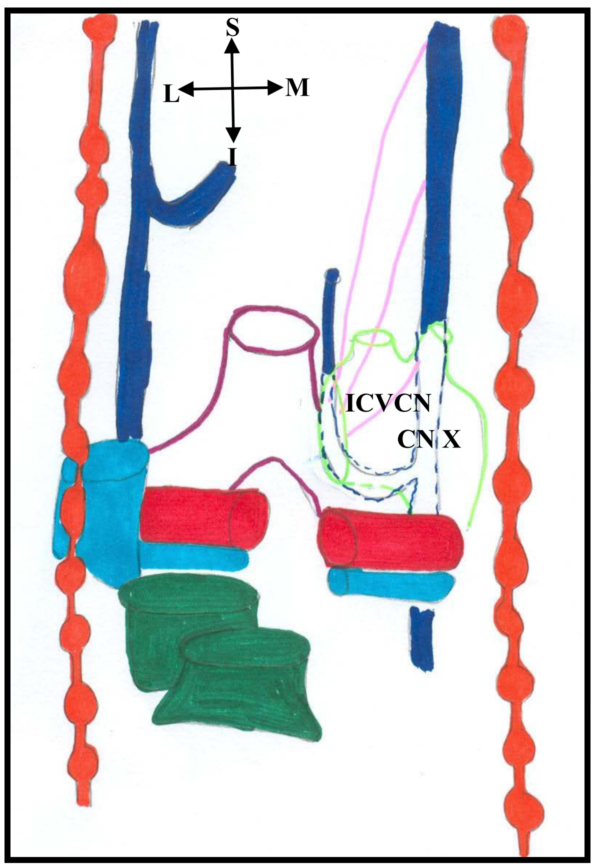


Figure 63: *Schematic diagram of the contribution from the left ICVCN to the SCP in a fetus.*

Key: ***IVCN***-*Inferior cervical vagal cardiac nerve,* ***CN X***-*Vagus nerve,* ***I***-*Inferior,* ***L***-*Lateral,* ***M***-*Medial,* ***S***-*Superior.*

4.8.2. THORACIC VAGAL CARDIAC NERVES

OVERALL INCIDENCE

A total of 48 thoracic vagal cardiac nerves (TVCN) were demonstrated in the specimens studied [*Plate 28* and *Figure 64*]. The overall incidence of the TVCN on the right side was 96% ($^{48}/_{50}$), these contributed to the deep cardiac plexus. No TVCN were noted from the left side. It had no contribution to DCP in 52% ($^{52}/_{100}$) of the specimens.

FETAL INCIDENCE

The TVCN were present in 50% ($^{40}/_{80}$) of the specimens. These arose from the right thoracic vagus nerve in all specimens. No contributions to the cardiac plexus were noted from the left thoracic vagus nerve. These were absent in 50% ($^{40}/_{80}$) of the specimens.

ADULT INCIDENCE

The TVCN were present in 40% ($^{8}/_{20}$) of the specimens. These nerves arose from the right TVCN in 80% ($^{8}/_{10}$), no contributions to the cardiac plexus were noted from the left thoracic vagus nerve. These were absent in 60% ($^{12}/_{20}$) of the specimens.

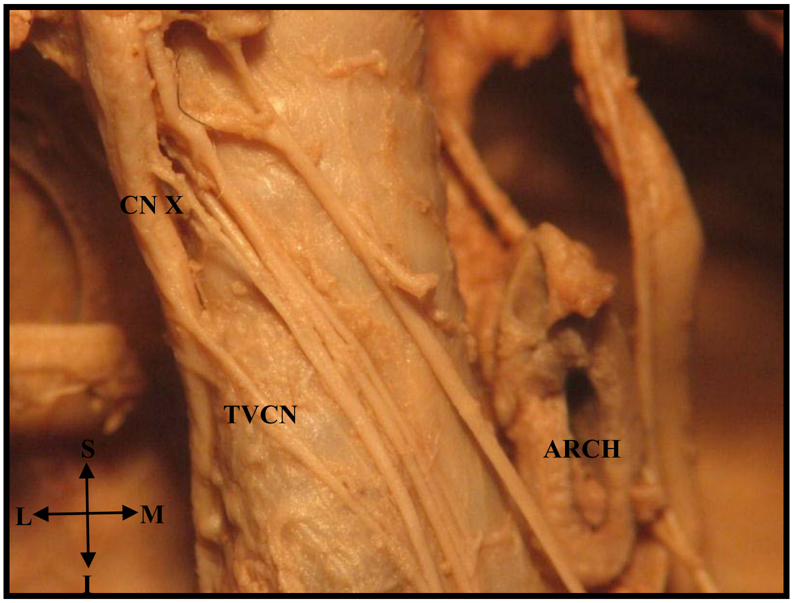


Plate 28: *Contribution from the right thoracic vagal cardiac nerve to the DCP in a fetus* (x4.0)

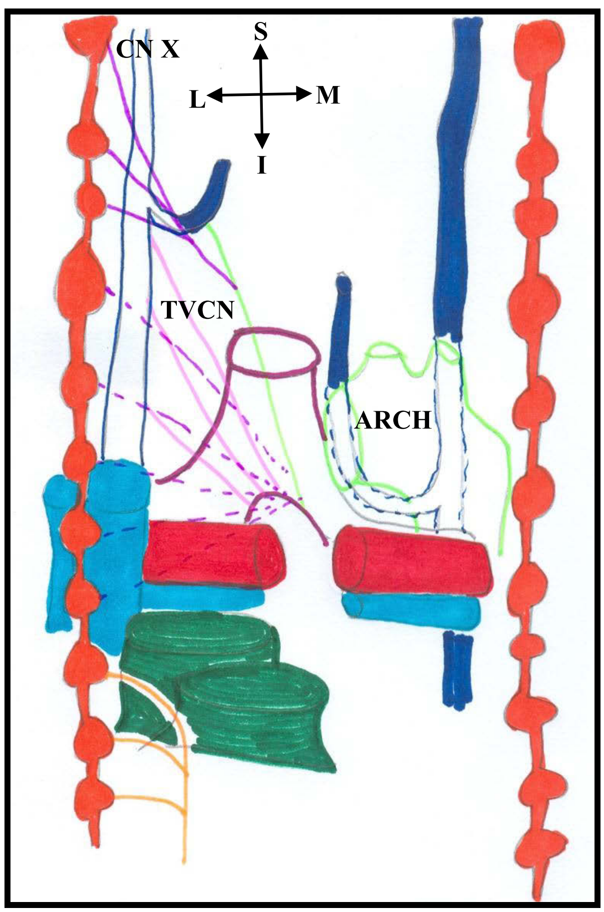


Figure 64: *Schematic diagram of the contribution from the right TVCN to the DCP in a fetus.*

Key: ***ARCH****-Arch of aorta,* ***TVCN****-Thoracic vagal cardiac nerve,* ***CN X****-Vagus nerve,* ***S****-Superior,* ***I****-Inferior,* ***M****-Medial,* ***L****-Lateral*

4.8.3. RECURRENT LARYNGEAL CARDIAC NERVES

OVERALL INCIDENCE

A total of 28 recurrent laryngeal cardiac nerves (RLCN) [*Plate 26* and *Figure 65*] were demonstrated in the specimens studied. The overall incidence of the RLCN on the right and left sides were 50% ($^{25}/_{50}$) and 6% ($^{3}/_{50}$), respectively. These were absent in 72% ($^{72}/_{100}$) of the specimens.

FETAL INCIDENCE

The RLCN was present in 31% ($^{25}/_{80}$) of the specimens [*Plate 26* and *Figure 65*]. The incidences of the RLCN on the right and left sides were 55% ($^{22}/_{40}$) and 8% ($^{3}/_{40}$), respectively. These were absent in 69% ($^{55}/_{80}$) of the specimens.

ADULT INCIDENCE

The RLCN was present in 15% ($^{3}/_{20}$) of the specimens. The incidence of the RLCN on the right sides was 30% ($^{3}/_{10}$); there was no incidence of RLCN on the left side. These were absent in 85% ($^{17}/_{20}$) of the specimens.

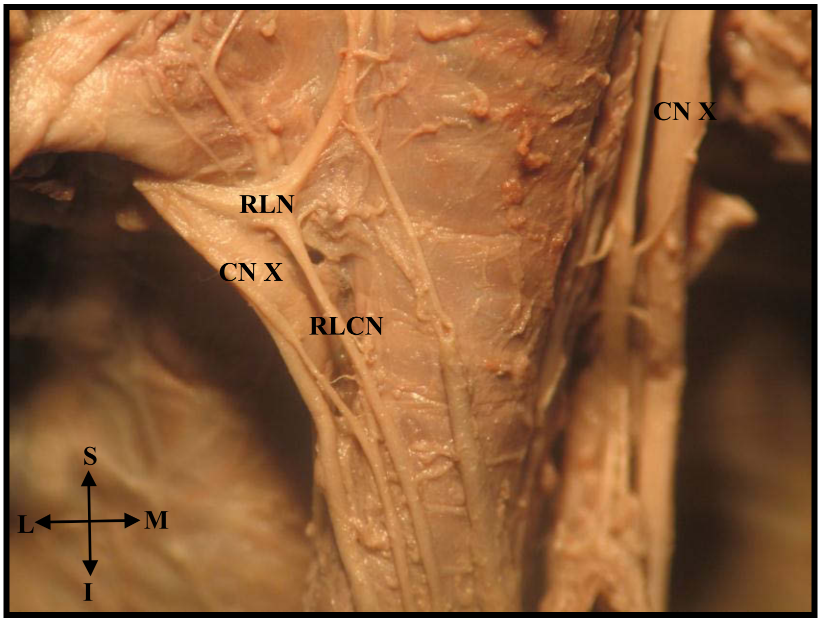


Plate 29: *Contribution from the right RLCN to the DCP in a fetus* (x4.0)

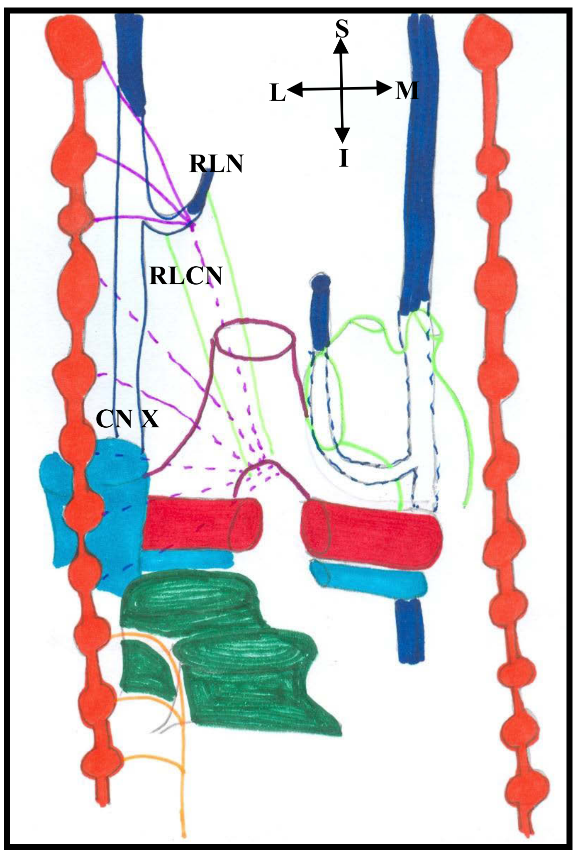


Figure 65: *Schematic diagram of the contribution from the right RLCN to the DCP in a fetus.*

Key: ***RLN***-*Recurrent laryngeal nerve,* ***RLCN***-*Recurrent laryngeal cardiac nerve,* ***CN X***-*Vagus nerve,* ***I***-*Inferior,* ***L***-*Lateral,* ***M***-*Medial,* ***S***-*superior*

CHAPTER 5

DISCUSSION

5.1 SAMPLE

The study was conducted on a sample size of fifty (100 sides) cadaveric specimens which consisted of forty fetuses (80 sides) and ten adults (20 sides). Since the fetal series comprised a greater number of the specimens compared to adults, it provided a unique overall view of the sympathetic nervous system in the fetus from its origin in the spinal nerves to its termination (Groen *et al*., 1987). It should also be noted that in fetuses, sympathetic nerve development beyond the 15mm stage, does not alter (Pather, 2001). Since the parietal pleura in fetuses is thinner and more transparent, micro-dissection although challenging was possible and contributed to a significant sample size.

5.2. CERVICAL SYMPATHETIC CHAIN

5.2.1. COURSE AND RELATIONS

In this study the CSC was located on the prevertebral fascia, posterior to the carotid sheath; this corroborated with standard anatomical descriptions (McMinn, 1994; Standring *et al.,* 2008). In a study by Lyons and Mills (1998), the CSC was reported to lie within the carotid sheath in two cases (17%) of their study of twelve cadaveric specimens; such a location of the CSC was not found in any of the specimens in the present study.

Standard anatomical textbooks (McMinn. 1994; Standring *et al.,* 2008) state that the CSC contains three interconnected ganglia viz. SCG, MCG and ICG [or CTG if fused with T1 ganglion]. Ellison and Williams (1969) and Bhatnagar *et al*. (2003) reported that there may occasionally be two or four ganglia present. Becker and Grunt (1957) termed the fourth ganglion related to the vertebral artery as VG which Wrete (1959) concurred with. This study reports a number of ganglia that varied from two (absent MCG and VG) to five (with double MCG and VG present). This did not concur with previous literature reviewed (Becker and Grunt, 1957; Ellison and Williams, 1969) and standard anatomical textbooks (McMinn, 1994; Standring *et al*., 2008).

The CSC was found to have a single interconnecting chain in 99% of these specimens and compared favourably with Kalsey *et al*"s (2000) incidence of 83%. This study records a CSC that divides into multiple branches in a single specimen (1%). This finding has not been reported in any of the literature reviewed. The literature reviewed describes a double sympathetic chain in the cervical region as a possible occurrence (Mitchell, 1953) while Kalsey *et al.* (2000) provides evidence of this in 17% of their specimens distal to the SCG. This study concurs with Kalsey *et al*. (2000) in that no duplication of the CSC proximal to the SCG exists. The observation by Kadowaki and Lewett (1986) of a double strand CSC around the subclavian arteries termed AS was a constant finding in all the specimens in the present study; this also concurred with standard anatomical descriptions (Standring *et al*., 2008). This present study recorded no duplication of the CSC around the ITA, disagreeing with Ellison and Williams (1969).

CERVICAL GANGLIA

The literature reviewed describes a constant incidence of 100% for the SCG while varying incidences of the MCG (62.3% to 100%), VG (58% to 94.4%), ICG (13.9% to 62.5%) or CTG (37.7% to 100%) are reflected in *Table 22* below. A review and description (with no statistical analyses) by Kadowaki and Lewett (1986) stated that the CSC consists of a series of ganglia that are variable in number and position, this study concurs as the CSC was also found to contain five ganglia in two specimens (2%).

TABLE 22: *REPORTED PERCENTAGE INCIDENCES OF CERVICAL GANGLIA*

AUTHOR	n=	SCG	MCG	VG	ICG	CTG
Pick &Sheehan (1946)	**25**	**100**	**-**	**-**	**20**	**80**
Becker &Grunt (1957)	**114**	**100**	**62.3**	**87.7**	**62.3**	**37.7**
Ellison & Williams (1969)	**24**	**100**	**75**	**58**	**-**	**88**
Groen et al. (1987)	**12**	**-**	**-**	**-**	**-**	**100**
Kalsey et al. (2000)	**30**	**100**	**100**	**33.3**	**-**	**100**
Pather (2001)	**58**	**100**	**81.1**	**-**	**15.5**	**84.5**
Kawashima (2005)	**36**	**100**	**91.7**	**94.4**	**13.9**	**86.1**
Kiray et al.	**24**	**100**	**33.3**	**33.3**	**?**	**?**
Canan et al.	**40**	**100**	**48**	**8**	**0**	**100**
De Gama (2010)	**100**	**100**	**71**	**48**	**45**	**48**

5.2.2. SUPERIOR CERVICAL GANGLION

Standard anatomical literature describes the SCG as the largest (Standring *et al*., 2008) and most constant ganglion of the three cervical sympathetic ganglia (Ellison and Williams, 1957; Wrete, 1959; Standring *et al*., 2008). This study confirms the 100% incidence of SCG, this concurred with the standard anatomical literature (Standring *et al*., 2008) and numerous authors (Mitchell, 1953; Becker and Grunt, 1957; Ellison and Williams, 1969). This study confirms that the SCG is constantly located behind the common carotid artery concurring with Kawashima (2005). This study also concurs with Standring *et al*. (2008) in that it is related to the internal carotid artery anteriorly; this was constantly found in all the adult specimens.

The SCG was found to have a fusiform (61%), oval-rounded (30%), elongated (6%) and irregular (3%) shape in the fetal specimens in this study. These findings compare favourably with those of Kalsey *et al*. (2000) with regards to the percentage of fusiform and elongated shapes [61% *vs.* 77% and 6% *vs.* 7%, respectively]. The findings of this study differ widely with those of Kalsey *et al*. (2000) with regard to the oval shaped SCG [30% *vs.*2%]. The fusiform shaped SCG was found in 61% in this study concurring with standard anatomical literature by Standring *et al*. (2008). This study also records oval-rounded, elongated and irregular shapes of SCG. This study concurs with Bhatnagar *et al*. (2003) on the incidence of a large oblong fusiform SCG located anterior to prevertebral fascia at the level of the bifurcation of the common carotid artery bilaterally; this was found in three specimens in this study (3%). In this study, the SCG was not found to communicate with any of the cranial nerves or vertebral plexus or phrenic nerve; this differs from findings by Kalsey *et al*. (2000) and Kawashima (2005).

5.2.3. MIDDLE CERVICAL GANGLION

Standard anatomical literature (Standring *et al*., 2008) describes this ganglion as the smallest of the three cervical ganglia or sometimes absent or replaced by minute ganglia while Kalsey *et al*. (2000) describes the location of this ganglion as anterior or just superior to the ITA and states that it may connect to the ICG. The study concurs with standard anatomical literature (Standring *et al*., 2008) in that the MCG is the smallest cervical ganglion. This study also confirms that the MCG is occasionally absent as reported by Standring *et al*. (2008); this occurred in 29% of the specimens. A double MCG in a single CSC was found in 3% of these specimens, this compared favourably with Kalsey *et al*. (2000) (3% vs. 5%). This confirmed the findings of Pick and Sheehan (1946) in that the MCG may have a double occurrence or represented by a tiny knot. This differed widely from the findings of Becker and Grunt (1957) and Pather (2001) (3% *vs*. 39% and 25.9%, respectively). This study disagrees with Axford (1928) and Standring *et al*. (2008) in that the MCG is occasionally replaced by minute ganglia in the sympathetic trunk; this was not found in any of the specimens in this study.

In the present study the location of the MCG was differentiated into three types based on their relation with the ITA based on Becker and Grunt"s (1957) description:

Type I: *MCG lying above the ITA-'high'* MCG;

Type II: *MCG lying on the ITA-'normal' MCG;*

Type III: *MCG lying below ITA-'low' MCG*

The findings of this study concur with Kalsey *et al*. (2000) with regards to the high and normal MCG as they were located superior (i.e. above the ITA) and anterior (i.e. on the ITA) to the ITA.

This study records the overall incidence of MCG to be 71%, this compared favourably with the findings of Becker and Grunt (1957) and Ellison and Williams (1969) (71% *vs*. 62.3% and 75%, respectively). This study also differs widely with findings by Saccommano (1943) who reported the MCG to be absent in a high percentage of cases in his study. This study differs widely with the findings depicted by Becker and Grunt (1957) on the incidence of "normal" MCG (35% *vs*. 82%). This study further disagreed with Mitchell (1953) and Saccomanno (1943) in describing the vertebral ganglion as the MCG. This study also disagrees with Wrete (1959) and Randal and Armour (1977) in referring to the MCG as an "intermediate ganglion" and the "thyroid cervical ganglion". Furthermore, this study disagrees with Axford (1928) in referring to the MCG located in close relation to the ITA as the "high type MCG"; this study describes such a ganglion as the "normal type MCG".

This study also confirms the findings by Pather *et al*. (2001) that individual low MCG may be found on a single CSC [5 *vs*. 2counts of low MCG]. The present study disagrees that the low type MCG is an intermediate ganglion as stated by Mizeres (1972), Elias (2000) and Kalsey *et al*. (2000). This study further recorded that two „normal" MCG can be present in a single CSC, as this occurred in two cases (2%) of this study. The bilateral incidence of MCG was found to be 27% in this study which compared favourably with the incidence of 31% reported by Pather (2001). This study further reports a higher incidence of the normal MCG, *Type II* (35%); this concurs with standard anatomical literature (Standring *et al*., 2008) and disagrees with Axford (1928) who reported a higher incidence of the low MCG as this is described as the normal type MCG in the present study.

The findings of this study (66%) show a greater contribution to the incidence of MCG lying at or below the ITA (these were either *Types II and III*), confirming the findings of Mitchell (1953) and Becker and Grunt (1957). The incidence of high MCG in this study differed widely with the results reported by Pather (2001) and Pick and Sheehan (1946) (7% vs. 27.6% and 56%). The incidences of low MCG in this study concur with Pather *et al*. (2001) (31% vs. 31.8%).

The MCG connected to the ICG or CTG by one or two cords that enclosed the subclavian artery. This study differs from standard anatomical literature (Saccomanno, 1943; Standring *et al*., 2008) on the posterior cord enclosing the vertebral artery; while this study concurs with literature on the anterior cord enclosing the subclavian artery.

5.2.4. VERTEBRAL GANGLION

This study concurs with Becker and Grunt (1957) in designating the fourth ganglion found on the CSC as “the vertebral ganglion” due to its close relation with the vertebral artery. The present study differs with Ionesco and Enachesco (1927) and Axford (1928) in referring to this ganglion as the “intermediate ganglion” and “low type of MCG” This study also confirms reports by Mitchell (1953), Elias (2000) and Kawashima (2005) in that the intermediate ganglia are to be referred to as the vertebral ganglion. This ganglion was found in close relation with the vertebral artery in 48% of these specimens; this differed from the findings of Becker and Grunt (1957) (87.7%) and of Kawashima (2005) (94.4%).

5.2.5. INFERIOR CERVICAL GANGLION

In the present study the ICG was located medial to the costocervical artery, this corroborated with Standring *et al*. (2008). The occurrence of a separate ICG and T1 ganglion varies amongst authors viz. Becker and Grunt (1957) reported an incidence of 62.3%; while Pather (2001) reported an incidence of 15%. Kawashima (2005) reported a separate ICG in 13.9%. This study recorded the overall incidence of ICG to be 45% which differed from the findings by these authors viz. Becker and Grunt (1957),Pather (2001) and Kawashima (2005) [45% *vs*. 62.3%, 15% and 13.9%, respectively].

5.2.6. CERVICOTHORACIC GANGLION

Previous literature reviewed reported that the CTG is larger than the MCG (Standring *et al*., 2008) and is formed by the fusion of the ICG and the first thoracic ganglion (Pick and Sheehan, 1946; Mitchell, 1953; Becker and Grunt, 1957, Ellison and Williams, 1969). This study confirms these reports as the CTG had a larger appearance on macroscopic view. With regard to the CTG being formed by the fusion of the ICG and the first thoracic ganglion, this study confirms reports by Mitchell (1953) and Ellison and Williams (1969). In five specimens in this study, the CTG was also formed by the fusion of the second, third and fourth thoracic ganglia which confirms the reports by Pather *et al*. (2006) and Standring *et al*. (2008).

This study also concurs with findings of Pather (2001) with regard to the CTG comprising of three shapes i.e. inverted "L", spindle and dumbbell. This study differs with Pather (2001) in reporting that the inverted "L" shaped CTG is the most prevalent shape (8% vs. 45.3%). This study describes the spindle shaped CTG as the most prevalent shape (36%) as depicted in *Table 23*.

TABLE 23: *COMPARISON OF PERCENTAGE INCIDENCE OF DIFFERENT SHAPES OF CTG.*

Shape	*Pather et al. (2006)*	*Present study (2010)*
Spindle	*28*	*75*
Dumbbell	*26.7*	*8*
Inverted "L"	*45.3*	*17*

Kawashima (2005) and current standard anatomical textbooks (Standring *et al*., 2008) reports that the CTG lies on or lateral to the lateral border of the longus colli muscle and posterior to the vertebral artery. This study confirms this anatomical relationship as it was found in 100% of our specimens. This study further agrees with Janes *et al*. (1986) on the CTG being an enlargement at the superior ends of the thoracic sympathetic chains being located over the heads of the first and second ribs; this was found in 5 specimens (5%).

The overall incidence of CTG in this study was found to be 48%. This compared favourably with Becker and Grunt (1957) (48% *vs.* 37.7%). This present study differs widely with the findings of Ellison and Williams (1969), Pather (2001) and Kawashima (2005) (48% *vs*.88%, 84.5% and 86.1%, respectively) on the incidence of CTG.

5.3. THORACIC SYMPATHETIC CHAIN

5.3.1 COURSE AND RELATIONS

The course and relations of the thoracic sympathetic chain in this study concurs with descriptions of previous literature reviewed (Hollinshead, 1974; Janes *et al*., 1986; Standring *et al*., 2008) as it was found to lie posterior to the parietal costal pleura with the upper chain (up to 6th vertebral level) lying on the neck of the ribs and intervening intercostal spaces.

5.3.2 THORACIC GANGLIA

The findings of the present study on the locations of the thoracic ganglia concur with standard anatomical literature (Hollinshead, 1974). This study also concurs with Zhang *et al*. (2009) with regard to the second to fourth thoracic ganglia being located in the corresponding intercostal spaces. This study differs with the incidences stated by Zhang *et al*. (2009) of 92%, 68% and 50% on thoracic ganglia; this study records a 100% incidence on all thoracic ganglia. This study also confirms standard anatomical descriptions (Standring *et al*., 2008) in that the third to the eighth thoracic ganglia are small and rested on the heads of the ribs posterior to the costal pleura. The third and fourth ganglia were found to fuse in most cases of the specimens in the present study; this disagreed with the findings of Groen *et al*. (1986) who reported the sixth and seventh ganglia to be fused in all their specimens.

5.3.3 ADDITIONAL MEDIAL BRANCHES

In this study, the GSN had its highest origin from the fourth thoracic ganglion (T_4G); this differed from standard anatomical literature (Cunningham, 1968; Standring *et al*., 2008) [T_4G *vs*. $_{T5}$G]. These findings also differed from Groen *et al*. (1987) [T_4G *vs*. T_6G].

5.4. CARDIAC PLEXUS

The literature reviewed has varying descriptions of the cardiac plexus. Romanes (1968) described the cardiac plexus as situated on the bifurcation of the trachea and made up of sympathetic and parasympathetic fibres. Mizeres (1972) described the cardiac plexus as lying on the anterior and posterior walls of the bifurcation of the pulmonary trunk, consisting of subplexuses viz. pulmonary, atrial, coronary and the plexus on the arch of aorta. Hollinshead (1974) stated that the innervation of the heart is from the cardiac plexus which received sympathetic and vagal branches and gave off two coronary plexuses and two atrial plexuses. This study concurs with the description that the cardiac plexus is made up of sympathetic and parasympathetic branches which are divided into superficial and deep portions (Gardner *et al*., 1975; McMinn 1994; Standring *et al*., 2008; San Mauro *et al*., 2009).

Janes *et al*. (1986) and Kawashima"s (2005) description of the nerves that made up the cardiac plexus differed widely from our study; this study does not record any right or left cardiac plexus. This study records the cardiac plexus consisting of superficial parts located on the arch of aorta and the pulmonary artery in 80% and on the ascending aorta in 20% of the specimens. The deep part was located posterior to the arch of aorta and anterior to the tracheal bifurcation in 100% of the specimens.

5.4.1. SUPERFICIAL CARDIAC PLEXUS

This plexus is described by Cunningham (1968) as the anterior extremity of the plexus extending from the bifurcation of the trachea to the concavity of the arch of aorta. He stated that it received a superior cervical cardiac branch from the left sympathetic trunk and an inferior cervical cardiac branch from the left vagus nerve. Hollinshead (1974) and McMinn (1994) described the SCP as located between the arch of the aorta and the pulmonary trunk, to the right of ligamentum arteriosum and continuous with the deep cardiac plexus. He further stated that it is joined by two small twigs from the left side, the superior sympathetic cardiac nerve (from SCG) and the inferior cardiac nerve from the left vagus nerve in the neck.

Standring *et al.* (2008) defined the superficial part of the cardiac plexus as lying inferior to the arch of the aorta and anterior to the right pulmonary artery; being formed by the cardiac branch of the SCG of the left sympathetic trunk and the lower of the two cervical cardiac branches of the left vagus nerve. San Mauro *et al*. (2009) reported that it was formed by left sympathetic cardiac branches and two cardiac branches of the vagus nerve. The findings of this study concur with Hollinshead (1974), McMinn (1994), Standring *et* *al*. (2008) and San Mauro *et al*. (2009) in that the SCP was constantly located inferior to the arch of aorta and above the right pulmonary artery or pulmonary trunk.

This study further records contributions from the right sympathetic chain and vagus nerve to the brachiocephalic trunk and ascending aorta in 20% of these specimens; this concurs with findings by Mizeres (1972).

This study differs from the findings of Kawashima (2005) as he described the SCP in terms of right and left-sided plexuses that surrounded the brachiocephalic trunk and aortic arch. He also noted a larger plexus located between the arch of aorta and the pulmonary trunk which differed from standard anatomical literature (Standring *et al*., 2008).

Percentage contributions from cervical sympathetic chain and ganglia to the SCP are depicted in *Table 24* below, which illustrates that the left cervical sympathetic cardiac nerves largely contribute to the formation of the SCP. These findings concur with Pather (2001) in that the SCP receives its contributions from the cervical sympathetic cardiac nerves that contribute primarily to the DCP. The findings of this study on contributions to the SCP (*Table 24*) could not be compared to any of the literature reviewed as they do not reflect percentages of these contributions in their studies.

TABLE 24*:* PERCENTAGE CONTRIBUTIONS TO THE SCP

SIDES	SCCN	MCCN	VCN	ICCN	CTCN	VN
RIGHT (n=50)	4	4	6	0	0	5
LEFT (n=50)	76	30	8	0	4	55

5.4.2. DEEP CARDIAC PLEXUS

In this study, the DCP was found to lie posterior to the arch of aorta and anterior to the tracheal bifurcation in this study; concurring with standard anatomical descriptions (Romanes, 1968; Hollinshead, 1974; McMinn, 1990; Standring *et al*., 2008; San Mauro *et al*., 2009). This study differs with Romanes (1968) and Hollinshead (1974) on the DCP being continuous with the SCP at the ligamentum arteriosum; this was not recorded in any of the specimens in the present study.

This study records that the nerve fibres that reach the DCP arise from (i) any part of the cervical cardiac branches of the CSC including the superior cervical cardiac nerve and from the cardiac branches of the TSC up to the level of the 5^{th} thoracic ganglion. (ii) any part of the vagus nerve on both sides and the recurrent laryngeal nerve except the left thoracic vagus nerve. These findings disagree with reports from standard anatomical literature (Romanes, 1968; Hollinshead, 1974; McMinn, 1990; Standring *et al*., 2008).

Percentage contributions from the cervical sympathetic chain and ganglia to the DCP are depicted in *Table 25* below. The DCP was found to receive contributions from the remaining right and left sympathetic and vagal cardiac contributions in accordance with standard anatomical literature (Standring *et al*., 2008). This study documents that sympathetic and parasympathetic contributions to the cardiac plexus lose their identity as they course near the heart due to connections that occur between these nerves. This is consistent with the views of other authors viz. Mizeres (1972) and Kawashima (2005).

***TABLE 25**: PERCENTAGE CONTRIBUTIONS TO THE DCP*

ORIGIN OF CONTRIBUTION	CONTRIBUTIONS	RIGHT (n=50)	LEFT (n=50)
SCG	**SCCN**	88	56
MCG	**MCCN**	58	68
VG	**VCN**	26	38
ICG	**ICCN**	20	22
CTG	**CTCN**	12	26
T_1G	**TCN_1**	22	50
T_2G	**TCN_2**	14	32
T_3G	**TCN_3**	14	20
T_4G	**TCN_4**	10	14
T_5G	**TCN_5**	6	0
VN	**VN_S**	16	4
VN	**VN_M**	26	4
VN	**VN_I**	74	6
VN	**VN_T**	96	0
RLN	**RLN**	50	6

5.5. CERVICAL SYMPATHETIC CARDIAC NERVES

The literature reviewed describes the cardiac nerves according to the closest ganglion from their point of origin or their direct ganglionic origin from the sympathetic trunk (Ellison and Williams, 1969; Pather *et al*., 2003).

This study describes these according to the ganglia closest to the point of origin andthe CSC chain below it or both. In this study, the incidence of the SCCN, MCCN, VCN, ICCN and CTCN were present in 92%, 65%, 39%, 21% and 21% of cases, respectively.

5.5.1. SUPERIOR CERVICAL CARDIAC NERVE

Kawashima (2005) stated that the SCCN received a twig from the trunk between the SCG and MCG. San Mauro *et al*. (2009) reported that the SCCN arose by two or more filaments from the lower part of the SCG. Standring *et al*. (2008) stated that this branch descended posterior to the common carotid artery, anterior to the longus colli muscle and crossed anterior to the inferior thyroid and recurrent laryngeal arteries. The course of this branch differs on both sides.

This study records an overall incidence of SCCN as 83%, which compares favourablywiththe incidence reported by Kawashima (2005) of 88.9%. This study further records the SCCN arising from the inferior aspect of SCG by one, two and three branches in 64%, 15% and 4% of cases, respectively of the specimens studied. These results support the reports by San Mauro *et al*. (2009) and Kalsey *et al*. (2000). The SCCN was found to originate from the SCG, the trunk between SCG and MCG; and both SCG and the trunk below it in 71%, 3% and 9% of these specimens, respectively. The results on the origin of the SCCN from the SCG and the trunk between it and MCG concur with reports by Saccomanno (1943), Mitchell (1953) and Kawashima (2005). The resultson the incidences of SCCN differed slightly from Kalsey *et al*., (2000) who reported incidences of 40%, 33.3% and 26.7%, respectively.

The right SCCN descended posterior to the common carotid and subclavian arteries and posterolateral to the brachiocephalic trunk to the back of the aortic arch where it joined the DCP. It contributed branches to the SCP and DCP in 35% and 38% of the specimens, respectively. This differed widely with the report of Kawashima (2005) who described incidences of 83% and 94%, respectively. This cardiac branch had a tendency to have connections with the external laryngeal nerve, the cervical vagal cardiac branches of vagus nerve in the neck and the RLN in the thorax; this concurred with current standard anatomical literature (Standring *et al*., 2008). This study differs widely with Randall and Armour (1977) in that there is no discrete SCCN on the right side as this study records an overall incidence of 90% [0% *vs*. 90%].

The left SCCN descended anterolateral to the left common carotid artery in the neck to reach the left side of the arch of aorta thus forming part of the SCP. It contributed to the SCP and DCP in 76% and 28%, respectively thus disagreeing with Standring *et al*. (2008) in that SCCN always contributes to the SCP and not DCP. In the present study the left SCCN was found to communicate with the MCCN and ICCN/CTCN on its course to the cardiac plexus, this concurred with Mizeres (1972). The left SCCN also communicated with the inferior cervical cardiac branches of the left vagus nerve in 20% of our specimens; this concurred with literature reviewed viz. Mizeres (1972) and Standring *et al*. (2008). Randall and Armour (1977) stated that there was no incidence of the left SCCN, this study differs with their findings (0% *vs*. 94%).

5.5.2. MIDDLE CERVICAL CARDIAC NERVE

The MCCN in this study originated from the MCG or from the sympathetic chain below it; these findings differed from Kawashima (2005). The findings of this study differ from Becker and Grunt (1957) in that the MCCN arose solely from the sympathetic trunk. This study also describes the nerve arising at the sympathetic chain corresponding to the level of MCG as an interganglionic branch of SCG and not MCCN. In its course the MCCN always passed posterior to the common carotid and anterior or posterior subclavian arteries comparing favourably with reports by Kalsey *et al*. (2000), Standring *et al*. (2008) and San Mauro *et al*. (2009).

Furthermore, Saccommano (1943) described the MCCN joining the ICCN and giving rise to a communicating branch to SCCN in the thorax. This study differs in that it describes a constant inosculation of this nerve with the SCCN and ICCN before reaching the cardiac plexuses on both sides of the neck. Randall and Armour (1977) depicted a major connecting nerve from this ganglion to the vagus nerve that may occur on the right side; our study confirmed this in 9% of these specimens.

This study recorded an incidence of MCCN as 71% which differed from the incidence reported by Kawashima (2005) of 87.8%. The number of branches of MCCN varied from one to four in number in the specimens comparing favourably with Kalsey *et al.* (2000) who reported numbers varying from one to three. Furthermore, Kalsey *et al*. (2000) reported MCCN to inosculate with RLN in 5.6% of their specimens comparing favourably with 3% in the present study.

On the right side, MCCN descended posterior to the common carotid artery, anterior or posterior to the subclavian artery to reach the trachea where it received filaments from the RLN before joining the right deep cardiac plexus (Standring *et al*., 2008; San Mauro *et al*., 2009). In the neck it joined the superior cardiac and the RLNs. On the left side, it entered the thorax between the left common carotid and subclavian arteries to join the left deep cardiac plexus. Some fine branches from this ganglion reach the trachea and oesophagus.

5.5.3. VERTEBRAL CARDIAC NERVE

This study records an overall incidence of 39%of the VCN. This differed from the incidences of Kawashima (2005) and Kalsey *et al*. (2000) [39% *vs*. 79.4 and 60%, respectively]. This study is unique in that it records the VCN arising by one or two branches from the VG.

5.5.4. INFERIOR CERVICAL CARDIAC NERVE

The inferior cervical cardiac nerve (ICCN) is reported to originate from the ICG or CTG by Kawashima (2005) concurring with this study as this nerve also arose from the ICG in the specimens dissected. The number of branches arising from ICG varied from one to two in this study differing slightly from Kawashima (2005) who reported the ICCN arising by a single nerve. The incidence of ICCN in this study was recorded to be 21% differing widely from the findings of Kawashima (2005) who reported an incidence of 75% as they also included branches from the ICG or CTG.

5.5.5. CERVICOTHORACIC CARDIAC NERVE

The CTCN arose from the CTG in this study from either the ICG or T_1G component which concurred with Randall and Armour (1977) who termed the cardiac nerves from the CTG as cervicothoracic cardiac nerves. The CTCN was also found to send branches to the subclavian artery in all the specimens concurring with Standring *et al*. (2008). The CTCN branches arose by a single branch in this study differing widely with Kalsey *et al*. (2000) who depicted the CTCN to give off 2-4 branches. The findings of this study compare favourably with Pather *et al*. (2006) in that the CTCN arose by a direct ganglionic branch from the CTG (100% vs. 83.7%, respectively). This study disagrees with Pather *et al*. (2006) in that the CTCN contributed to the DCP only as this study records CTCN contributing to the SCP in 4% of these specimens as well.

5.6. THORACIC CARDIAC NERVES

The literature reviewed has reflected varying limits of the thoracic cardiac nerves with limits varying from T2 (Perman, 1924) to T7 ganglion (Saccomanno, 1943) as shown in *Table 26*. This study records the thoracic limit of cardiac nerves to be the fifth thoracic ganglion. This corroborated the findings of previous authors (Kuntz and Morehouse, 1930; Ellison and Williams, 1969; San Mauro *et al*., 2009) but differed with the findings of Saccomanno (1943) who described the thoracic limit as T6 or T7 ganglia. A great number of contributions below the level of T5 ganglion were found to contribute to the GSN in the present study (see Appendices B and C).

This study differs widely with Randall and Armour (1977) in that the cardiac plexuses do not receive any contributions from the thoracic sympathetic chain below the CTG as no branches exist below this point; however the findings of this study reflect contributions up to the level of T5 ganglion.

TABLE 26: RECORDED THORACIC LIMITS OF THORACIC CARDIAC NERVES

Author	Year	Composition	Lowest thoracic limit (Ganglia)
Perman	1924	Adults	T2
Ionesco and Enachescu	1928	Fetuses and adults	T5
Kuntz and Morehouse	1930	Adult, young cadavers and fetuses	T5
Saccomanno	1943	Adults	T6/T7
Mitchell	1953	Adults	T4
Ellison and Williams	1969	Fetuses	T5
Mizeres	1972	Adults	T4
Fukuyama	1982	?	T4-T5
Pather *et al*.	2003	Adults and fetuses	T5/T6
Kawashima	2005	Adults	T7
San Mauro *et al*.	2009	Adults	T4-T5
De Gama (2010)	2010	Adults and fetuses	T5

5.7. VAGUS NERVE

5.7.1.CERVICAL VAGAL CARDIAC NERVES

The cervical vagal cardiac branches were described in terms of superior, middle and inferior based on Mitchell‟s description (1953) differing from Mizeres (1972) who described it in terms of cervical and cervicothoracic branches. This study also differed from the nomenclature adopted by standard anatomical literature (Standring *et al*., 2008) and Kawashima (2005), who described these nerves as superior and inferior branches that arose from the vagus nerve and the RLN respectively.

The vagus nerve was found to contribute superior, middle and inferior cervical vagal cardiac rami in 19%, 34% and 69% of cases, respectively to the cardiac plexuses; these differed widely with the findings of Kawashima (2005) who described a 100% incidence ofboth the superior and inferior cardiac nerves. However, no middle vagal cardiac nerve was described in Kawashima‟s (2005) study.

5.7.2. THORACIC VAGAL CARDIAC NERVES

Kawashima (2005) described these nerves as arising from the vagus nerve when it curves to form the RLN. This study describes these branches as arising from the thoracic part of the vagus nerve based on Mitchell‟s description (1953).

Thoracic vagal cardiac rami were found in 48% of the specimens in this study; this differed from Kawashima‟s (2005) incidence of 77%. The thoracic vagal cardiac nervesin this study ranged from 1-5 branches (Figure 24). These findings concur with Kawashima (2005) and Randall and Armour (1977).

5.7.3.RECURRENT LARYNGEAL CARDIAC NERVES

These nerves have been described as cervicothoracic branches of the vagus nerve by Mizeres (1972) and were found to contribute chiefly to the DCP on the right side (Kawashima, 2005). Mitchell (1953) described these nerves as those that arose from the RLN to reach the cardiac plexus while San Mauro *et al*. (2009) only described the nerves that arose below the origin of the RLN as inferior cardiac nerves. In this study these are described as branches that arise from the RLN and contribute to the cardiac plexuses as described by Mitchell (1953) thus reflecting the discrepancy that exists in the nomenclature in the literature reviewed. The incidence of these nerves in this study was 28% with a lower incidence on the left side (3%) corroborating the findings from Kawashima (2005), in that the right side had a higher contribution to the DCP.

The incidence of RLCN in the present study was 48%. This differed from the incidence of 100% reported by Kawashima (2005). The SCP received no contributions from the RLN in this study confirming reports by standard anatomical literature (Romanes, 1968; Hollinshead, 1974; Standring *et al*., 2008). This study differs from the standard anatomical literature reviewed (Romanes, 1968; Hollinshead, 1974; Standring *et al*., 2008) as the RLN contributed 28 cardiac nerves to the DCP.

CHAPTER 6

CONCLUSION

6.1. CERVICAL SYMPATHETIC CHAIN

The course and relation of the cervical and thoracic sympathetic chains described in this study compare favourably with that reported in the current literature. This study records a single cervical sympathetic chain in 99% and a CSC made up of multiple branches in 1% of the specimens. This study does not record any incidence of a double CSC; however it has been described in some of the literature reviewed.

CERVICAL GANGLIA

This study describes cervical ganglia that vary from two to five; this confirms the previous findings in the literature. This study also confirms the constant presence of SCG and reports an incidence of MCG that is favourable to previous descriptions in the literature reviewed. The vertebral ganglion is described as a separate ganglion that is not a detached portion of the MCG nor is it a low type of MCG. The incidences of the ICG and CTG were unfavourable to incidences described by the literature reviewed.

6.2 THORACIC SYMPATHETIC CHAIN

The course and relations of the thoracic sympathetic chain concurred with standard anatomical literature.

THORACIC GANGLIA

This study confirmed the location of the second to fourth thoracic ganglia. This study also confirms the 100% incidence of the second to fourth thoracic ganglia.

6.3 CARDIAC PLEXUS

The cardiac plexus was described in terms of superficial and deep components in this study. Their locations confirmed those reviewed in literature.

6.3.1 SUPERFICIAL CARDIAC PLEXUS

This study describes a SCP related to the ascending aorta in 21% of our specimens, agreeing with Mizeres (1972). This study also agrees with standard anatomical literature with regards to the location of the SCP. Furthermore, this study differs with standard anatomical description of the contributions to the SCP and rather describes it as being formed predominantly by the inferior cervical vagal cardiac nerve and all cervical cardiac nerves.

6.3.2 DEEP CARDIAC PLEXUS

This study describes the location of the DCP as posterior to the arch of aorta and anterior to the tracheal bifurcation which is similar to the literature reviewed. However, this study differs with the standard anatomical literature in that it is formed by contributions from cervical and thoracic ganglia that do not contribute to the superficial cardiac plexus. This study found that cervical cardiac nerves inosculated in their course to the cardiac plexuses.

6.4 CERVICAL CARDIAC NERVES

This study describes varying incidences of cervical cardiac nerves compared to the 100% described in the literature. A vertebral cardiac nerve that originated from a separate vertebral ganglion to the cardiac plexus is also described. This appears to be a unique finding of this study.

6.5 THORACIC CARDIAC NERVES

This study describes an inferior limit of thoracic cardiac nerves to be the T4 and T5 interganglionic chain; this compared favourably to previous reports.

6.6 CERVICAL VAGAL CARDIAC NERVES

The cervical vagal cardiac nerves were described in terms of superior, middle and inferior vagal cardiac nerves according to Mitchell's description (1953). This study also describes the inferior cervical vagal cardiac nerve as the main contributor to the SCP.

6.6.1 THORACIC VAGAL CARDIAC NERVES

This study describes thoracic vagal cardiac rami that varied from 1-5 in numbers, this agreed with recent findings of other authors.

6.6.2 RECURRENT LARYNGEAL CARDIAC NERVES

This study describes cardiac nerves arising from the RLN that contributed to the DCP; the incidence of the occurrence of these was unclear in the literature reviewed.

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APPENDIX

APPENDIX A

Cervical sympathetic contributions to the cardiac plexus-Right

Specimen

Fetal	No.	AGE (wks)	SCG	IG	MCG	IG	VG	IG	ICG	IG	CTG	IG
Cohort 1	1	18	1	0	1	1	0	0	0	0	0	0
16-20wks	2	17	1	0	1	1	0	0	0	0	0	0
	3	18	1	1	0	0	0	0	0	0	0	0
	5	20	2	0	0	0	0	0	0	0	0	0
	7	19	1	0	1	1	1	0	0	0	1	0
	9	18	0	2	0	0	0	0	1	0	0	0
	17	20	2	1	1	0	0	0	0	0	0	0
	18	19	1	1	1	0	0	0	0	0	1	0
	20	17	1	1	1	0	0	0	0	0	0	0
	22	18	0	1	1	0	0	0	0	0	0	0
	23	19	0	1	1	0	1	0	0	0	0	0
	24	19	1	0	1	0	1	0	0	0	0	0
	25	20	0	1	0	0	0	0	0	0	1	0
	26	16	1	0	1	0	1	0	0	0	0	0
	28	18	1	1	1	0	1	0	0	0	1	0
	30	17	0	0	0	0	0	0	1	0	0	0
	31	16	1	2	0	0	1	0	0	0	0	0
	33	16	1	4	0	0	0	0	0	0	0	0
	34	19	2	0	2	0	0	0	0	0	0	0
	37	18	1	2	0	0	0	0	0	0	0	0
	38	19	1	0	1	0	0	0	0	0	0	0
	40	18	1	0	1	0	2	0	0	0	0	0

Cohort 2	4	25	1	1	0	0	1	0	0	0	0	0
21-25wks	6	25	1	0	1	0	0	0	0	0	0	0
	8	23	1	0	3	0	0	0	1	0	0	0
	10	21	1	2	0	0	1	0	2	0	0	0
	11	22	1	0	1	0	0	0	0	0	0	0
	13	22	0	1	0	0	0	0	1	0	0	0
	14	22	1	1	2	0	1	0	1	0	0	0
	15	22	0	1	0	0	2	0	0	0	0	0
	19	21	0	0	1	0	0	0	0	0	0	0
	21	24	1	0	2	0	1	0	0	0	0	0
	27	23	1	2	1	1	1	0	1	0	0	0
	29	23	0	1	2	0	0	0	0	0	0	0
	32	24	0	2	1	0	1	0	1	0	0	0
	36	23	2	0	2	0	0	0	0	0	0	0
	39	21	1	2	0	0	0	0	0	0	1	0
Cohort 3	12	27	1	1	0	0	0	0	0	0	0	0
26-30wks	16	27	1	0	2	0	0	0	0	0	1	0
	35	30	2	0	1	0	0	0	0	0	0	0
Adults	1		1	1	0	0	0	0	1	1	0	0
	2		0	1	0	0	1	0	0	0	0	0
	3		0	0	1	0	0	0	0	0	0	0
	4		3	0	1	0	0	0	0	1	0	0
	5		1	0	0	0	0	0	0	0	0	0
	6		0	0	0	0	0	0	0	0	0	0
	7		3	1	0	0	1	0	0	0	0	0
	8		2	0	1	0	0	0	0	0	0	0
	9		1	1	0	0	0	0	0	0	0	0
	10		0	0	1	0	1	0	0	0	0	0

APPENDIX B

Cervical sympathetic contributions to the cardiac plexus-Left

Specimen

Fetal	**No.**	**AGE (wks)**	**SCG**	**IG**	**MCG**	**IG**	**VG**	**IG**	**ICG**	**IG**	**CTG**	**IG**
Cohort 1	1	18	0	0	3	0	1	0	1	0	0	0
16-20wks	2	17	1	2	1	0	0	0	1	0	0	0
	3	18	2	1	2	0	0	0	0	0	1	0
	5	20	2	0	0	0	1	0	0	0	1	0
	7	19	1	0	1	1	0	0	0	0	0	0
	9	18	1	1	1	0	2	0	0	0	1	0
	17	20	2	1	4	0	0	0	1	0	0	0
	18	19	1	3	1	0	1	0	0	0	1	0
	20	17	2	1	1	0	0	0	0	0	0	0
	22	18	1	0	2	0	1	0	0	0	0	0
	23	19	1	1	1	0	0	0	0	0	0	0
	24	19	1	0	1	0	1	0	1	0	0	0
	25	20	3	1	1	0	0	0	0	0	0	0
	26	16	0	1	1	0	1	0	0	0	0	0
	28	18	1	1	1	1	0	0	0	0	0	0
	30	17	1	1	1	0	0	0	0	0	0	0
	31	16	1	2	0	0	1	0	0	0	0	0
	33	16	1	1	0	0	0	0	0	0	0	0
	34	19	2	0	1	0	0	0	1	0	0	0
	37	18	1	1	0	0	0	0	0	0	1	0
	38	19	0	2	1	0	0	0	0	0	0	0
	40	18	1	0	1	0	1	0	0	0	0	0

Cohort 2	4	25	2	0	2	0	0	0	0	0	1	0
21-25wks	6	25	1	0	1	0	1	0	0	0	0	0
	8	23	1	3	0	0	0	0	1	0	0	0
	10	21	1	2	1	2	1	0	0	0	0	0
	11	22	1	1	1	0	1	0	1	0	0	0
	13	22	1	1	1	0	0	0	0	0	1	0
	14	22	1	0	1	0	0	0	0	0	1	0
	15	22	2	0	1	0	1	0	0	0	0	0
	19	21	1	3	0	0	2	0	1	0	0	0
	21	24	1	0	4	0	0	0	0	0	1	0
	27	23	0	0	1	0	2	0	0	0	1	0
	29	23	0	2	2	0	0	0	0	0	1	0
	32	24	1	0	3	1	1	0	0	0	1	0
	36	23	3	0	0	0	2	0	0	0	0	0
	39	21	1	3	0	0	1	0	0	0	0	0
Cohort 3	12	27	3	1	1	0	1	0	1	0	0	0
26-30wks	16	27	3	3	0	1	0	0	0	0	1	0
	35	30	2	1	1	0	0	0	0	0	0	0
Adults	1		1	2	0	0	1	0	2	0	0	0
	2		0	0	1	0	1	0	0	0	1	0
	3		1	0	1	0	0	0	1	0	0	0
	4		3	1	0	0	0	0	0	0	0	0
	5		1	0	0	0	0	0	0	0	0	0
	6		0	1	0	0	0	0	0	0	0	0
	7		0	1	0	0	0	0	0	0	1	0
	8		0	2	0	0	1	0	0	0	0	0
	9		1	0	2	0	0	0	0	0	0	0
	10		0	2	0	0	0	0	0	0	0	0

APPENDIX C

Thoracic sympathetic contributions-Right

Fetal

No.	Age	**T1G**	**IG**	**T2G**	**IG**	**T3G**	**IG**	**T4G**	**IG**	**T5G**	**IG**	**T6G**	**IG**	**T7G**	**IG**	**T8G**	**IG**
Cohort 1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-20wks	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	18	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	24	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Cohort 2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-25wks	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0
	11	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	14	1	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0
	15	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	21	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	39	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cohort 3	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26-30wks	16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Adults	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX D

Thoracic sympathetic contributions-Left

Specimen

Fetal	No.	AGE (wks)	T1G	IG	T2G	IG	T3G	IG	T4G	IG	T5G	IG	T6G	IG	T7G	IG	T8G	IG
Cohort 1	1	18	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
16-20wks	2	17	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	3	18	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7	19	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	18	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
	17	20	1	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0
	18	19	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
	20	17	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	22	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	23	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	24	19	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	25	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	30	17	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	31	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	34	19	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	37	18	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0
	38	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	40	18	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0

Cohort 2	4	25	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-25wks	6	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	21	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
	11	22	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	13	22	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	14	22	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
	15	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	19	21	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
	21	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27	23	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
	29	23	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	32	24	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
	36	23	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	39	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cohort 3	12	27	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26-30wks	16	27	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	35	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Adults	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	6		0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	7		1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
	8		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX E

Parasympathetic contributions to the cardiac plexus-Right

Specimen

Fetal	No.	AGE		Vagus		Thoracic	RLN
			Superior	Middle	Inferior		
Cohort 1	1	18	0	0	1	3	1
16-20wks	2	17	0	0	0	3	0
	3	18	0	0	1	2	0
	5	20	0	0	2	3	1
	7	19	0	0	1	3	0
	9	18	0	0	1	1	1
	17	20	2	0	0	4	0
	18	19	0	1	1	2	0
	20	17	0	0	2	2	2
	22	18	0	1	1	1	2
	23	19	1	1	1	2	2
	24	19	0	0	1	3	0
	25	20	0	0	1	4	0
	26	16	0	0	1	2	1
	28	18	0	0	1	3	0
	30	17	0	0	0	3	0
	31	16	0	0	2	3	1
	33	16	0	0	1	2	1
	34	19	0	1	0	3	1
	37	18	0	1	1	2	1
	38	19	1	0	0	3	1
	40	18	0	1	1	2	0

Cohort 2	4	25	0	1	0	2	0
21-25wks	6	25	0	1	1	2	1
	8	23	0	0	1	3	0
	10	21	1	0	1	5	1
	11	22	0	0	1	3	1
	13	22	1	0	0	2	1
	14	22	1	0	0	4	0
	15	22	1	1	1	2	1
	19	21	0	0	1	2	0
	21	24	0	1	1	2	1
	27	23	0	0	1	1	1
	29	23	0	0	1	2	1
	32	24	0	0	1	3	0
	36	23	0	0	0	3	1
	39	21	0	1	1	3	0
Cohort 3	12	27	0	1	1	4	0
26-30wks	16	27	0	1	1	3	1
	35	30	1	1	1	1	0
Adults	1		0	0	1	3	0
	2		0	0	1	3	0
	3		0	0	0	2	0
	4		0	0	1	0	0
	5		0	1	1	2	1
	6		0	0	0	3	0
	7		0	0	0	3	1
	8		0	0	1	3	1
	9		0	1	0	0	0
	10		0	0	1	3	0

APPENDIX F

Parasympathetic contributions to cardiac plexus-Left

Specimen							
Fetal	No.	**AGE**		**Vagus**		**Thoracic**	**RLN**
			Superior	**Middle**	**Inferior**		
Cohort 1	1	18	0	0	1	0	0
16-20wks	2	17	0	0	0	0	2
	3	18	1	0	0	0	0
	5	20	0	2	0	0	0
	7	19	1	0	0	0	0
	9	18	0	0	1	0	0
	17	20	0	1	1	0	0
	18	19	1	0	1	0	0
	20	17	0	0	0	0	0
	22	18	0	0	1	0	0
	23	19	0	1	0	0	0
	24	19	1	0	0	0	0
	25	20	0	0	0	0	0
	26	16	0	1	1	0	0
	28	18	0	0	1	0	0
	30	17	0	1	1	0	0
	31	16	0	1	0	0	0
	33	16	0	0	1	0	0
	34	19	0	1	1	0	0
	37	18	0	0	1	0	0
	38	19	0	0	0	0	0
	40	18	0	0	1	0	0

Cohort 2	4	25	1	0	1	0	0
21-25wks	6	25	0	0	1	0	0
	8	23	1	0	1	0	0
	10	21	0	1	1	0	0
	11	22	0	0	3	0	0
	13	22	1	1	0	0	0
	14	22	0	0	1	0	0
	15	22	1	0	1	0	0
	19	21	0	0	0	0	0
	21	24	0	1	1	0	0
	27	23	0	1	0	0	2
	29	23	0	1	1	0	0
	32	24	2	0	2	0	0
	36	23	0	2	1	0	0
	39	21	0	1	1	0	2
Cohort 3	12	27	1	0	1	0	0
26-30wks	16	27	1	1	0	0	0
	35	30	0	0	2	0	0
Adults	1		0	0	0	0	0
	2		0	1	1	0	0
	3		0	0	1	0	0
	4		0	0	1	0	0
	5		0	1	1	0	0
	6		0	0	2	0	0
	7		0	0	0	0	0
	8		0	0	0	0	0
	9		0	1	1	0	0
	10		0	0	2	0	0