

**ANATOMY OF THE LAMINA TERMINALIS AND THE CISTERNA
CHIASMATICA: A CADAVERIC STUDY AT THE UNIVERSITY
TEACHING HOSPITAL LUSAKA ZAMBIA**

**By
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**A dissertation submitted in partial fulfilment of the requirements for the
Degree of Master of Science in Human Anatomy**

**The University Of Zambia
Lusaka
2019**

DECLARATION

I Vivienne Nambule Syamuleya declare that this Dissertation represents my own work and that all the sources I have quoted have been indicated and acknowledged by means of complete reference. I further declare that this Dissertation has not previously been submitted for a Diploma or Degree or other qualifications at this or other University. It has been prepared in accordance with the guidelines for Master of Science Degree in Human Anatomy Dissertations of the University of Zambia.

Signed (Candidate) _____ **Date** _____

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APPROVAL

The University of Zambia approves this dissertation on the Anatomy of the Lamina Terminalis and Cisterna Chiasmatica a Cadaveric Study in a Zambian population in partial fulfillment of the Master of Science Degree in Human Anatomy.

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ABSTRACT

The Lamina Terminalis represents an important neuroanatomical structure by which third Ventriculostomy could be performed into the subarachnoid space (Cisterna Chiasmatica). Recent studies have indicated a role for LT fenestration in approaching pathologies of the third ventricle. However, there is limited knowledge on the anatomical features, variations and the vasculature of the LT in a Zambian population. This study was aimed to explore the anatomy of the Lamina Terminalis, the Cisterna Chiasmatica and its neurovascular relationships as seen in a Zambian population and compare with the findings in the literature. This was a descriptive cross-sectional design in which 32 post-mortem human cadaveric brains were systematically sampled. The LT region was examined in 27 male cadavers and five female cadavers of age range 25 and 66 years (mean 34.05 ± 9.24 years). Data was collected using a data collection form, entered and analyzed by descriptive statistics using Statistical Package for Social Sciences (SPSS) software version 22. Mean and standard deviations were used to describe variables. The base of the brain was detached from the floor of the cranial cavity and the LT exposed fully by retracting both optic nerves and the optic Chiasma posteroinferiorly. The triangular LT measurements were performed as the distance between the midportion of the upper aspect of the chiasma and the lower aspect of the anterior commissure (height), which averaged 8.62 ± 1.00 mm. The distance between the medial edges of the optic tracts (base) averaged 13.11 ± 1.12 mm and the area averaged 56.93 ± 11.56 mm². The LT membrane showed variations in appearance; 20 were transparent with a large dark midline gap and 10 were less transparent with a slender midline gap and two were indistinct. The Cisterna Chiasmatica was observed as a dilated subarachnoid space adjacent to the Optic Chiasma. For neurovascular relationships, 24 cadavers showed arterioles arising from the posterosuperior aspect of the anterior cerebral artery to perforate the anterior perforating substance(s), supplying the chiasma, and optic tracts; whereas, eight cadavers showed arterioles arising posteroinferiorly and ramifying on the LT. The LT membrane is variably developed. There are variations in the membrane appearance, measurements and neurovascular relationships. These findings will supplement a knowledge gap in neuroanatomy and help prevent complications during Lamina Terminalis fenestration in approaching pathologies of the third ventricle.

Key words: *Lamina Terminalis, Cisterna Chiasmatica, Third Ventriculostomy*

DEDICATION

To God be the honor for the grace upon my life and the strength given to me to complete this dissertation.

To my siblings for their encouragement, support and prayers offered for me to complete this project.

To my loving and supportive husband for his love, patience, understanding encouragement, inspiration and support emotionally, spiritually and physically in my pursuit of this project.

I give glory to God for my wonderful and lovely children; Christine, Jonathan, Zewelangi and Joshua for their love, care, support, encouragement, prayers and containing with my absence in order for me to complete this project.

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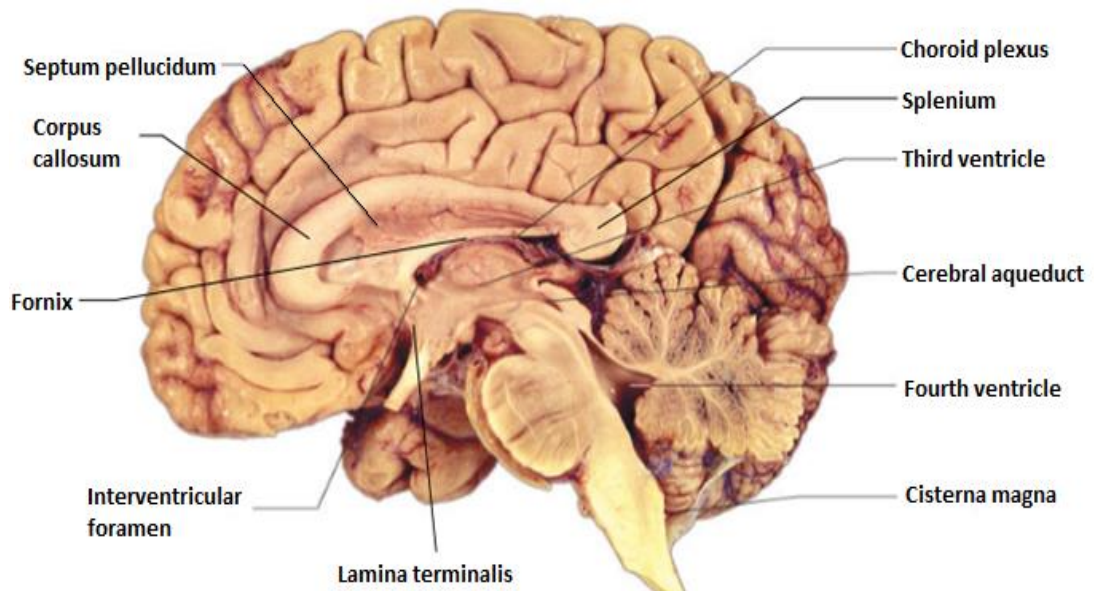
ABBREVIATIONS

LT	Lamina Terminalis
VPS	Ventriculoperitoneal Shunt
CSF	Cerebrospinal fluid
ETV	Endoscopic Third Ventriculostomy
AComA	Anterior Communicating Artery
ACA	Anterior Cerebral Artery
A1	First segment of ACA
OC	Optic Chiasma
AC	Anterior Commissure
CC	Cisterna Chiasmatica
CVO	Circumventricular Organs
UTH	University Teaching Hospital
SPSS	Statistical Package for Social Sciences

CHAPTER ONE

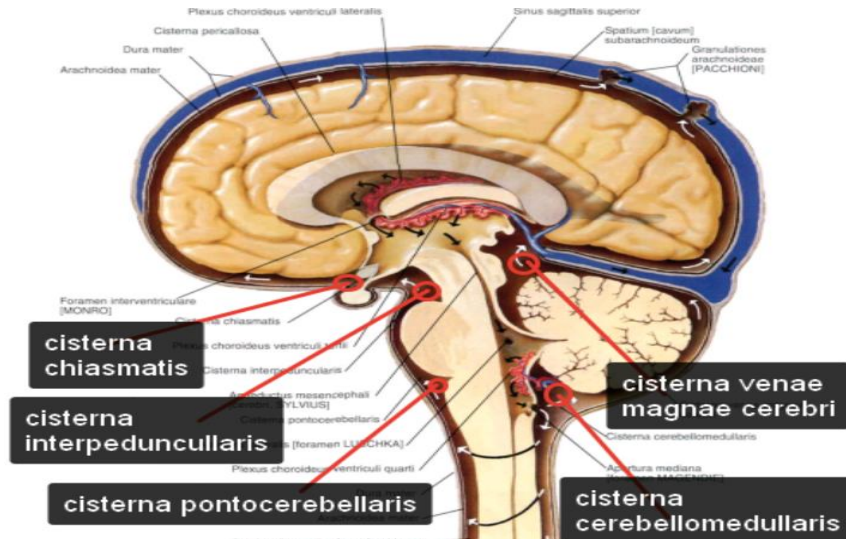
INTRODUCTION

The Lamina Terminalis (LT) represents an important Neuro-anatomical structure by which to fenestrate the third ventricle into the subarachnoid space through the Cisterna Chiasmatica (Tubbs 2012) as shown in Figure 1. The Cisterna Chiasmatica is a dilatation of the subarachnoid space, Figure 2 and lies adjacent to the Optic Chiasma filled with freely circulating cerebral spinal fluid (Siegel 2006). Rhoton (1987) described the LT as a triangular, transparent whitish membrane found at the base of the brain and forms the anterior wall of the third ventricle. It attaches to the upper surface of the Chiasma and stretches upward to fill the interval between the optic Chiasma and the corpus callosum (Retzius G, 1896). The LT and the Optic Chiasma (OC) form part of the anterior wall of the third ventricle visible on the surface, and when viewed from within, the boundaries of the anterior wall from superiorly to inferiorly are formed by the LT together with columns of the fornix, interventricular foramen (or foramen of Monro), the anterior commissure, optic recess, and optic Chiasma (Rhoton 1987). LT is also part of the Circumventricular organs (CVOs) which lies in the wall of the third ventricle and monitors chemical changes in the blood (Tortora and Nielsen 2012).



Source: He'caen H. *Neuroanatomy*

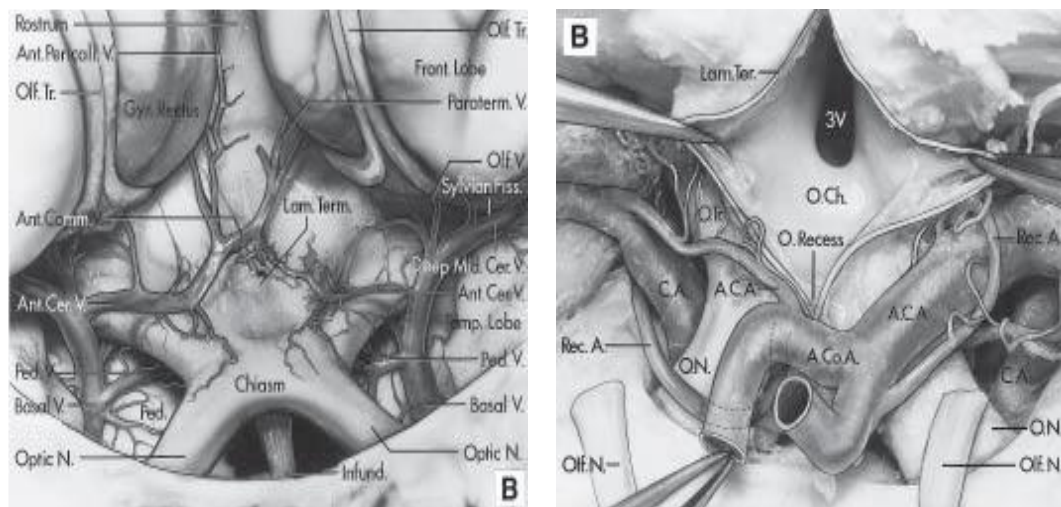
Figure 1: Lamina Terminalis forms the anterior wall of the third ventricle



Source: Illustrations by Frank H. Netter

Figure 2: Cisterna Chiasmatica

There are neurovascular structures that course adjacent to the LT as shown in Figure 3 such as the anterior communicating artery (A. Com A) which gives rise to a series of perforating arteries (Perf. A.) that enter the region of the anterior perforating substance on either side of the LT. The anterior cerebral (A.C.A.), recurrent (Rocha.), and anterior communicating arteries (AComA) are related to the LT; to expose the LT these structures have to be retracted. Other structures in the exposure include the optic nerves (O.N.), optic Chiasma (O.C.), and optic tracts (O.T) and olfactory nerves (Olf. N.).



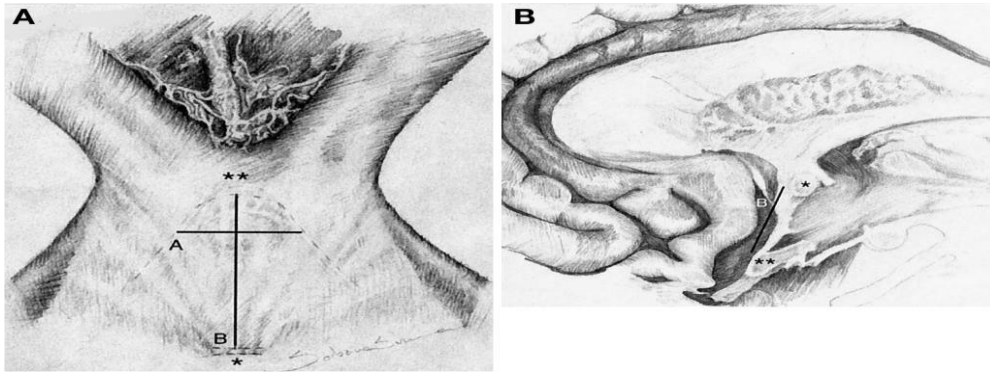
Source: Neurosurgery, Vol. 50, No. 3, March 2002

Figure 3: Lamina Terminalis with neurovascular structures: base of the brain

The anterior cerebral artery ascends in front of the LT and the anterior wall of the third ventricle, and passes around the corpus callosum.

De Divitiis *et al.*, (2002) reviewed the micro anatomic features of the LT and its neurovascular relationships. The authors examined ten cadaveric heads with particular attention to the structure of the presumed triangular shaped LT. Measurements were performed of the distance between the mid portion of the upper edge of the Chiasma and the lower edge of the anterior Commissure (height), which averaged 8.25 mm. The distance between the medial edges of the optic tracts (base) measured the average of 12.81 mm with an area averaging 52.84 mm². Tubbs *et al.*, (2012) in the anatomical study of the LT as a neurosurgical relevance in approaching lesions within and around the third ventricle explored the anatomy of the LT through micro dissection of twenty one adult cadaver heads with a focus on the working distance available to enter the third ventricle and related vascular structures. It was found that, inferior to the anterior communicating artery is a safe region; where there is lack of perforating arteries with a working distance of 1 cm through the LT and with such information neurosurgeons could be aided when carrying out procedures used to manage the lesions of the third ventricle through the LT. To indicate that the LT region is a safe region in approaching pathologies of the third ventricle during neurosurgery, Joachim *et al.*, (2010) opened the LT without causing injury to either the optic Chiasma or the anterior cerebral arteries in 4 human cadavers. The interest in this structure is based on recent observations indicating a role for LT fenestration in approaching pathologies of the third ventricle (Tomasello, 1999) considering that a variety of lesions can occur within the area of the third ventricle and the endoscopic LT opening in surgery may provide a safe and effective approach to treatment (Abdou, 2000).

De Divitiis *et al.*, (2002) calculated the linear dimensions of the LT as illustrated schematically in Figure 4 with the *anterior commissure* being presented with one star * and the *optic chiasma* being presented with two stars**.



Source: *Neurosurgery*. 2002 Mar; 50(3):563-9

Figure 4: artist's drawings illustrating the Lamina Terminalis base and height micro anatomic measurements in the axial (a) and sagittal (b) planes

*, anterior commissure; **, optic chiasm; A, base; B, height (figure 4)

In 2007, the Beit Cure Hospital (BCH) in Zambia introduced the Endoscopic Third Ventriculostomy (ETV) as primary management for selected cases of childhood hydrocephalus and it's currently being practiced in the Beit Trust/Cure Hospital and the University Teaching Hospital in Lusaka (Mweshi et al., 2010). Fenestration of the floor of the third ventricle is not without complications Garg et al., (2009) for instance difficulty in perforating the Liliequist membrane (imperforate), damage to hypothalamus and injury to vessels (basilar artery). It is for this reason that some studies have shown interest in the structure of the LT based on recent observations indicating a role for LT fenestration.

The aim of this study was to explore the anatomy of the LT, the CC and its neurovascular relationships as seen in a Zambian population and compare with the findings in the literature. Therefore identification of the features of the LT the structure of the adjacent CC is important in a specific population.

1.1 Statement of the Problem

Different surgical approaches to and through the LT have been proposed to treat pathologies of the anterior aspect of the third ventricle, however, the anatomy of the LT has not been extensively described (Spena, 2008). The LT represents an important neuroanatomical structure through which the cisterna Chiasmatica and the subarachnoid space can be accessed from the third ventricle.

A comprehensive review of its anatomy in the management of various pathologies is lacking in the literature (Tubbs, 2012).

The dimensions of the LT are such that an opening would permit adequate flow of cerebrospinal fluid from the third ventricle into the cisterna Chiasmatica and into the subarachnoid space thus draining excess fluid in the brain.

In our region hydrocephalus is one of the commonest neurosurgical conditions in children (Ryan *et al.*, 2016). Such children usually undergoing repeated surgical revisions as a result of complications that stands at 25.8 % in developing countries (Komolafe *et al.*, 2008).

According to Makani (2010) at the University Teaching Hospital, Lusaka, Zambia from September 2009 to August 2010 revision rates stood at 19.3% in children with hydrocephalus who were managed using the basic principle of shunting by placing one end of the shunt in the lateral ventricle and the other end tunnelled subcutaneously to an extra cranial site such as the peritoneal cavity.

However the major drawback of this technique was that a shunt was a foreign body associated with increased complications. Ventriculostomy obviates such complications as no shunt is implanted in the brain. In Zambia; Sub Saharan Africa; and Africa as a whole, there has been no adequate documentation and literature concerning the anatomy of the LT as a potential site for third Ventriculostomy which currently is performed through the floor of the 3rd ventricle but has also shortcomings (Garg 2009). It is for this reason that this research is to be conducted at the University Teaching Hospital, Lusaka, Zambia.

1.2 Significance of the Study

The LT is a structure of neurosurgical interest (de Divitiis *et al.*, 2002). The dimensions of the LT are such that an opening would permit adequate flow of cerebrospinal fluid from the third ventricle into the cisterna Chiasmatica and into the subarachnoid space thus draining excess fluid in the brain. Fenestration of the LT is a safe procedure, provided that the relevant anatomic landmarks are identified and respected (de Divitiis *et al.*, 2014).

There are also various surgical procedures to Ventriculostomy in managing certain pathologies of the third ventricle such as hydrocephalus (Spena, 2008). However; detailed anatomy of the LT needs to be extensively studied in order to avoid iatrogenic injuries to vital structures which are related to the LT. Precise knowledge regarding the normal anatomical features of the LT and CC is required, for such information may aid neurosurgeons to determine the appropriate approaches and the fenestration site safely (Tubbs *et al.*, 2012).

1.3 Research Question

What are the anatomical features of the LT and CC in a Zambian population?

1.4 General Objective

To explore the anatomical features of the LT and the CC in autopsy cases at the University Teaching Hospital, Lusaka, Zambia.

1.5 Specific Objectives

1. To establish the morphology of the LT and the CC
2. To estimate the length, base and area of the LT
3. To establish the relationship of the LT and CC to neurovascular structures.

1.6 Ethical Considerations

Approval was sought from ERES and the UTH Pathology department with Consent sought from the relatives. The cadavers were treated with respect during data collection and the results of the research was confined to this particular study. Safety measures were observed during the study in accordance with departmental guidelines.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The Lamina Terminalis (LT) attaches to the upper surface of the Chiasma and stretches upward to fill the interval between the optic Chiasma and the rostrum of the corpus callosum (Retzius, 1896). It gradually enlarges to the maximal width, and finally shrinks again to reach the anterior commissure (Rhoton 1987). The part of the anterior wall of the third ventricle visible on the surface is formed by the optic Chiasma and the LT, and when viewed from within, the boundaries of the anterior wall from superiorly to inferiorly are formed by the columns of the fornix, foramen of Monro, anterior Commissure, LT, optic recess, and optic Chiasma (Rhoton, 1987). Retzius (1896) more than one century ago described the LT as slightly bulging and extending from the divergent subcallosal gyri to the chiasma inferiorly and anteriorly and the middle of the LT was seen as a rhomboid or better pentagonal darker part surrounded by a delicate frame and giving off a whitish rod projecting upward. This is the transparent part of the LT. During brain embryology the LT develops from the telencephalon (Sadler, 2012). The LT is variably developed Retzius (1896). It may be quite large or of moderate size. In some cases it is, however, indistinct and less transparent or reduced to a slender midline gap of variable shape closed by the LT membrane. Whatever its size and development, the LT cerebri is of considerable morphological interest and it is one of the thinnest structures of the brain wall.

2.2 Circumventricular Organs

The LT is part of the Circumventricular organs (CVOs) which lie in the wall of the third ventricle and monitor chemical changes in the blood because they lack a blood–brain barrier. Functionally CVOs coordinate homeostatic activities of the endocrine and nervous systems, such as the regulation of blood pressure, fluid balance, hunger, and thirst. (Tortora and Nielsen 2012).

2.3 Commissure of the brain

The rostrum is the thin part of the anterior end of the corpus callosum, which is prolonged posteriorly to be continuous with the upper end of the LT. The anterior Commissure is a small bundle of nerve fibers that crosses the midline in the LT (Snells, 2010). Sadler (2012) explains that in adults, a number of fiber bundles, the commissures, cross the midline and connect the right and left halves of the hemispheres and the most important fiber bundles make use of the LT. The first of the crossing bundles to appear is the anterior commissure indicated in Figure 5 consisting of fibers connecting the olfactory bulb and related brain areas of one hemisphere to those of the opposite side. The second commissure to appear is the hippocampus commissure, or fornix commissures with whose fibers arise in the hippocampus and converge on the LT close to the roof plate of the diencephalon. From here, the fibers continue, forming an arching system immediately outside the choroid fissure, to the mammillary body and the hypothalamus. The most important commissure is the corpus callosum. It appears by the 10th week of development and connects the non-olfactory areas of the right and the left cerebral cortices. Initially, it forms a small bundle in the LT. These are the three commissures developing in the LT.

Source: Snell 2010 *Clinical Neuroanatomy*

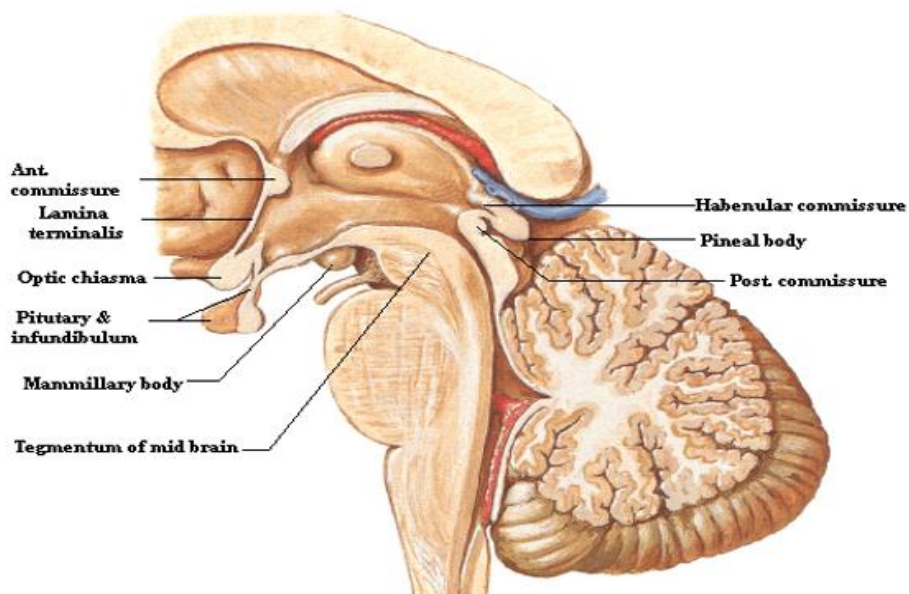


Figure 5: Hypothalamic lines of communication

2.4 Neurovascular structures

Rhoton (1987) explains the veins in relation to the LT stating that the anterior communicating (Ant. Comm. V.), Para terminal (Para term. V.) and anterior pericallosal veins (Ant. Pericall. V.) join the anterior cerebral veins in the region of the LT (Lam. Ter.). The anterior cerebral artery according to Rhoton (1987) ascends in front of the LT and the anterior wall of the third ventricle, and passes around the corpus callosum. Rhoton further points out that, the anterior cerebral and anterior communicating arteries give rise to perforating branches that terminate in the whole anterior wall of the third ventricle and reach the adjacent parts of the hypothalamus, fornix, septum pellucidum, and striatum. A precallosal artery may originate from the anterior cerebral or the anterior communicating artery, run upward across the LT, and send branches into the anterior wall of the third ventricle (Rhoton, 1987). The LT constitutes a clearly identifiable microsurgical target (deDivitiis *et al.*, 2014)

CHAPTER THREE

METHODS AND MATERIALS

3.1 Study Design

This was a cross-sectional descriptive study which was completed in six months.

3.2 Study Setting

The study was conducted at the University Teaching Hospitals (UTH), in the Department of Pathology. The site was selected purposely because of the nature of the study which had the focus on the cadaveric heads that were dissected during autopsy.

3.3 Study Population

The target population comprised both male and female human (forensic) cadavers between 25 and 75 years of age that underwent autopsy at the time of the study and met the eligible criteria. .

3.4 Sample size and Sampling technique

The sample size will be calculated using the formula;

$$N = \frac{Z^2 \times P(1-P)}{d^2}$$

N = Sample required

Z = Z statistic for a given level of confidence = 1.96 when using a 95% CI

P = expected prevalence of the condition in the population being studied; anatomy of the LT is 0.17%.

d = confidence interval, 0.05 (+/- 5%)

$$n = \frac{1.962 \times 0.17 \times (1 - 0.17)}{(0.05)^2}$$

$$n = 3.8416 \times 0.17 \times 0.83 / 0.0025$$

$$n = 0.5382 / 0.0025 = 215$$

$$n = n/1 + n/N$$

$$n = 215/1 + 215/30$$

$$n = 215/7.1 = 30$$

None response rate was calculated at 5%. $5/100 \times 30 = 2$ cadavers.

$$\text{Sample Size} = \underline{30 + 2 = 32}$$

3.5 Criteria for Selection

Age was obtained from the autopsy and police report files and for the purpose of identifying an ideal and representative sample for the study, the following inclusion and exclusion criteria was considered

3.5.1 Inclusion Criteria

1. Brains used were from both male and female cadavers between the ages of 25 and 75 years as most experts suggest that the brain is fully developed by age 25 (<https://mentalhealthdaily.com>>2015/02/18).
2. Cadavers were collected within 48 hours of death to avoid the natural decay process which sets in post-mortem.
3. All black Zambians

3.5.2 Exclusion Criteria

1. Damaged cadaveric heads either by trauma or a pathologic process leading to distortion of the brain morphology.

3.6 Data collection

Data was collected using a data collection form and sample selection was done through systematic sampling. The average number of forensic autopsy cases per month is 108, that is; 27 per week and 6 per day as recorded at the University Teaching Hospital, Lusaka. Thus data was collected every week, $27/6 = 4$. This implies that every fourth cadaver being dissected during autopsy was included in the study.

Serial numbers in place of names for confidentiality were used; age and gender were taken from police files and recorded as demographic data. The shape and appearance of the LT was recorded, height, base and area of the LT was measured, and neurovascular relationships of the LT and CC were noted and recorded.

3.7 Data collection tool

The tools used during dissection of the LT area, were a dissection kit, magnifying glass, digital camera and measurements of the LT height, and base were taken with a Vernier Caliper.

3.8 Procedure of Data Collection

The brains were removed intradurally. Each Calvarium was opened with a saw, the cut was made a fingers breadth above the orbit and extended a finger's breadth above the helix of the ear and through the lambdoid suture. Separation of the dura from the skull was done superiorly, anteriorly, laterally and posteriorly with a chisel. Falx cerebri was cut along its border just below the superior sagittal sinus to the posterior end of the straight sinus. Starting anteriorly the cerebral hemisphere was lifted from the anterior cranial fossa, the optic nerves were cut at the entrance to the optic canal and all other neurovascular structures attaching the brain to the base of the skull were divided. The brain stem was cut at the junction between spinal cord and medullar oblongata at the level of the foramen Magnum and the brain was lifted out of the skull. Following removal of the brain it was examined on the post-mortem table. The optic nerves and the optic Chiasma were retracted posteroinferiorly carefully to avoid damaging the delicate structures. The Vernier Caliper was used to obtain the measurements. The height and base of the LT were measured and the morphology with the neurovascular relationships was recorded with special attention given to the LT and CC structures.

The LT base and height anatomical measurements in the axial and sagittal planes were taken. The base (mm) was calculated as the distance between the medial edges of the optic tracts, and the height (mm) calculated as the distance between the midportion of the posterosuperior surface of the Chiasma and the anterior Commissure. The area of the LT (mm²) was also calculated. Distance of AComA to the LT (mm), and Length (mm) of OC to AC were measured and the shape of the LT was described. Photographs were taken after dissection using a digital camera. The photographs were later used to study the LT, the CC and the related structures in detail. The anatomical features of the LT and CC were observed and noted. The shape and dimensions of the LT area were measured using a Digital Vernier caliper.

The CC a dilated subarachnoid space was examined in particular with neurovascular structures adjacent to the LT. A Head held magnifying glass/loop was used to magnify minute structures.

3.9 Data Analysis Plan

Data variables included height, base, area, length, distance, and shape as independent variables and the LT as a dependable variable as indicated in Table 1. Data was analyzed by descriptive statistics using Statistical Package for Social Sciences (SPSS) software version 22 shown in Table 2. The data was analyzed using the mean and standard deviations.

Table 1: Variables

Independent variables	Scale of measure	Dependent
Length	Continuous	Lamina Terminalis
Base	Continuous	
Height	Continuous	
Distance	Continuous	
Area	Continuous	
Shape	Categorical	

Table 2: Data Analysis Plans

Statistical Package for social sciences version 22		
Goals of analysis	Normal distribution	Not normally distributed
To describe categorical variables Shape of LT	Chi-square	
To describe continuous variables Height of the LT (mm) Base of the L T (mm) Area of the L T (mm ²) Distance between AComA and LT Length of OC to AC	Mean + SD Mean + SD Mean + SD	Median + IQR Median + IQR Median + IQR

3.10 Limitations of the Research

The LT membrane is delicate and was difficult to access without mobilizing surrounding structures. Both optic nerves and the optic Chiasma were retracted posterior inferiorly to fully dissect and expose an intact structure without disrupting it. It was not easy to preserve all the small vascular branches intact. Time was limited as the bodies were being awaited for burial by relatives and for this reason the brain was removed intradurally other than extradural.

CHAPTER FOUR

DATA ANALYSIS AND PRESENTATION OF RESULTS

4.1 Introduction

In this chapter research findings have been presented using frequency tables, pie chart and figures using data which was collected through the data collection form.

4.2 Data Analysis

Data variables included *height, base, area, length, distance, and shape* as independent variables and LT as a dependable variable. Data was analyzed by descriptive statistics using Statistical Package for Social Sciences (SPSS) software version 22. The data was analyzed using the mean and standard deviations.

4.3 Presentation of results

The results of the study have been presented according to the morphometric and neurovascular relationships as recorded on the data collection form. Data is grouped according to the variables under discussion. The results are presented using the frequency Tables, pie chart and Figures with the mean and standard deviations being used to describe variables.

4.4 Dissemination of the results

The results of this study were presented at the postgraduate seminar week at the UNZA main campus and five copies were printed, bound and submitted to the School of Medicine, UNZA. Dissemination of the project results will be done to various other institutions such as the Ministry of Health, the University Teaching Hospital and other researchers and institutions.

4.5 Demographic Data and Morphometric of the Lamina Terminalis and Cisterna Chiasmatica

Demographic Characteristics

(a) Gender

The majority of the cadavers during the study were male as compared to female and this is evidenced in Table 3(a)

Table 3(a): Shows twenty-seven (84.4%) male and five (15.6%) female

Characteristics	Frequency	Percentage	Valid Percent	Cumulative Percent
Male	27	84.4	84.4	84.4
Female	5	15.6	15.6	100
Total	32	100	100	

(b) Age

The age range in the study was between twenty-five to sixty-six years of age (mean 34.05 ± 9.237 years) as shown in Table 3(b).

Table 3(b), Age range

Characteristic	Number	Minimum	Maximum	Mean	St. Deviation
Age	32	25	66	34.05	9.237

In all the thirty-two (100%) cadavers the LT was recorded as a paper thin membrane and triangular in shape and the CC was observed as a dilated subarachnoid space extending forward anterosuperior to the optic chiasma. In twenty (62.5%) cadavers the LT was seen as a transparent membrane, ten (31.25%) translucent membrane and two (6.25%) indistinct membrane as tabulated in Table 4

Table 4: Shape and Appearance of the L T and CC

Characteristics		Percent	Valid Percent	Cumulative Percent
Triangular shape	32	100	100	100
Appearance				
-Transparent	20	62.5	62.5	62.5
-Translucent	10	31.25	31.25	93.75
-Indistinct	2	6.25	6.25	100
CC- observed as dilated subarachnoid space	32	100	100	

4.6 Lamina Terminalis, Cisterna Chiasmatica and Neurovascular Relationships

The Lamina Terminalis is evidenced as a thin transparent membrane forming the anterior wall of the third ventricle as shown in Figure 6. The LT forms the base of the superior surface of the optic Chiasma. To fully expose the LT both optic nerves and the optic Chiasma were retracted posteroinferiorly.

The CC was observed as a dilated subarachnoid space extending forward anterosuperior to the optic chiasma. (Figure 6).

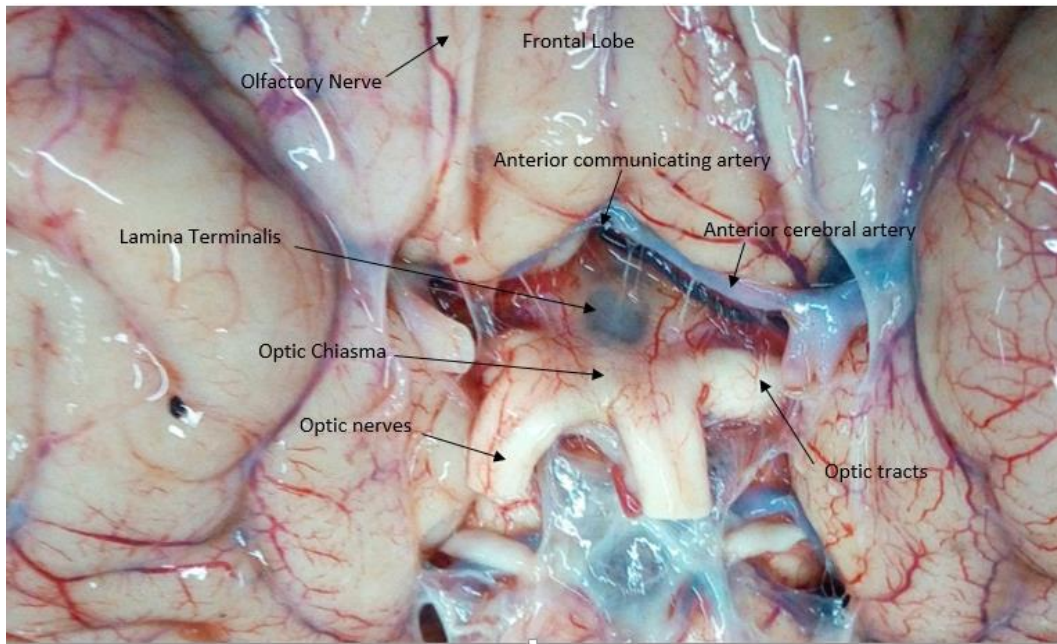
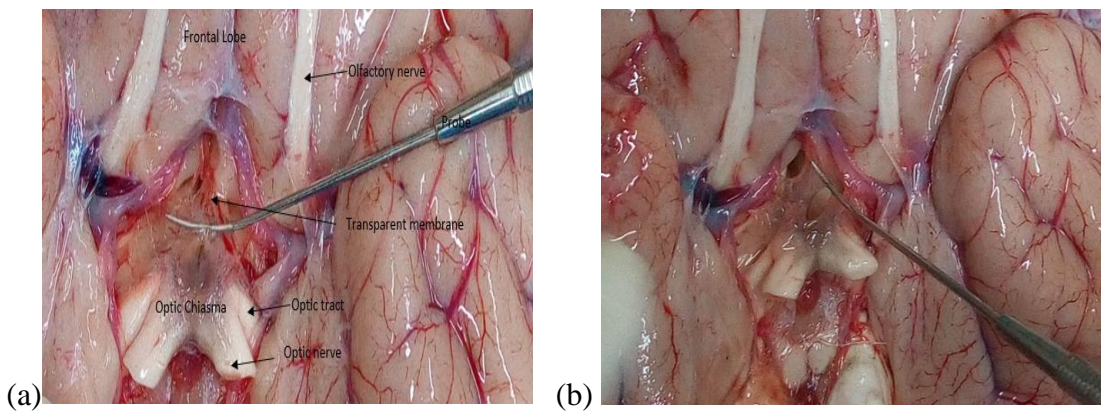


Figure 6: Morphology of the Lamina Terminalis and its neurovascular relationships

4.7 Lamina Terminalis membrane

Figure 7(a) and (b) shows the Lamina Terminalis as a paper thin transparent membrane lifted by a probe and it is triangular in shape with a wider base and narrow apex.



Figures 7 (a) and (b): Transparent Lamina Terminalis

4.8 Anterior end of the 3rd Ventricle

Figure 8 shows the LT at the base of the brain and forms the anterior wall of the third ventricle. In this figure the LT was opened to expose the cavity of the third ventricle (3V).

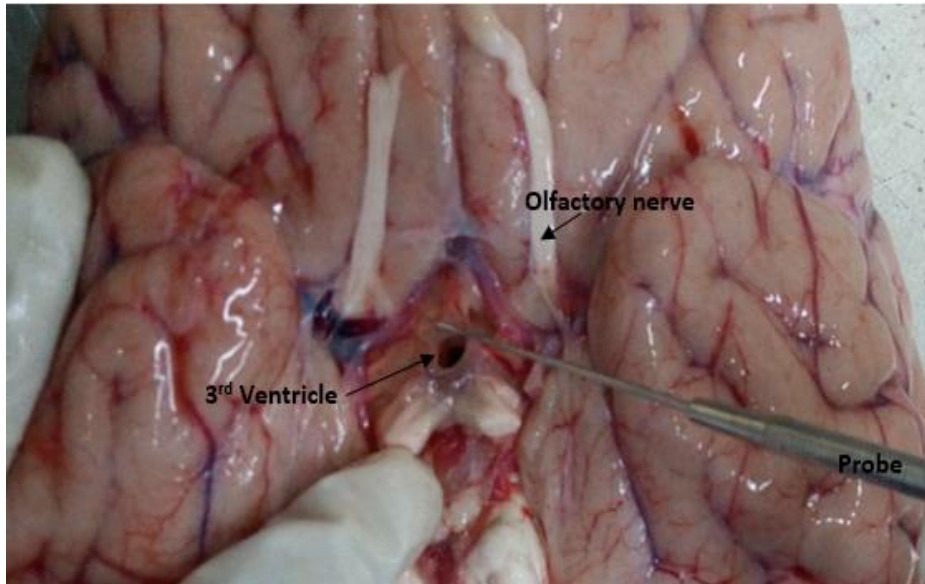


Figure 8: Third Ventricle

4.9 Variations of the Lamina Terminalis membrane

Figure 9 shows the LT variations with Picture (A) showing a large and transparent LT membrane, (B) has shown a less transparent and reduced to a slender midline gap while (C) is less distinct and less transparent. Optic nerves were cut and retracted to expose the LT fully.

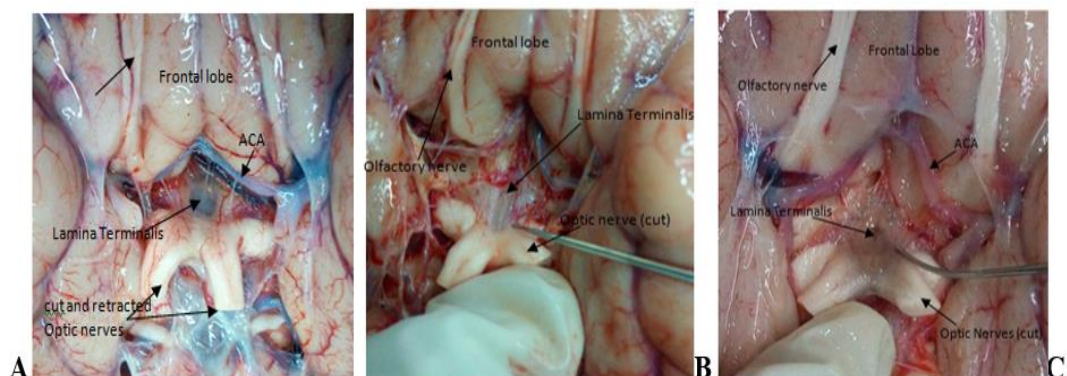


Figure 9: Variations of the Lamina Terminalis

4.10 Morphometry of the Lamina Terminalis

Figure 10 shows two planes in which the LT base and height were measured i.e. (a) and (b) respectively. The base was calculated as the distance between the medial edges of the optic tracts and the height was calculated as the distance between the mid portion of the anterosuperior surface of the Chiasma and the anterior commissure.

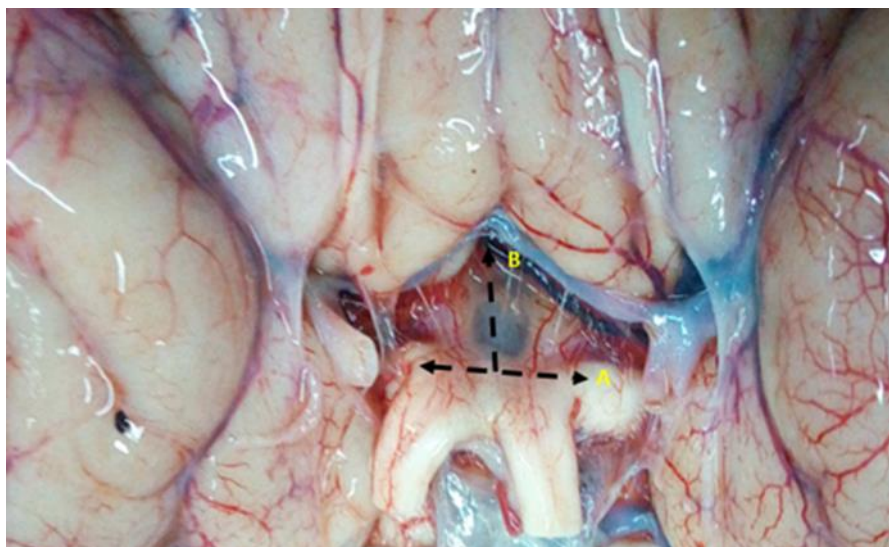


Figure 10: Dimensions for Lamina Terminalis measurements

Table 5 shows that the Height of LT (mm) in all the thirty-two cadavers ranged from 7.80 - 12.20mm (mean 8.62 ± 1.00 mm) whilst the Base ranged from 11.10 - 16.30mm (mean 13.11 ± 1.12 mm) and the Area ranged from 43.29 - 99.43mm²(mean 56.93 ± 11.56 mm²).

Table 5: Height, Base and Area of the Lamina Terminalis

Measurements	Number	Minimum	Maximum	Mean	Std.Deviation
Height of LT (mm)	32	7.80	12.20	8.62	1.00
Base of LT (mm)	32	11.10	16.30	13.11	1.12
Area of LT (mm ²)	32	43.29	99.43	56.93	11.56

In Table 6, the relationship between AComA and Lamina Terminalis is seen ranging from 7.80 - 15.00mm (mean 9.79 ± 1.98 mm)

Table 6: Relationship between AComA and Lamina Terminalis

Measurements	Number	Minimum	Maximum	Mean	Std. Deviation
Distance between AComA and LT (mm)	32	7.80	15.00	9.79	1.98

The relationship between the Optic Chiasma and Anterior Commissure in length as seen in Table 7 ranges from 7.80 - 12.20mm (mean 8.57 ± 0.93 mm).

Table 7: Relationship between the Optic Chiasma and Anterior Commissure

Measurements	Number	Minimum	Maximum	Mean	Std. Deviation
Length from OC to AC	32	7.80	12.20	8.57	0.93

Perforating Vessels from the Anterior Cerebral Artery as indicated in Table 8 shows that in twenty-four (75%) cadavers the Perforators from the anterior cerebral artery were found perforating the anterior perforating substance(s) whilst eight (25%) cadavers showed very small branches from the anterior cerebral artery ramifying on the Lamina Terminalis.

Table 8: Perforating Vessels from the Anterior Cerebral Artery

Area Perforated by ACA branches	Frequency	Percent	Valid Percent	Accumulative Percent
Anterior Perforating Substance	24	75	75	75
Lamina Terminalis	8	25	25	100
Total	32	100	100	

4.11 Perforating Vessels from the Anterior Cerebral Artery

The pie chart in Figure 11 indicates that twenty-four (75%) cadavers had small branches from the ACA perforating the Anterior Perforating Substance(s), lateral chiasma, and optic tracts. While eight (25%) cadavers had small arterioles ramifying on the Lamina Terminalis from the ACA segment A1.

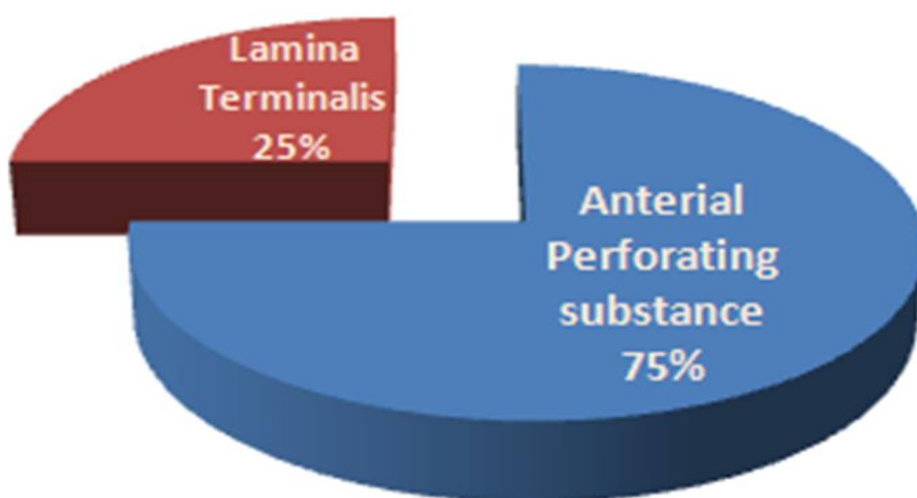


Figure 11: Perforating vessels

Small arteriole branches from the anterior cerebral artery segment A1 are seen ramifying on the Lamina Terminalis. (Figure 11 and Figure 12 respectively).

4.12 Few small branches, arterioles from ACA segment A1

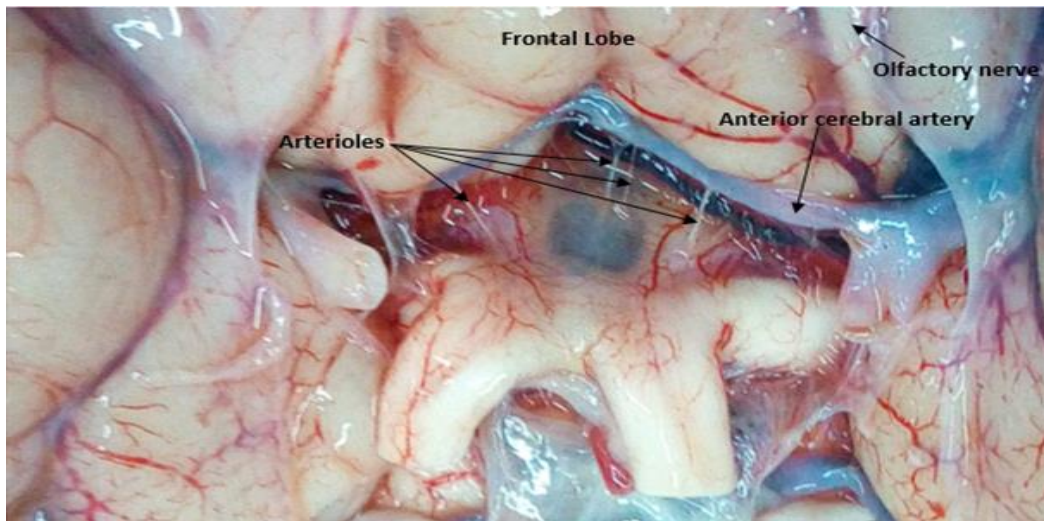


Figure 12: Arteriole branches from the ACA segment A1 ramifying on the Lamina Terminalis

4.13 Many small branches, arterioles from ACA segment A1

Figure 13 shows very small twigs and many in number (6-8 in number). These were arising from the posterior inferior surface of the ACA segment A1 to the superior surface of the chiasma and to the optic tracts.

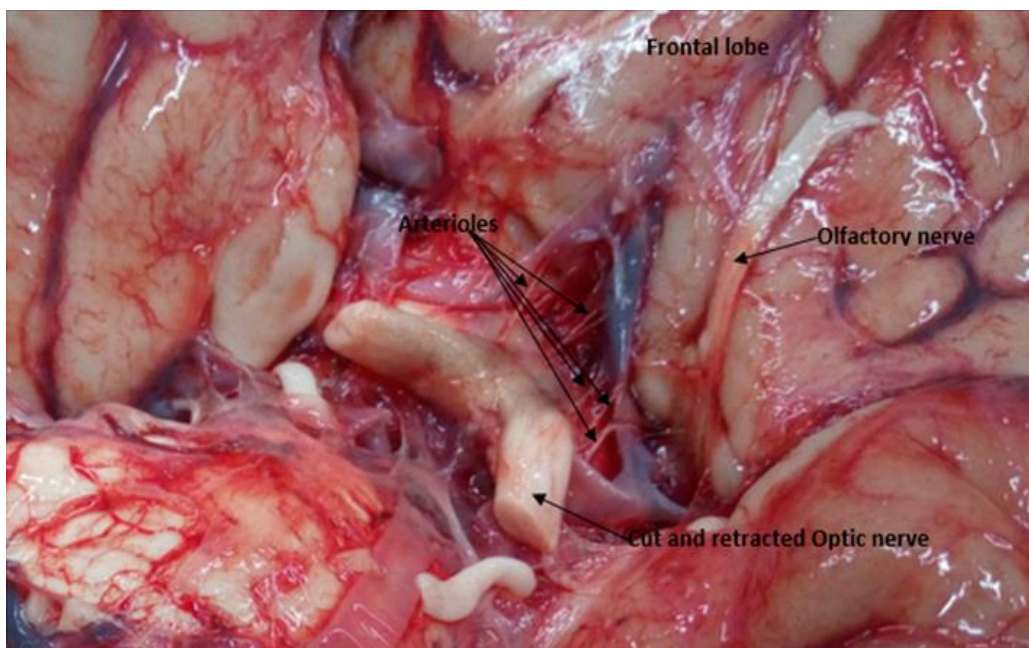


Figure 13: Arterioles from ACA (6-8in number) A₁ segment

CHAPTER FIVE

DISCUSSION OF THE FINDINGS

5.1 Introduction

This chapter discusses the results of the study on the anatomy of the LT and Cisterna Chiasmatica in a Zambian population. The aim was to explore the anatomy of the LT through cadaveric dissection and describe the morphometric and the neurovascular relationships. This study was conducted on thirty-two cadavers in a Zambian population and the findings were compared to the findings in other studies of different populations. Studies on the anatomy of the LT were found to be infrequent in the literature. The study was conducted at the University Teaching Hospital, Pathology department, Lusaka.

5.2 Demographic Characteristics

Gender

Table 1: Shows that the majority twenty-seven (84.4%) were male compared to five (15.6%) female cases and the reason being that during the time of study the frequency of male cases undergoing autopsy was higher compared to female cases. However no differences in the anatomy and measurements of the LT between males and females were noted in this study statistically.

Age

Table 2 shows that the age range was from twenty-five to sixty-six years (mean 34.05 ± 9.23 years). It is stated that although brain development is subject to significant individual variation, most experts suggest that the brain is fully developed by age twenty-five years (<https://mentalhealthdaily.com>>2015/02/18). This study was conducted at an age when the question of age affecting LT dimensions does not arise. In the study conducted by de Divitiis (2002), the author also chose this age range; equally Castilla (2012) in his study used the mean age of 28 years. They did not take into consideration the effect of age, and brain size on LT dimensions.

5.3 Morphology of the Lamina Terminalis

The results in Table 4 showed thirty two (100%) triangular shaped LT with a paper thin membrane variable in appearance. In twenty (62.5%) the LT membrane appeared transparent and in ten (31.25%) translucent membrane and two (6.25%) indistinct membrane. See figure 6, figure 7(a) and (b), figure 8 and 9(a), (b) and (c). The results are similar to the studies conducted by Retzius (1896) and Rhoton (1986). In all cases the Cisterna Chiasmatica was seen as a space extending forward anterosuperior to the optic chiasma. Retzius (1896) more than a century ago, described the LT as extending to the chiasma inferiorly and anteriorly, with a rhomboid or better pentagonal darker part, surrounded by a delicate frame, and had a transparent part. Retzius then stated that “Like most other rudimentary parts, the LT membrane has variations in development.

It may be quite large or of moderate size and whatever its size and development, the LT cerebri is of considerable morphological interest”. Rhoton (1987) also described the LT as a triangular, transparent membrane located at the base of the brain and formed the anterior wall of the 3rd ventricle. In both studies the LT was described as one of the thinnest structures of the brain wall.

5.4 Morphometry of the Lamina Terminalis

Results in table 5 showed the triangular LT measurements: Height ranged from 7.80 - 12.20mm (mean 8.62 ± 1.00 mm) the Base ranged from 11.10 - 16.30mm (mean 13.11 ± 1.12 mm) and the Area ranged from 43.29 - 99.43mm²(mean 56.93 ± 11.56 mm²). The results are within similar ranges with de Divitiis (2002) showing height range from 7.0- 10.0mm (mean 8.25mm), the base range from 8.0 – 18.5mm (mean 12.81mm) and the area range from 31.5 – 83.25mm² (mean 52.84mm²). Differences between Divitiis and this study was seen in the mean range of the area by 4.1 mm² larger in this study. Comparing the mean range of the height with Yamamoto and Lang the results showed; Yamamoto et al (1981) height ranging from 8.0 - 12.0mm (mean 10.0mm) whilst Lang (1985, 1992) showed height ranging from 5.0 - 16.0m (mean 10.85mm). Therefore results in the mean average of the height in Divitiis and this study are similar but with Yamamoto and Lang studies has shown a discrepancy of 2mm. Figure 10 shows two planes in which the LT base and height were measured in this study.

5.5 Neurovascular relationships

Results in table 7 of the current study showed the length from the Optic Chiasma to the Anterior Commissure as ranging from 7.80 - 12.20mm (mean 8.57 ±0.93mm) whilst distance between the AComA and the LT ranged from 7.80- 15.00mm (mean 9.79mm ±1.98mm). See table 6. The mean range in length from the Optic Chiasma to the Anterior Commissure in this study and that of de Divitiis (2002) show similar results whilst the mean range in distance between AComA and the LT between the two studies has shown a difference in results with this study having a longer distance by 6.29mm. To establish the neurovascular relationships de Divitiis (2002) measured the length from the Optic Chiasma to the Anterior Commissure which ranged from 7.00 - 10.00mm (mean 8.25mm) and the distance between AComA and the LT ranged between 0 - 14.00mm (mean 3.5mm).

5.5.1 Perforating Vessels

Results in Table 8 showed twenty-four (75%) posterior superior branches, arising from the ACA to perforate the Anterior Perforating Substance(s) and taking a similar course as in the study by Pai (2005) to supply the optic chiasma, anterior commissure, hypothalamus and the internal capsule while eight (25%) showed small arterioles arising from the posterior inferior surface of the ACA segment A1 to ramify across the LT. This is in contrast to Pia and other findings which do not indicate branches ramifying on the LT. (Figure 12).

A study by Pai (2005) discussed the *anterior cerebral artery segment A1 perforators*. The perforator arteries are divided into two groups, posterior inferior and posterior superior. Pai's findings showed that the Posteroinferior branches arise from the Posterior inferior surface of the ACA segment A1 and supplied the optic nerve, optic chiasma and sometimes the optic tract (Pai, 2005). These were situated more medially than laterally and were generally very small and few in number (2-3 per segment). The posterosuperior branches were said to arise from the posterosuperior surface of the A1 segment and course upwards and perforate the anterior perforating substance to supply the optic chiasma, the anterior commissure, the hypothalamus and the internal capsule.

Gomes et al (1986) also found that the perforating branches of the proximal segment of the anterior cerebral artery penetrated the brain at the anterior perforating substance(s), lateral chiasma, and optic tracts.

Salauud et al (2018) has also shown blood supply to the Optic Chiasma from the ACA, AComA and hypophyseal arteries. Although there have been many studies of the arterial cerebral blood supply, no literature has adequately focused on the vasculature of the LT structure.

De Divitiis (2002) found 70% of small arterial branches arising from the Posteroinferior aspect of the Anterior Communicating Artery entering the area surrounding the LT but none passed through the LT to enter the walls of the third ventricle. Cowell and Morawetz (2018) discussed that the dorsal branches of the AComA were followed to the LT, optic chiasma, hypothalamus, corpus callosum, and fornix. However, in our study none of the small branching vessels were observed to be ramifying on the LT from the Anterior Communicating Artery. Retzius (1896) indicated that the transparent part of the LT can be considered for incision because it constitutes the midline avascular area immediately above and anterosuperior to the optic chiasma; whereas the branches of the ACA-AComA complex which were directed to the optic chiasma and the hypothalamus were positioned laterally and thus would not interfere with the surgical procedure.

As shown in Figure 12 *small branches arising from the Posteroinferior surface of the anterior cerebral arteries ramified across the peripheral aspects of the LT as well as supplying the optic tract, optic chiasma and the optic nerves.* This finding shows arterial supply from the ACA to the LT through very small vessels and disregarding these small vessels in this area may cause unacceptable morbidity and mortality during surgery (Pia 2005), thus we concur with Retzius that surgical procedures should be confined to the central area of the LT to avoid such vessels.

5.6 Comparison of Previous Descriptions of the Lamina Terminalis and its Neurovascular Relationships with other studies: The descriptions of the Lamina Terminalis and its Neurovascular Relationships in the current study has been compared with other studies in literature as tabulated in Table 9 and Table 10

Table 9: The Lamina Terminalis Morphometry compared with other studies.

Measurements	Yamamoto et al 1981	Lang 1985, 1992	Serizawa et al 1997	de Divitiis 2002	Present Study
Height (length) of LT mm	10(8.0-12.0)	10.85(5.0-16.0)	Not reported	8.25(7.0-10.0)	8.62(7.80-12.20)
Base of LT mm	Not reported	Not reported	Not reported	12.81(8.0-18.5)	13.11(11.10-16.30)
Area of LT mm ²	Not reported	Not reported	Not reported	52.84(31.5-83.25)	56.93(43.29-99.43)
A Com A distance to LT mm	Not reported	Not reported	30% over LT	3.5(0-14)	9.79(7.80-15.00)

Table 10: Summary of Relevant Data on Lamina Terminalis and Neurovascular Relationships

Measurements	de Divitiis	Present Study
Length of OC to AC -	8.25 (7 - 10) mm	8.57 (7.80 – 12.20) mm
Area (Base x ½ Height)	52.84 (31.5 - 83.25) mm ²	56.93 (43.29 – 99.43mm ²)
Distance between AComA and LT -	3.5 (0 – 14) mm	8.57 (7.80 – 12.20) mm
No. of Perforators - from AComA - from ACA	6 in 20 6 0	8 in 32 0 in 32 8 in 32 (6-bothRight and Left sides 2-Right side only)

5.7 Conclusion

The Lamina Terminalis membrane is variably developed with variations in the membrane appearance, measurements and neurovascular relationships. These findings will supplement a knowledge gap in neuroanatomy and help prevent complications during Lamina Terminalis fenestration in approaching pathologies of the third ventricle.

5.8 Recommendations

1. It is recommended that other studies should be conducted in formalin embalmed brains in a controlled environment which will offer more flexibility with time.
2. Extradural approach to the removal of the brain with an extended posterior craniectomy should be considered. Such a method is less likely to distort basal structures of the brain.
3. Focused studies should be done on the vascularization of the LT.
4. Further studies should be conducted to investigate the variations of the LT

5.9 Utilization and dissemination of results

1. The anteroinferior region of the third ventricle known as the hypothalamus is the location of the autonomic centre of the brain. There is limited knowledge on the dimensions, variations and vasculature of the LT which forms the rostral termination of the hypothalamus. The results of this study will supplement a knowledge gap in neuroanatomical studies of the region.
2. Such knowledge can offer surgeons' potential alternative approaches to the formation of Third Ventriculostomy in the management of pathologies of the third ventricles such as hydrocephalus.

Results of the study will be presented at the post-graduate seminar week in October 2018 at the University of Zambia, main campus and to the Department of Surgery, University Teaching Hospital, Lusaka. The research article will be submitted for possible publication in journals such as the *Zambian Medical Journal*, the *E-Journal of Zambia (UNZA)* and *International Anatomical or surgical journals*.

The researcher will disseminate the results of the study by submitting bound copies of the study documents to the following: University of Zambia Medical library and the main campus Library, School of Medicine, Ministry of Health, University Teaching Hospital, Lusaka and where relevant to other medical Education Facilities/ Institutions.

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APPENDIX 1: Approval letter from Assistant Dean Post Graduate



UNIVERSITY OF ZAMBIA SCHOOL OF MEDICINE

Telephone : +260211252641
Telegram: UNZA, Lusaka
Telex: UNZALU ZA 44370
Email: assistantdeanpgmedicine@unza.zm

P.O Box 50110
Lusaka, Zambia

5 January 2018

Mrs. Syamuleya Nambule Vivienne
Department of Anatomy
University of Zambia
LUSAKA

Dear Mrs. Syamuleya

RE: GRADUATE PROPOSAL PRESENTATION FORUM

Following the presentation of your proposal entitled "Anatomy of the Lamina Terminalis and Cisterna Chiasmatica: A Cadaveric Study at the University Teaching Hospital, Lusaka Zambia" your supervisor has confirmed that the necessary corrections to your research proposal have been done.

You can proceed and present to the Research Ethics.

Yours Sincerely

A handwritten signature in black ink, appearing to read "Prashar".

Dr. Lavina Prashar
Assistant Dean, Postgraduate



cc: HOD – Anatomy

APPENDIX 2: Approval letter from Eres Converge



33 Joseph Mwilwa Road
Rhodes Park, Lusaka
Tel: +260 955 155 633
+260 955 155 634
Cell: +260 966 765 503
Email: eresconverge@yahoo.co.uk

L.R.B. No. 00005948
E.W.A. No. 00011697

25th January, 2018

Ref. No. 2017-Nov-025

The Principal Investigator
Ms. Vivienne Nambule Syamuleya
The University of Zambia
School of Medicine
Dept. of Human Anatomy
P.O. Box 50110,
LUSAKA.

Dear Ms. Syamuleya,

**RE: ANATOMY OF THE LAMINA TERMINALIS AND THE CISTERNA
CHIASMATICA: A CADAVERIC STUDY AT THE UNIVERSITY TEACHING
HOSPITAL, LUSAKA.**

Reference is made to your corrections dated 19th January, 2018. The IRB resolved to approve this study and your participation as Principal Investigator for a period of one year.

Review Type	Ordinary	Approval No. 2016-Nov-025
Approval and Expiry Date	Approval Date: 25 th January, 2018	Expiry Date: 24 th January, 2019
Protocol Version and Date	Version - Nil	24 th January, 2019
Information Sheet, Consent Forms and Dates	• English.	24 th January, 2019
Consent form ID and Date	Version - Nil	24 th January, 2019
Recruitment Materials	Nil	24 th January, 2019
Other Study Documents Questionnaires,	Data Collection Sheet.	24 th January, 2019
Number of participants approved for study	-	24 th January, 2019

Specific conditions will apply to this approval. As Principal Investigator it is your responsibility to ensure that the contents of this letter are adhered to. If these are not adhered to, the approval may be suspended. Should the study be suspended, study sponsors and other regulatory authorities will be informed.

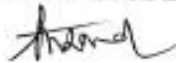
Conditions of Approval

- No participant may be involved in any study procedure prior to the study approval or after the expiration date.
- All unanticipated or Serious Adverse Events (SAEs) must be reported to the IRB within 5 days.
- All protocol modifications must be IRB approved prior to implementation unless they are intended to reduce risk (but must still be reported for approval). Modifications will include any change of investigator/s or site address.
- All protocol deviations must be reported to the IRB within 5 working days.
- All recruitment materials must be approved by the IRB prior to being used.
- Principal investigators are responsible for initiating Continuing Review proceedings. Documents must be received by the IRB at least 30 days before the expiry date. This is for the purpose of facilitating the review process. Any documents received less than 30 days before expiry will be labelled "late submissions" and will incur a penalty.
- Every 6 (six) months a progress report form supplied by ERES IRB must be filled in and submitted to us.
- ERES Converge IRB does not "stamp" approval letters, consent forms or study documents unless requested for in writing. This is because the approval letter clearly indicates the documents approved by the IRB as well as other elements and conditions of approval.
- Every 6 (six) months a progress report form supplied by ERES IRB must be filled in and submitted to us. Late submission of these will attract a penalty.

Should you have any questions regarding anything indicated in this letter, please do not hesitate to get in touch with us at the above indicated address.

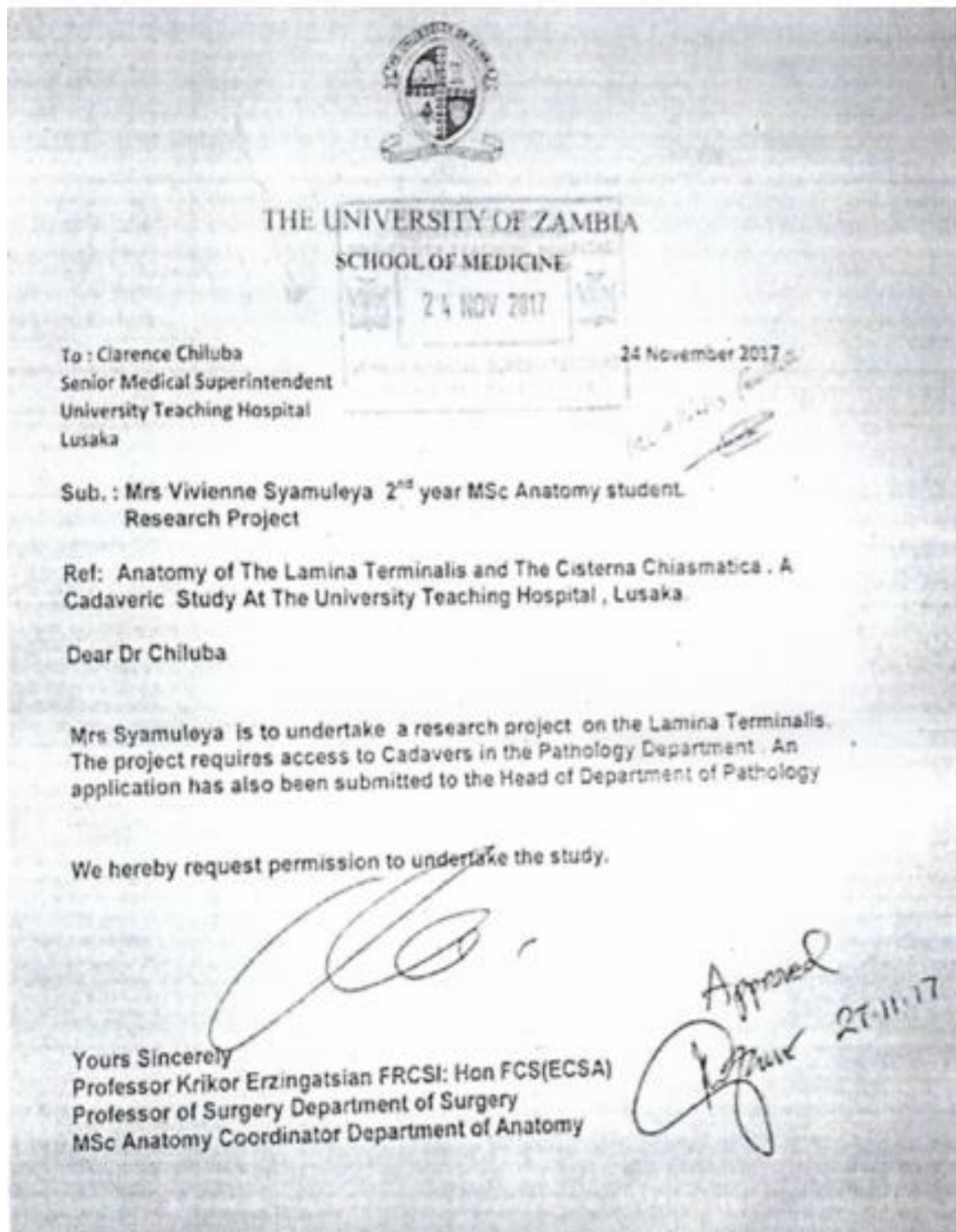
On behalf of ERES Converge IRB, we would like to wish you all the success as you carry out your study.

Yours faithfully,
ERES CONVERGE IRB



Prof. E. Munalula-Nkandu
BSc (Hons), MSc, MA Bioethics, PgD R/Ethics, PhD
CHAIRPERSON

APPENDIX 3: Letter of permission and approval to conduct research at UTH.



APPENDIX 4: Participant Information Sheet

Participant Information Sheet

I Vivienne Nambule Syamuleya, a 2nd year student at the University of Zambia (Ridgeway campus) school of medicine, am expected to carry out a research study in partial fulfillment of the requirements for Masters of Science in Human Anatomy. This will contribute to the body of knowledge and health delivery in our country.

The aim is to describe the anatomical features of the Lamina Terminalis (LT) and Cisterna Chiasmatica: a cadaveric study in both male and female falling under the forensic post-mortem cases at the University Teaching Hospital (UTH).

Your authorization of your deceased relative's body to be used in this study will permit the researcher to open the skull with the use of a chisel and extract the brain. The brain will be removed from the skull and examined on the post-mortem table with special attention given to the Lamina Terminalis and Cisterna Chiasmatica which are structures of neuroanatomy interest guiding neurosurgery and found at the base of the brain. Careful dissections (cutting) will be done to avoid injuries to the surrounding tissues. The whole procedure will take 30 minutes. Photographs will be taken after dissection using a digital camera. The shape and dimensions of the LT area will be measured using a Digital vernier caliper. The CC structures will be examined in particular with nerves and vessels adjacent to the Lamina Terminalis. Your agreement to allow the body to participate in this study is purely voluntary and the information that you will provide will be confidential. Serial numbers will be used in place of the deceased's name to avoid identification. All detailed information of the body will be recorded on a form and kept secure that no one will have access to it. You may withdraw the deceased's body from the study at anytime that you wish to do so and this will not affect your future medical care.

Be informed that there is no monetary or material gain in participating in this study as it is purely an academic exercise.

APPROVED

25 JAN 2019

ERES CONVERGE
P/BAG 125. LUSAKA.

CONTACT

The Secretary
ERES CONVERGE RIB
33 Joseph Mwilwa Road
Rhodes Park
Lusaka
Tel: 0955155633/4
E-mail: eresconverge@yahoo.co.uk

Vivienne Nambule Syamuleya
University of Zambia
School of Medicine
Department of Anatomy
P/Bag RW IX
Lusaka.

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25 JAN 2017

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APPENDIX 5: Consent form

Study Title: Anatomy of the Lamina Terminalis and Cisterna Chiasmatica: A Cadaveric Study at the University Teaching Hospital.

Consent record form (To be kept by Researcher)

I confirm that I have fully read and understood the information I have been presented with about the whole study. I agree that the body of my relative is used in the study and I confirm that it is out of my free will without being influenced that the body of my relative is used in the study. I can withdraw the body at any time I feel like without affecting my rights of medical care available to me. I understand what will be required of the body.

Name.....

Signature (or thumbprint).....

Date.....

Signature (or thumbprint) witness.....

Name.....

Date.....

I the member of the study team. I confirm that I have explained information fully and Answered any question.

Signed for the study team

Name.....

Date.....

APPENDIX 6

Data collection sheet

Table 1. Description of LT

MORPHOMETRIC OF LAMINA TERMINALIS									
S/N	SEX	AGE	D.O.D	C.O.D	SHAPE	LENGTH	BASE	AREA	THICKNESS
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

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Data collection sheet

Table 2. Description of related structures of the LT and CC

NEUROVASCULAR RELATIONSHIPS								
S/N	SEX	AGE	AComA	Lamina Terminalis	Cisterna Chiasmatica	Lamina Terminalis	Optic Chiasma	Anterior Commissure
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

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APPENDIX 7: Dissection Instruments, magnifying glass and Digital Vernier Calliper used to measure the height and base of the Lamina Terminalis

