A CADAVERIC STUDY OF SURGICAL ANATOMY OF THE OBTURATOR NERVE IN THE ADULT KENYAN POPULATION

BY

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A THESIS SUBMITTED TO THE SCHOOL OF MEDICINE IN PARTIAL FULFILLMENT FOR THE AWARD OF DEGREE OF MASTER OF MEDICINE IN ORTHOPEDIC SURGERY OF MOI UNIVERSITY.

DECLARATION

Declaration by candidate

I declare that this thesis is my original work and has not been submitted elsewhere for any academic purpose or research in any institution of higher learning.

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DEDICATION

This study is dedicated to the donors of cadavers to the Department of Human Anatomy Moi University, School of Medicine.

LIST OF ABBREVIATIONS

IREC Institutional Research and Ethics Committee

MTRH Moi Teaching and Referral Hospital

ORIF Open Reduction and Internal Fixation

SPSS Statistical package for social sciences

DEFINITION OF TERMS

Adult: Person who is 18 years and above**.**

Cadaver: Dead human body used in scientific or medical research

Course: The route or direction followed by a nerve.

Distribution: The area supplied by a nerve.

Surgical Anatomy- the application of knowledge of the course, branching patterns and distribution of obturator nerve to surgery.

ACKNOWLEDGEMENT

I would like to thank my supervisors Prof M.G.Y. EL-Badawi and Dr. Ayumba, B. R. for their guidance, support and contribution towards this proposal, Mr Mwangi Henry and Prof. Anne Mwangi for guiding me through the statistical aspects, my family and colleagues for their unyielding support throughout the duration of this proposal.

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ABSTRACT

Background: Anatomical ethnic variations of the obturator nerve have been described in other populations. Chronic groin pain especially in athletes due to obturator nerve neuropathy has been reported in local population. Iatrogenic injury to the nerve has also been documented especially in acetabular reconstruction. Good anatomical understanding and relevance in surgical approaches and intervention in situations such as pelvic fractures, acetabular labral cysts, obturator nerve ganglions among others are important.

Objective: To determine the variations in the course of obturator nerve main trunk, level of division into anterior and posterior branches and distribution of branches in the adult Kenyan population.

Methods: Anatomical descriptive cross-sectional study done at Human Anatomy Laboratory, Moi University, involved census of sixty adult black Kenyan specimens which were dissected from obturator nerve main trunk, divisions, and distribution of anterior and posterior branches. Location of the nerve in obturator foramen was measured in relation to most medial, inferior and superolateral points. Photography done and data recorded in a structured data collection sheet. Analysis for variables was done using STATA version 13 SE and presented in prose and diagrams. Comparison of the measurements between the sexes and left and right side were done using two sample ***t***-tests.

Results: Main trunk emerged from the medial border of the psoas major muscle, descended on the lateral wall of the lesser pelvis towards the obturator foramen. Intatrapelvic branch to the obturator externus occurred in 3.33% of specimens.The nerve exited obturaor canal at mean distance of 14.95mm from the most medial point of obturator foramen. Majority divided into anterior and posterior branches in the obturator canal at 88.3% and in the thigh at 11.7%. Anterior division branches innervated all of adductor longus, gracilis, 98.3% of adductor brevis and 6.7% of pectineus in all specimens recorded. Supply to adductor longus and gracilis were from the same division in 70% with the rest arising independently from the anterior division branches. The posterior division branches supplied adductor magnus in all specimens, 1.7% of adductor brevis specimens and all of obturator externus. Articular branch in the specimens came from anterior division branches in 60%, 30% from common trunk and 10% from posterior division branches. No statistical difference between the sexes and the sides were noted as shown by the p-values.

Conclusion: Intrapelvic branch to obturator externus is present in local population. The division into anterior and posterior in majority occurred within the obturator canal. Anterior division branches supplied adductor longus, gracilis, most of adductor brevis and occasionally pectineus. Posterior division branches supplied adductor magnus, obturator externus and rarely adductor brevis.

Recommendations: Surgeons should be aware of variations in obturator nerve main trunk, divisions, and branches during surgery. The most medial and most inferior points of the obturator foramen allow for safe transforaminal procedures.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

The obturator nerve arises from the ventral division of the second to fourth lumbar ventral rami (Horwitz, 1939). The obturator nerve descends within the substance of psoas major to emerge from its medial border at the level of the pelvic brim. It crosses the sacroiliac joint behind the common iliac vessels and lateral to the internal iliac vessels. It then descends on the lateral wall of the lesser pelvis covered by the fascia over obturator internus and lies anterosuperior to the obturator vessels before running into the obturator foramen, entering the thigh by its upper part. It has no branches in the abdomen or pelvis. Near the foramen, it divides into anterior and posterior branches which are separated at first by part of obturator externus and more distally by adductor brevis (Standring, 2015)

1.1.1 Anterior branch

The anterior branch leaves the pelvis anterior to obturator externus, descending in front of adductor brevis, behind pectineus and adductor longus. At the lower border of adductor longus it communicates with the medial cutaneous nerve of the thigh and saphenous branches of the femoral nerve, to form a subsartorial plexus that supplies the skin on the medial side of the thigh. It descends on, and supplies, the femoral artery. Near the obturator foramen the anterior branch supplies the hip joint. Behind pectineus it supplies adductor longus, gracilis, usually adductor brevis and often pectineus, and connects with the accessory obturator nerve (when this nerve is present). Occasionally the communicating branch to the femoral medial cutaneous and saphenous branches continues as a cutaneous branch to the thigh and leg. When this occurs, the nerve emerges from behind the distal border of adductor longus to descend along the posterior margin of sartorius to the knee, where it pierces the deep fascia and connects with the saphenous nerve to supply the skin halfway down the medial side of the leg (Standring, 2015).

1.1.2 Posterior branch

The posterior branch pierces obturator externus anteriorly, supplies it and passes behind adductor brevis to the front of adductor magnus, dividing into branches to its pubic part and adductor brevis when the latter is not supplied by the anterior division or when it receives dual innervation from both anterior and posterior divisions. It usually sends an articular filament to the knee joint which either perforates adductor magnus distally or traverses its opening with the femoral artery to enter the popliteal fossa. Within the fossa the nerve descends on the popliteal artery to the back of the knee, pierces its oblique posterior ligament and supplies the articular capsule. It gives filaments to the popliteal artery (Standring, 2015).

1.2 Problem Statement

The obturator nerve injuries occur commonly in orthopedic conditions and during surgeries involving the pelvis and the hip joint (Barrick, *et al*., 1998) . With the acquisition of new skills and specialization of Kenyan orthopedic surgeons more complex hip and pelvic revision and reconstruction surgeries are being carried out. These surgeries come with a higher risk of nerve injuries including injury to the obturator nerve. This is indeed true when it comes to acetabular reconstruction where the obturator nerve may be injured during retraction or during placement of acetabular screws (Lavernia, *et al*., 2007). More total hip arthroplasties and revision arthroplasties are being done at MTRH and environs annually even though no research has been done to document the figures currently. Some of these surgeries end with up with complications of paralysis or atrophy of the adductor muscles, loss of hip adduction, referred pain at the hip or knee or loss of sensation of pain on the medial aspect of the thigh secondary to obturator nerve palsies.

In addition the orthopedic surgeon of today is faced with the management of the upcoming and seasoned athletes who are high in number due to the many training facilities available at MTRH catchment area. Groin pain is one of the leading causes of morbidity in these athletes as demonstrated by local study by Mbarak, *et al*., (2019). One of the common causes of groin pain in athletes is obturator nerve neuropathy causing weakness of adduction, groin pain and sensory loss on the medial side as demonstrated by a study done in Michigan (Tipton, 2008).

Therefore, accurate knowledge of variability in human morphology is important to improve diagnostic and interventional performance especially against the background of contemporary Imaging and other investigation techniques like ultrasound, magnetic resonance imaging, nerve conduction studies and electromyography(Ogeng'o, 2013). The study of surgical anatomy of the obturator nerve will therefore help improve in the management of conditions affecting the obturator nerve.

1.3 Justification

Detailed and accurate anatomic knowledge is needed for safe practice as the human body is subjected to many investigative and interventional procedures (Turney, 2007). Variable anatomy of the obturator nerve may present a challenge during regional blocks, pelvic and hip surgeries and procedures targeting it (Willan & Humpherson, 1999). This study will therefore provide a good understanding of the obturator nerve in our population and aid in surgical practices

1.4 Research Question

How is the course of main trunk, level of divisions and branches of the obturator nerve in the adult Kenyan population?

1.5Objectives

1.5.1 Broad Objective

To determine the course of main trunk, level of divisions and branches of the obturator nerve in the adult Kenyan population.

1.5.2 Specific Objectives

1. To describe the course of the main trunk of obturator nerve after it emerges from medial border of psoas major muscle.
2. To determine the level of division of the obturator nerve into anterior and posterior divisions.
3. To describe the pattern of distribution of both the anterior and posterior branches of the obturator nerve among Kenyan adult population.

CHAPTER TWO

2.0 LITERATRE REVIEW

2.1 Obturator nerve anatomy variations

While textbook anatomical descriptions of the obturator nerve do not differ much in reality several variations have been described especially in recent times. Unlike other parts of the body where dozens of publications can be found only a handful of data on the obturator nerve had been published.

2.1.1 Course of the main trunk

The obturator nerve arises from the lumbar plexus with most textbooks agreeing on ventral divisions of L2, 3 and 4. Several studies on the lumbar plexus have been carried out however with some variations being noted in different populations. In the dissections by Arora, *et al*., (2014) done in Patiala, India the lumbar plexus originates from the ventral rami of the L1-L4 nerve roots and projects laterally and caudally from the intervertebral foramina, posterior to the psoas major muscle. He also noted that occasionally a communicating branch from the T12, also known as the subcostal nerve, may join the first lumbar nerve to form the obturator nerve. There were other nerves emerging from the lumbar plexus including the iliohypogastric nerve(L1), ilioinguinal nerve(L1), lateral femoral cutaneous nerve(L2-3,dorsal), and femoral(L2-4,dorsal) all appearing in that order from above downwards, at the lateral border of psoas major muscle, the genitofemoral nerve(L1-2) appears on the anterior surface and the obturator nerve(L2-4,ventral) appears along the medial border of that muscle. The pattern of formation of lumbar plexus is altered if the plexus is prefixed or postfixed, that is, the fiber contribution is moved cranially or caudally, respectively.

When the plexus is prefixed, the obturator nerve usually also received fibres from L1, and when it is postfixed, it usually received fibres from L5 (Arora, *et al*., 2014).

The most frequent origin of the obturator nerve in a study by Horwitz who dissected a larger number (228) than Arora in Philadelphia was from the third and fourth lumbar nerves 76%. The rest from the second through the fourth lumbar in only 23; in the remainder it arose from the first through the fourth lumbar twice, from third through fifth 10 times, from the third alone 3 times, from the fourth alone 12 times, and from fourth and fifth 3 times (Horwitz, 1939).

More recent studies done on the African continent have shed more on the expected variations of the obturator nerve. These are the work done by Tshabalala, (2015) in Pretoria, South Africa and Ka, *et al*., (2020) in Ethiopia. Ka, *et al*., (2020) in their dissections over several universities in Ethiopia found that the majority, 88% had origin of obturator nerve from L2, L3 and L4 lumbar spinal nerves like what is published in most Anatomy textbooks. This was in agreement to what , Tshabalala, (2015) found in the south African dissections at 82%. This was in stark contrast to earlier dissections by Horwitz who had the higher number being L3 and L4. Ka, *et al*., (2020) still found these present but they only comprised a small number (12%) while Tshabalala, (2015) found 18% (Ka, *et al*., 2020; Tshabalala, 2015)

While variations in the origin of the obturator nerve have been well documented this study could not add to the existing information due to the fact that the specimens in the human anatomy laboratory had already been transected above the level of the pelvis for other studies including teaching of undergraduate students. Variations throughout the course of the obturator nerve including its pattern of innervation have been documented to exist though the only other African study that had been done was by Tshabalala, (2015) in South Africa (Tshabalala, 2015). Ka, *et al*., (2020) carried out a similar study in the Ethiopian population at around the same time that this study was being done (Ka, *et al*., 2020)

After formation of the nerves of the lumbar plexus, a study by Tubbs, *et al*., (2005) looked at anatomical landmarks for the lumbar plexus on the posterior abdominal wall found that the obturator nerve normally appeared at a mean distance of 5 cm inferior to the supracristal plane (a horizontal line connecting the superior-most aspect of the left and right iliac crests approximating the L4–5 vertebrae) on a vertical line through the ASIS and had a mean distance of 3 cm lateral to the midline (Tubbs, *et al*., 2005).

The obturator nerve then descends in the pelvis in close association with the obturator vein and artery. A study done by Won, *et al*., (2016) showed that the obturator nerve(ON), obturator artery(OA) and obturator vein(OV) ran in that order (from upper to lower) within the lateral pelvic wall in 46.7 % of specimens. In 32 % of cases, the three structures were separated at the posterior portion of the wall and then converged toward the obturator canal. In 10 %, the OA and OV were in contact with each other and separate from the ON; in 2 %, the ON was contiguous with the OA and separate from the OV; in 2.7 %, all three structures were in contact with each another. Alternately, the order of ON, OA, and OV was altered in the lateral pelvic wall in 41.3 % of specimens. Finally, in 12 % specimens, either the OA or OV or both were absent from the lateral pelvic wall (Won, *et al*., 2016).

From the pelvis the obturator nerve descends through the obturator canal to the thigh. The obturator foramen itself has been described to have a high degree of variability in shape and size. This may directly contribute to some of the variability that may be observed in the obturator nerve at the obturator canal. One such study by Ridgeway, *et al*., (2008) showed that there is considerable variability in the bony architecture of the obturator foramen and pubic arch of the pelvis. Race and height may account for some of these variabilities (Bierry, *et al*., 2010; Ridgeway, *et al*., 2008).

This is especially important as demonstrated by Whiteside and Walters, (2004) that the trans-obturator sling passes on average 2.4 cm inferior-medial to the obturator canal. The anterior and posterior divisions of the obturator nerve are on average 3.4 and 2.8 cm, respectively, from a passed trans-obturator device. The device passed on average 1.1 cm from the most medial branch of the obturator vessels. The small distance between the device and the neurovascular structures mean that if there is a variation in the location of the obturator nerve in the local population we could be at a greater risk. Widespread popularity and use of tension-free vaginal tape has led to significant vascular and bowel injuries that may have been avoided with improved familiarity of the anatomy of the retropubic space and anatomy around the obturator foramen (Whiteside & Walters, 2004).

2.1.2 Level of division of the obturator nerve

The obturator nerve usually divides into anterior and posterior branch around the obturator foramen. This can be divided into three; intrapelvic, within the obturator canal and extrapelvic (thigh). Intrapelvic divisions are the ones where the obturator nerve divides into anterior and posterior branches before entering the obturator canal on the obturator foramen. Those that divided within the obturator canal, a fibro-osseous tunnel in the upper part of the obturator foramen have also been documented. Lastly division can occur in the thigh after the obturator nerve has exited the obturator foramen also sometimes referred as extrapelvic (Anagnostopoulou, *et al*., 2009; Tshabalala, 2015).

A study done in Athens, Greece in 2009 demonstrated that the point of division for the obturator nerve into the anterior and posterior branches was intrapelvic in 23.22%, within the obturator canal in 51.78%, or in the thigh in 25% of the cadavers dissected (Anagnostopoulou, *et al*., 2009). This concurs with the findings by Ka, *et al*., (2020) in Ethiopia which found that the divisions into anterior and posterior branches occurred in 24% intrapelvic, 45% within the obturator canal and 31% in the thigh (Ka, *et al*., 2020). A contrast was however noted in the dissections done in South Africa by Tshabalala, (2015) who found an overwhelming majority (93%) of the specimens divided within the canal with intrapelvic and extrapelvic being 2% and 5% respectively (Tshabalala, 2015).

2.1.3 Pattern of distribution of both the anterior and posterior branches of the obturator nerve

After division into anterior and posterior branches various notable variations have been documented in the distributions with the majority (66.7%) giving 3 branches innervating the adductor longus, adductor brevis, and gracilis muscles. The rest giving rise to four or two branches in 4.76% and 28.57% of cases, respectively (Anagnostopoulou, *et al*., 2009)

In another study by Akkaya *et al*., (2008) describing obturator nerve anatomy to increase efficacy of obturator nerve block, the anatomical positions of the structures entering and leaving the canal were defined. The position of the obturator nerve and its branches and their relation with the obturator artery, vein, and with the internal iliac and femoral veins were investigated. A model of the obturator canal was created. Detailed measurements were performed on the cadavers and models. The obturator canal was in the shape of a funnel compressed from superior to inferior, with anterior and posterior openings. At the entrance of the canal, the nerve lay superiorly; the artery was in the middle, and the vein lay inferiorly. The obturator nerve ran close to the lateral wall of the obturator canal. The distance of lateral wall of obturator canal to the median plane was 41.4 +/- 1.1 mm. After leaving the canal, the nerve lay laterally while the anterior branch of the artery was medial. A venous plexus lay between the two structures. The presence of the branches of the obturator artery and vein alongside the obturator nerve may increase the risk of injury to these structures during anaesthetic procedures. The anterior division of the obturator nerve has a close relationship with these vessels (Akkaya, *et al*., 2008).

The posterior branch divided into two branches in most of the cases providing innervation to the adductor brevis and adductor magnus muscles in 60.11% of the cases. In a few cases however it gave one or three or four muscular branches which was 13.69%, 19.04% and 7.14% respectively (Anagnostopoulou, *et al*., 2009).

2.2 Surgical relevance of the obturator nerve

2.2.1 Obturator nerve entrapment and neuropathy

Obturator nerve entrapment has been described as one of the major cause of chronic groin pain in athletes by Bradshaw, *et al*., (1997). Due to the large number of anatomical structures in the groin it is often difficult to accurately diagnose and manage groin pain leading to frustrations of both the athletes and the doctor in addition to preventing the athletes from training well and losing income. Bradshaw, *et al*., (1997) in Australia looked at 32 cases of fascial obturator nerve entrapment as it enters the thigh leading to neuropathy presenting with medial thigh pain. With this condition having not been described previously the study was set out to describe signs and symptoms and modalities of treatment. Non operative management was unsuccessful with surgical neurolysis being the definitive management especially in cases where denervation had already started as demonstrated by electromyography (Bradshaw, *et al*., 1997). Obturator nerve neuropathies is further supported by a local study by Mbarak, *et al*., (2019) who found groin injuries afflicting mainly the male athletes with an incidence of 22%. This demonstrated that the local Kenyan athletes suffered higher rates of groin injuries than what other studies elsewhere found further highlighting the need to explore and find management solutions for these groin pain locally (Mbarak, *et al*., 2019).

Even though most nerve injuries associated with fractures or disruptions of the pelvic ring usually occur posteriorly, obturator nerve entrapment has been described after pelvic fracture by Barrick, (1998). There was fracture of the superior pubic ramus and the subsequent callus formation placed the obturator nerve under tension. Decompression of the nerve was accomplished by removal of the overlying section of the pubis (Barrick, 1998).

2.2.2 Obturator nerve block

Several indications of obturator nerve blocks exist such as in the therapeutic and diagnostic procedures on the knee (Macalou, *et al*., 2004), diagnostic and therapeutic purpose of pain syndromes of the hip and, spasticity of adductor muscles (Hong, *et al*., 1996) and transurethral resection of parts of the bladder wall (Augspurger & Donohue, 1980).

Winnie, *et al*., (1973) introduced the inguinal paravascular block, which allegedly provides anesthesia of three nerves, the femoral, lateral cutaneous nerve of the thigh, and obturator nerves with a single injection (Winnie, *et al*., 1973).

This concept was undisputed until the success of the obturator nerve block was reassessed by using evidence of adductor weakness rather than cutaneous sensory blockade, the latter being variable in its distribution and often absent. Selective obturator nerve blockade was then developed by Macalou, *et al*., (2004) which has been successfully used to provide postoperative analgesia in many cases. Effective pain control postoperatively is the main target for surgeons and anaesthetists. Several researches have been done in different areas to try and reduce the amount of analgesia required postoperatively. One such study recruited three different groups with one group receiving inguinal paravascular block as described by Winnie, *et al*., (1973) while the second group was receiving obturator nerve block in addition and the third group receiving a placebo. The second group which received obturator nerve block in addition demonstrated significant reduction of morphine required post total knee athroplasty compared to the first and third groups (Macalou, *et al*., 2004).

Another study supporting the administration of obturator nerve block in post total knee replacement by McNamee, *et al*., (2002) where post-operative patients were divided into two groups with the first group receiving sciatic and femoral nerve blockade and the second group receiving obturator nerve blockade in addition was done. The second group demonstrated a much longer period before requesting for an analgesic postoperatively (McNamee, *et al*., 2002).

The classic approach to femoral and obturator nerve blocks by approach using the pubic tubercle are complicated by pain and discomfort leading to low patient acceptance. Studies have been done to try and reduce the discomfort by trying other approaches. Choquet, *et al*., (2005) conducted one such study to look at inguinal approach which was found to significantly reduce patient discomfort. While in the traditional pubic and the inguinal approach for obturator nerve block the insertion point of the needle is 2 cm lateral and 2 cm inferior to the pubic tubercle. In the inguinal approach, the insertion point of the needle is at the midpoint of the line drawn between the femoral arterial pulse and the inner border of the adductor longus tendon (Choquet, *et al*., 2005).

Some other modifications of the traditional approach have been done with one such study achieving high level of effectiveness using vertical obturator nerve block with a success rate of 93.75% (Feigl, *et al*., 2013).

2.2.3 Obturator nerve transfers

Nerve repair forms a very important part in orthopedic surgery and rehabilitation. These procedures are being done increasingly with success. The surgeon has 3 choices for nerve repair: direct coaptation, nerve graft, and nerve transfer (neurotization). Direct coaptation is infrequently used because typically there is too large a gap between the 2 ends of the severed nerve. The gold standard is end to end repair for nerve repair while other options for manging nerve gaps exist including placement of nerve grafts between the 2 ends of the nerve (Domeshek, *et al*., 2019; Korus, *et al*., 2016).

Nerve transfer involves sacrifice of 1 nerve for purposes of reinnervating another more important nerve. The obturator nerve have been successfully used in the repair of the femoral nerve (Campbell, *et al*., 2010; Tung, *et al*., 2012). Femoral nerve lesion causes more significant disability. In many cases, the availability of the proximal stump is in question and further complicates surgical management by severely limiting reconstructive options and precluding nerve graft reconstruction. The purpose of the report by Campbell, *et al*., (2010) was to describe the successful restoration of quadriceps function by distal nerve transfer at the level of the thigh without functional donor morbidity (Campbell, *et al*., 2010).

2.2.4 Surgical complications affecting obturator nerve

Orthopedic complications associated with this condition include poor acetabular screw placement, cement extrusion, direct trauma, and injury during the surgical approach. Obturator nerve entrapment has been demonstrated after pelvic ring fractures (Barrick, 1998).

Obturator nerve palsy has also been reported after fixation of acetabular reinforcement ring with transacetabular screws. The risk has been reported to be higher if the fixation screws are placed on the anterior or central part of the acetabulum (Fricker and Troeger., 1997) .

In the fixation of acetabular reconstruction cages Lavernia, *et al*,. (2007) showed that the implications of screw placement, drill plunge and the potential insult to anatomical structures when implanting acetabular reconstruction cages was significant with 60% of the screws placed in the posterior rim endangering the obturator nerve (Lavernia, *et al*., 2007).

In another study done in England on complications of posterior and lateral approaches to hip arthroplasty, the study showed that the obturator nerve was the most injured as demonstrated by electro physiologic tests (Weale, *et al*., 1996).

Obturator nerve ganglion has also been described as a cause of adductor weakness and groin pain in athletes with no improvement of the symptoms achieved till after decompression of the nerve by excision of the ganglion (Schwabegger, *et al*., 2004).

Obturator nerve palsies have also been reported after cemented total hip arthroplasties. This is after extrusion of the cement into the pelvis (Mahadevan, *et al*., 2009; Zwolak, *et al*., 2011).

In addition other causes of obturator nerve neuropathy have been described like synovial cyst of the hip (Stuplich & Hottinger, 2005).

2.3 Sonographic visualization of obturator nerve

With the role of the obturator nerve being increasingly appreciated in anesthesia and surgery, radiological techniques of improving the accuracy of identifying the obturator nerve are being improved daily. One study by Soong, *et al*., (2007) demonstrated that it is the flattest nerve visualized in the inguinal region with measurements being made in relation to the pubic tubercle. The study showed that the obturator nerve can be sonographically visualized by scanning along the known course of the nerve; the anterior division characteristically converges toward the posterior division along the lateral border of the adductor brevis muscle to form the common obturator nerve more proximally. The common obturator nerve was visualized 1.3 - 1.5 cm distal and 2.3 - 1.2 cm lateral to the pubic tubercle. Divisions were visualized 2.1 -2.0 cm distal and 2.1 -1.2 cm lateral to the pubic tubercle (Soong, *et al*., 2007).

2.4 Transobturator procedures

Procedures through the obturator foramen have gained a lot of popularity in recent years among urologists and gynaecologists. Transobturator procedures have been used in the treatment of stress urinary incontinence in females and in male incontinence post prostatectomies. The fact that minimally invasive techniques are gaining popularity in all surgical fields places structures at a greater risk of injury because this is usually at the expense of direct visualization of all the surgical field.

Transobturator tape procedure (TOT) is a treatment for urodynamically proven stress incontinence in women. TOT is a minimally invasive procedure that involves the placement of a small piece of polypropylene mesh through the obturator foramen and underneath the urethra.

In a study by Whiteside and Walters, on anatomy of the obturator region and relations to a trans-obturator sling it showed that though the sling passed medial to obturator canal in most simulations, the obturator nerve and vessels were at a greater risk of injury (Whiteside & Walters, 2004).

Mid urethral slings can be performed using open retropubic technique or using transobturator techniques. Retropubic method was shown to have a slightly higher efficacy in the treatment of stress urinary incontinence but transobturator techniques are still more popular due to the lower complications rates (Whiteside & Walters, 2004).

Retrourethral transobturator slings are a safe treatment option for male nonintrinsic sphincter deficiency stress urinary incontinence, with the main postoperative complication being transient acute urinary retention. This has provided some level of comfort in patients who have undergone prostatectomy especially radical prostatectomy even though preoperative radiation has been shown to reduce its efficacy (Bauer, *et al*., 2010; Cornel, *et al*., 2010; Cornu, *et al*., 2009).

In females transobturator tape procedures have been proven to work in stress urinary incontinence. This has been shown to have good short term and long term cure and patient satisfaction rates (Heinonen, *et al*., 2013; Yonguc, *et al*., 2014). It has also been shown to improve female sexual satisfaction by reducing urine leakage and reducing pain associated with sex (Arts-De Jong, *et al*., 2011).

2.5 Gracilis muscle transfer

Gracilis muscle has been used over the years to improve anal continence as described in many studies including one by Kalra, *et al*., (2016). Anal incontinence may be as a result of complications of surgical procedures performed or due to any other cause. Anal incontinence may sometime result in the fashioning of stomas. Stomas and incontinence are sometime associated with low confidence level and reduced quality of life in those affected. Gracilis muscle transfer provides a good alternative with subsequent improvement of anal tone manometric measurements and significantly better quality of life. Gracilis is used as an encircling anal sphincter. Through separate, short longitudinal incision in lower thigh, a suitable length of gracilis muscle is freed to allow for it to be withdrawn by its severed tendon into the perianal tunnel at the sides and back of the anorectum (Kalra, *et al*., 2016).

Free gracilis muscle transfer has also been used on the face. Facial paralysis can contribute to disfigurement, psychological difficulties, and an inability to convey emotion via facial expression. In patients unable to perform a meaningful smile, free gracilis muscle transfer has been used to restore smile function (Bae, *et al*., 2006; Lindsay, *et al*., 2014).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study site

The study was conducted at the Human Anatomy Laboratory, Moi University School of Medicine which is based at the Moi Teaching and Referral Hospital (M.T.R.H) situated in Eldoret Kenya.

3.2 Study design

This was an anatomical descriptive cross sectional study involving the observation of the patterns of distribution of the obturator nerve seen in cadaveric specimens at the Department of Human Anatomy, Moi University.

3.3 Study population

This included the selected adult formalin prefixed cadaveric hemipelvis's and lower limbs from the Department of Human Anatomy, Moi University School of Medicine that meet the eligibility criteria.

3.4 Eligibility Criteria

3.4.1 Inclusion and exclusion criteria

All adult hemipelvises and lower limbs (of either sex) without gross evidence of prior surgery, fractures or pathologies were included. Deformed, decomposed or mutilated limbs were excluded from the study.

Researcher decided to do the right and left sides to avoid missing out on some variations. As demonstrated by Tshabalala, (2015) who also dissected the left and right sides and found that where there were some variations they always did not occur bilaterally. He found anterior branch in 1% on the right innervating pectineus with none on the left (Tshabalala, 2015).

3.5 Sample size determination

This was a census study because at Moi University Anatomy Laboratory, the maximum number of hemipelvises with their corresponding lower limbs are approximately 60. Therefore, all cadavers that meet the inclusion criteria were included in the study as long as the inclusion criteria were fulfilled. Considering that one of the measurement to be estimated is the distance between the most superior point of the foramen and the obturator nerve within the obturator canal. Which was found to be on average 6.25 ±1.76mm in a study done by Tshabalala, (2015) in South Africa (Tshabalala, 2015). The minimum sample size should be 48 lower limbs. This was arrived at using a formula for estimating a single population mean as described by Ogston, *et al*., (1991) (Ogston, *et al*., 1991).

$$n \geq \left[\frac{Z_{1-\propto/2} \times \sigma}{d}\right]^2$$

Where:

n= minimum sample size required

$Z_{1-\alpha/2}^2$= Critical value for standard normal distribution at α-level of significance (α=0.05, $Z_{\alpha/2}$=1.96).

□ = Standard deviation = 1.76 (Tshabalala, 2015)

d =Margin of error (which is taken as 0.5mm difference from the mean)

3.6 Study procedure

The cadavers were dissected, and the parameters mentioned in the objectives; course of the nerve in the obturator foramen from most superolateral,medial and inferolateral ponts, level of division of the nerve and patterns of innervation including level of muscular divisions in the thigh were measured using a digital calibrated caliper (Neiko® Tools Digital Calipers) accurate to 0.01mm.

Dissections were done according to the techniques described by The Cunningham's Manual of Practical Anatomy 16th Edition (Koshi, 2017).

The obturator nerve is then followed as it descends in the abdomen after emerging from the medial border of the psoas major muscle into the pelvis where it exits through the obturator foramen into the thigh (Agur & Dalley, 2009; Tshabalala, 2015). In the obturator foramen the location of the obturator nerve was documented by taking measurements from the most superior part A to B, most medial part B to C and most inferior part B to D as shown in appendix 6.

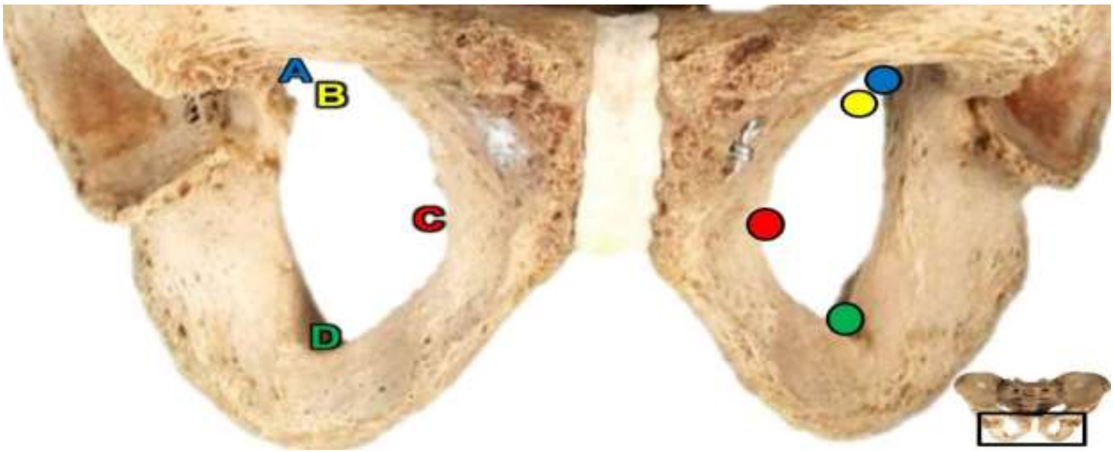

Figure 1: Indicating the points from which the measurements of the obturator nerve (B) were taken from. A=most superior part, C=most medial part and D=Most inferior part. Adopted from Tshabalala, (2015).

The course of the nerve was then followed into the lower limb, as the obturator nerve exited the obturator canal. The obturator nerve was firstly observed as it terminates into its anterior and posterior branches, noting whether it terminated within the pelvis (intrapelvic), the obturator canal (within canal) or the thigh (extrapelvic). Within the canal was defined as a point between the obturator canal and the anterior surface of the obturator externus muscle.

The innervation patterns of both the anterior and posterior branches of the obturator nerve were also photographed using a digital camera and measurements from the obturator foramen were taken.

3.7 Data management, analysis and presentation

The data obtained was recorded and coded in structured data collection forms. Computer hardware, memory sticks and compact discs were used to sore the data obtained for future backup. Photographs of dissected specimens will be recorded using a digital camera.

Data captured using structured data collection forms were entered into an electronic database. The database was encrypted with password to ensure confidentiality. The password was only accessible to the main investigator. The forms, once conversion to electronic database was complete, were shredded upon completion of the study and disposed of in an appropriate way.

Data was imported into STATA/MP version 13where coding. Cleaning, manipulation and analysis were done. Categorical variables such as sex of the cadavers were summarized as frequencies and corresponding percentages. Continuous variables such as the distance between most superior point of the foramen and the obturator nerve; distance between the obturator nerve and the most medial point of the obturator foramen were summarized as mean and the corresponding standard deviation when they assumed the Gaussian distribution. When Gaussian assumptions were violated then the median and the corresponding inter quartile range were used to summarize these characteristics. Gaussian assumptions were assessed using Shapiro-Wilk test for normality.

Comparison of the means was done using two sample t-test when the Gaussian assumptions were satisfied otherwise the nonparametric analogue (two sample Wilcoxon rank sum test) was used to compare medians.

Finally the data obtained was presented in form of tables, charts and figures.

3.8 Ethical considerations

Ethical approval was sought from the Institution Research and Ethics Committee (IREC) Moi University and the Department of Human Anatomy prior to commencement of the study. IREC FAN 3207.

The study was conducted in accordance with the Anatomy Act Chapter 243-9 (Attorney General, 2012) of The Laws of Kenya which entitles a person registered as a student in an approved school of anatomy to examine and conduct anatomical research on human cadavers as long as the requirements stipulated in the act are strictly adhered to. Data confidentiality will be strictly maintained and this will include use of pass words in the database.

Results obtained will be disseminated through an oral defense of thesis and thereafter the results may be presented at relevant conferences/seminars and publication in a peer reviewed scientific journal.

3.9 Study Limitations

1. Available specimens at the Human Anatomy Department had been transected at the level of supracristal line therefore the level of origin of the obturator nerve could not be studied.
2. Dissection of the articular branch presented a challenge beacause of the small level of caliber of the nerve and the condition of the specimens. Fresh specimens and micro dissection tools may be required to fully study the hip articular branch of the obturator nerve in the local population,

CHAPTER FOUR

4.0 RESULTS

4.1 INTRODUCTION

The findings are based on 60 adult cadaveric samples of lower limbs extending to the level of hemi pelvises from the Department of Human Anatomy, Moi University School of Medicine. Data collection was done between the month of January and December 2019 both months included.

Table 1: Description of cadaveric samples (n=60)

Variable	Category	Frequency	Percentage
Laterality	Left	32	53.33%
	Right	28	46.67%
Gender	Male	42	70.00%
	Female	18	30.00%
Pelvic course as described in	No	2	3.33%
Grays anatomy 41st edition	Yes	58	96.67%

The measurements of obturator nerve was taken from the left side for 53.3% of the sample compared to the right side (46.7%) where most (70.0%) of the cadavers were males.

4.2 Course of the main trunk of obturator nerve as it emerges from medial border of psoas major muscle.

The obturator nerve exited from the medial border of the psoas major muscle, beneath the common iliac vessels after coursing in substance of the muscle. It then descended towards the lesser pelvis on its way being suspended by fatty and connective tissues. It then coursed along the wall of the lesser pelvis, almost horizontally just below the junction between the greater and lesser pelvis towards the obturator foramen where it entered the obturator foramen. On the wall of the lesser pelvis it is covered by thick fascia extending to cover obturator internus.

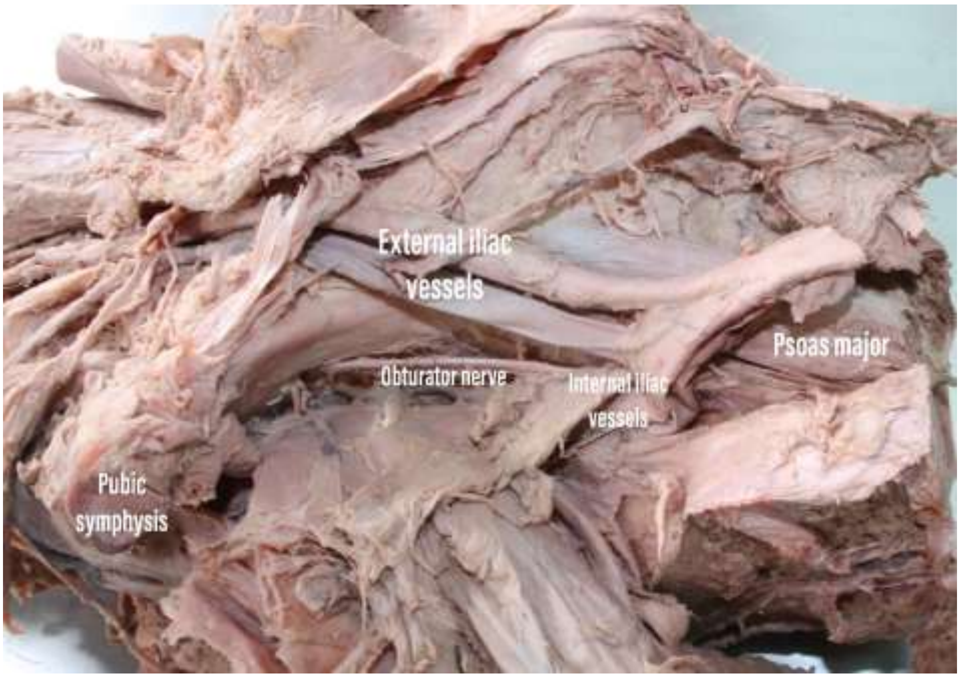

Figure 2: Image showing obturator nerve in the pelvis as it exits from the medial border of psoas major muscle to course towards the obturator foramen

This was the case in almost all (96.7%) samples with the exception of the two variations as a result of a branch arising in the pelvis. In all the specimens the main trunk traversed the pelvis without dividing into anterior and posterior branches. This division occurred either in the obturator foramen or in the thigh. In instances where the main trunk reached the thigh it did so by going through obturator canal which passed obliquely with the entry on the obturator internus being in the lateral part of the foramen while the exit on obturator externus almost approaching the middle of the superior portion of the foramen.

4.2.1 Intrapelvic branch to obturator externus

During the dissections a variation in the intrapelvic course of the main trunk of obturator nerve was noted in 3.33% of the specimens through the occurrence of a branch to the obturator externus, this was in a male and a female specimen both on the left side. After being given off, the branch started to diverge slightly inferiorly on its course along the main trunk to enter the substance of the obturator internus while the main trunk proceeded to the obturator canal. The intrapelvic branch to obturator externus moved through the substance of obturator internus without supplying it. On reaching the obturator externus it ramified supplying multiple branches to the muscle. In these specimens no other nerve supply to the obturator externus was found either in the obturator canal or in the thigh.

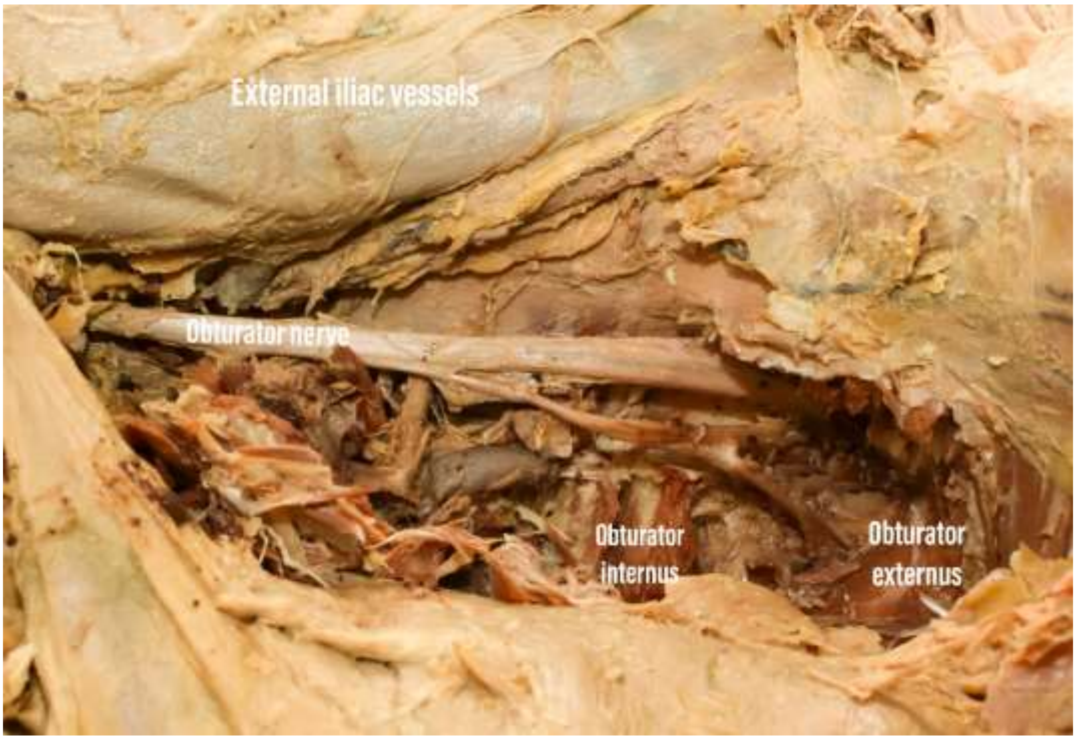

Figure 3: Image showing the intrapelvic branch of the obturator nerve with the obturator internus removed to expose it subdividing before entering the substance of obturator externus to supply it.

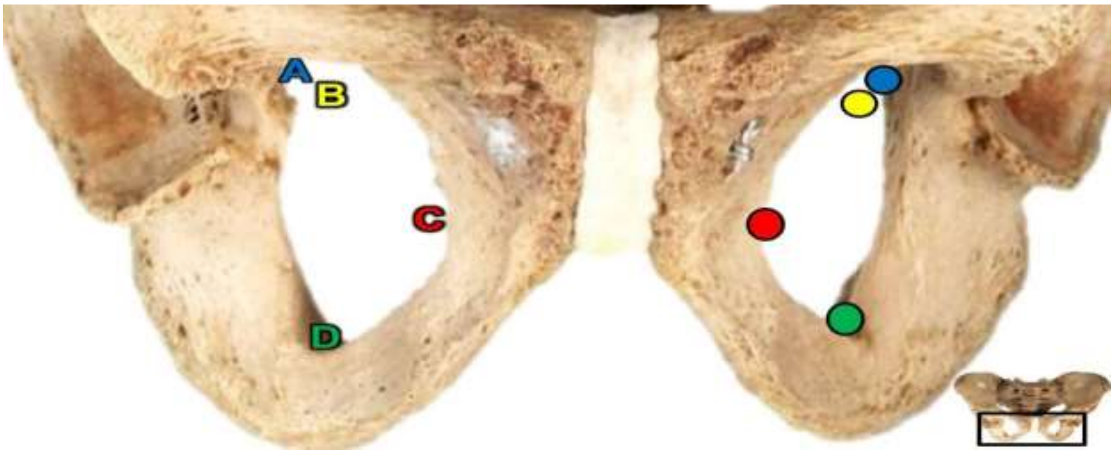

Figure 4: Image indicating the points from which the measurements of the obturator nerve (B) were taken from. A=most superior part, C=most medial part and D=Most inferior part. Adopted from Tshabalala, (2015).

Table 2a: Location in the obturator foramen (n=60)

Distance from	Mean	SD	Min	Max
Most superior point (A to B)	10.29mm	2.41	5.6mm	16.8mm
Most medial point (B to C)	14.95mm	3.46	7.3mm	24.6mm
Most inferior point (B to D)	33.93mm	7.81	17.2mm	50.1mm

The distance from most superior point ranged from 5.6 to 16.8 mm with a mean of 10.3 ±2.4 mm. The distance from most medial point ranged from 7.3 to 24.6 mm with a mean of 15.0 ±3.5 mm. While the distance from most inferior point ranged from 17.2 to 50.1 mm with a mean of 33.9 ±7.8 mm.

Table 2b: Location in the obturator foramen by gender (n=60)

Distance from	Male		Female		p-value
	Mean(SD)	**Min-Max**	**Mean(SD)**	**Min-Max**	
Most superior point (A to B)	10.12mm(2.1)	5.6mm-14.7mm	10.68mm(3.0)	7.1mm-16.8mm	0.408^{t}
Most medial point (B to C)	14.93mm(3.2)	9.4mm-22.2mm	14.98mm(4.1)	7.3mm-24.6mm	0.960^{t}
Most inferior point (B to D)	33.67mm(7.2)	18.7mm-46.5mm	34.53mm(9.3)	17.2mm-50.1mm	0.701^{t}

^{t} ttest

The average measurements of the three points were not different statistically between the genders. However females seemed to have slightly higher measurements compared to their male counterparts with no change in the proportions. This however could be attributed to well recognized differences between male and female obturator foramens.

Table 2c: Location in the obturator foramen by laterality (n=60)

Distance from	Left		Right		p-value
	Mean(SD)	**Min-Max**	**Mean(SD)**	**Min-Max**	
Most superior point (A to B)	10.20mm(2.2)	5.6mm-15.9mm	10.38mm(2.6)	5.6mm-16.8 mm	0.776[t]
Most medial point (B to C)	15.09mm(3.7)	9.4mm-24.6mm	14.79mm(3.2)	7.3mm-21.7mm	0.742[t]
Most inferior point (B to D)	33.70mm(8.6)	18.7mm-50.1mm	34.20mm(7.0)	17.2mm-48.5mm	0.807[t]

[t] ttest

There was no significant difference in measurements of the three points between left and right.

4.3 Level of division of the main trunk of obturator nerve

Table 4: Level of division of the main trunk of obturator nerve

Level	Category	Frequency	Percentage
Intrapelvic	No	58	96.67
	Yes	2	3.33
Obturator canal	No	9	15.00
	Yes	51	85.00
Distance from obturator canal to point of division in the thigh in mm	8.7	7	11.67
	9.2		
	9.5		
	10.1		
	10.4		
	10.6		
	10.9		

The two intrapelvic brances were due to the aberrant finding of intrapelvic branch to obturator externus. There were no specimens however that divided into anterior and posterior divisions in the pelvis. The mean distance from obturator canal to the point at which the obturator nerve divided into anterior and posterior divisions in the thigh is 9.91±0.80 mm in the seven specimens listed in the table above.

4.3.1: Level of division of the main trunk of obturator nerve into anterior and posterior division

Table 5: Level of division of the main trunk of obturator nerve into anterior and posterior division

	Frequency	Percentage
Intrapelvic	0	0%
Obturator canal	53	88.33%
Extrapelvic (Thigh)	7	11.67%

4.4 Patterns of distribution of anterior and posterior division of the obturator nerve.

4.4.1 Anterior division

In a majority of the specimens where the division into anterior and posterior divisions occurred in the obturator canal, the anterior and posterior branches were initially separated by some fibres of the obturator externus as they emerged from the foramen. It then run beneath pectineus and adductor longus in that order in the craniocaudal direction where it provided supply to the pectineus occasionally and to all of the adductor longus. The nerve then proceeded to supply the gracilis muscle. On the posterior aspect was the adductor brevis separating it from the posterior division where it provided most of the nerve supply to the muscle. In the specimens where the obturator nerve divided into anterior and posterior divisions in the thigh, it did so before arriving at the proximal edge of adductor brevis muscle which then separated the two branches.

Table 6: Muscles innervated by the subdivisions of anterior division of obturator nerve

Muscular division	**Frequency**	**Percentage**
Pectineus (n=60)	4	6.67%
Adductor longus (n=60)	60	100%
Adductor brevis (n=60)	59	98.33%
Gracilis (n=60)	60	100%

PATTERNS OF DISTRIBUTION OF ANTERIOR BRANCH

Figure 5: Showing division that occurred in 70% of the cases

Figure 6: divisions which comprised 30%with innervation to pectineus 6.7%

Most of the specimens dissected (76.67%) had an innervation pattern with one subdivision supplying two muscles with the rest having their muscular innervations arising independently from the anterior division. Their distribution was as shown in the table below.

Table 7: Showing the specimens dissected (76.67%) had an innervation pattern with one subdivision supplying two muscles with the rest having their muscular innervations arising independently from the anterior division

Muscular divisions	Frequency	Percentage
Adductor longus and Gracilis (n=60)	42	70%
Adductor longus and Adductor brevis (n=60)	4	6.67%
Separate subdivisions to all muscles (n=60)	14	23.33%

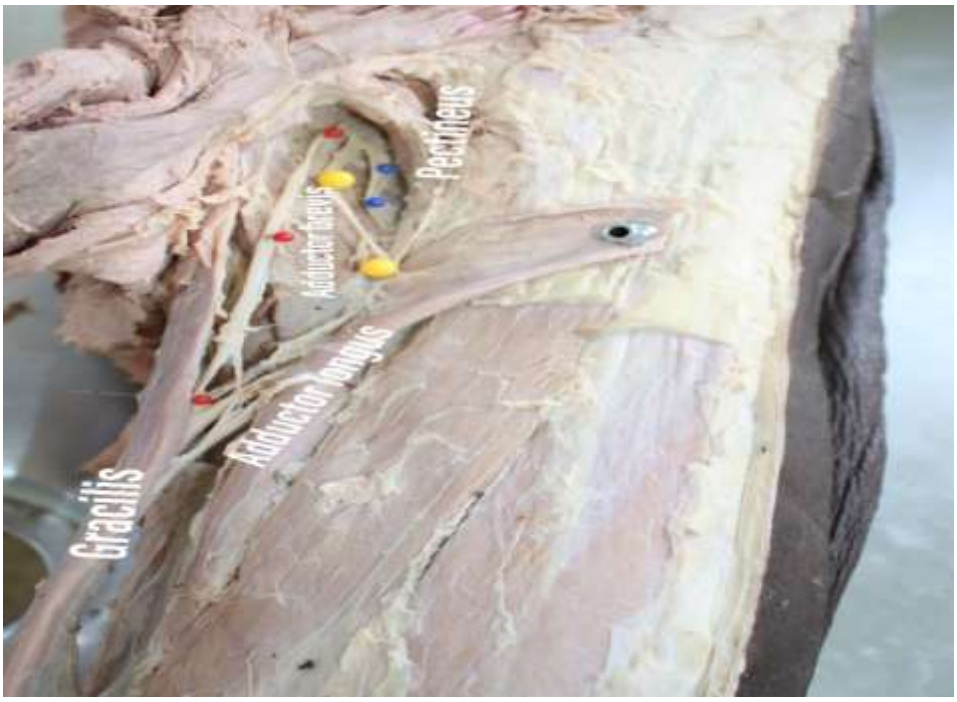

Figure 7: Image showing the anterior branch of the obturator nerve emerging between pectineus anteriorly with the obturator externus and adductor brevis posteriorly before dividing to provide muscular branches adductor longus(yellow), adductor brevis(blue) and gracilis(red)

The distance from the obturator nerve exit to the superior pole of the patella was of interest in determining the level of divisions of obturator nerve branches in the thigh. The distance from obturator nerve exit in obturator foramen to superior pole of patella ranged from 271 to 437 mm with an average of 373.0 ±26.3mm. The average for males (378.3 ±19.9mm) was significantly high (p=0.016) compared to females (360.6.3 ±34.9mm). However, the average for left side (373.8 ±31.9mm) was not statistically different (p=0.800) compared to right side (372.0 ±18.60mm).

Table 8: Level of first muscular division of anterior branch of obturator nerve

Muscle	Mean	Sd	Min	Max
Adductor longus (n=60)	77.11mm	14.25	47.5mm	105.9mm
Adductor brevis (n=60)	35.60mm	6.68	18.4mm	56.6mm
Gracilis (n=60)	114.78mm	18.45	78.5mm	178.7mm
Pectineus (n=4)	14.35mm	3.80	10.6mm	19.1mm

First muscular division of anterior branch of obturator nerve only occurred in 4 different muscles as shown in the table 4 above. In all the samples the first division occurred in adductor longus, adductor brevis and gracilis, pectineus division occurred in only 4 samples. In all the muscles there were several nerve ramifications but of interest was the point at which the first division to the muscle was given off.

At adductor longus it occurred on average at 77.1 ±14.3mm, 35.6 ±6.7mm for adductor brevis and 114.8 ±18.5mm for gracilis. For level of first division at pectineus muscle the average measurement was 14.4 ±3.8mm ranging from 10.6 to 19.1mm.

Table 9a: Level of first muscular division of anterior branch of obturator nerve

Muscle	Proximal third	Middle third	Distal third
Adductor longus (n=60)	60(100)	0	0
Adductor brevis (n=60)	60(100)	0	0
Gracilis (n=60)	45(75)	15(25)	0
Pectineus (n=4)	4(100)	0	0

The first muscular division from the anterior branch of the obturator nerve were all given off in the proximal third of the thigh with the exception of 25% of the first division to gracilis which arose in the middle third of the thigh.

Table 9b: Level of first muscular division of anterior branch of obturator nerve by gender

Muscle	Male		Female		p-value
	Mean(SD)	Min-Max	Mean(SD)	Min-Max	
Anterior adductor longus	77.6mm(13.3)	47.5mm-105.9mm	75.9mm(16.6)	47.7mm-97.5mm	0.669
Anterior adductor brevis	36.3mm(6.9)	18.4mm-56.6mm	34.1mm(5.9)	25.2mm-47.2mm	0.252
Anterior gracilis	116.9mm(19.6)	78.5mm-178.7mm	109.8mm(14.7)	87.9mm-134mm	0.170
Anterior pectineus	15.6mm(4.9)	12.1mm-19.1mm	13.1mm(3.5)	10.6 mm–15.6mm	-

^{t} ttest

There was no significant difference in the level of first muscular division of anterior branch of obturator nerve at different level between gender and the sides.

Table 9c: Level of first muscular division of anterior branch of obturator nerve by laterality

Muscle	Left		Right		p-value
	Mean(SD)	Min-Max	Mean(SD)	Min-Max	
Adductor longus	77.4mm(15.5)	47.7mm-105.9mm	76.8 mm(12.9)	47.5mm-98.9mm	0.857
Adductor brevis	36.8mm(7.5)	25.2mm-56.6mm	34.2mm(5.4)	18.4mm-43.2mm	0.127
Gracilis	116.5mm(20.8)	78.5mm-178.7mm	112.8mm(15.5)	83.9mm-140.5mm	0.438
Pectineus	11.4mm(1.1)	10.6mm-12.1mm	17.4mm(2.5)	15.6mm-19.1mm	-

^{t} ttest

4.4.2 Posterior division

As described earlier there were no intrapelvic divisions of the main trunk into anterior and posterior branches. In the majority of the cases where the division occurred within the canal the posterior division was initially separated from the anterior division by some fibres of the obturator externus. Further along the course in both those that divide within the canal and in those that divided in the thigh it lay posterior to adductor brevis, rarely providing nerve supply to it. It ran on the surface of adductor magnus enclosed by the thick fascia covering the muscle providing multiple branches to supply the muscle along its course.

Table 10: distribution of muscular divisions of posterior branch of obturator nerve

Muscular division	Frequency	Percentage
Obturator externus (n=60)	58	96.67%
Adductor brevis (n=60)	1	1.67%
Adductor magnus (n=60)	60	100%

The obturator nerve supplied all of the obturator externus however the posterior branch was responsible for supplying 96.67% with the rest receiving their supply from the main trunk in the pelvis. Posterior division supplied 1.67% of adductor brevis with the rest being supplied by anterior division. Posterior division supplied all of adductor magnus.

Table 11: Level of muscular divisions of posterior branch of obturator nerve

Muscle	Median(mm)	IQR	Min	Max
Adductor brevis (n=1)	55.2mm	-	-	-
Adductor magnus (n=60)	55.7mm	47.8, 65.6	33.2mm	107.4mm
Obturator externus (n=7)	11.3mm	11, 12.4	10.5mm	26.3mm
(51 within obturator canal)				

The level of division to obturator externus was calculated for the seven specimens where it occurred in the thigh. However as indicated majority of the innervation to obturator externus was in the obturator canal with the two not captured here being supplied by main trunk in the pelvis.

Muscular divisions of posterior branch of obturator nerve occurred in 3 different muscles as shown in the table 5 above. It is only adductor magnus in which all the samples the posterior branch of obturator nerve was observed.

Table 12a: Level of muscular divisions of posterior branch of obturator nerve

Muscle	Proximal third	Middle third	Distal third
Adductor brevis (n=1)	1(100)	0	0
Adductor magnus (n=60)	60(100)	0	0
Obturator externus (n=7)	7(100)	0	0

All the first muscular divisions from the posterior branch of the obturator nerve were all given off in the proximal third of the thigh

Table 12b: Level of muscular divisions of posterior branch of obturator nerve

Muscle	Male		Female		p-value
	Median(IQR)	**Min-Max**	**Median(IQR)**	**Min-Max**	
Adductor magnus	56.5mm(48.7,65.5)	34.1mm-104.8mm	51mm(45.3,63.4)	33.2mm-107.4mm	0.337[t]
Obturator externus	11.3mm(11.1,11.3)	10.5mm-26.3mm	-	-	-

[t] ttest

There was no significant difference in the level of muscular divisions of posterior branch of obturator nerve at different level between genders.

Table 12c: Level of muscular divisions of posterior branch of obturator nerve

Muscle	Left		Right		p-value
	Median(IQR)	**Min-Max**	**Median(IQR)**	**Min-Max**	
Adductor magnus	52.7mm(46, 63.9)	33.2-107.4	58.1mm(51.3,66.8)	34.1mm-87.8mm	0.205[t]
Obturator externus	11.3mm(11,12.4)	10.5-26.3	-	-	-

[t] ttest

There was no significant difference in the level of muscular divisions of posterior branch of obturator nerve at different level between sides.

4.4.3 Articular branch to the hip

Dissection of the articular branch to the hip proved difficult due to its small size and high variability. This might need further research using fresh specimens in our population. The branch to the hip was only identified in 10 of the specimens with 6 originating from anterior division, 3 from common trunk and 1 from the posterior division of the obturator nerve

CHAPTER FIVE

5.0 DISCUSSION

Anatomical variations have been described in almost all parts of the body with a few studies on the obturator nerve showing some variabilities. Variations are usually due to the variable genetic composition in different populations, which is an inheritance carried over long periods of time. Most of the anatomical variations are benign. These variations are due to the errors of embryological development as described by Arora, *et al*., (2014) (Arora, *et al*., 2014).

5.1 COURSE OF THE MAIN TRUNK OF OBTURATOR NERVE AS IT EMERGES FROM MEDIAL BORDER OF PSOAS MAJOR MUSCLE

The obturator nerve descended within the substance of psoas major to emerge from its medial border at the level of the pelvic brim. It is at this level where this study began because the specimens provided at the Moi University Human Anatomy department at the time of the study had been transected just above the level of the pelvic brim. The obturator nerve exited from the medial border of the psoas major muscle after coursing in its substance beneath the common iliac vessels. It then descended towards the lesser pelvis on its way being suspended by fatty and connective tissues. It then coursed along the wall of the lesser pelvis, lying anterosuperior to the obturator vessels almost horizontally just below the junction between the greater and lesser pelvis. It then moves towards the obturator foramen where it entered the obturator canal. On the wall of the lesser pelvis it is covered by thick fascia extending to cover obturator internus. This was the case in almost all (96.7%) samples with the exception of the two variations as a result of a branch arising in the pelvis. This concurs with the findings from the study by Tshabalala, (2015) in South Africa and by

Anagnostopoulou, *et al*., (2009) in Greece (Anagnostopoulou, *et al*., 2009; Tshabalala, 2015) In all the specimens the main trunk traversed the pelvis without dividing into anterior and posterior branches. This division occurred either in the obturator foramen or in the thigh. This concurs with the study by Tshabalala, (2015) who found a small percentage of 3% dividing in the pelvis (Tshabalala, 2015) but differed from the studies in Ethiopia and Greece which found intrapelvic division in 23.9% and 23.22% by Ka, *et al*., (2020) and Anagnostopoulou, *et al*., (2009) respectively (Anagnostopoulou, *et al*., 2009; Ka, *et al*., 2020).

In instances where the main trunk reached the thigh it did so by going through obturator canal which passed obliquely with the entry on the obturator internus being in the lateral part of the foramen while the exit on obturator externus almost approaching the middle of the superior portion of the foramen which concurs with the study by Tshabalala, (2015) (Tshabalala, 2015).

Notable variation was observed in the dissections through the finding of intrapelvic branch to obturator externus which was in contrast with what has been observed by Standring who stated that there is no intrapelvic branch (Standring, 2015).

There were no significant differences between the right and left sides which concurs with the study by Tshabalala, (2015) (Tshabalala, 2015). There were small differences on male and female dimensions with the females having slightly larger measurements owing mainly to the anatomical differences of the obturator foramen which is supported by the study on the gender differences of the obturator foramen conducted by Bierry, *et al*., (2010) in the French study (Bierry, *et al*., 2010).

5.2 LEVEL OF DIVISION OF THE OBTURATOR NERVE INTO ANTERIOR AND POSTERIOR BRANCHES

The obturator nerve was noted to divide within the obturator canal in majority of the specimens with 53 of the 60 (88%) dividing in the canal. This concurs with findings by Tshabalala, (2015) in South Africa who found majority (92%) of the specimens dividing within the canal (Tshabalala, 2015) while it contrasts with both the studies in Greece by Anagnostopoulou, *et al*., (2009) and in Ethiopia by Ka, *et al*., (2020) who found almost half of the specimens divided within the canal at 51.8% and 44.8% respectively (Anagnostopoulou, *et al*., 2009; Ka, *et al*., 2020)

There were no specimens which were found to divide into anterior and posterior divisions within the pelvis. This concurs with the findings by Tshabalala, (2015) who found a small percentage (3%) dividing within the pelvis (Tshabalala, 2015). This was however in contrast to the findings by Ka, *et al*., (2020) who found intrapelvic division to be 23.9% and Anagnostopoulou, *et al*., (2009) who found 23.22% (Anagnostopoulou, *et al*., 2009; Ka, *et al*., 2020)

In 2 out of the 60 (3.33%) specimens there was an intrapelvic branch to the obturator externus. This was however an independent branch as the division into anterior and posterior divisions occurred in the canal in both cases.

In 7 of the 60 (11.67%) specimens divided into anterior and posterior divisions after exiting the obturator canal in the proximal thigh. This concurs with findings by Tshabalala, (2015) who found 5% dividing into anterior and posterior branches in the thigh (Tshabalala, 2015) and differs from 31.3% in found by Ka, *et al*., (2020) and 25% by Anagnostopoulou, *et al*., (2009) (Anagnostopoulou et al., 2009; Ka et al., 2020)

5.3 DISTRIBUTION OF ANTERIOR BRANCH OF OBTURATOR NERVE

Most of the specimens dissected (76.67%) had an innervation pattern with one subdivision supplying two muscles with the rest having their muscular innervations arising independently from the anterior division. Majority of those that were sharing innervation was adductor longus and gracilis which comprised 70% of the total. This was however the only division from anterior branch in 29% by Anagnostopoulou, *et al*., (2009) and in 9% Ka, *et al*., (2020) (Anagnostopoulou, *et al*., 2009; Ka, *et al*., 2020). A small proportion of 6.7% supplied adductor longus and adductor brevis with the remainder 23% arising separately to each supply a specific muscle. This was not observed to my knowledge in the other studies because none of the studies set out to look at how the branching occurred rather, they were keen on what the anterior branch supplied.

Innervation of pectineus occurred in the study 6.7%. this concurs with 4.76% found by Anagnostopoulou, *et al*., (2009) and 1% found by Tshabalala, (2015) (Anagnostopoulou *et al*., 2009; Tshabalala, 2015). This was however in contrast to what Ka, *et al*., (2020) found which was 25.4% (Ka, *et al*., 2020). This shows that even though a small number of pectineus derived innervation from anterior branch of the obturator nerve majority is still dependent on femoral nerve like in anatomical literature.

Majority of adductor brevis was supplied by anterior branch with the remainder being supplied by posterior branch. This concurs with Ka, *et al* (2020) who found 91% of adductor brevis deriving innervation from the anterior branch (Ka, *et al*., 2020). This however contrasts with the findings by Anagnostopoulou, *et al*., (2009) who found 71.4% deriving innervation from the anterior diviosion of the obturator nerve. This was as a result of the 28.6% having only two branches to adductor longus and gracilis a finding that was not reflected in the study (Anagnostopoulou, *et al*., 2009).

Anterior division supplied all of adductor longus and gracilis. This concurs with the other studies by Ka, *et al*., (2020) Anagnostopoulou, *et al*., (2020) and Tshabalala, (2015) even though the branching patterns differed slightly in all the ended up supplying all of adductor longus and gracilis (Anagnostopoulou, *et al*., 2009; Ka, *et al*., 2020; Tshabalala, 2015). Anagnostopoulou, *et al*., (2009) however found 7% of adductor longus had dual innervation from both the anterior and posterior divisions of the obturator nerve. This was in contast to this study which did not find dual innervation to adductor longus just like in the studies by Ka, *et al*., (2020) and Tshabalala, (2015).

No dual innervation was noted in gracilis that was supplied by anterior division in this study supplied by the anterior division. Tshabalala, (2015) had similar findings on the innervation of gracilis with none having dual innervation.

There was also no dual innervation to adductor brevios noted in this study. This was in contrast to findings by Tshabalala, 2015 who found a small proportion of 10% of adductor brevis had dual innervation from both the anterior and posterior branches of the obturator nerve (Tshabalala, 2015). Ka, *et al*., (2020) and Anagnostopoulou *et al*., (2009) found a higher proportion of adductor brevis having dual innervation at 34% and 70% respectively.

The level of first muscular division to adductor longus, adductor brevis and pectineus all occurred in the proximal third of the thigh. This was not the case for gracilis which even though the majority arose from the proximal third 25% arose in the middle third of the thigh. The other studies did not look at the level of muscular divisions in relation to the position in the thigh.

5.4 DISTRIBUTION OF POSTERIOR BRANCH OF THE OBTURATOR NERVE

The posterior division in summary supplied obturator externus, adductor magnus and a small proportion of adductor brevis. Innervation to adductor brevis was noted in 1.7%. In these the adductor brevis was supplied solely by posterior division of the obturator nerve. This contrasts with findings by Tshabalala, (2015) who found 10% of adductor brevis receiving innervation from posterior division. This was also in contrast with the findings by Ka, *et al*., (2020) and Anagnostopoulou, *et al*., (2009) who found a higher percentage of 34% and 70% respectively. It is worth noting however as discussed earlier that in this other studies the adductor brevis being supplied by posterior division actually had dual innervation with anterior division (Anagnostopoulou, *et al*., 2009; Ka, *et al*., 2020; Tshabalala, 2015).

Innervation to adductor magnus was observed in all of the specimens. This concurs with the findings by Anagnostopoulou, *et al*., (2009) and Tshabalala, (2015) (Anagnostopoulou, *et al*., 2009; Tshabalala, 2015).

Majority of innervation to the obturator externus with majority arising from the obturator canal. This concurs with 100% found by Tshabalala, (2015) with the small difference being brought by the aberrant findings of intrapelvic branch to obturator externus in this study (Tshabalala, 2015).

No innervation to adductor longus was noted in this study. This was similar to the studies by Ka, *et al*., (2020) and Tshabalala, (2015) (Ka, *et al*., 2020; Tshabalala, 2015). This was in contrast to the findings by Anagnostopoulou, *et al*., (2009) who noted that 7% of adductor longus was supplied by posterior division in the form of dual innervation with anterior branch (Anagnostopoulou, *et al*., 2009).

In all the specimens the first muscular divisions of the posterior branch of the obturator nerve were in the proximal third of the thigh. The muscular division to obturator externus majorly arose within the obturator canal 53(88.3%) of the samples with the rest arising in the proximal thigh as indicated in the table above. This could not be compared to the other studies as none of them looked at level of muscular divisions in the thigh.

5.5 SURGICAL RELEVANCE

5.5.1 Obturator nerve entrapment and neuropathy

Obturator nerve entrapment has been described as one of the major cause of chronic groin pain in athletes. A local study by Mbarak, *et al*., (2019) on running-related musculoskeletal injuries, risk factors and treatment among kenyan runners found that 22% of athletes had groin issues (Mbarak, *et al*., 2019). Surgical management has been shown to be the effective choice of management for obturator nerve entrapment with non operative managemet largely unsuccessful (Bradshaw, *et al*., 1997). This study is therefore relevant because of the consideration of the intrapelvic branch to the obturator externus which could be the culprit. In addition the course and patterns of branching and innervation as described in this article for the Kenyan population will enable the surgeons to systematically follow the nerve while looking for the point of entrapment.

This information could also be applied in obturator nerve ganglion that has also been described as a cause of neuropathy presenting with adductor weakness and groin pain in athletes with no improvement of the symptoms achieved till after decompression of the nerve by excision of the ganglion (Schwabegger, *et al*., 2004).

5.5.2 Obturator nerve block

The use of the results from this study which demonstrates that in majority of the cases the obturator nerve divided into anterior and posterior branches within the canal and the others just after exiting the obturator canal with a mean distance of 9.91±0.80 mm from the canal is useful because targeting the nerve just after the obturator canal is going to theoretically anaesthetize both branches of the obturator nerve. This information coupled with the advances in imaging especially the use of ultrasounds in nerve blocks should be able to improve the efficacy of obturator nerve blocks in therapeutic and diagnostic procedures on the knee, diagnostic and therapeutic purpose of pain syndromes of the hip and, spasticity of adductor muscles and during transurethral resection of parts of the bladder wall.

Intrapelvic branch to obturator cases which occurs in a small percentage of the population should be kept in mind during assessment of efficacy of the block or during transurethral resection of bladder wall where the nerve may be stimulated. This may result in sudden extermal rotation of the thigh which should not be misconstrued as failure of the block rather it could be due to the aberrant intrapelvic branch.

5.5.3 Obturator nerve transfers

Nerve repair forms a very important part in orthopedic surgery and rehabilitation. The gold standard for nerve repair involves placement of nerve grafts between the 2 ends of the nerve. Nerve transfer involves sacrifice of 1 nerve for purposes of reinnervating another more important nerve. The obturator nerve have been successfully used in the repair of the femoral nerve (Campbell, *et al*., 2010; Tung, *et al*., 2012). Femoral nerve lesion causes more significant disability making the possibility of sacrificing the obturator nerve seem logical.

Using the anatomy of the main trunk of the obturator nerve as already discussed in this study. The obturator nerve could then be dissected free and mobilized for transfer to the distal stump of the femoral nerve to allow for the process of healing and reinnervation of the areas supplied by the femoral nerve. This includes the return of quadriceps function

5.5.4 Transobturator procedures

In this study the findings of obturator nerve exit in the obturator foramen in this study being noted to be slightly lateral to the midline like in the study by Tshabalala, (2015) (Tshabalala, 2015). This then confirms that it is safe to continue performing transobturator tape procedures for female stress urinary incontinence and male incontinence post prostatectomy. This is because the entry through the obturator foramen is usually medial which has been shown in our study to be devoid of the obturator nerve in our population thus inadvertaent injury is expected to be low.

5.5.5 Gracilis muscle transfer

Gracilis free muscle transfer is used when the duration of facial paralysis is longer than 2 years. In these cases, the facial muscles can no longer receive new nerve input. The gracilis muscle is carefully dissected ensuring the neurovascular structures are left intact so that revascularization and reinnervation can be done after the transfer to the face.

In urology gracilis muscle flap can be used to improve the outcomes of urethral stricture repairs. After urethral repair gracilis flap is placed on the site to provide a well-vascularised soft tissue reinforcement for urethral repair. This technique promotes vascular induction, whereby a new blood supply is introduced to the repair site.

Gracilis muscle transposition for anal incontinence has been in use for sometime. Gracilis muscle is used in encircling anal sphincter with its neurovascular system intact. It has been demonstrated to improve the quality of life by improving continence and increasing resting anal tone.

In all this the variation in the location of first muscular division of the obturator nerve must be kept in mind to avoid inadvertaent injury to the nerve. Our findings demonstrate that while a majority of the first muscular division occurs in the proximal thigh, a significant number arises in the middle third of the thigh. Utmost care should therefore be applied when dissecting the muscle free.

Figure 8: Intraoperative photograph showing gracilis muscle harvest (adopted from (Kalra, *et al*., 2016))

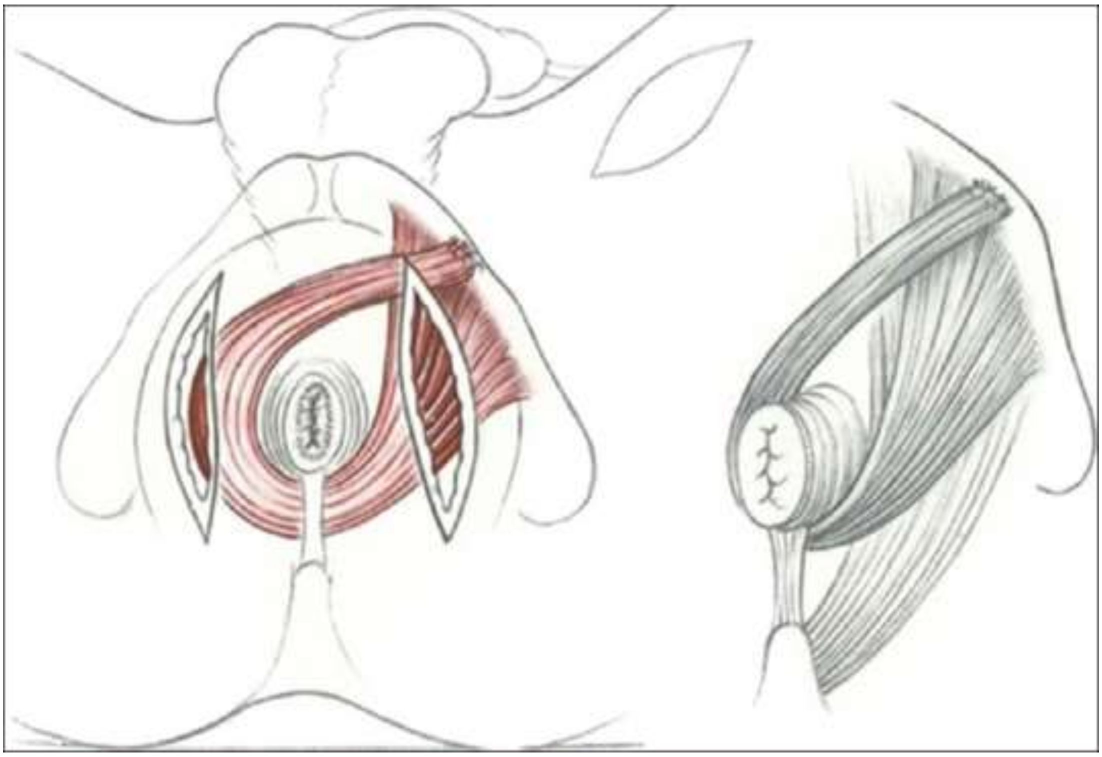

Figure 9:Line diagram showing gracilis muscle warp around anal canal (adopted from (Kalra et al., 2016))

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

1. Obturator nerve emerged from the medial border of psoas muscle at the level of pelvic brim.
2. Descended on the lateral wall of the pelvis towards obturator foramen exiting on the superolateral aspect.
3. Majority divided within the obturator canal to anterior and posterior divisions. Intrapelvic branch to obturator externus.
4. Anterior division innervates adductor longus, adductor brevis,gracilis and in a few instances pectineus. Adductor longus and gracilis was innervated by a single division in majority of the cases.
5. Posterior division innervated obturator externus, adductor part of adductor magnus and rarely in 1.7% adductor brevis.

6.2 Recommendations

1. Surgeons should be aware of variations in obturator nerve main trunk, divisions and branches during surgery to avoid injuries.
2. Administration of local blocks at the extrapelvic region efficacious since both branches are within the same vicinity.
3. Supply to gracilis muscle in the middle third of the thigh- nerve explorations, muscle transpositions and free flaps.
4. There is need for study of obturator nerve articular branches in the local population using fresh cadavers and fine disection tools.

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APPENDICES

Appendix 1: IREC Approval

MU/MTRH-INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE (IREC)

MOI TEACHING AND REFERRAL HOSPITAL
P.O. BOX 3
ELDORET
Tel: 33471//2/3

MOI UNIVERSITY
COLLEGE OF HEALTH SCIENCES
P.O. BOX 4606
ELDORET

Reference: IREC/2018/290
Approval Number: 0003207

31st January, 2019

Dr. Cheruiyot J. Kipkoech,
Moi University,
School of Medicine,
P.O. Box 4606-30100
ELDORET-KENYA.

INSTITUTIONAL RESEARCH & ETHICS COMMITTEE
31 JAN 2019
APPROVED
P. O. Box 4606-30100 ELDORET

Dear Dr. Cheruiyot,

RE: FORMAL APPROVAL

The MU/MTRH- Institutional Research and Ethics Committee has reviewed your research proposal titled: -

"Surgical Anatomy of the Obturator Nerve in the Adult Kenyan Population: A Cadaveric Study".

Your proposal has been granted a Formal Approval Number: ***FAN: IREC 3207*** on 31st January, 2019. You are therefore permitted to begin your investigations.

Note that this approval is for 1 year; hence will expire on 30th January, 2020. If it is necessary to continue with this research beyond the expiry date, a request for continuation should be made in writing to IREC Secretariat two months prior to the expiry date. You will be required to submit progress report(s) on application for continuation, at the end of the study and any other times as may be recommended by the Committee.

Furthermore, you must notify the Committee of any proposal change (s) or amendment (s), serious or unexpected outcomes related to the conduct of the study, or study termination for any reason. You will also be required to seek further clearance from any other regulatory body/authority that may be appropriate and applicable to the conduct of this study.

Sincerely,

DR. S. NYABERA
DEPUTY-CHAIRMAN
INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE

cc	CEO -	MTRH	Dean -	SOP	Dean -	SOM
	Principal -	CHS	Dean -	SON	Dean -	SOD

Appendix 2: Equipment and instruments

1. Measuring instruments: Vernier calipers, calibrated rulers.
2. Dissecting instruments: scalpel, blade holders, forceps, retractors
3. Digital camera
4. Stationery
5. Gloves
6. Printer
7. Hypodermic needles
8. Sutures (Nylon 2-0)

Appendix 3: Time Frame

Activity	Start	End
IREC Review	November 2018	January 2019
Collection of data	February 2019	November 2019
Data analysis	January 2020	March 2020
Thesis writing and presentation to the department of orthopedics and rehabilitation	May 2020	September 2020
Presentation of thesis to the school of medicine for examination purposes and defense	August 2020	March 2021

Appendix 4: Proposed Budget

Item	Quantity	Unit cost Kshs	Total Kshs
Laptop	1	65,000	65,000
Biostatistician	1	30,000	30,000
Printer	1	30,000	30,000
Questionnaire	Once	10,000	10,000
Printing cartridges	3	10,000	30,000
Flash disc	3	2500	7,500
Marker pens	5	50	250
Folders	100	60	6000
Box files	10	800	8,000
Printing papers	30	500	15,000
Paper punch	1	500	500
Stapler	2	300	600
Staples	3 packets	100	300
Biro pens	2 dozens	250	500
Pencils	1 dozen	300	300
Erasers	1 dozen	250	250
Digital calibrated caliper	2 pieces	10,000	20.000
Airtime/ internet bundles	6 months	3000 per month	18,000
Note books	12 pieces	100	12,000
Digital camera	1	30,000	30,000
Correspondence with publishing journal	1	12,000	12,000
Miscellaneous 10% of the total cost			29,620
Grand total			325,820

Appendix 5: Data collection sheet/form

1. Date………………………………………………………………………………

2. Identification code…………………………………………………………….

3. Side of the body: Right/Left……………………..….…

4. Sex of the limb: Male/Female………………….………….

5. Abdominal and pelvic course as described in Grays anatomy 41st edition

   Yes □ No □

   If no describe the variability…………………………………………………….

   ……………………………………………………………………………..

   ……………………………………………………………………………..

6. Location in the obturator foramen

   Distance from most superior point (A to B)……………………………………

   Distance from most medial point (B to C)……………………………………..

   Distance from most inferior point (B to D)…………………………………….

7 Level of division of the main trunk of obturator nerve.

LEVEL	DISTANCE FROM OTURATOR CANAL
Intrapelvic	
Obturator canal	
Thigh	

6. Distance from obturator nerve exit in obturator foramen to superior pole of patella…………………………..

7. Level of muscular division of anterior branch of obturator nerve

MUSCLE	DISTANCE FROM O.C
Adductor longus	
Adductor brevis	
Gracilis	
Pectineus	
Obturatorexternus	

Others ……………………………………………………………..

8. Level of muscular divisions of posterior branch of obturator nerve

MUSCLE	DISTANCE FROM O.C
Adductor longus	
Adductor brevis	
Adductor magnus	
Obturator externus	

Others ………………………………………………………..

9. Origin of articular branch of obturator nerve to the hip

Main trunk ……………………………………….

Anterior branch…………………………………..

Posterior branch …………………………………

Any observed variations (specify)

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Appendix 6: Obturator foramen measurements

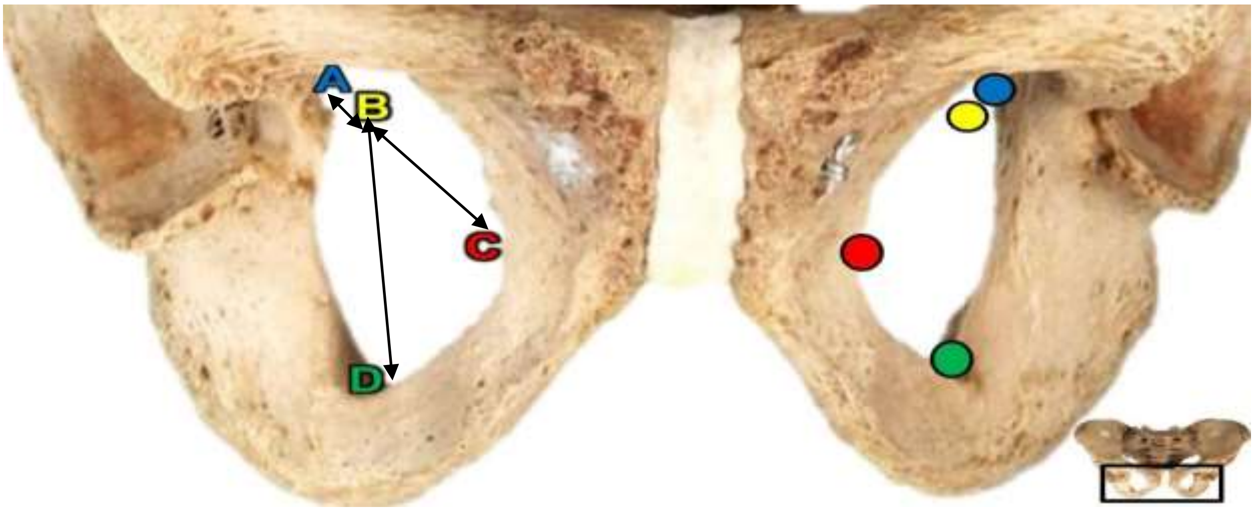

Figure indicating the points from which the measurements of the obturator nerve (B) will be taken from. A=most superior part, C=most medial part and D=Most inferior part. Adopted from Tshabalala, (2015).