CLINICAL IMPLICATIONS OF THE VARIATIONS OF SCIATIC NERVE BIFURCATION ON THE POPLITEAL NERVE BLOCK

By

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DECLARATION

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ABSTRACT

The sciatic nerve (SN) is a major nerve of the lower limb, innervating the posterior thigh, the hip and knee as well as structures below the knee through its branches. The SN division occurs in the popliteal fossa (PF) at the level of the knee. However, various studies report great variations in the level of division of the SN, ranging between 3.3 and 65.1%. These variations were suggested as a possible cause in failures of the popliteal block (PB). Therefore, the aim of this study is to describe the level of division of the SN in a South African cohort and to evaluate the success rate of three approaches to the PB. Following the simulation of the PB in 22 lower limb specimens, the popliteal fossae of 61 cadavers were dissected and the sciatic nerve properly exposed. The level of division was described and the location and distance between the dye and the nerve measured. Variations represented only 11.48% of cases, similar to textbooks' description (12%). The bifurcation pattern of the SN in this South African cohort was therefore comparable to the standard one. The distance between the SN and the PC varied between 20 mm and 405 mm, with a median of 55 mm, close to 60 – 70 mm found in most studies. The prevalence of variations was higher in females (ratio F:M=2.78) and 55.56% were bilateral. With the SN dividing in the PF, the simulation predicted a 100% success rate with no difference between the approaches used. Nevertheless, a higher division of the SN would compromise the success of the block. Overall, the SN division in our study population follows the normal pattern with a lesser degree of variations (11.48%). The division of the nerve in the PF might ensure a successful block in 95 to 100% of cases, in contrast to cases of high variations. Nevertheless, a preoperative imagery is strongly recommended, especially in women for early identification of variations to avoid failures of the PB, irrespective of the approach used.

OPSOMMING

N. ischiadicus is 'n hoof senuwee in die onderste ledemaat, wat die posterior kompartement van die dy, en die heup en knie voorsien, asook strukture onder die knie deur takke afkomstig vanaf die senuwee. Verdeling van n. ischiadicus vind plaas in die popliteale fossa (PF) op die vlak van die knie. Verskeie studies toon egter ʼn groot aantal variasies, wat wissel tussen 3.3% en 65.1%, ten opsigte van die vlak van verdeling van die senuwee. Daar is voorgestel dat hierdie variasies moontlik die oorsaak van mislukte toediening van ʼn popliteale blok (PB) kan wees. Die doel van hierdie studie is dus om die vlak van verdeling van n. ischiadicus in 'n Suid-Afrikaanse kohort te beskryf, en die voorkoms van sukses ten opsigte van drie benaderings tot die toediening van ʼn PB te evalueer. Na simulasie toediening van ʼn PB in 22 onderste ledemaatmonsters, is die popliteale fossa in 61 kadawers oopgedissekteer en n. ischiadicus blootgelê. Die vlak van verdeling is beskryf, en die ligging van die kleurstof en afstand tussen die kleurstof en die senuwee bepaal. Variasies het slegs in 11.48% van die gevalle voorgekom, vergelykbaar met gemiddelde aanduidings in handboeke (12%). Die bifurkasie patroon van n. ischiadicus in hierdie Suid-Afrikaanse kohort is dus vergelykbaar met die aanvaarde standaarde. Die afstand tussen n. ischiadicus en die popliteale plooi (PC) wissel tussen 20 en 405 mm, met 'n mediaan van 55 mm, in vergelyking met 60 tot 70 mm in die meeste studies. Die voorkoms van variasies was hoër by vroue as by mans (verhouding V : M = 2.78 : 1), en in 55.56% was die voorkoms van variasies bilateraal. Met verdeling van n. ischiadicus in die PF, het simulasie van ʼn PB 'n 100% voorspelde suksessyfer, met geen verskil ten opsigte van die benadering wat gebruik word nie. 'n Hoër verdeling van n. ischiadicus kan die toediening van ʼn PB moontlik nadeling beïnvloed. Oor die algemeen volg die verdeling van n. ischiadicus in ons studiepopulasie die normale patroon met 'n lae voorkoms van variasies (11.48%). Verdeling van die senuwee in die PF kan 'n suksesvolle blok in 95 tot 100% van gevalle waarborg, in teenstelling met hoër variasies. Beelding word preoperatief aanbeveel, veral by

vroue, vir vroeër identifikasie van variasies om mislukking met toediening van 'n PB te vermy, ongeag die benadering wat gebruik word.

RESEARCH OUTPUTS

Peer-reviewed manuscripts submitted for publications

- Simulation of the popliteal block: anatomical correlation with the sciatic nerve division
  C. Mady-Goma and V Tchokonte-Nana
- Variations of the sciatic nerve division in a South African coloured population: implications on the popliteal block
  C. Mady-Goma and V Tchokonte-Nana

Conferences

Oral Presentations

- Variations of the sciatic nerve division in a mixed ancestry Western cape cohort in South Africa: implications on the popliteal block
  C. Mady-Goma and V Tchokonte-Nana
  45th annual conference of the Anatomical society of Southern Africa (ASSA) at Langebaan, South Africa, April 2017.
- Variations of the sciatic nerve in a mixed ancestry South African population
  C. Mady-Goma and V Tchokonte-Nana
  Annual Academic Day, Faculty of Medicine and Health Sciences, Stellenbosch University, August 2016.

Poster Presentation

- A cadaveric simulation of the popliteal block
  C. Mady-Goma and V Tchokonte-Nana
  Annual Academic Day, Faculty of Medicine and Health Sciences, Stellenbosch University, August 2017

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ABBREVIATIONS

BF	Biceps femoris
BMI	Body mass index
CPA	Classic posterior approach
CFN	Common fibular nerve
GM	Gluteus maximus
IT	Intertendinous approach
LA	Lateral approach
LAT	Lateral
MED	Medial
MRI	Magnetic Resonance Imagery
NS	Neurostimulation/neurostimulator
PB	Popliteal block
PC	Popliteal crease
PCB	Distance between the popliteal crease and the point of bifurcation
PF	Popliteal fossa
PM	Piriformis muscle
PT	Posterior thigh
RA	Regional anaesthesia
SM	Semimembranosus
SN	Sciatic nerve
ST	Semitendinosus
SD	Standard deviation
US	Ultrasound

Chapter 1 - INTRODUCTION

The sciatic nerve (SN) is one of the major nerves of the lower limb with clinical and therapeutic significance. It is the longest and largest nerve of the body. It runs from the pelvis to the distal third of the posterior thigh (PT), where it normally divides after entering the popliteal fossa (PF), giving two main branches: the tibial nerve (TN) and the common fibular nerve (CFN) (Drake, Vogl and Mitchell, 2015). The SN can be involved in pathologic mechanisms or used in regional anaesthesia (RA) for surgical procedures of the lower limb (Lewis *et al*., 2016). Different techniques of SN block are available, the most distal approach being the popliteal block (PB) , defined as the block of the SN in the PF, before its bifurcation (single-injection technique) (Chelly, 2004, 2009; Hadzic and Vloka, 2004). It is the method of choice for foot and ankle surgery. Nevertheless, variations of the SN, specifically in its level of division (high divisions or high variations), were frequent and acknowledged to be one of the main causes of unsuccessful SN block. As a matter of fact, the SN is generally described as dividing in the PF in 85-89% of cases (Kiros and Woldeyes, 2015). However, different studies reported variations in the levels of division with a high percentage of high divisions (division above or out of the PF). The normal pattern (division in the PF) occured in only 72% in Poland (Okraszewska *et al*. 2002), 72,5% in Serbia (Ugrenović *et al.*, 2005) and 67,1% in Kenya (Ogeng'O *et al.*, 2011). These results differ from the normal description. On the other hand, when performing the PB, the needle is generally inserted approximately 7cm above the popliteal crease (Hadžic *et al.*, 2002; Hadzic and Vloka, 2004; Nader *et al.*, 2009), which explains the failure in case of high division of the SN (Saleh, El-Fark and Abdel-Hamid, 2009; Prakash *et al.*, 2010). The neurostimulator (NS) and the ultrasound (US), are two main methods used to help localizethe nerve (Chelly, 2004; De Andrés *et al.*, 2005), thus improving the success rate of the PB.

Regional anaesthesia such as PB is preferred to general anaesthesia because of the many advantages and the few complications. The PB provides sufficient anaesthesia and excellent control of pain, which shortens the length of hospital stay; theses characteristics are essential for foot and ankle surgery because of the pain induced. In addition, the consumption of analgesics (opioids) is lowered as well as their side effects. Furthermore, the effects on the cardiorespiratory function and the vagal system such as headaches, vomiting or nausea are limited (Hansen, Eshelman and Cracchiolo 3rd, 2000).

At present, studies on SN division are not well documented in Southern African populations and data available are limited because of the small samples used. Besides, the South African population is heterogenous… Therefore, this study, which aims both to describe the level of division in a South African cohort and evaluate implications of variations on the popliteal block, will add to the knowledge of the SN anatomy and improve the success rate of the PB.

Chapter 2 - LITERATURE REVIEW

The term "popliteal block" (PB) refers to a regional anaesthetic (RA) technique that targets the sciatic nerve close to its termination in the popliteal fossa (PF) (Hadzic and Vloka, 2004). This anaesthetic technique encompasses many approaches which can be performed during surgical procedures below the knee, especially for foot and ankle (Barbosa *et al.*, 2015). The advantages offered are numerous and of better value than other anaesthetic techniques such as general anaesthesia or spinal anaesthesia (Benzon, 2005; Hansen and Netter, 2014). Nevertheless, the success of the PB is related to a deep knowledge of the sciatic nerve (SN) and the identification of the landmarks among which are the superior margins of the PF (Reinoso-Barbero *et al.*, 2014; Barbosa *et al.*, 2015). The following sections describe the anatomy of the SN, the PB as well as the anatomical landmarks used, and the clinical implications of SN variations.

2.1. Sciatic nerve

The sciatic nerve (SN) is part of the peripheral nervous system (PNS) that establishes connections between the centre of command in the central nervous system and the periphery. Through the PNS, sensory information is carried to the CNS (centre of command) and responses are sent to the muscles (motor). Peripheral nerves such as the SN therefore have both a sensory and motor function (Schoenwolf *et al.*, 2014).

2.1.1. Development of the sciatic nerve

The development of peripheral nerves is simultaneous with the limb development (Schoenwolf *et al.*, 2014). The lower limb buds appear at a later stage than the upper limb buds, around 28-29 days (Cochard *et al.*, 2012). According to Schoenwolf *et al.* (2014), around 10 weeks post-coitum (pc), the SN is essentially made of unmyelinated fibres. Schwann cells, that will later form the myelin sheath start proliferating from 12 to 17 weeks pc. Consequently, the structure of the nerve changes progressively and myelination begins at 18 weeks pc.

The final structure of the SN is similar to that of other peripheral nerves (Benzon, 2005) with three main connective tissue layers. First, the endoneurium encloses each nervous fibre, which are later grouped in fascicles. Secondly, these fascicles are bound together by the perineurium and held together by some connective tissue. The most external layer is the epineurium. The whole structure is surrounded by the epineural tissue.

2.1.2. Anatomy

Most prominent nervous structure of the human body, the SN is also one of the major nerves of the lower limb (Okraszewska *et al.*, 2002; Prakash *et al.*, 2010; Drake, Vogl and Mitchell, 2015). This nerve innervates a large area in the lower limb and mainly the posterior thigh (Drake, Vogl and Mitchell, 2015). The SN finds its origin in the lumbosacral plexus and arises from the fusion of the anterior rami of spinal nerves, namely the fourth and fifth lumbar nerves as well as the first, second and third sacral nerves (Vloka *et al.*, 1997; Adibatti, Sangeetha and Adibatti M, 2014; Hansen and Netter, 2014; Drake, Vogl and Mitchell, 2015). The merging of these spinal branches of the lumbosacral plexus occurs in the pelvis (Kukiriza, Ibingira and Ochieng, 2015). From its origin, the sciatic nerve presents two distinct components: the tibial nerve (TN) and the common fibular nerve (CFN) (**Figure 2-1**).

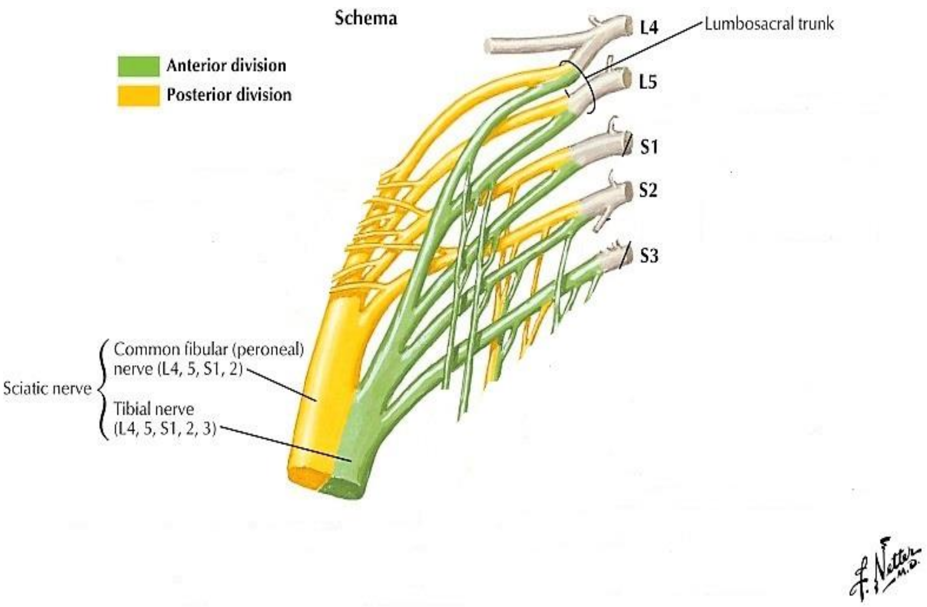


Figure 2-1 Origin of the sciatic nerve and components.
Source: Atlas of Anatomy (Netter, 2011)

Anatomically, these branches are enjoined in a common epineural sheath; however, they are functionally distinct (Guvencer *et al.*, 2009). This sheath plays a role in the diffusion of the anaesthetic and contributes to the anaesthesia of both the TN and the CFN (Vloka *et al.*, 1997). The rami contributing to the formation of the SN gives rise to anterior divisions (L4-S3) for the tibial component and posterior divisions (L4-S2) for the common fibular component.

Between its origin and termination, the SN successively runs through the pelvis, the gluteal region and the posterior thigh until its distal third, in the popliteal fossa (PF).

The sciatic nerve (SN) enters the gluteal region via the greater sciatic foramen, underneath the piriformis muscle (Saleh, El-Fark and Abdel-Hamid, 2009; Ekanem *et al.*, 2015) (**Figure 2-2**).

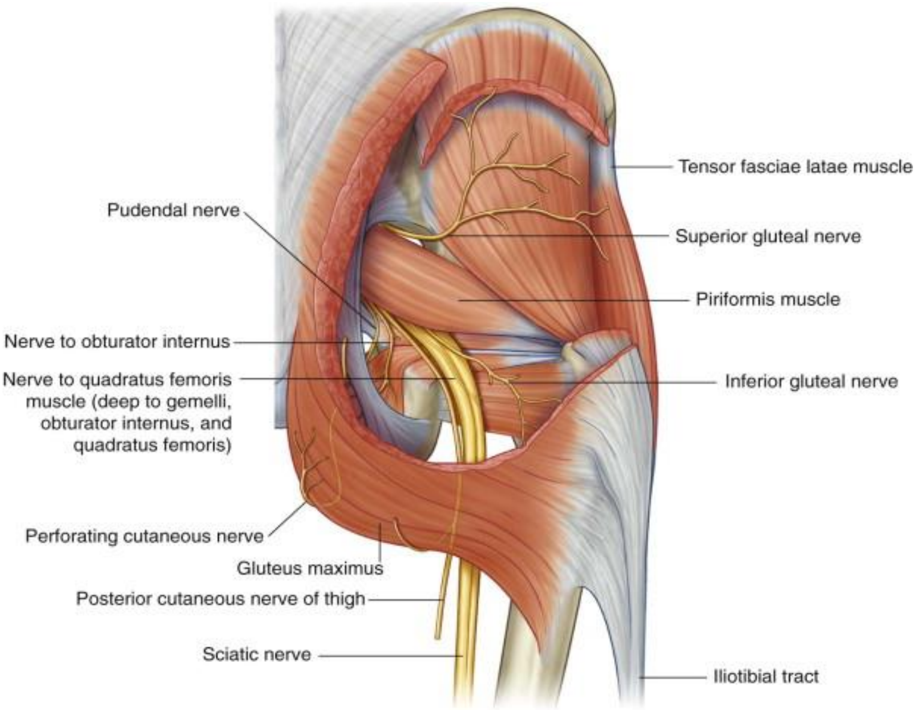


Figure 2-2: Exit of the sciatic nerve below the piriformis muscle. This figure shows the exit of the SN hust below the piriformis muscle as a single trunk.

Source: Gary's Anatomy for students (Drake, Vogl and Mitchell, 2015).

The rapport between the SN and the PM shows anatomic variations which have previously been reported in many populations (Guvencer *et al.*, 2009). They are mostly associated with a bifurcation of the SN in the pelvis and a classification, elaborated by Beaton and Anson in 1937 (Okraszewska *et al.*, 2002; Guvencer *et al.*, 2009), is used to label the different variants (Guvencer *et al.*, 2009). These variations can lead to clinical manifestations recognised as the piriformis syndrome, caused by the compression of one of the branches or the common trunk of the sciatic nerve (Rani and Kalra, 2015). However, they are not the focus of this study.

In the gluteal region, the SN is in relation with the posterior surfaces of the gemelli muscles, the quadratus femoris and the obturator internus that are crossed posteriorly (***Figure 2-2***) (Adibatti, Sangeetha and Adibatti, 2014). Close to the inferior border of the quadratus femoris, the SN enters the posterior thigh and runs parallel to the biceps femoris muscle until its termination in the PF (Drake, Vogl and Mitchell, 2015) (**Figure 2-3**).

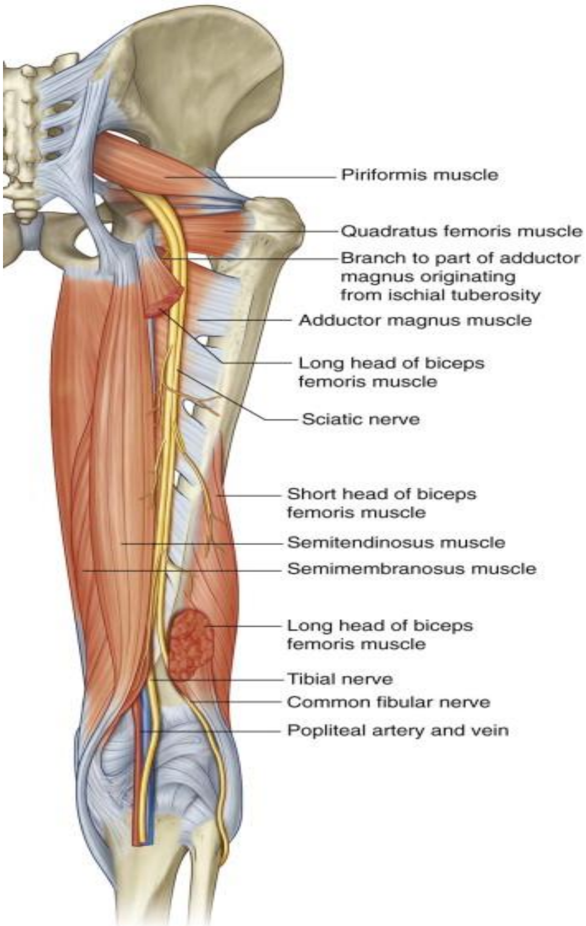


Figure 2-3: Route and termination of the SN. The SN from its origin to the PF and along its route gives muscular branches to the hamstring.

Source: Gary's Anatomy for students (Drake, Vogl and Mitchell, 2015)

The SN terminates and bifurcates in the PF and at this level, the SN is superficial, localised at a depth of 20-30 mm (James Phillips, Troutman and Lerant, 2011). The description of the pattern of division is given below and is comparable to findings by Sohn *et al.* (2015) who also found the SN at a depth of 20.6 ± 7.1 mm from the skin.

2.1.3. Branches of the sciatic nerve

The tibial nerve (TN) and common fibular nerve (CFN) are two subdivisions of the sciatic nerve after it branches in the PF. The TN descends vertically, whereas the CFN descends laterally and twists around the neck of the fibula. Their anatomical description as given in textbooks (Hansen and Netter, 2014; Drake, Vogl and Mitchell, 2015) will be detailed here.

2.1.3.1. Tibial nerve

The TN is the branch of the SN made of the anterior divisions of L4 to S3. After the division of the SN in the PF, the TN travels vertically downward, parallel to the midline. From there, it penetrates the posterior compartment of the leg in the space between the two heads of the gastrocnemius. Along its course, the TN gives a branch (medial), which combined to another branch from the CFN (lateral), forms the sural nerve. Close to the termination, the TN gives the medial calcaneal nerve before ending its course in the foot with the plantar nerves (medial and lateral). The two branches of the SN are surrounded by the epineural sheath until their separation in the PF (Vloka *et al.*, 1996).

2.1.3.2. Common fibular nerve

The CFN exits the PF by following the Biceps Femoris' long head. It spirals around the neck of the fibula, crossing successively the lateral and anterior sides of the leg. The CFN divides and gives two branches: Superficial and Deep fibular nerves, respectively for the lateral and anterior compartments of leg.

Figure 2-4 gives a brief overview of the divisions and subdivisions of the sciatic nerve. All these branches contribute to the muscular innervation of the foot and leg as well as a partial cutaneous innervation of that area. Terminal branches are not represented in this diagram.

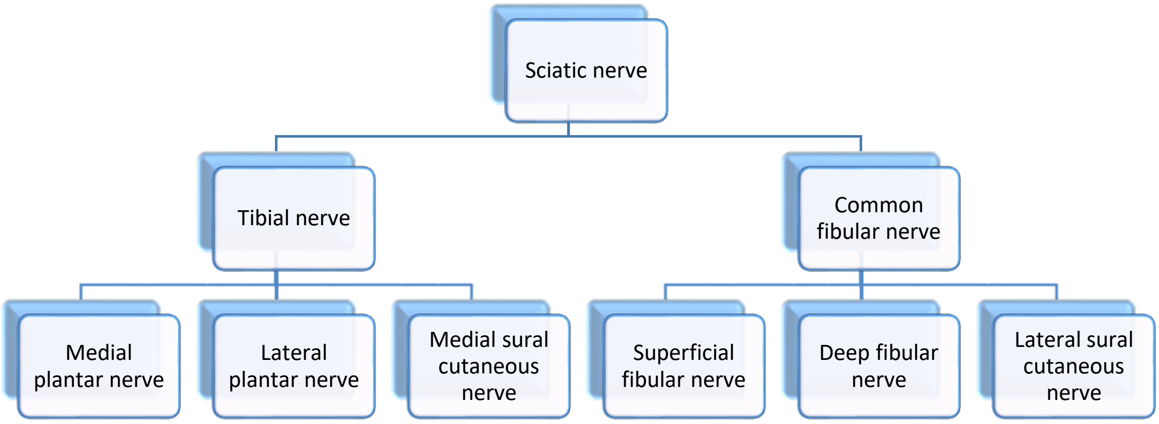


Figure 2-4: Branching pattern of the sciatic nerve (diagram based on descriptions).
Source: Gary's Anatomy for students (Drake, Vogl and Mitchell, 2015).

The distance of the point at which the SN bifurcates from the popliteal crease is not described in textbooks. Vloka *et al*. (1997) first evaluated this distance as ranging between 0 and 73 mm, while the distance ranged between 0 and 115 mm in another of their study (Vloka *et al.*, 2001). However, these observations are limited, due to the small sample sizes used for the analysis (10 specimens only for the first study and 28 in the second).

2.1.3.3. Variations in the branching pattern

The anatomy of the sciatic nerve varies greatly (**Table 2-1**) according to studies carried out in different populations (Okraszewska *et al.*, 2002; Ugrenović *et al.*, 2005; Guvencer *et al.*, 2009; Ogeng'O *et al.*, 2011; Adibatti, Sangeetha and Adibatti M, 2014; Kiros and Woldeyes, 2015).

Table 2-1: Variations in the SN anatomy (expressed in % of total limbs examined)

Authors	N*	Variations **	A	B	C	D
Okraszewska *et al*. (2002)	36	27.8	13.9	-	13.9	72.2
Pokorny *et al*. (2005)	182	20.9	-	-	-	-
Ugrenovic *et al*. (2005)	200	27.5	-	18.5	9	72.5
Vicente *et al*. (2007)	40	15	-	-	-	-
Guvencer *et al*. (2009)	50	24	-	-	-	-
Prakash *et al*. (2010)	86	65.1	16.3	2.3	46.5	34.9
Patel *et al*. (2011)	86	8.1	-	-	-	-
Ogeng'o *et al*. (2011)	164	32.9	20.1	2.4	10.4	67.1
Natsis *et al*. (2013)	294	6.4	.	-	-	-
Adibatti *et al*. (2014)	50	8	6	-	2	92
Kiros *et al*. (2014)	36	8.3	-	-	-	-
Berihu *et al*. (2015)	56	25	-	-	-	-

*N: total number of specimens (limbs) examined

**Percentages. Variations correspond to cases of division above the PF, sometimes coupled with anomalies of the relationship with the piriformis muscle. The results for each category (A, B, C, D) are also expressed in percentages.

Levels of division: A= pelvis, B= gluteal region, C= posterior thigh, D= apex of the popliteal fossa, E= below the apex (no case found)

Sources: (Okraszewska *et al.*, 2002; Triadó *et al.*, 2004; Ugrenović *et al.*, 2005; Pokorný *et al.*, 2006; Guvencer *et al.*, 2009; Prakash *et al.*, 2010; Ogeng'O *et al.*, 2011; Patel *et al.*, 2011; Adibatti, Sangeetha and Adibatti M, 2014; Natsis *et al.*, 2014; Berihu and Debeb, 2015; Kiros and Woldeyes, 2015).

Generally speaking, most of the variations in the SN anatomy are of two types: variations in the relationship with the piriformis muscle (PM) (Guvencer *et al.*, 2009; Natsis *et al.*, 2014) and variations in the level of division of the SN. Both types are sometimes associated, especially in cases of SN division in the pelvis (Okraszewska *et al.*, 2002). Besides, variations such as trifurcations or emergence of the sural nerve directly from the sciatic nerve could be rarely observed (Prakash *et al.*, 2010; Adibatti, Sangeetha and Adibatti M, 2014; Berihu and Debeb, 2015). In this study, the focus was only on variants in the level of bifurcation of the SN. In most cases, the terms high variations and high divisions were used interchangeably to describe a SN dividing above (outside of) the PF.

Many studies reported a bifurcation of the SN at any point along its course between the pelvis and the PF (see **Table 2-1**). The symmetry (division at the same level on both sides) was individually variable (Rani and Kalra, 2015) and only a few comparisons were made between male and female. Because multiple surgical procedures are carried out in the gluteal region, a precise knowledge of the SN division would be essential for surgeons (Rani and Kalra, 2015). Also, many clinical situations such as nerve injuries (Adibatti, Sangeetha and Adibatti M, 2014; Berihu and Debeb, 2015; Ekanem *et al.*, 2015; Kiros and Woldeyes, 2015), muscular atrophy (Ogeng'O *et al.*, 2011), non-discogenic sciatica or piriformis syndrome by entrapment of the sciatic nerve or its branches (Guvencer *et al.*, 2009; Patel *et al.*, 2011; Supriya, 2012; Adibatti, Sangeetha and Adibatti M, 2014) are the most frequent clinical presentations related to variations in the level of division of the sciatic nerve (Kiros and Woldeyes, 2015; Tomaszewski *et al.*, 2016). To avoid all these complications, surgeons and physicians in general must be aware of these variations (Ogeng'O *et al.*, 2011). In addition, any case of SN injury leading to paralysis could cause an atrophy of the muscles supplied.

In a normal setting, the SN divides in the popliteal fossa in 85 to 89% (Supriya, 2012; Ekanem *et al.*, 2015; Kiros and Woldeyes, 2015). Adibatti *et al.* (2014) in their study on the Indian population showed the lowest rate of variations with a normal pattern visible in 92% of the lower limbs examined. While the sciatic nerve is was described as varying in almost 10% of cases, a review of the literature showed that the variations of the sciatic nerve anatomy in general could vary between 6.4% (Natsis *et al.*, 2014) and 65.1% (Prakash *et al.*, 2010). This frequency is highly variable in different populations and even among the same population. Studies carried out in Kenya (Ogeng'O *et al.*, 2011) and Serbia (Ugrenović *et al.*, 2005) for example, showed that variations occurred respectively in 32.9% and 27.5% of the specimens examined. There is no uniformity in the frequencies found in different study populations and this interpopulation variability could be the result of methodological differences. The Serbian study (Ugrenović *et al.*, 2005) was indeed carried out on 200 specimens while the Kenyan study (Ogeng'O *et al.*, 2011) was on 164 specimens. Meanwhile, a polish study on 36 lower limbs (Okraszewska *et al.*, 2002) presented with 27.8% of variations, however similar to the findings in the Serbian population (Ugrenović *et al.*, 2005), bringing the frequency of division in the PF to approximately 72% (Okraszewska *et al.*, 2002; Ugrenović *et al.*, 2005). In addition, great differences can also be observed in the same population such as the Indian population with variations of 8% and 65.1%, respectively found by Adibatti *et al.* (2014) and Prakash *et al.* (2010). Therefore, methodology can play a role but cannot explain all these differences, which appear to be present among populations. They could be interpersonal differences resulting from genetic arrangements. We did not intend in our study to look at the causes of these variations but we will essentially restrict it to the description of the sciatic nerve division.

According to classifications in the literature (Kiros and Woldeyes, 2015) relating to the level at which the bifurcation occurs, the SN division was grouped in 5 categories as follows:

- Category A: Division in the pelvis
- Category B: Division in the gluteal region
- Category C: Division in the posterior thigh
- Category D: Division at the apex of the popliteal fossa
- Category E: Division below the apex of the popliteal fossa

In certain classifications, category C (division in the posterior thigh) has three subtypes namely divisions in the proximal, mid and distal third. Besides, division at the apex and below the popliteal fossa can be grouped under popliteal fossa, as we are more interested in the high divisions. Division below the apex of the popliteal fossa would not be inconvenient, considering also the fact that no study was precise about what they considered as being below the apex of the PF and it does not affect the outcome of the PB.

Concerning the distance at which the SN divides above the PC, high variations affect the distance between the PC and the point of bifurcation of the nerve. The mean varied between 44 and 82 mm (Vloka *et al.*, 1997, 2001; Saleh, El-Fark and Abdel-Hamid, 2009; Schiarite *et al.*, 2015; Sohn *et al.*, 2015; Tomaszewski *et al.*, 2016). When the distance was recorded, the lowest point at which the sciatic nerve divided was at the level of the popliteal crease (Vloka *et al.*, 1997, 2001). The highest point was in the posterior thigh at a distance of 180 mm (Saleh, El-Fark and Abdel-Hamid, 2009).

As discussed earlier, these variations of the sciatic nerve would affect the outcome of the PB. The common technique consists in locating the common trunk of the SN before the bifurcation;

it therefore shows the importance of the sciatic nerve anatomy and the existing variations, paramount to a successful PB.

2.1.4. The popliteal fossa

The popliteal fossa is a transition area between the thigh and leg, posterior to the knee joint. Its shape corresponds to that of a diamond (**Figure 2-5**) and the boundaries are essentially muscular (Gosling, 2008; Creech and Meyr, 2013). As described in **Figure 2-5**, the biceps femoris constitutes the superior lateral border, while the semitendinosus and semimembranosus form the superior medial border. These muscles all together are called hamstring. On the other side, the gastrocnemius muscles and the plantaris muscle form the inferior boundaries (Creech and Meyr, 2013).

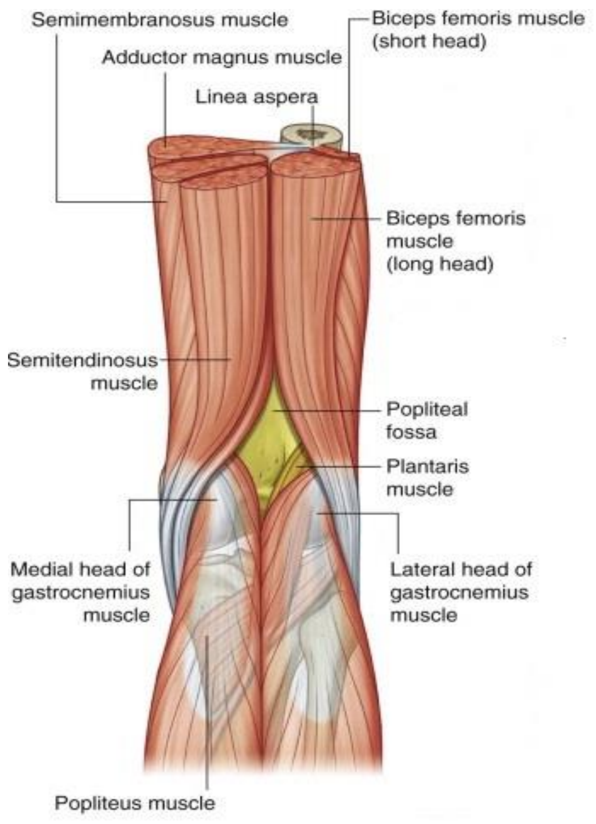


Figure 2-5: Popliteal fossa. Margins and landmarks. The superior margins are biceps femoris, semitendinosus, and semimembranosus while the inferior margins are both lateral and medial head of gastrocnemius.

Source: Gary's Anatomy for students (Drake, Vogl and Mitchell, 2015)**.**

The popliteal fossa (PF) is considered to be the normal level for the division of the SN (Adibatti, Sangeetha and Adibatti M, 2014). However, there are cases of high bifurcation which occur outside of the PF, at any point along the course of the nerve (Ekanem *et al.*, 2015). Besides the SN and its branches, the PF contains a lot of adipose tissue and the popliteal vessels, located medially and deeper to the SN (Rorie *et al.*, 1980; Creech and Meyr, 2013). This detail is of importance when injecting in that area, to avoid the risk of vascular punctures. Also, the fat present in the PF could be favourable as it extends the duration of action of local anaesthetics (Creech and Meyr, 2013) even though there is a risk of impairment in the distribution of the anesthetic around the nerve (Rorie *et al.*, 1980).

2.1.5. Structures innervated by SN

The sciatic nerve (SN) is described as a mixed nerve with a motor and sensory function (Adibatti, Sangeetha and Adibatti M, 2014; Drake, Vogl and Mitchell, 2015). It innervates the hamstring (Biceps femoris, Semitendinosus and Semimembranosus) as well as a portion of the Adductor magnus. It also supplies the hip joint and the knee joint through articular branches (Okraszewska *et al.*, 2002; Drake, Vogl and Mitchell, 2015). It therefore contributes to the flexion of the knee and the extension of the hip. After bifurcation, the tibial nerve (TN) and the common fibular nerve (CFN) serve most muscular structures of the leg and foot. The TN supplies muscles of the posterior aspect of the leg and the planter surface of the foot while the CFN supplies the other muscles of the leg and of the dorsal surface of the foot. Both nerves participate in the cutaneous innervation below the knee, save the anteromedial side of the leg and the foot (Lewis *et al.*, 2016).

According to the territory innervated, the TN and CFN participate to musculoskeletal movements of the lower limb. The TN supplies the muscles that produce plantarflexion and inversion movements of the foot as well as flexion of the toes. The CFN on the other hand, ensures the eversion of the foot as well as foot dorsiflexion and eversion of the toes. The sensory cutaneous innervation is destined to the leg and foot (**Figure 2-6**), except from the anteromedial aspect of the leg and foot innervated by the saphenous nerve (Okraszewska *et al.*, 2002; Adibatti, Sangeetha and Adibatti M, 2014).

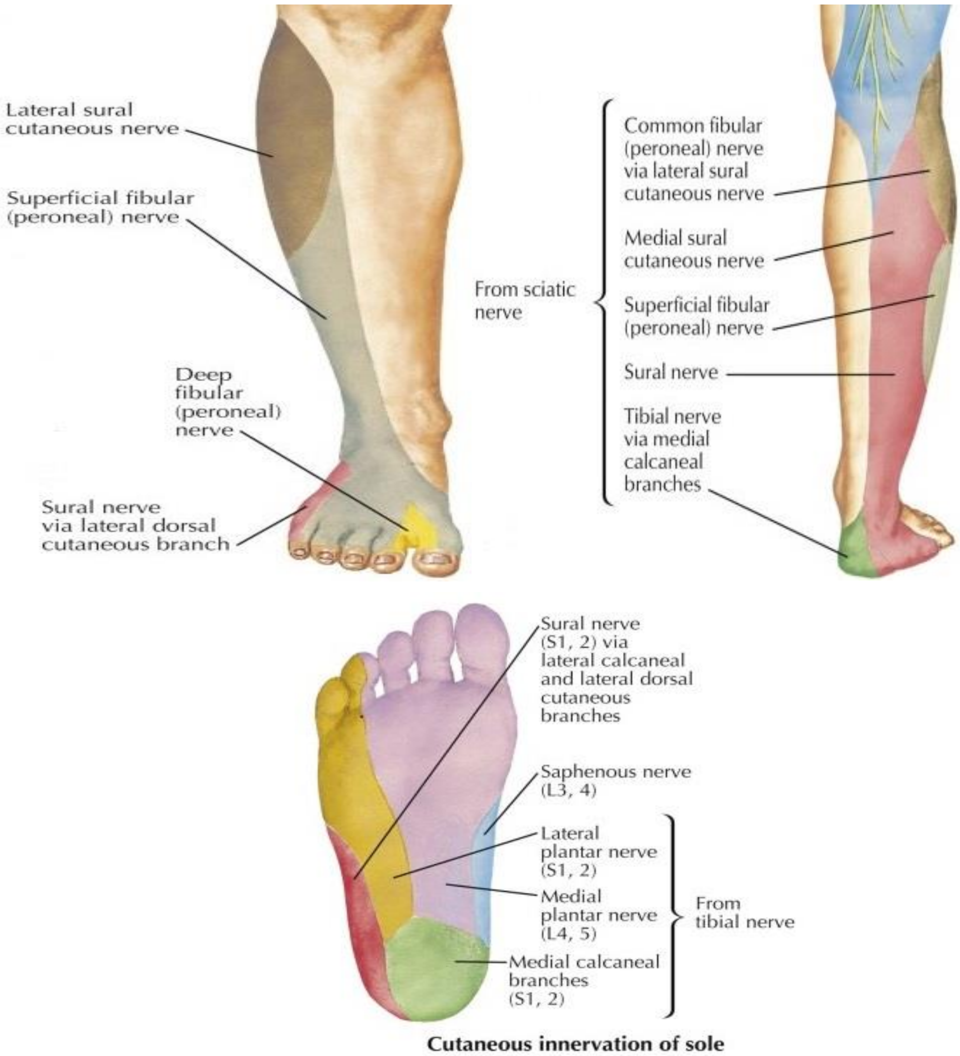


Figure 2-6: Cutaneous innervation of the lower limb through the branches of the sciatic nerve

Source: Atlas of Human Anatomy (Hansen and Netter, 2014)

2.2. Popliteal block

The popliteal block is one the distal approaches to the blockade of the SN and is realised in the PF. While a blockade of the nerve above that point is more difficult due to the deep location of the nerve, the popliteal block is easier and gives more satisfaction (Herring *et al.*, 2011; Barbosa *et al.*, 2015).

2.2.1. Definition

The popliteal block (PB) is a peripheral nerve block which entails an obstruction to the nervous conduction of the SN from the PF and downwards. It is the most distal approach to the sciatic nerve, first performed by Labat in 1923 (Hegewald *et al.*, 2014). Compared to the double-injection technique that targets each branch (TN and CFN), the single-injection targets the common trunk of the SN before its bifurcation (March *et al.* , 2006); this would reduce the risk of vascular puncture because the popliteal vessels are still located deeper (Phillips *et al.*, 2011).

The infrequent use of the popliteal block was due to the risk of complications or failure. Yet, it remained a technique of choice for foot surgery (Rorie *et al.*, 1980). Hadzic *et al.* (2002) also suggested the insufficient preparation of the operating room, the variable outcome and a problem in the training of anaesthesiologists. There are different ways to perform a peripheral nerve blockade: blind methods, PB using a neurostimulator or PB using ultrasound (US). Blind techniques are still used even though the use of neurostimulator or ultrasound (US) is more beneficial. The neurostimulator is a great tool in localising the nerve and therefore improving the success rate by allowing a better localization of the nerve than blind methods (Hadzic and Vloka, 2004). Nevertheless, lately the US brings a new dimension to PB with more precision, the possibility to visualize the nerve and therefore less complications (Prasad *et al.*, 2010).

2.2.2. Indications

The PB is the preferred anaesthetic technique used for foot and ankle surgery (Rorie *et al.*, 1980; Prasad *et al.*, 2010). It can be used as a single technique or combined to other regional anesthetic techniques for a larger action in below-the-knee anaesthesia or analgesia (Bouaziz *et al.*, 1999). Initially this technique of RA was not widely used. Nowadays, it can even be used as a postoperative analgesic technique in the emergency department, as reported by Philips *et al.* (2011).

2.2.3. Technique

The PB encompasses different approaches and techniques. The block is commonly easy to perform (Chelly, 2003; Triadó *et al.*, 2004). Nevertheless, with the blind method (without the use of NS or US to locate the nerve), the PB has a high rate of failure especially in situations of high variations of the nerve (Reinoso-Barbero *et al.*, 2014). The PB is sometimes combined to the saphenous block to obtain a good desensitisation of the lower limb (Mendicino, Statler and Catanzariti, 2002).

The equipment needed to perform a popliteal block includes needles of 22 gauge (function of the approach used), syringes, ruler, marking pen, disinfectant, drapers, sterile gloves, gauze pack, etc. When injecting the anaesthetic, it is essential to place the needle near the nerve to avoid impairment of the substance distribution in the popliteal fossa (Rorie *et al.*, 1980). As stated before, the US or the NS (neurostimulator) aids the localisation of the nerve. When using the NS, the best predictive factor for complete blockade is foot inversion (Ter Rahe and Suresh, 2002; De Andrés *et al.*, 2005; Arcioni *et al.*, 2007).

The approaches to the PB described in the literature are numerous but only three will be the focus of this study: classic posterior, intertendinous and lateral approaches. They differ in the placement of the patient and the point at which the needle is inserted. The surface landmarks and the points of injection will be described in the description of each technique. The posterior approaches have more constraints when it comes to placing the patient (Muñiz *et al.*, 2003); the prone position is indeed difficult to adopt for certain categories of patients while the position for the lateral approach offers more comfort with the patient lying face upwards.

2.2.3.1. Posterior approaches

The patient is commonly placed lying on the bed, face downwards (prone position). The classic landmarks are the hamstring borders and the popliteal crease (PC); they are outlined with a marker. Slight differences in the point of injection were described. Some authors would place the needle at 5 to 7 cm (Rorie *et al.*, 1980; Vloka *et al.*, 1997; Hadzic, 2007) above the crease while others advocate a placement of the needle at 10 cm to ensure a higher success rate (Singelyn, Gouverneur and Gribomont, 1991). More recently, modified approaches were experimented with the needle inserted at 12 to 14 cm above the PC (Nader *et al.*, 2009). Many factors should be taken into consideration when choosing the approach, including the preference of the surgeon, the patient pathology and the position of the patient (Chelly, 2003). Two variants of the posterior approach have been developed: the classic posterior approach and the intertendinous approach. The needle would be introduced at a depth of approximately 3 cm (Casalia, Carradori and Moreno, 2006).

2.2.3.1.1. Classic posterior approach (CPA)

For this approach (**Figure 2-7**), the needle is generally inserted at 7cm above the popliteal crease. However, variants have been described. Rorie *et al.* (1980) suggested a placement of the needle at 5 cm above the crease. The anaesthesia was successful in 82.3% of cases though the point of injection was lower than in techniques proposed by Hadzic *et al*. (2002) who inserted the needle 7 cm above the PC and perpendicular to the skin. Other authors inclined the needle 60° proximally (Chelly, 2003).

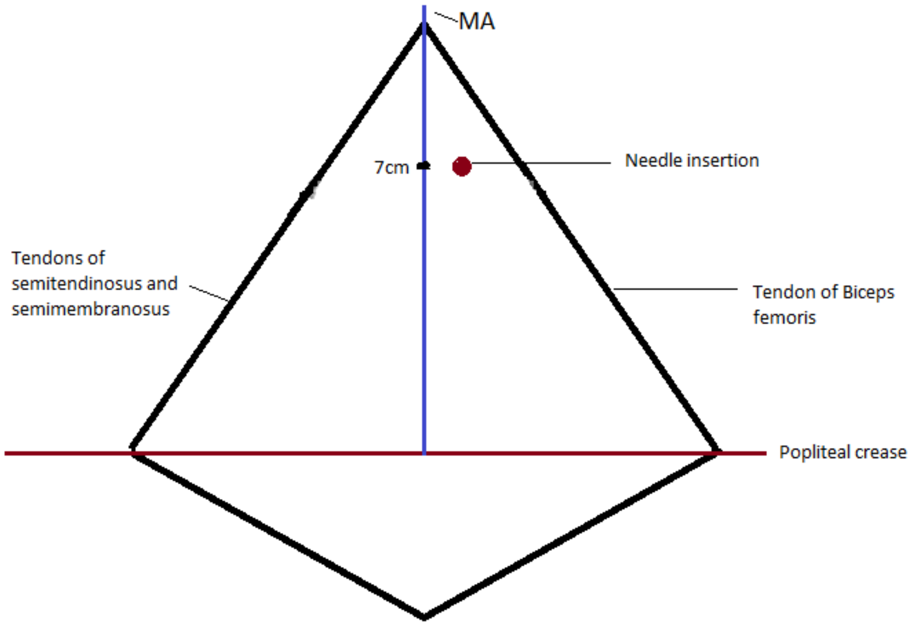


Figure 2-7: Popliteal block using the classic posterior approach. The point of injection, represented in red is 1 cm lateral to the midline axis.

2.2.3.1.2. Intertendinous approach (IA)

The landmarks are the same as those used for the CPA. In this approach (**Figure *2-8***), the needle is inserted at 7 cm above the crease, at an equal distance of the tendons of the hamstring. A modified approach was proposed by Nader *et al*. (2009) in which the needle was pushed from a point just distal to the junction of the muscular tendons (semitendinosus and biceps femoris), approximately 12 to 14 cm from the crease. The same approach was also experimented by Minville *et al.* (2007), with the knee not flexed.

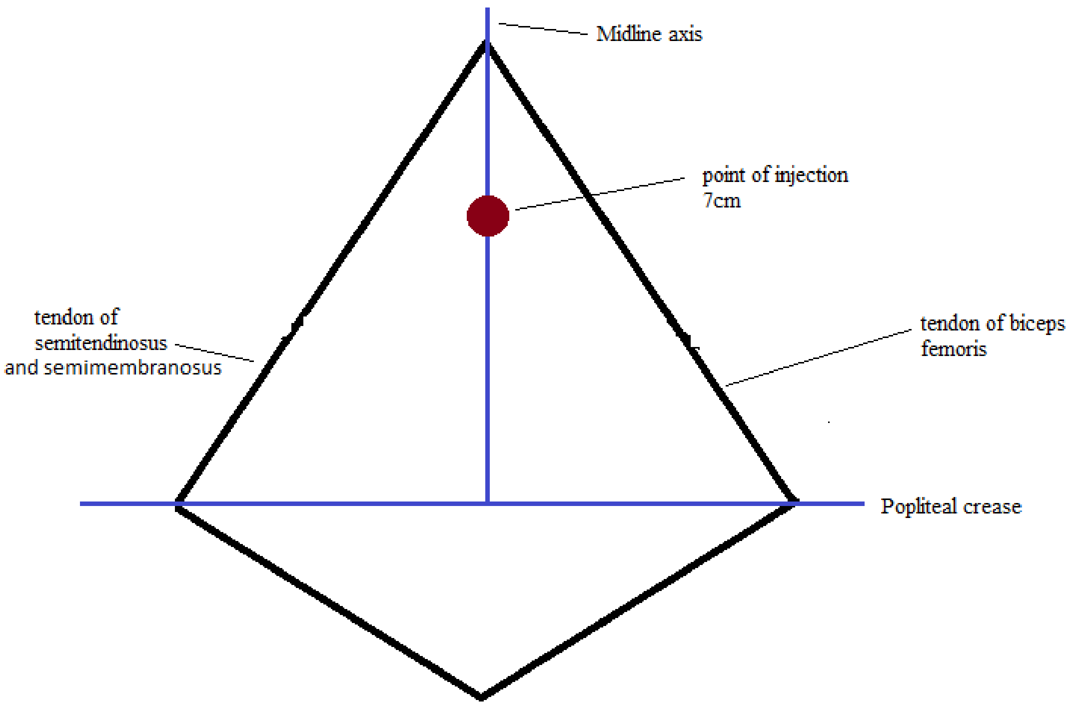


Figure 2-8: Popliteal block using the intertendinous approach. The point of injection is at equal distance of the medial and lateral margins, just on the midline axis.

2.2.3.2.Lateral approach

The benefit of this approach is the placement of the patient in supine, which contributes to his/her comfort (Casalia, Carradori and Moreno, 2006). The lower limb is extended on the bed and the intermuscular groove on the lateral side of the thigh identified. As described by Vloka *et al*. (1996) and Hadzic *et al*. (1998), the needle is first introduced horizontally in that space 7cm above the lateral femoral condyle (**Figure 2-9**). After contact with the femur, the needle is withdrawn and reoriented 30° posteriorly.

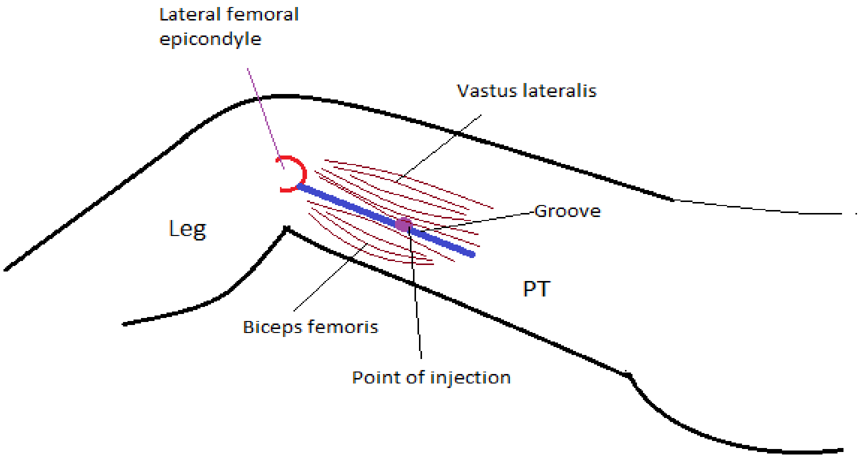


Figure 2-9: Popliteal block through the lateral approach. The point of injection is in the intermuscular groove, 7 cm above the lateral femoral condyle.

Source: Illustration made by the investigator using "Paint"

To reduce the pain that can be caused by the passage of the needle through the muscles, Al-Nasser (2002) proposed a modified approach by inserting the needle posterior to the tendon of the biceps femoris. Nevertheless, this variant called for more trials before considering it as a clinical approach with tangible results (Al-Nasser, 2002).

2.2.4. Advantages and disadvantages of the PB

Like any procedure for peripheral nerves, the PB offers both positive and negative aspects. Among the disadvantages, the risk of toxicity, intravascular injection or injury of the nerve was highlighted in the literature (Mendicino, Statler and Catanzariti, 2002). One of the most reported complications was a temporary paraesthesia in the postoperative period (Herring *et al.*, 2011; Joshi *et al.*, 2016). Complications were observed in up to 8.2% of cases (Joshi *et al.*, 2016), which contrasts with the observations of Rorie *et al*. (1980) who reported that complications were rare in the PB. Another difficulty encountered is the positioning of the patients, mainly for the posterior approaches. While in these approaches the patients tend to be placed in prone, this approach is not suitable for patients with conditions like pregnancy, obesity, traumatisms, those displaying an hemodynamic instability or ventilated (Arcioni *et al.*, 2007). However, an alternative was proposed by placing the subject in supine and elevating his leg (James Phillips, Troutman and Lerant, 2011; Sohn *et al.*, 2015).

On the other hand, the benefits of the PB are many (Joshi *et al.*, 2016). Peripheral techniques become popular because of their advantages and the good control of pain (Casalia, Carradori and Moreno, 2006). This regional anaesthetic technique is secure, compared to other anaesthetic techniques (general, spinal), the side effects being lowered (Sohn *et al.*, 2015; Joshi *et al.*, 2016). Indeed, the side effects related to general or spinal anaesthesia include headaches, vomiting, cardiorespiratory depression, toxicity to only mention a few (Hadžic *et al.*, 2002). The PB provides with an analgesia that is prolonged in the postoperative period, therefore reducing the consumption of opioids (Hadžic *et al.*, 2002; Ter Rahe and Suresh, 2002; Perlas *et al.*, 2008; Creech and Meyr, 2013; Joshi *et al.*, 2016) for a pain that is either moderate or severe in foot and ankle surgery. Consequently, the side effects associated with the opioids (urinary retention, nausea, constipation, vomiting, addiction) are also reduced (Hadžic *et al.*, 2002; Ter Rahe and Suresh, 2002; Perlas *et al.*, 2008; Joshi *et al.*, 2016). With reduced morbidity, the length of hospital stay is decreased (Mendicino, Statler and Catanzariti, 2002). Furthermore, the PB provides an adequate desensitization, adapted to the surgical procedure to realise.

Another advantage of this regional technique of anaesthesia is the conservation of the hamstring; this allows an early ambulation with crushes and therefore reduces the hospital stay, overall decreasing the medical costs (Ter Rahe and Suresh, 2002; Joshi *et al.*, 2016).

All these characteristics contribute to the popularity of the PB in today's setting where outpatient surgery is growing and there is a need to make surgery costs affordable for everyone

(Greenberg, 1995; Joshi *et al.*, 2016; Ng-Kamstra *et al.*, 2016). Overall, this anaesthetic method has proven to be satisfactory for patients.

2.2.5. Outcome of the PB

The outcome of a PB varies widely from one study to another (Muñiz *et al.*, 2003). Despite its reliability, many factors influence the outcome such as the level of training of the operator and the proximity of the needle (Rorie *et al.*, 1980). Hegewald *et al*. (2014) also evoked the patient age and BMI as factors influencing the outcome of the PB; a low BMI and increasing age were considered as improving the success rate. The use of neurostimulators or imagery also enhances success rates. The imagery could be the ultrasound or like in certain cases the MRI (Minville *et al.*, 2007; Sohn *et al.*, 2015). The ultrasound appeared in some studies as the method of choice to have a good success rate (McCartney, Brauner and Chan, 2004; Sinha and Chan, 2004). Hence, those studies reported a successful block in 76.2%, close to the results of Provenzano *et al.* reported in a study by Hegewald *et al*. (2014) who found 79% of successful cases. On the other hand, Rorie *et al.* (1980) had slightly better results with 82.3% of satisfactory blocks. Many other authors (Barbosa *et al.* 2015; Danelli *et al*. 2009; Hansen *et al.*, 2000; Mariano et al. 2009; Migues et al.2005; Phillips *et al.*, 2011) had the best outcomes with a block successful in 90 to 100% of cases. Monso *et al*. (2000) reviewed the PB in more than 700 patients and found 86% successful blocks, closely similar to the reports from Rorie *et al.* (1980) or Perlas *et al*. (2008) who found 89% successful blocks. Comparable to the findings of Herring *et al.* (2011), Wadhwa *et al*. (2010) reported a better outcome with the use of ultrasound compared to blocks aided by neurostimulation. The use of both techniques (US and NS) indeed improves to a certain extent the outcome of the block (De Andrés *et al.*, 2005), as confirmed by Van Geffen *et al*. (2010) who asserted that US helped in visualising the nerve and therefore with a good placement of the needle and the observation of the anaesthetic's spread. Besides, US also improves the patient's comfort by reducing the number of attempts in needle puncture and position (Danelli *et al.*, 2009). However, a combination of both techniques is recommended to avoid wrong interpretations of US images (Van Geffen *et al.*, 2010; Creech and Meyr, 2013).

Compared to previous authors, Hadzic *et al.* (2002) used MRI and succeeded in 100% of cases for the intertendinous block. When the block fails, one of the main causes suggested was the high division of the sciatic nerve, such as reported in a case study by Clendenen *et al.* (2008). In this case, the block would not have been complete without the use of US. Another cause of failure was the difficulty to clearly identify the boundaries of the PF in living patients (Hadžic *et al.*, 2002). A preoperative imagery is therefore advisable for a better success (Adibatti, Sangeetha and Adibatti M, 2014).

2.3 Problem statement

The popliteal block (PB) is a widespread anaesthetic procedure nowadays (Sinha and Chan, 2004; Migues *et al.*, 2005; Bruhn *et al.*, 2008). It relies heavily on the knowledge of the sciatic nerve (SN) anatomy, essential for surgeons and anaesthetists (Casalia, Carradori and Moreno, 2006). However, the variations highlighted in the literature are prejudicial to the block to the extent that they contribute to cases of failures, even more during blind injections (Prakash *et al.*, 2010; Reinoso-Barbero *et al.*, 2014).

Variations of the SN division are highly inconsistent from one population to another. In addition, only few data are available in Africa (Ogeng'O *et al.*, 2011) and on a homogenous population. This study is therefore beneficial as it identifies these variations in a heterogeneous South African population as well as determines the outcome of the block after simulation using three different approaches.

2.4 Aim

The aim of this study is to describe the level of division of the sciatic nerve in a South African cohort and evaluate the implications of variations on the popliteal block.

2.5 Objectives

- To simulate the popliteal block by injecting coloured silicone
- To examine the branching patterns of the sciatic nerve and identify high variations
- To evaluate the distance between the popliteal crease and the point of bifurcation of the nerve
- To establish an anatomical correlation between the dye of silicone and the nerve
- To compare the results between males and females
- To analyse the results and compare with other reports in the literature.

Chapter 3 - MATERIALS AND METHODS

This cross-sectional study took place at the division of Anatomy and Histology of the Faculty of Medicine and Health Sciences, Stellenbosch University.

3.1. Study population

The study population was composed of 61 cadavers of mixed ancestry or Coloured (n = 45), African descent (n = 9) and European descent (n = 7) as detailed in **Table 3-1**. The cadaveric cohort was representative of the heterogeneity of the Western Cape population with a high representativity of the Coloured population (73.77%).

Table 3-1: Demographic characteristics of the study population

	Group			
Sex	Black	Mixed	White	Total
Male	8	23	6	37
Female	1	22	1	24
Total	9	45	7	61

These embalmed cadavers were prepared for the anatomical and physiological training of the students in the Faculty of Medicine and Health Sciences.

3.2. Ethical issues

To comply with the University's policy on the use of human material, ethics approval (S16/03/052) was obtained from the Health Research and Ethics Committee (HREC) prior to the commencement of the study.

3.3. Exclusion criteria

Both left and right lower limbs of 65 cadavers (n = 130 specimens) were examined. Specimens whose sciatic nerve was damaged during the dissection process were excluded as well as one cadaver with results on the right limb only (SN damaged during the dissection of the left lower limb) because it could not be used to evaluate symmetry. This resulted in a total of 61 cadavers (n = 122 lower limb specimens).

3.4. Procedure

The study consisted in three consecutive steps. Firstly, a pilot study was carried out to test the preparation of the dye and ascertain the technique of the popliteal block (PB) on 7 cadavers. The second step consisted in data collection during the medical students' dissections of the lower limb specifically. Lastly, the investigator performed the simulation of the PB, then dissected the lower limbs of the cadavers prepared for physiology training.

The preparation of the dye, the PB simulation as well as the dissection procedure are developed in this section.

3.4.1. The dye

Matching a work on cerebral arteries in the division of Anatomy and Histology, the dye consisted of mixtures of silicone.

3.4.1.1. Materials and equipment

The tools and substances used for the preparation are listed in ***Table 3-2***. Most tools were provided by the university. Plastic tubes, wooden sticks, syringes, gloves and disposable spoons were changed as often as necessary. Therefore, the quantities of these items are not mentioned in the table.

Table 3-2: Tools used for the preparation of the dye

Material/Equipment	Trade name	Quantity
Silicone MM922	Acc silicone Europe, UK	5 kg
Catalyst	Acc silicone Europe, UK	
Turpentine	DEKRO PAINTS, SA	1 bottle of
Powder paint	Dala, SA	3 bottles of
Plastic tubes	-	-
Disposable coffee spoons	-	-
Wooden stick	-	-
Nitrile Gloves	Lasec, Malaysia	
Disposable syringes (1ml)	China	-

3.4.1.2. Composition of the dye

The dye consisted in a mixture of silicone. The quantities used for each preparation are detailed in **Table 3-3**.

Table 3-3: Composition of a mixture of silicone

Material	Quantity
Silicone	30 ml
Catalyst	1.5ml
Turpentine	3 drops
Powder paint	Half spoon

During the pilot test, the 30 ml of silicone were put in a tube using a 10 ml syringe. Thereafter, the limit was drawn on the tube with a marker and reported on the other tubes. As for the catalyst, the quantity was measured using 1ml syringes.

3.4.1.3. Preparation of the dye

The silicone was mixed with half a teaspoon of powder paint in a tube. When the mixture obtained became homogenous, the catalyst was slowly incorporated in a clockwise movement. The drops of turpentine were then added last to slow down the hardening process. During PB simulation, three different approaches were used. Hence, three separate mixtures of different colours (**Figure 3-1**) were made to differentiate each technique.

Figure 3-1: Mixtures of silicone for the three approaches of popliteal block. Each colour of dye corresponded to a specific approach; in this image, the dye was solidified 48h after preparation.

The blue, red and green mixtures were used respectively for the lateral approach (LA), the classic posterior approach (CPA) and the intertendinous approach (IA). The green dye was obtained after mixing the blue and yellow powder paints.

3.4.2. Popliteal block

Three different approaches were used: the classic posterior approach, the intertendinous approach and the lateral approach.

3.4.2.1. Materials and equipment

The different instruments used for the simulation of the block are illustrated in **Figure 3-2**. They consisted of:

- Mixtures of silicone (**Figure 3-1**),
- Needles 14-18G a length of 48-80mm by Viggo-spectramed, Bio-On and B.Braun with short to regular bevels,
- Disposable syringes of 1ml,
- A measuring tape,
- A black marker,
- Nitrile gloves by Lasec, Malaysia.

Figure 3-2: Equipment used for the simulation. As shown in the picture, it consisted of mixture of silicone, needles, syringes, measuring tape, and marker.

3.4.2.2.Simulation of the popliteal block

The cadavers were successively placed in prone and supine position to perform the block. The prone position was used for the posterior approaches (classic posterior and intertendinous) while the supine position was for the lateral approach. Classic posterior and intertendinous approaches are two variants of the posterior approach to the PB, which only differ in the distance from the midline axis to the point of insertion of the needle. They were both used in this study because not only did we study the level at which the dye was deposited but also the proximity between the dye and the nerve.

The simulation was performed on the lower limbs of 11 cadavers and the three approaches were used on each limb.

3.4.2.2.1. Classic posterior approach

The cadaver was placed in prone position. The steps followed were as previously described by Hadzic *et al*. (2002). The superior borders of the popliteal fossa (biceps femoris, semitendinosus and semimembranosus) were identified and outlined with a permanent marker. The bisector of the superior angle of the PF or midline axis was traced. After identification of the landmarks, the needle connected to a syringe containing the red dye was inserted 7 cm above the popliteal crease and 1cm lateral to the midline axis (

Figure 3-3), perpendicular to the skin and at a depth of 4 cm approximately.

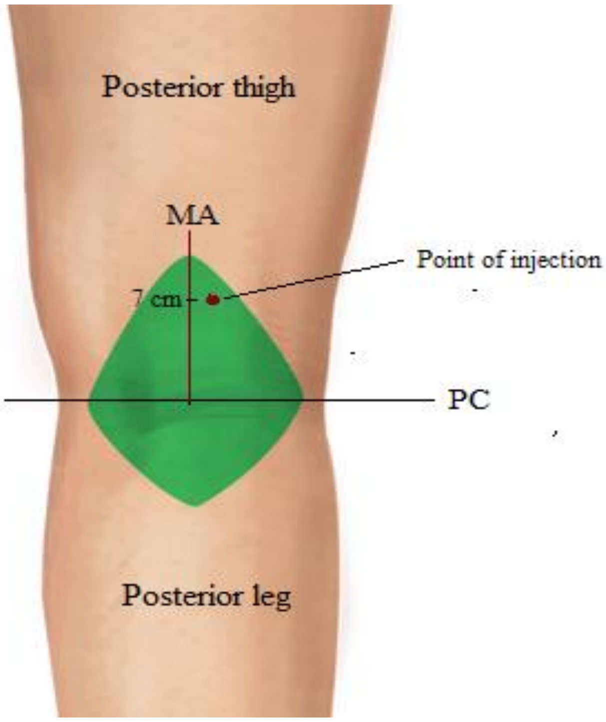


Figure 3-3: Classic posterior approach: point of injection on a right lower limb with the popliteal fossa highlighted in green.
Source: modified from Kenhub (Jones, 2015)**.**

3.4.2.2.2. Intertendinous approach

The intertendinous approach (IA), variant of the CPA, followed the same steps with the difference that the needle was mounted on a syringe filled with a green dye and inserted on the midline axis (at midpoint between the muscular tendons), still 7 cm above the PC (**Figure 3-4**). Similarly to Triado *et al*. (2004), a 48 mm needle was used. The depth of insertion of the needle was 4 cm approximately from the insertion point on the skin.

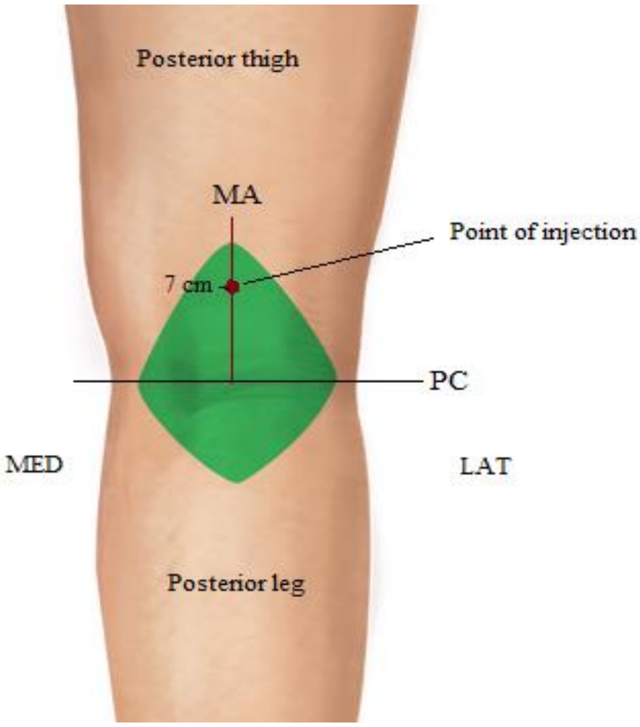


Figure 3-4: Intertendinous approach: point of injection in the popliteal fossa highlighted in green. MED = Medial, LAT = Lateral, PC = Popliteal Crease, MA = Midline Axis.

Source: modified from Kenhub (Jones, 2015).

3.4.2.2.3. Lateral approach

The cadaver placed in supine position, the landmarks were identified: vastus lateralis, biceps femoris and lateral femoral condyle. These landmarks were traced with the marker and the syringe filled with the blue dye. The needle was introduced in the groove between both muscles, 7 cm above the lateral femoral condyle (**Figure 3-5)**. From the skin, the needle was directed posteriorly with an inclination of 30 degrees and inserted at a depth of approximately 4 cm, knowing that Vloka *et al*. (1996) suggested 33 to 54 mm.

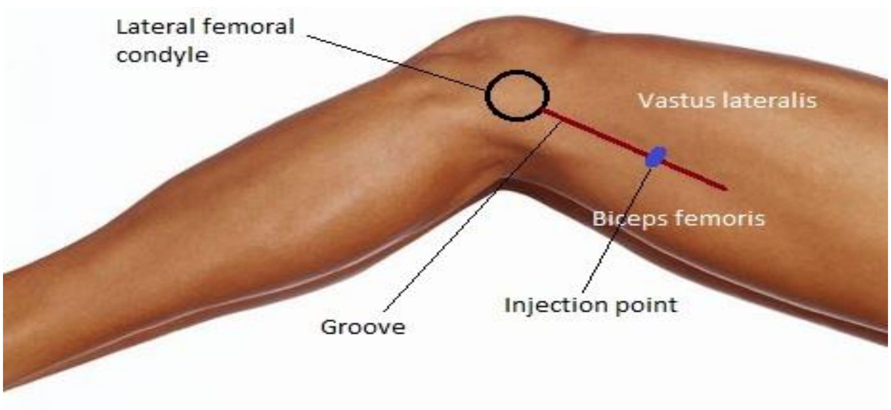


Figure 3-5: Lateral approach to the popliteal block

Source: modified image from "google search"

3.4.3. Dissection of the lower limb

The lower limb was dissected following the instructions from the Grant's Dissector (Tank, 2013) as indicated in **Figure 3-6**. After skin removal, the fascia was opened and posterior to the knee the popliteal fossa cleaned and explored to retrieve the nerve.

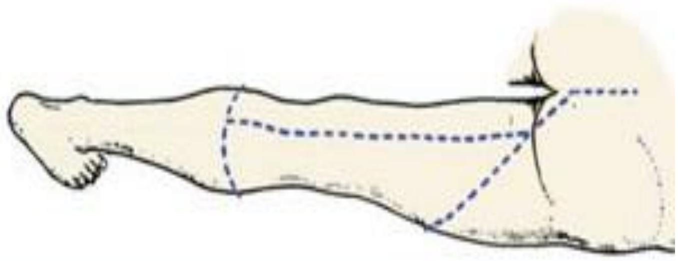


Figure 3-6: Skin landmarks for dissection (*Duke Anatomy - Lab 13: Gluteal Region & Posterior Thigh*, 2013)

A good exposure of the SN (**Figure 3-7**) in the PF required a thorough cleaning of the area because of the significance of the adipose tissue; however, the cleaning was careful to avoid any damage to the nerve or its branches.

Legend: GM = Gluteus Maximus, BF = Biceps Femoris, CFN = Common Fibular Nerve, TN = Tibial Nerve, ST= Semitendinosus, SM = Semimembranosus

Figure 3-7: Sciatic nerve exposed after dissection of the posterior thigh. The SN divided in the upper third of the posterior thigh

After identification, the level of division was classified based on previous classifications and adapted to this study. It consisted of 4 categories:

- Category A: division of the nerve in the pelvis. The branches of the SN are already individualised at the exit of the pelvis below the piriformis muscle.
- Category B: division of the nerve in the gluteal region. The nerve divides between the inferior border of the piriformis muscle and the gluteal fold.
- Category C: division of the nerve in the posterior thigh, between the gluteal fold and the popliteal fossa.
- Category D: division of the nerve in the popliteal fossa (**Figure 2-5**), from the apex and below.

The division of the SN in the popliteal fossa (category D) corresponded to the normal pattern described in textbooks, whereas Categories A, B and C were considered as high variations of the nerve. After identification of the SN and categorisation of the level of division, the PF was examined to locate the dye and observe its position to the nerve. The success of the PB was related to the location of the dye above SN bifurcation while failures or incomplete blocks would be considered when the dye was deposited below the point of bifurcation of the nerve. Cases where the dye was outside of the PF (**Figure 3-8**) were attributed to technical glitches and excluded from the study.

Figure 3-8: Dye located outside the popliteal fossa just superficial to the fascia

On the other hand, we also evaluated the proximity of the needle by looking at the closeness between the dye and the nerve to see if there would be a significant difference between the approaches used, especially the classic posterior and the intertendinous approaches. Consequently, an approach was superior to another if the dye was closer to the nerve compared to other approaches.

3.5. Morphometric analysis

Measurements were taken to give a quantitative evaluation of the distance (in mm) at which the sciatic nerve divides. In addition, they also helped in appreciating the closeness of the dye to the nerve. Because the distribution of data was skewed, the results were expressed in median, 25th percentile, 75th percentile as well as the minimum and maximum. On the other hand, the distance between the nerve and the dye was also recorded to determine the closeness of the tip of the needle to the nerve.

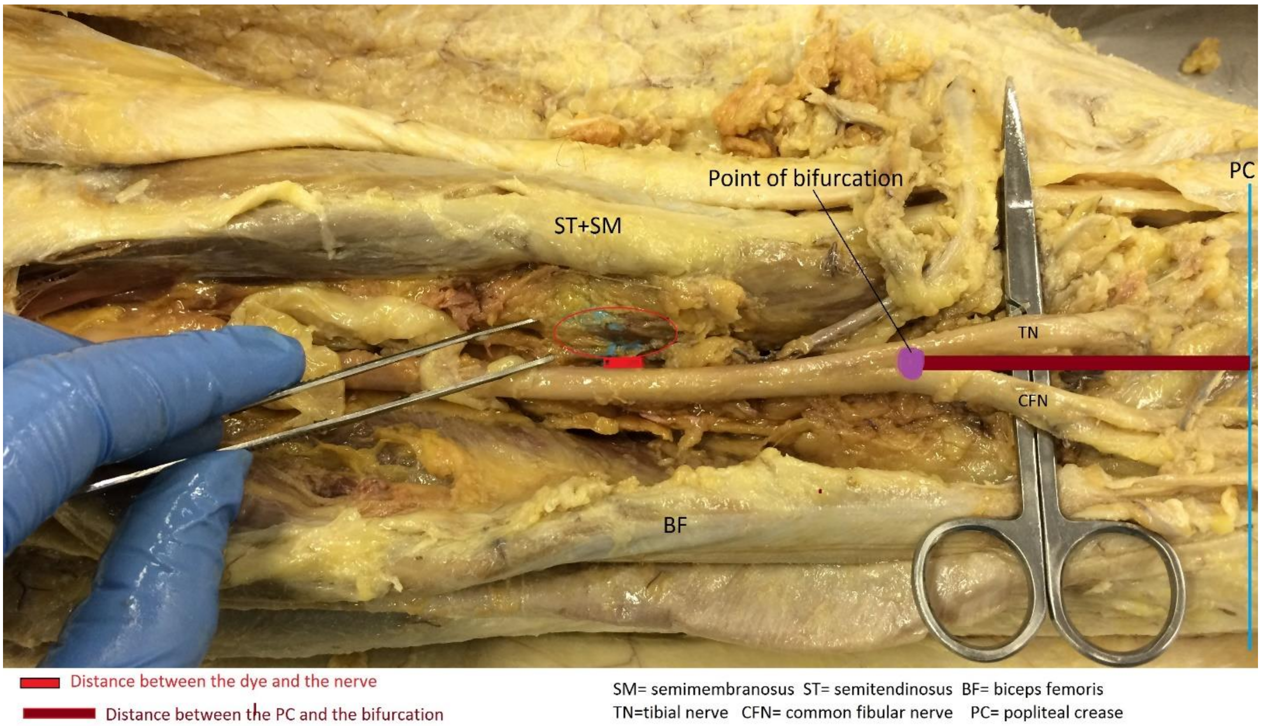


Figure 3-9: Sciatic nerve exposed in the popliteal fossa; the blue line represents the distance between the popliteal crease and the point of bifurcation of the nerve

3.6. Statistical analysis

Two forms (appendix C) were used for data collection. The variables in analysis, classified as qualitative and quantitative, are detailed in **Table 3-4**.

Table 3-4: Variables considered for analysis

Qualitative variables	Quantitative variables
• Sex • Population group • Side • Level of division • Location of the dye	• Distance to the PC • Distance between the nerve and the dye

Data collected (appendix B) were reported in Excel 2016 and the analysis made using Excel and Stata 2015. For the level of division, the prevalence of variations was determined for the whole sample with its confidence interval (CI). The frequency of variations would then be determined for each gender, population group as well as each side, and comparisons made thereof using the chi square test.

On the other hand, the distances were expressed in mm for more accuracy. In most cases, medians were used because the distribution was skewed. Nevertheless, the mean and standard deviation were reported for each level of division. Due to the skewness of the data set, the Kruskal-Wallis test was used to determine if the difference was statistically significant between gender, population groups or sides.

Finally, the success rate of the simulation of the PB was predicted in terms of location of the dye. If the dye was located below the point of bifurcation, the PB was considered as failed whereas a dye located around or above the point of bifurcation was equivalent to a successful PB. The proximity of the dye to the nerve was used to compare the three approaches to the popliteal block and see which one would help deposit the dye closer to the nerve and therefore contribute to improving the success rate.

Chapter 4 - RESULTS

The sample consisted of 122 lower limb specimens including both left and right lower limbs of 61 cadavers. All the specimens were examined to describe the branching pattern of the SN and the distance at which the SN divides. Twenty-two of these specimens were used for the experi:mentation of the popliteal block.

4.1. Level of division

From the classification used in this study (page 36), 3 categories (B, C and D) were identified (**Figure 4-1**: ***Levels of division of the SN*** and corresponded to the division in the popliteal fossa (category D), the posterior thigh (category C) and the gluteal region (category B). No case of division of the SN in the pelvis (category A) was recorded.

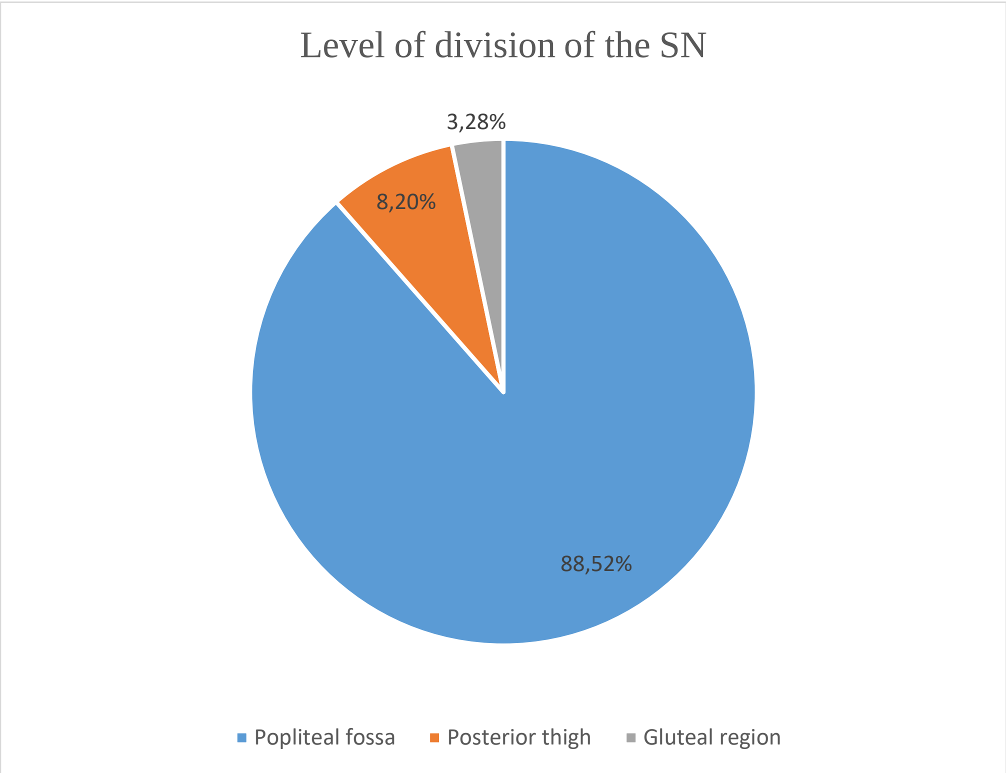
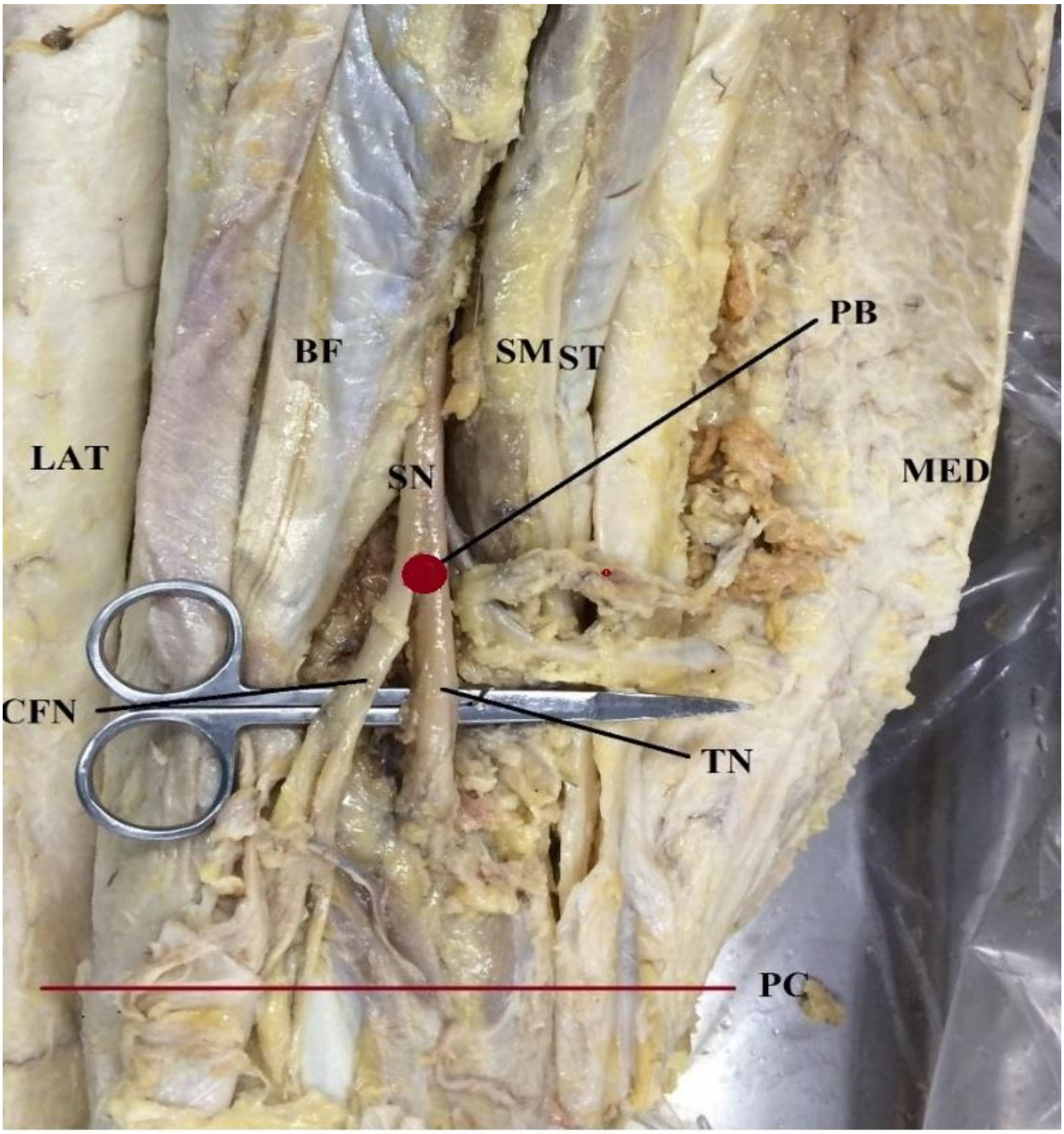


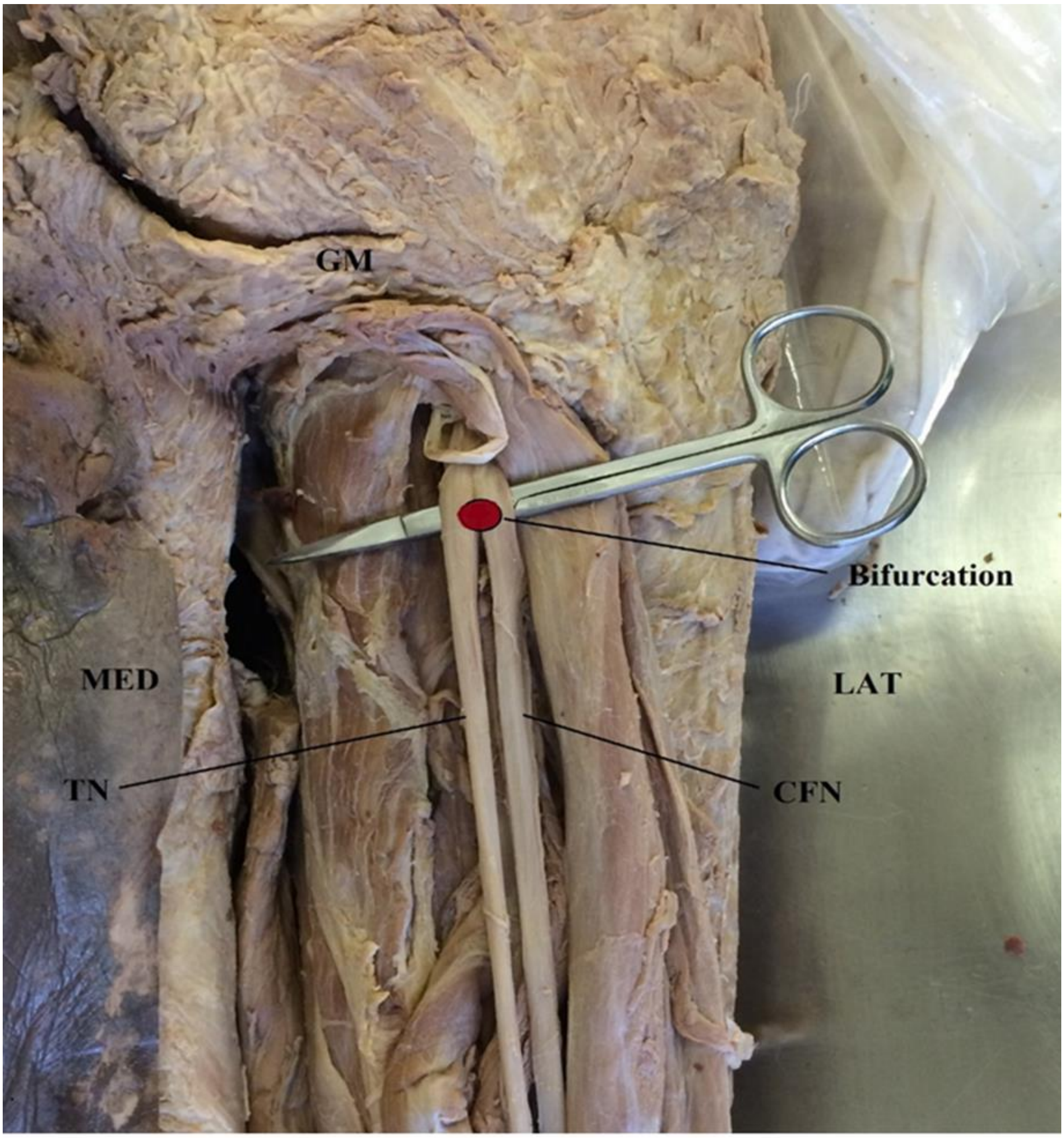
Figure 4-1: Levels of division of the SN

The bifurcation of the SN in the popliteal fossa (**Figure 4-2**) was observed in 108 specimens (88.52%) while the division in the posterior thigh (**Figure 4-3)** and the gluteal region (**Figure 4-4**) were observed in 10 (8.20%) and 4 (3.28%) specimens respectively.



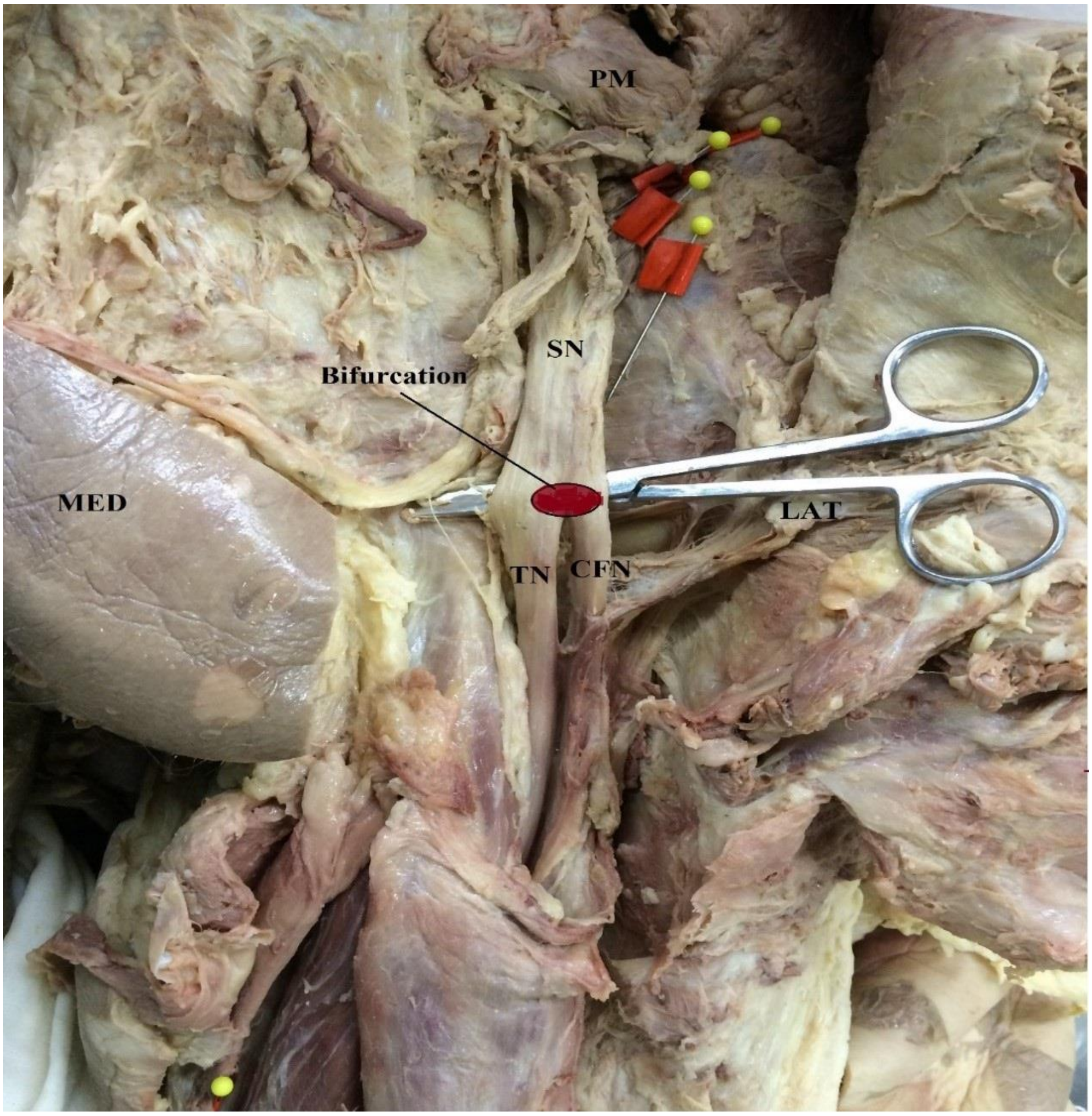
Legend:
BF: biceps femoris; CFN: common fibular nerve; LAT: lateral; MED: medial; PB: point of bifurcation;
PC: popliteal crease; SM: semimembranosus; SN: sciatic nerve; ST: semitendinosus; TN: tibial nerve

Figure 4-2: Division of the SN in the popliteal fossa. The observation was made on a left lower limb and the division occurred at the apex of the PF. Image obtained during the present study.



Legend:
CFN: common fibular nerve; GM: gluteus maximus muscle; LAT: lateral; MED: medial; TN: tibial nerve

Figure 4-3: Division of the SN in the proximal third of the posterior thigh. The high division was obvious with both branches of the SN running down, with parallel routes before separating in the PF. Image obtained during the present study.



Legend
CFN: common fibular nerve; LAT: lateral; MED: medial; PM: piriformis muscle, SN: sciatic nerve; TN: tibial nerve

Figure 4-4: Division of the sciatic nerve in the gluteal region. The division occurred in the gluteal area, a few centimeters below the piriformis muscle. Image obtained during the present study.

4.1.1. Prevalence of variations

Division of the SN in the posterior thigh and the gluteal region were both identified as high variations. These variations were observed in 11.48% with a 95% confidence interval (CI) of [5.82; 17.13], showing a risk of SN variation in 11.48 ± 5.66% of cases.

The occurrence of high variations in the posterior thigh (8.20%) was superior to that of high variations in the gluteal region (3.28%).

4.1.2. Level of division per population group

Representing the heterogeneity of the South African population, three population groups were represented: coloured, black and white. **Table 4-1** depicts the level of division for each population group.

Table 4-1: Representation of the level of division of the SN by population group

	Normal division		Variations		Total
Group population	N	Percentage*	N	Percentage*	N
Coloured	80	88.89%	10	11.11%	90
Black	16	88.89%	2	11.11%	18
White	12	85.71%	2	14.29%	14
p = 0.9					

* Percentage of row total

The level of division of the SN did not differ among these population groups.

4.1.3. Symmetry

The symmetry explored the bilateral aspect of the level of division in each cadaver. Two main groups were considered: normal division (popliteal fossa) and variations (posterior thigh and gluteal region). Out of the 61 cadavers examined, the level of division appeared to be symmetrical in both lower limbs of 57 cadavers (93.44%) with a confidence interval of [89.05 ; 97.83]; this included 5 cadavers showing bilateral variations. In these cases, when the level of division was normal (at the level of the popliteal fossa) in one limb, the same observation applied to the other limb; or, a high variation observed in one limb specimen would be observed in the contralateral limb.

In the four remaining cadavers out of 61 (6.56%), there was an asymmetry, meaning that in one limb the division would be normal while a high variation would be observed in the other limb.

Considering the variations specifically, on the 9 patients who had variations on the one side, 5 (55.56%) had variations on the other side as well. The 95% confidence interval was [23.1; 88] and the risk of having bilateral variations was 55.56 ± 32.46%.

4.1.4. Level of division by side

Table 4-2: Level of division in each side

	Normal		Variations		Total
	N	Percentage*	N	Percentage*	N
Left	56	91.80%	5	8.20%	61
Right	52	85.25%	9	14.75%	61
p = 0.25					

* Percentage of row total

Table 4-2: Level of division in each side**Table 4-2** depicts the level of division per side and shows there is no significant difference between both groups of specimens, which is in favour of the high symmetry described beforehand.

4.1.5. Level of division by sex

The sample consisted of 74 male specimens and 48 female specimens. The level of division for each gender is tabulated in **Table 4-3**.

Table 4-3: Level of division for each gender

	Normal division		Variations		Total
	N	Percentage*	N	Percentage*	N
Males	69	93.23%	5	6.76%	74
Females	39	81.25%	9	18.75%	48
p = 0.042					

* Percentage of row total

Variations, observed in 9 female specimens and 5 male specimens, corresponded to a sex ratio F /M of 2.78 : 1.

4.2. Distance to the popliteal crease

The distance from the point of bifurcation of the SN to the PC was measured in 96 specimens while on the remaining specimens the nerve had been damaged before the distance could be recorded. The distribution was skewed due to variations (high values). The distance varied between 20 and 405 mm, with a median of 55 mm. The shortest distance (20 mm) corresponded to the division of the nerve in the popliteal fossa and the highest (405 mm) to the division of the nerve in the gluteal region.

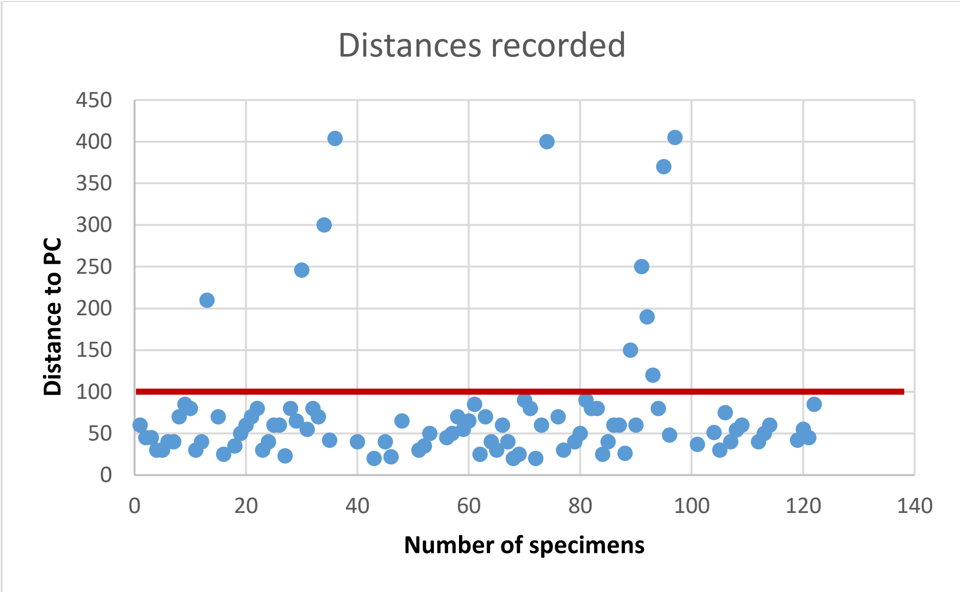


Figure 4-5: Scatter plot of the distances recorded

Figure 4-5 illustrates distances and shows that in 85 specimens (88.54%) the distance ranged between 0 and 100 mm. The outliers or data above 120 mm corresponded to high variations.

4.2.1. Distance by level of division

With regards to the level of division, the distribution was normal, therefore, means and SD are given in **Table 4-4**. These data evaluate the distance at which the sciatic nerve divides for each category of division.

Table 4-4: Mean distance from popliteal crease and standard deviation per level of division (in mm).

Category	Ranges	Means	SD*	P25	Median	P75
Popliteal fossa	20-90	51.5	19.5	40	50	65
Posterior thigh	120-300	209.4	62	150	210	250
Gluteal	370-405	394.8	16.6	385	402	404.5

* SD= standard deviation

The distance recorded was proportional to the level at which the SN divided.

4.2.2. Distance by population group

The median of the distance from the point of bifurcation to the popliteal crease for coloured, black and white specimens was respectively 55 mm, 40 mm and 85 mm.

The difference between the population groups was not statistically significant (p = 0.1297) as for the level of division.

4.2.3. Distance by sex and side

The results by sex and side are reported in **Table 4-5**, giving overall statistics for each group. Table 4.6 describes overall statistics for each side

Table 4-5: Overall statistics by sex and side

Side	Sex	P25	Median	P75	Min	Max
Left	Males	35	50	70	22	300
	Females	41	60	80	20	404
Right	Male	33.5	50	80	20	370
	Female	46.5	60	82.5	20	405
Overall	Male		50		20	370
	Female		60		20	405

4.2.3.1. Distance by side

The overall statistics for each side are depicted in **Table 4-6**.

Table 4-6: Overall statistics by side

Side	Median	Min	Max
Left	52.5	20	404
Right	57.5	20	405

4.3. Popliteal Block Simulation

4.3.1. Pilot study

In the pilot study, the popliteal block (PB) was performed on seven cadavers. After dissection, the dye was visualised in the popliteal fossa. One cadaver out of 7 presented a bilateral variation of the sciatic nerve division with the SN dividing in the posterior thigh on the left limb and in the gluteal region for the right limb. The distances (PCB) were 300 mm and 370 mm respectively. As shown in

Figure 4-6, the dye, which was found in the popliteal fossa, was far from the main trunk of the sciatic nerve (SN). Therefore, the popliteal block in that case was considered as unsuccessful.

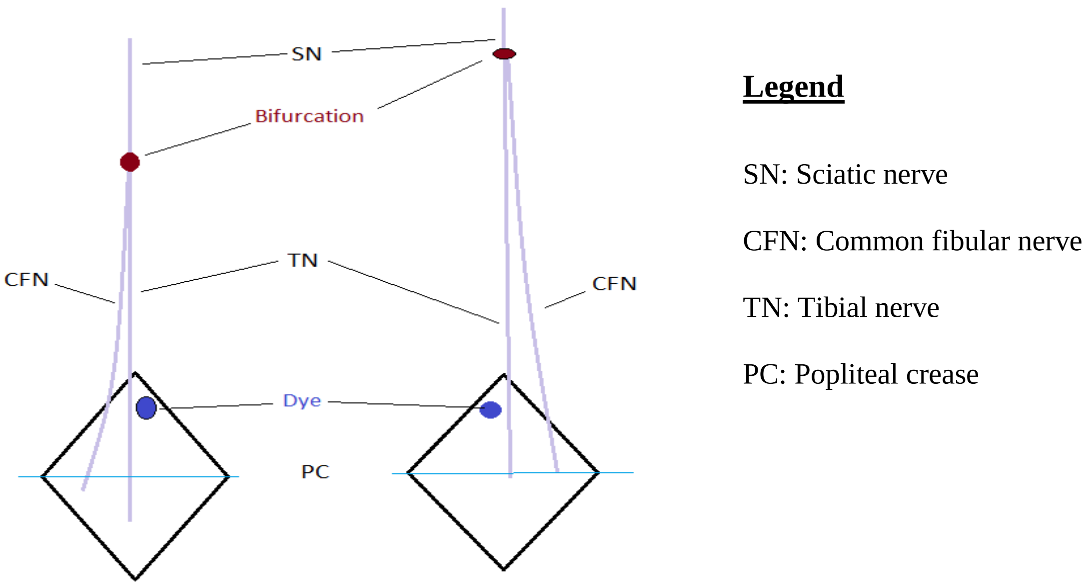


Figure 4-6: Diagram showing the dye in the PF with a high division of the SN.

4.3.2. Simulation of the PB

The PB was simulated on 22 lower limbs from 11 cadavers. These cadavers were part of the sample used to determine the level of division of the SN. Results were obtained in 69.23% of cases while in the remaining 30.77% the dye was found outside of the PF; the latter could not be used for analysis (

Figure 4-7).

Figure 4-7: Case of simulation with the dye outside of the popliteal fossa.

In all the specimens used for analysis, the SN divided in the PF. After identification, the dye was found in the PF, deposited above the bifurcation of the SN in all cases (100%). The dye was in direct contact with the SN (needle-to-nerve contact) in 68.89% (**Figure 4-8**).

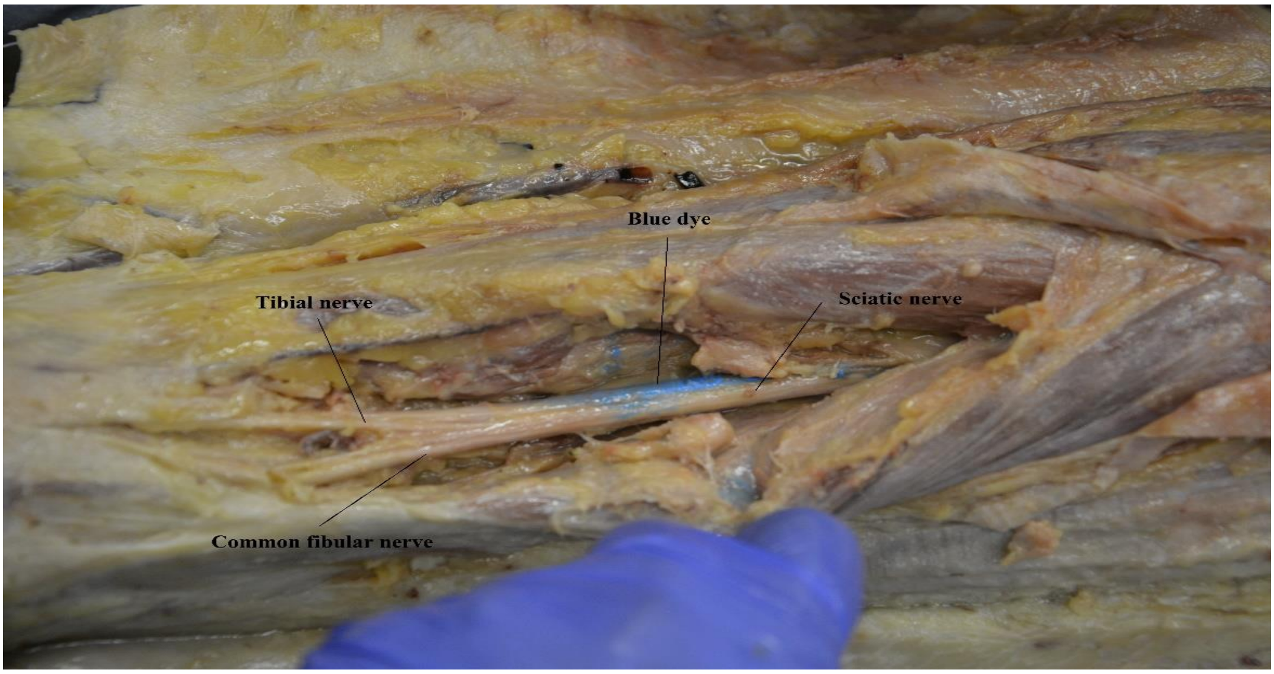


Figure 4-8: Dye visible in the PF, in direct contact with the Sciatic nerve.

The needle-to-nerve contact was achieved in 68.75%, 76.92% and 58.82% of cases, respectively for the lateral, classic posterior and intertendinous approaches. In other cases (31.11%), the dye was a few millimetres away from the SN. Whether in contact or away from the SN, the distance between the dye and the nerve ranged from 0 to 25mm. The median was 0 mm for all three approaches, corresponding to a close contact with the nerve.

There was no statistical difference between the three techniques used for the simulation ($p > 0.05$).

Chapter 5 - DISCUSSION

The focus of this study was to describe the pattern of the sciatic nerve bifurcation and to identify variations in the level of division and their frequency in a South African population. In addition, a simulation of the popliteal block was performed with a dye made of silicone to evaluate the success rate of the PB as well as discriminate the most successful approach.

This study described the SN division in 122 lower limbs; so far, the third largest study after those of Ugrenovic *et al.* (2005) and Ogeng'O *et al*. (2011). While Okraszewska et *al.* (2002) and Saleh *et al*. (2009) studied 36 and 30 specimens respectively, the smallest sample used for the SN division was that of Vloka *et al*. (1997)involving 10 specimens. In most studies, observations on the sciatic nerve bifurcation were based on the examination of 40 to 60 specimens (Triadó *et al.*, 2004; Guvencer *et al.*, 2009; Shewale, Karambelkar and Umarji, 2013; Adibatti, Sangeetha and Adibatti M, 2014; Barbosa *et al.*, 2015; Kiros and Woldeyes, 2015). The results of this study therefore cover a larger population, therefore giving a better overview of the level of division of the SN. This work is also unique in that the cadavers used were of three population groups: black, white and coloured, a representation of the Western Cape population of South Africa.

5.1. Variations in the level of division of SN

The standard description of the SN division which is a bifurcation in the PF (Berihu and Debeb, 2015) was found in 88.52% of cases. This result corresponds to the normal rate of 85-89% (Kiros and Woldeyes, 2015). Similarly, Adibatti *et al.* (2014) found a high frequency (92%) of the normal pattern in their research on the Indian population. However, results in other studies (Okraszewska *et al.*, 2002; Ugrenović *et al.*, 2005; Ogeng'O *et al.*, 2011) reported a lower prevalence of the normal division, between 65 and 75% (**Table 5-1**).

Table 5-1: Variations observed in different studies (ours included)

Author (Year)	Country	N	Normal (%)	Variations (%)
Okraszewska *et al.* (2002)	Poland	36	72,2	27,8
Ugrenovic *et al*. (2005)	Serbia	200	72,5	27,5
Prakash *et al*. (2010)	India	86	34,9	65,1
Ogeng'o *et al*. (2011)	Ethiopia	164	67,1	32,9
Shewale *et al*. (2013)	India	90	77.78	32.22
Adibatti *et al*. (2014)	India	50	92	8
Kiros *et al*. (2015)	Ethiopia	50	64	36
Present study	South Africa	122	88,5	11,5

N= number of specimens examined. Variations consisted in cases of division above the PF.

Sources: (Okraszewska *et al.*, 2002; Ugrenović *et al.*, 2005; Prakash *et al.*, 2010; Ogeng'O *et al.*, 2011; Shewale, Karambelkar and Umarji, 2013; Adibatti, Sangeetha and Adibatti M, 2014; Kiros and Woldeyes, 2015)

Most studies display a higher prevalence of variations than the normal description.

High variations in the literature included cases of division in the pelvis, the gluteal region or the posterior thigh. Most of these variants were observed in this work except from variations with division of the SN in the pelvis, supporting previous works by Ugrenovic *et al.* (2005) and Shewale *et al*. (2013). In studies where a division of the SN in the pelvis was observed, the prevalence varied between 5 and 15% (Okraszewska *et al.*, 2002; Adibatti, Sangeetha and Adibatti M, 2014; Kiros and Woldeyes, 2015) and higher, about 16.3% for Prakash *et al*. (2010) and 20.1% for Ogeng'O *et al*. (2011)

The low prevalence of division in the gluteal region (< 5%) found in most studies (Okraszewska *et al.*, 2002; Prakash *et al.*, 2010; Ogeng'O *et al.*, 2011; Adibatti, Sangeetha and Adibatti M, 2014; Kiros and Woldeyes, 2015) was comparable to the findings in this South African cohort (3.28%). Nevertheless, Ugrenovic *et al.* (2005) as well as Shewale *et al*. (2013) found more that 10% of cases of this variant.

On the other hand, the division of the SN occurred in the posterior thigh in 8.20% of cases. The results for this variant were comparable to those of Ugrenovic *et al.* (2005), Ogeng'o *et al.* (2011) and Shewale *et al*. (2013) who found 9%, 10.4% and 11.11% respectively while Adibatti *et al.* (2014) only found 2% of cases of division at that level. On the contrary, Prakash *et al.* (2010) observed this variant in 46.5% of the specimens studied.

Overall, the prevalence of variations was 11.48% and this prevalence for 95% of the population to display a variation in one or the other limb would vary between 5.82 and 17.13%. This description is in accord with the standard description of the sciatic nerve bifurcation, but far below the findings in most studies which are in the order of approximately 30% (Okraszewska *et al.*, 2002; Ugrenović *et al.*, 2005; Ogeng'O *et al.*, 2011; Shewale, Karambelkar and Umarji, 2013; Kiros and Woldeyes, 2015).

The differences in prevalence of variations from one study to another show the great changes in the levels of the division of the SN. Both similarities and differences were observed between this study and others. Even though a larger sample would improve the accuracy of the results, it remains that the sciatic nerve displays a highly variable anatomy in terms of level of bifurcation. In addition, many factors were reported by other authors as possible causes of the variations in the level of division of the nerve. First, the branching patterns vary between population groups (Prakash *et al.*, 2010). For example, while in Ethiopia the frequency of variations is around 35% in two different studies (Ogeng'O *et al.*, 2011; Kiros and Woldeyes, 2015), the studies in India are different in that the variations ranged between 8% and 65% of the specimens (Prakash *et al.*, 2010; Shewale, Karambelkar and Umarji, 2013; Adibatti, Sangeetha and Adibatti M, 2014). In South Africa, studies on the sciatic nerve are hard to find, making it impossible for us to compare or to have global results.

A second factor suggested by Ogengo *et al.* (2011), was that the division especially in the pelvis resulted of a separate course of the two components of the SN (TN and CFN) during the embryonic period. In neonates, high variations are also observed, hence variations could be present at any age (Reinoso-Barbero *et al.*, 2014).

5.1.1. Level of division by population group

The diversity and heterogeneity of the South African population might be symptomatic of differences due to genetic arrangements. However, this study did not highlight any statistical difference ($p > 0.05$) between the three main population groups studied, namely white, black and coloured. Nonetheless, the sample was composed mainly of coloured specimens. Hence, a larger study with a larger proportion of black and white specimens is required to confirm these findings. Hence, the results of one group should not yet be applied to another group.

5.1.2. Level of division of the SN by sex

A clear numerical difference was observed between males and females in terms of variations. Indeed, most variations were found in female specimens with a sex ratio F : M of 2.78 : 1. This ratio showed that the risk of variation in females was two times the risk in male specimens, and this difference was confirmed statistically ($p = 0.042$). Consequently, maneuvers related to the SN would call for more precautions, such as during a popliteal block or hip surgery in females.

5.1.3. Level of division by side and symmetry

The comparison of both left and right side demonstrated there was no difference between both sides, what is in favour of the high symmetry. Interestingly, symmetry was not considered as a variable of analysis in studies on the SN, making it difficult to determine whether variations are bilateral or not. In this work, the level of division of the SN was symmetrical in 93.44%, comparable to the findings of Ugrenovic *et al*. (2005) who observed that all variations were bilateral. On the contrary, Kiros *et al.* (2015) reported a high asymmetry of 32% (8 out of 25). Even though they did not specify it, this difference could be attributed to the fact that we grouped variations together instead of considering them as individual variants. Nevertheless, based on previous observations on the high symmetry, a patient showing a variation in the bifurcation point of the SN is at risk to present a variation in the other limb. For this reason, any variation identified in one limb should call for the exploration of the other limb.

5.2 Variations in the distance between the point of bifurcation and the popliteal crease

In various studies, the level of division was the focus of the research while the distance was not always recorded. Hence, only a few studies considered the distance between the PC and the bifurcation of the sciatic nerve as a variable in their analysis (Vloka *et al.*, 2001; Saleh, El-Fark and Abdel-Hamid, 2009; Schiarite *et al.*, 2015; Sohn *et al.*, 2015). The results of these studies are consigned in **Table 5-2**.

Table 5-2: Distances (in mm) reported in different studies

Authors	Sample size	Minimum	Maximum	Mean	SD
Vloka *et al.* (1997)	10	0	73	44	20
Vloka *et al*. (2001)	28	0	115	60.5	27
Saleh *et al.* (2009)	30	50	180	81.37*	5.84
Lee et al. (2013)	50	-	-	79	26
Barbero *et al.* (2014)	48	150	400	-	-
Schiarite *et al.* 2015)	124	-	-	61.78**	11*
Sohn *et al*. (2015)	40	-	-	63.9	9.8
Present study	122	20	405	72.42	81.47

*** Calculated from averages for male and female**

****Calculated from averages for left and right limbs. SD: Standard deviation**

Sources: (Vloka *et al.*, 1997, 2001; Saleh, El-Fark and Abdel-Hamid, 2009; Lee *et al.*, 2013; Schiarite *et al.*, 2015; Sohn *et al.*, 2015)**.**

The average distance between the popliteal crease and the point of bifurcation of the SN varied from one study to the other. All studies combined, the distance varied between 0 and 405 mm. The lowest distance was reported by Vloka *et al*. (1997, 2001), while the highest distance for the point of bifurcation so far was observed in the present study, at 405 mm above the PC. The maximal distance was related to the presence of high variations, considering that higher variation would correspond to higher distance value. The sample size could also be a factor of difference because a large sample improves the accuracy and gives a better overview of variations, therefore encompassing higher distances. For example, Vloka *et al.* (2001) examined 28 specimens and had the higher distance at 115 mm (in the popliteal fossa), while Barbero *et al*. (Reinoso-Barbero *et al.*, 2014) who worked on 48 specimens found a maximum at 400 mm. Much more, the large sample used in this study increases the probability to observe variations which are not so frequent as well as high distances.

The interpretation using the mean was made impossible due to the abnormal distribution of the different distances recorded. According to findings reported in **Table 5-2**, the average was approximately 65 mm for most studies, close to the median (55mm) in the present study.

5.2.1.Distance by level of division

In general, the distance is proportional to the level of division and therefore increases with it. Casalia *et al.* (2006) stipulated that the division of the SN occurs in a range of 0 to 113 mm above the popliteal crease. This corroborates this study's results with a distance ranging between 20 and 90 mm for the normal pattern, as described in **Table 4-4**. This is indeed comparable to the analysis of the scatter plot **Figure 4-5** which shows that for most of the specimens, the distance was below 100 mm. These findings are close to those of Vloka *et al.* (2001) who found a distance ranging between 0 and 115 mm. All these results apply for cases of division in the PF. On the other hand, Saleh *et al.* (2009) reported a distance varying between 50 and 180 mm above the crease, which according to **Table 4-4** corresponds to cases of divisions in the PF and the posterior thigh.

Besides the normal pattern, the high variations included the cases in which either the SN branched in the posterior thigh or the gluteal region and the ranges were 120 to 300mm and 370 to 405 mm respectively.

Globally, the distance in the cases of normal division varies between 0 and 115 mm while the distance for high variations varies between 120 to 405 mm. Consequently, a high distance from the PC would increase the risk of piriformis syndrome and nerve injury during muscular injections or even surgical procedures in the gluteal region and could reduce the success of the popliteal block as shown in the pilot study of the PB simulation (**Figure 4-6**).

5.2.2. Distance by sex

Our results were reported as medians as opposed go other studies, due to the skewness of the distribution. As reported in

Table 5-3, Saleh *et al*. (2009) reported a mean distance higher in males while the mean distance was approximately the same in both groups for Schiarite *et al*. (2015). Considering the median in this study, females displayed a greater distance (**Table 4-5**) though not significant. On the other hand, Vloka *et al*. (2001) showed a distance greater in females than males. However, in all these observations, the difference was not statistically significant.

Table 5-3: Compilation of means by sex for different studies

	Males		Females	
	Mean	STDEV	Mean	STDEV
Vloka *et al.* (2001)	55.1	25.5	64.2	27.5
Saleh *et al.* (2009)	83.9	4.14	78.85	7.54
Schiarite et al. (2015)	62.56	6	61.35	5
This study	50*		60*	

STDEV: standard deviation, *represents the median

Sources: (Vloka *et al.*, 2001; Saleh, El-Fark and Abdel-Hamid, 2009).

5.2.3. Distance by side

Similarly to other studies (Vloka *et al.*, 2001; Saleh, El-Fark and Abdel-Hamid, 2009), the difference between the right and left lower limb in terms of distance from the PC to the bifurcation was not statistically significant. This is in accord the bilateral characteristic of the level of division or symmetry. Results are close for left and right lower limbs (**Table 5-4**). The symmetry could also explain the absence of significant difference by side in males and females.

Table 5-4: Compilation of mean by side in different studies

	Left		Right	
	Mean	STDEV	Mean	STDEV
Vloka et al. (2001)	57.5	25.7	66.2	23.9
Saleh et al. (2009)	83.3	3.98	79.2	7.21
Schiarite et al. (2015)	61.27	11	62.29	11
This study	52.5*		57.5*	

STDEV: standard deviation

Sources: (Vloka *et al.*, 2001; Saleh, El-Fark and Abdel-Hamid, 2009; Schiarite *et al.*, 2015).

5.3. Popliteal block simulation

There are no previous reports on simulation of the popliteal block in the literature. The pilot study carried out during this study highlighted a case of high variation in one of the stimulated limbs. In this case, the block would be unsuccessful as the dye was located 150 mm below the SN bifurcation. Hypothetically, considering the proximal spread of the anaesthetic, the block could be successful following a suggestion that for variations located 210 mm above the PC and even higher when the needle is inserted with a proximal inclination of 40 to 60°, the blockade could occur (Vloka *et al*. 1997).

On the other hand, our definitive results were comparable to the reports of Mariano *et al*. (Mariano *et al.*, 2009) with a success rate predictable in 100% of cases. In all cases, the dye was deposited before the bifurcation of the nerve. Other authors suggested a satisfactory block in approximately 90 to 97% of cases (Rongstad *et al.*, 1996; Hansen, Eshelman and Cracchiolo 3rd, 2000; Migues *et al.*, 2005; Perlas *et al.*, 2008; Barbosa *et al.*, 2015), and in 82.3% of cases (Rorie *et al.*, 1980). Nevertheless, a better outcome of the PB was obtained with the aid of the ultrasound (Wadhwa, Gebhard and Obal, 2010) when compared to the neurostimulation. This could be as a result of a good visualisation of the nerve with the ultrasound therefore ensuring a better placement of the needle before injection of the anaesthetic.

The success rate predicted for the popliteal block was high because the SN showed a normal bifurcation in the PF for all the specimens used for simulation. On the opposite, the existence of variations would compromise the block as demonstrated in the pilot study. For this reason, the use of a neurostimulation or better the ultrasound would improve the placement of the needle and above all help identify such variations for a better choice of the anaesthetic method.

In most cases, the presence of an undivided nerve at 7 cm above the crease would lead to the placement of the needle at that distance above the crease (Hadžic *et al.*, 2002). However, taking into account the variations in which the nerve divided at a minimum of 120 mm above the crease, the technique suggested by Singelyn *et al*. (1991) would improve the quality of the block. An approach with a placement of the needle 12 to 14 cm (Nader *et al.*, 2009) above the crease would also be beneficial. Despite the benefits of all these approaches, the technique used remains the choice of the surgeon or the anaesthetist, adapted to the condition of the patient.

Concerning the three approaches used for the simulation, a closer needle-to-nerve contact was achieved with the classic posterior approach, followed by the lateral approach and lastly the intertendinous approach. This approach could therefore improve the success rate. However, this difference was not proven statistically. Another simulation on a larger number of specimens could be interesting for a better comparison and analysis of the proximal spread to ensure successful blocks even in some cases of high variations.

Chapter 6 - CONCLUSION, STRENGHTS, LIMITATIONS & RECOMMENDATIONS

6.1. CONCLUSION

The knowledge of the anatomy of the sciatic nerve, especially its level of division, is essential for accurate placement of the needle during the popliteal block, therefore contributing to the success of this anesthesia. There is no standard description of bifurcation, due to the high variability of bifurcation of the SN. However, the South African population might display a normal pattern of bifurcation as described in this study. The mean distance at which the nerve divides varies between 50 and 70 mm approximately above the popliteal crease, and variations of the SN bifurcation could be observed in as low as 8% or a high as 60% of cases approximately. Therefore, because the level of division of the SN is generally bilateral, the identification of a variation in one limb calls for the exploration of the other limb. Moreover, more precautions would be required in females than in males, due to the high prevalence in this subgroup. Consequently, systematic preoperative imagery should be enforced to avoid failures of the block or injuries of the nerve.

Furthermore, as no difference was highlighted among the three approaches used, this study demonstrated that a normal division of the sciatic nerve in the popliteal fossa ensures a 100% success rate of the popliteal block. On the other hand, variations would compromise the block, hence techniques such as those suggested by Singelyn *et al.* (Casalia, Carradori and Moreno, 2006) or Nader *et al*. (2009) using a needle inserted between 10 and 14 cm above the crease would yield better results.

In summary, high variations of the sciatic nerve lead to failures of the popliteal block, hence surgeons and anaesthesiologists need to consider these variations when making surgical decisions.

6.2. STRENGHTS

The strength of this study is based on the large sample size unlike most previous studies. It therefore gives a large spectrum of the level of division of the sciatic nerve and the distance at which it divided. Moreover, the heterogeneous study population contributes to a broader view of the sciatic nerve division.

6.3. LIMITATIONS

There could be some bias in this study arising from data being collected and analysed by a single observer (Schiarite *et al.*, 2015). Besides, the distance between the PC and the point of bifurcation was recorded in only 79.5% of our sample because data collection was a two-step process. The first step consisted in recording the levels of division on a form while measurements, part of the second step, would be taken afterwards. For some specimens, the measurements could not be taken because the sciatic nerve had been damaged during the dissection process after identification of the location of the point of bifurcation. Distances were recorded in millimetres (mm) for more precision and better comparison.

In addition, the simulation was carried out by a general practitioner with no training in block procedures. This could explain the glitches excluded from the analysis of the popliteal block simulation. Despite those limitations, data was collected meticulously and the pilot study was used to understand and master the technique of the popliteal block.

6.4. RECOMMENDATIONS

The assessment of the sciatic nerve by preoperative imagery should be a prerequisite to any surgical procedure of the lower limb using the popliteal block as a regional anaesthesia. In addition, this study should be carried further on a larger sample to confirm these findings and explore further the differences among population groups. It would therefore improve the accuracy of the results obtained and make them applicable to the South African population. Furthermore, multiple observers should collect the results in order to reduce the risk of bias.

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ADDENDA

ADDENDUM A: Sample forms used for data collection

FORM 1

Cadaver N°	Division-left	Division-right	Distance apex-left	Distance apex-right
00/15	*popliteal fossa*	*gluteal*	*25 mm*	*56 mm*

FORM 2

	Distance nerve-dye			Location to bifurcation	
Cadaver N°	Blue	Green	Pink	Above	Below

Addendum B: Data used for analysis

- Level of division and distance between the crease and the SN bifurcation

ID cadaver	Sex	Race	Side	Distance to apex	Level of division
17/16	M	C	L	15	Popliteal fossa
19/16	F	C	L	55	Popliteal fossa
16/16	F	B	L	50	Popliteal fossa
11/16	F	C	L	50	Popliteal fossa
4/16	F	C	L	30	Popliteal fossa
8/16	F	C	L	45	Popliteal fossa
5/16	F	C	L	50	Popliteal fossa
7/16	M	C	L	20	Popliteal fossa
6/16	M	W	L	5	Popliteal fossa
13/16	M	C	L	0	Popliteal fossa
15/16	M	B	L	60	Popliteal fossa
127/15	M	W	L	50	Popliteal fossa
134/15	F	C	L		Post thigh
118/15	M	C	L		Popliteal fossa
60/15	F	C	L	15	Popliteal fossa
119/15	M	C	L	70	Popliteal fossa
71/15	F	C	L	80	Popliteal fossa
135/15	M	C	L	15	Popliteal fossa
100/15	M	C	L	15	Popliteal fossa
120/15	M	C	L	20	Popliteal fossa
66/15	M	C	L	10	Popliteal fossa
76/15	F	C	L	65	Popliteal fossa
133/15	M	C	L	50	Popliteal fossa
64/15	M	C	L	60	Popliteal fossa
89/15	F	C	L	20	Popliteal fossa
121/15	F	C	L	10	Popliteal fossa
126/15	M	C	L	70	Popliteal fossa
128/15	F	C	L	0	Popliteal fossa
130/15	F	C	L	60	Popliteal fossa
59/15	F	C	L		Popliteal fossa
98/15	M	C	L	0	Popliteal fossa
57/15	M	B	L	30	Popliteal fossa
10/15	M	C	L	15	Popliteal fossa
61/15	M	W	L	35	Popliteal fossa
88/15	F	C	L	45	Popliteal fossa
101/15	F	C	L		Gluteal

143/15	M	B	L		Popliteal fossa
106/15	F	C	L		Popliteal fossa
104/15	M	B	L		Popliteal fossa
86/15	M	C	L	65	Popliteal fossa
63/15	M	W	L		Popliteal fossa
107/15	F	C	L		Popliteal fossa
47/15	F	C	L	65	Popliteal fossa
62/15	M	C	L		Popliteal fossa
22/15	M	C	L	53	Popliteal fossa
42/15	M	B	L	60	Popliteal fossa
15/15	M	B	L		Popliteal fossa
14/14	M	C	L	10	Popliteal fossa
56/15	M	C	L		Popliteal fossa
125/15	M	W	L		Popliteal fossa
70/15	M	B	L	50	Popliteal fossa
116/15	M	W	L	45	Popliteal fossa
140/15	F	C	L	25	Popliteal fossa
142/15	M	B	L		Popliteal fossa
111/15	F	C	L		Post thigh
146/15	M	C	L	48	Popliteal fossa
65/15	M	C	L	50	Popliteal fossa
137/15	M	C	L	20	Popliteal fossa
83/15	M	C	L	32	Popliteal fossa
75/15	F	C	L	34	Popliteal fossa
138/15	F	W	L	10	Popliteal fossa
17/16	M	C	R	55	Popliteal fossa
19/16	F	C	R	20	Popliteal fossa
16/16	F	B	R	50	Popliteal fossa
11/16	F	C	R	40	Popliteal fossa
4/16	F	C	R	60	Popliteal fossa
8/16	F	C	R	40	Popliteal fossa
5/16	F	C	R	70	Popliteal fossa
7/16	M	C	R	60	Popliteal fossa
6/16	M	W	R	0	Popliteal fossa
13/16	M	C	R	10	Popliteal fossa
15/16	M	B	R	70	Popliteal fossa
127/15	M	W	R	25	Popliteal fossa
134/15	F	C	R		Gluteal
118/15	M	C	R		Popliteal fossa
60/15	F	C	R	3	Popliteal fossa
119/15	M	C	R	60	Popliteal fossa

71/15	F	C	R	60	Popliteal fossa
135/15	M	C	R	15	Popliteal fossa
100/15	M	C	R	15	Popliteal fossa
120/15	M	C	R	0	Popliteal fossa
66/15	M	C	R	0	Popliteal fossa
76/15	F	C	R	60	Popliteal fossa
133/15	M	C	R	25	Popliteal fossa
64/15	M	C	R	65	Popliteal fossa
89/15	F	C	R	20	Popliteal fossa
121/15	F	C	R	20	Popliteal fossa
126/15	M	C	R	60	Popliteal fossa
128/15	F	C	R	0	Popliteal fossa
130/15	F	C	R	65	Popliteal fossa
59/15	F	C	R		Popliteal fossa
98/15	M	C	R	0	Popliteal fossa
57/15	M	B	R	30	Popliteal fossa
10/15	M	C	R	0	Popliteal fossa
61/15	M	W	R	30	Popliteal fossa
88/15	F	C	R	43	Popliteal fossa
101/15	F	C	R		Gluteal
143/15	M	B	R		Popliteal fossa
106/15	F	C	R		Popliteal fossa
104/15	M	B	R		Popliteal fossa
86/15	M	C	R	67	Popliteal fossa
63/15	M	W	R		Popliteal fossa
107/15	F	C	R		Popliteal fossa
47/15	F	C	R	42	Popliteal fossa
62/15	M	C	R	62	Popliteal fossa
22/15	M	C	R	20	Popliteal fossa
42/15	M	B	R	44	Popliteal fossa
15/15	M	B	R	60	Popliteal fossa
14/14	M	C	R	20	Popliteal fossa
56/15	M	C	R		Popliteal fossa
125/15	M	W	R		Popliteal fossa
70/15	M	B	R	40	Popliteal fossa
116/15	M	W	R	30	Popliteal fossa
140/15	F	C	R	15	Popliteal fossa
142/15	M	B	R		Post thigh
111/15	F	C	R		Post thigh
146/15	M	C	R		Popliteal fossa
65/15	M	C	R		Popliteal fossa

137/15	M	C	R	46	Popliteal fossa
83/15	M	C	R	32	Popliteal fossa
75/15	F	C	R	56	Popliteal fossa
138/15	F	W	R	10	Popliteal fossa

- Distance between the dye and the SN

Cadaver n	Sex	Race	Side	Blue	Pink	Green
4/16	F	C	L	3		0
5/16	F	C	L		0	0
6/16	M	W	L	10		
7/16	M	C	L		0	0
8/16	F	C	L	0	0	10
11/16	F	C	L	0		0
13/16	M	C	L	0		
15/16	M	B	L	0		0
16/16	F	B	L	0	0	10
17/16	M	C	L	0		
19/16	F	C	L	0	0	15
4/16	F	C	R		0	0
5/16	F	C	R	0	0	0
6/16	M	W	R			0
7/16	M	C	R		20	20
8/16	F	C	R		0	
11/16	F	C	R	0	25	25
13/16	M	C	R	25	0	10
15/16	M	B	R			0
16/16	F	B	R	0	5	0
17/16	M	C	R	0	0	
19/16	F	C	R	5		5