

# Anatomical variations of the iliohypogastric - and ilioinguinal nerves: clinical consideration within a South African population

Zithulele N. Tshabalala<sup>1</sup>, Tuahir H.N. Hussain<sup>2</sup>, Daniël J. van Tonder<sup>3</sup>, Albert van Schoor<sup>4</sup>

<sup>1</sup>Department of Human Biology and Integrated Pathology, School of Medicine, Faculty of Health Sciences, Nelson Mandela University, Gqeberha, South Africa

<sup>2</sup>Department of Biological Sciences, College of Medicine and Health Sciences, Khalifa University, Abu Dhabi, United Arab Emirates

<sup>3</sup>Department of Basic Sciences, College of Medicine, Roseman University of Health Sciences, Las Vegas, Nevada, United States of America

<sup>4</sup>Department of Anatomy, Faculty of Health Sciences, University of Pretoria, Pretoria, South Africa

## SUMMARY

Inguinal hernias are a common occurrence in both infants and adults. Several surgical procedures to repair these hernias have been introduced, with varying success rates. Decreasing the rate of complication incidence requires an absolute understanding of the anatomical structures involved. A literature review indicated that surgeons favor using the Lichtenstein tension-free method. This study describes the anatomy of the iliohypogastric and ilioinguinal nerves clearly and accurately for application in the successful performance of the Lichtenstein tension-free inguinal hernia repair within a South African population. Together with an extensive literature search, a bilateral dissection was conducted to expose the spinal nerve of the iliohypogastric and ilioinguinal nerves in a sample that included 105 formalin-fixed adult cadavers. The anatomy of the iliohypogastric and ilioinguinal nerves aligned with existing descriptions in anatomical textbooks and literature. The L1 spinal nerve was observed

predominantly bifurcating into the iliohypogastric and ilioinguinal nerves within the transversus abdominis muscle before coursing towards the anterior superior iliac spine. The distances of the iliohypogastric and ilioinguinal nerves to the anterior superior iliac spine lie within the recommended 30-40 mm muscle flap described for the Lichtenstein tension-free repair to visualize the nerves. This study reiterates the safety of an iliohypogastric and ilioinguinal nerve block procedure, which is recommended for inguinal hernia repairs within a South African population. It is important to note the variability observed in the study for safe performance and successful early postoperative pain management using the ilioinguinal and iliohypogastric nerve blocks.

**Key words:** Inguinal hernia – Lichtenstein tension – Free hernioplasty – Lumbar plexus – Nerve entrapment – Nerve block

## Corresponding author:

Daniël Johannes van Tonder. Department of Basic Sciences, College of Medicine, Roseman University of Health Sciences, Las Vegas, Nevada, United States of America. E-mail: [dvantonder@roseman.edu](mailto:dvantonder@roseman.edu) - ORCID: <https://orcid.org/0000-0001-8246-915X>

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## INTRODUCTION

Inguinal hernias are a common occurrence in both infants and adults (Samakar et al., 2019). A study by McDonnell and Wakefield (2018) estimated that approximately 20 million inguinal hernia repairs are performed worldwide annually. Hernias in adults are more commonly observed in males (Gatabi et al., 2018; McDonnell and Wakefield, 2018). A study by de Goede et al. (2015) reported the incidence of inguinal hernias mostly in middle-aged and elderly males.

The protrusion of abdominal contents, such as the intestines, through a weakened part of the abdominal wall within the inguinal canal is termed an inguinal hernia. The inguinal canal serves as a passageway for multiple blood vessels and nerves, which often endure complications in the context of hernias. With respect to inguinal hernias and surgical interventions, a greater understanding of anatomy, including the functionality of specific nerves, is crucial (Caserta et al., 2021). During the process of surgical repair, management of these nerves becomes essential in order to make sure that sensory deficits and new onset of pain do not arise. Therefore, surgical precision is key, as the preservation of the sensory foundations from the targeted area would lead to a more effective and comfortable recovery (Shakil et al., 2020).

For hernia repairs, the Lichtenstein tension-free technique is a commonly used method for open inguinal hernia repair, as a result of its low complication rate (Schumpelick and Klinge, 2003; Neogi et al., 2018; Tan and Blatnik, 2018; Vasu and Sagar, 2018). The procedure was first described by Lichtenstein et al. (1989) as an alternative to the techniques at that time, which had a high recurrence rate after repair. The importance of visualizing the iliohypogastric and ilioinguinal nerves was reported by Ferzli et al. (2008), who reported that the terminal branches of the anterior ramus of the first lumbar spinal nerve (L1), additional contributions from the twelfth thoracic (T12) and second lumbar spinal nerves (L2) (Klaassen et al., 2011; Tagliafico et al., 2015; Kale et al., 2019) were most at risk of compression in the placement of a mesh in the inguinal region (Ferzli et al., 2008). Knowledge of the course and variations of these nerves is essential for surgeons, as it is analogous

to the surgical methods used by them to preserve these nerves.

As such, this study aimed to accurately describe the anatomy of the iliohypogastric and ilioinguinal nerves for application in the successful performance of the Lichtenstein tension-free inguinal hernia repair.

## MATERIALS AND METHODS

An extensive literature search was conducted using the PubMed, Science Direct, Ovid, and Google Scholar journal databases, as well as current anatomy, surgical, and anesthetics textbooks and guidelines. Relevant clinical and surgical procedures were selected to be compared to the results of this study. The keywords in the database searches mentioned previously were: *nervus iliohypogastricus*, *iliohypogastric nerve*, *nervus ilioinguinalis*, *ilioinguinal nerve*, *iliohypogastric and ilioinguinal nerve anatomy*, *iliohypogastric and ilioinguinal nerve injury*, *inguinal hernia repair complications*, *iliohypogastric and ilioinguinal nerve analgesia*, *Pfannenstiel incision*, *iliohypogastric nerve*, *hernioplasty ilioinguinal iliohypogastric*. Several relevant surgical procedures were found during the search, but not all of them were reviewed for the study. The selected procedure was the Lichtenstein tension-free inguinal hernia repair. The applications of the results of these procedures are detailed in the discussion.

In addition, bilateral dissection of 105 formalin-fixed adult cadavers was performed to expose the anterior (ventral) ramus of the spinal nerve, course, and patterns of the iliohypogastric and ilioinguinal nerves along the posterior abdominal wall. These cadavers were donated to the Department of Anatomy, Faculty of Health Sciences, University of Pretoria, Pretoria, South Africa. The bodies were donated in accordance with the provisions of the South African National Health Act, 61 of 2003, for research and teaching purposes. This study was approved by the University of Pretoria's Faculty of Health Sciences Research Ethics Committee (Ref #: 397/2017). Within the study, a donor was excluded if there was any evidence of pathology and or previous dissection disturbance to the area of investigation.

### *Spinal nerve and bifurcation pattern*

The following dissection protocol was consistently followed for all cadaveric specimens to expose the ilioinguinal and iliohypogastric nerves:

**Step 1:** A midline abdominal incision was made through the skin from the xiphoid process to the pubic symphysis to allow full visualization of the anterior abdominal wall. Further bilateral horizontal incisions intersecting the midline abdominal incision at the cranial and caudal ends were made until the respective midaxillary lines.

**Step 2:** The skin and subcutaneous tissue were reflected laterally to expose the external oblique muscle aponeurosis and underlying musculature of the anterior abdominal wall.

**Step 3:** The external oblique, internal oblique, and transversus abdominis muscles were sequentially incised and reflected to expose the neurovascular plane between the internal oblique and transversus abdominis muscles. Care was taken not to disturb the ilioinguinal and iliohypogastric nerves coursing within the abdominal wall and inguinal canal (see step 6).

**Step 4:** The abdominal viscera and parietal peritoneum on the posterior abdominal wall were carefully removed in order to isolate and expose the lumbar plexus in relation to the psoas major muscle. The latter was exposed, and blunt dissection was used to trace the anterior ramus of the L1 spinal nerve as it emerged lateral to the muscle. In all instances, the spinal nerves cranial and caudal to L1 (between T11 and L3) were also exposed in order to determine whether there were cranial and/or caudal contributions to the anterior ramus of the L1 spinal nerve.

**Step 5:** The nerves were then followed as they ran anterior to the posterior abdominal wall, before piercing the transversus abdominis muscle. The course of the nerve in relation to the psoas major muscle and the anterior and posterior abdominal walls, their spinal nerve contributions, whether the iliohypogastric and ilioinguinal nerves bifurcated from the anterior ramus of the L1 spinal nerve at the vertebral column, or whether the bifurcation occurred after piercing the transversus abdominis muscle, and any variations were recorded.

**Step 6:** To investigate the iliohypogastric and ilioinguinal nerves along the anterior abdominal wall at the level of the anterior superior iliac spine (see step 3), the external oblique muscle was reflected laterally from its insertion. To achieve this, three incisions were made in the external oblique muscle. A vertical incision was made along the linea semilunaris from the level of the umbilicus to the superficial inguinal ring. Thereafter, a horizontal incision was made at the level of the umbilicus, from the vertical incision laterally towards the midaxillary line. To allow the external oblique muscle to be reflected laterally from the anterior abdominal wall, an oblique incision was made from the cranial border of the superficial inguinal ring to the anterior superior iliac spine, taking care not to damage or disturb any underlying structures. This approach allowed the inguinal canal to be opened without disturbing the ilioinguinal nerve within it, as well as the iliohypogastric, as it courses over the internal oblique muscle towards the hypogastric region of the abdomen.

**Step 7:** The anterior superior iliac spine was pinned at the midpoint of its most anterior projection.

**Step 8:** The course of the nerves was observed and followed to their termination, and the iliohypogastric and ilioinguinal nerves were identified and pinned where each pierced the internal oblique muscle.

**Step 9:** To determine the location of the iliohypogastric and ilioinguinal nerves in the anterior abdominal wall, measurements were taken in a straight line from the anterior superior iliac spine to where each nerve pierced the internal oblique muscle to run between it and the external oblique muscle. All measurements were taken using a mechanical dial sliding caliper (accuracy = 0.01 mm). The measurements were recorded and captured in a Microsoft 365 Excel (©2024, Microsoft Corporation, Redmond, Washington, USA) spreadsheet.

### Statistical analysis

All statistical tests were performed using the IBM® SPSS® Statistics (©2024, SPSS Inc., Chicago, Illinois, USA) program, version 25. For the results on the anterior ramus of the spinal nerves and

their bifurcation patterns of the iliohypogastric and ilioinguinal nerves, contingency tables were drawn up to determine the frequency of the observations. Furthermore, a Chi-squared test was executed on the left and right sides to determine whether sex had an influence on the observations.

Quantitative measurements utilized a Shapiro-Wilk test for normality to test for normality of the distribution of the data. In cases where the data was not normally distributed, a Wilcoxon Signed Rank test was performed to compare the left and right sides. A Chi-squared test was performed to determine whether sex had an influence on the observed results. Thereafter, descriptive statistics were executed to describe the mean, standard deviation (SD) and 95% confidence interval (CI) of the samples. Furthermore, a correlation test was executed to determine whether a linear relationship exists between the distances of the iliohypogastric and ilioinguinal nerves to the anterior superior iliac spine with age, height, weight, and body mass index (BMI).

**RESULTS**

**Spinal nerve and bifurcation patterns**

Standard anatomical texts describe the origin of the spinal nerve of the iliohypogastric and ilioinguinal nerves (Fig. 1) as originating from the anterior ramus of the L1 spinal nerve, with contributions from the T12 or L2 spinal nerves (Romanes, 1986; Standring et al., 2020; Moore et al., 2022). This pattern was observed on both the left and the right sides for the entire sample (n = 105) without any noted variation. As a result, no further statistical tests were performed for the spinal nerve origin. Regarding bifurcation of the anterior ramus of the L1 spinal nerve, a difference was observed on both sides (Table 1). On the left side, the L1 spinal nerve bifurcated after piercing the transversus abdominis muscle in 79 cases (75%; 41 male and 38 female) and at the vertebral column in 26 cases (25%; 18 male and 8 female). On the right side, it bifurcated after the transversus abdominis muscle in 90 cases (86%; 49 male and 41 female) and in 15 cases (14%; 10 male and 5 female) at the vertebral column. A Chi-square test determined that there is no apparent influence of sex on the bifurcation pattern on both the left (p = 0.12) and

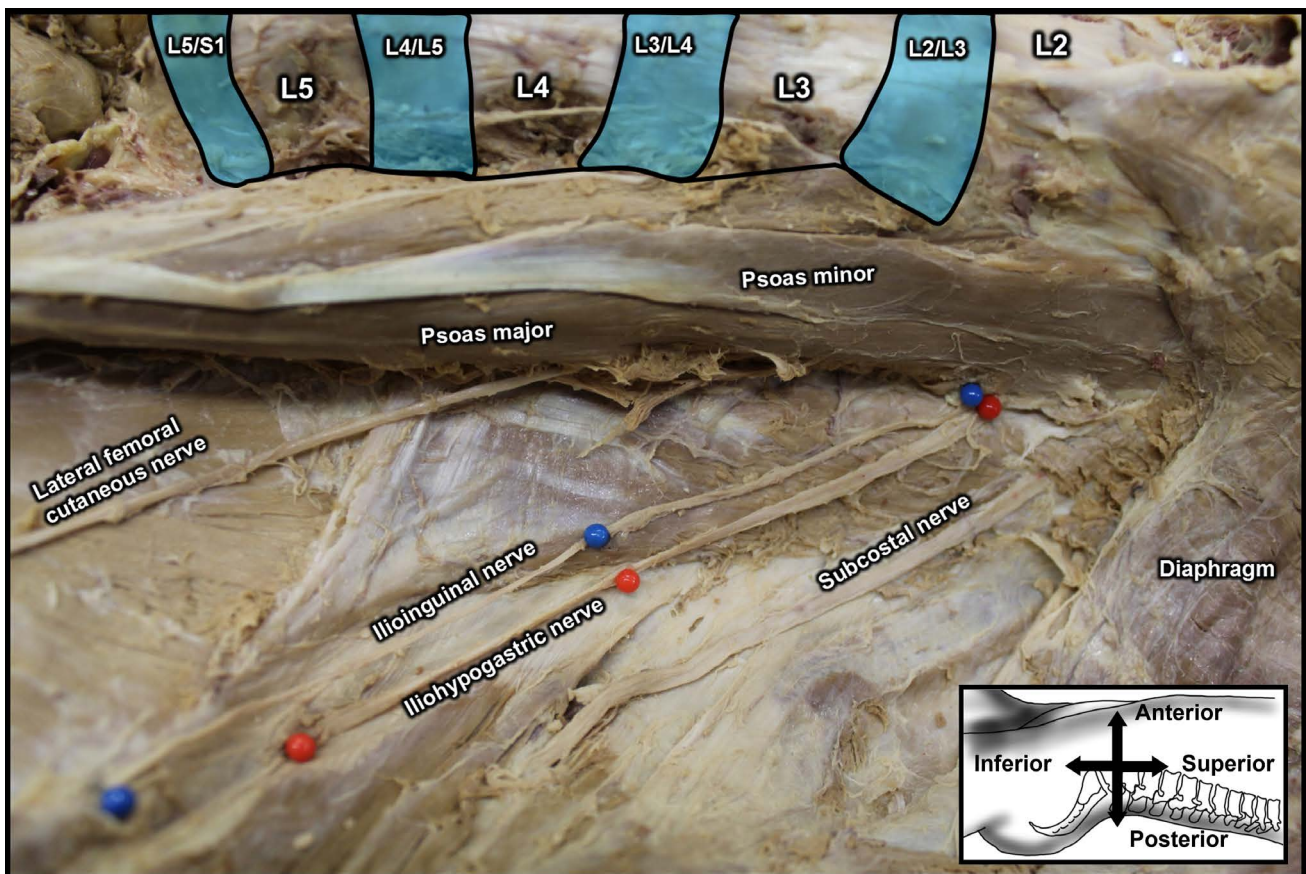


Fig. 1.- Lateral view of the posterior abdominal wall (left side), indicating the position and course of the iliohypogastric (red) and the ilio-inguinal (blue) nerves, and the other branches of the lumbar plexus on the posterior abdominal wall as they pass lateral to the psoas major muscle.

the right sides ( $p = 0.38$ ). This allowed the left and right sides to be combined into an overall sample size of 210. In the new sample, the bifurcation at the muscle was seen in 169 cases (81%) and in 41 cases at the vertebral column (19%).

### ***The iliohypogastric and ilioinguinal nerves in relation to anterior superior iliac spine***

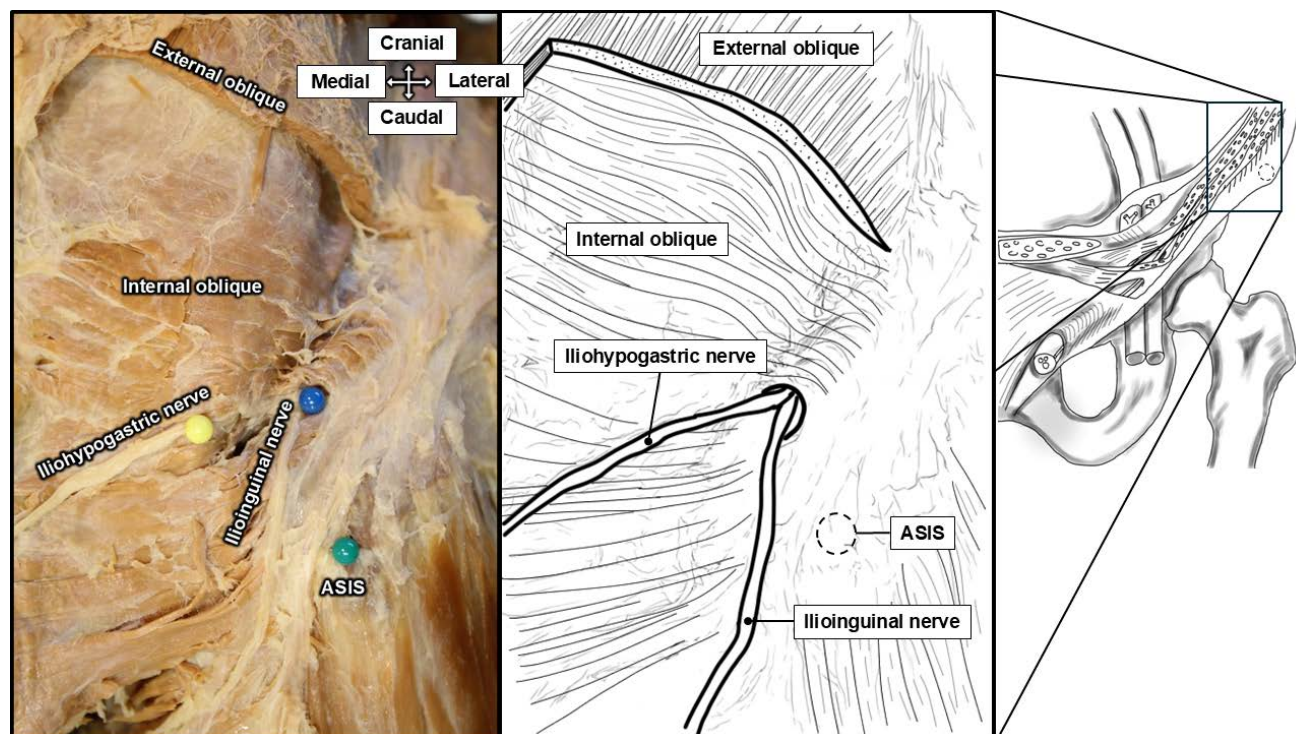
When locating the iliohypogastric and ilioinguinal nerves in relation to the anterior superior iliac spine (Fig. 2), as per the exclusion criteria, only 36 body donors were included within this sample ( $n=36$ ). The measurement from the anterior superior iliac spine to the iliohypogastric nerve (Table 2) was found on the left side in only 33 cases, and on the right side in 36 cases. A Chi-squared test resulted in  $p$ -values of 0.42 on the left and 0.36 on

the right sides, indicating no apparent influence of sex on the data. A Shapiro-Wilk test indicated that the data were not normally distributed on the two sides ( $p < 0.05$ ). A Wilcoxon signed-rank test showed no statistically significant difference between the left and right sides, with a  $p$ -value of 0.22.

Similar observations were made for the distance from the anterior superior iliac spine to the ilioinguinal nerve (Table 2). No statistically significant influence of sex on the data was observed after a Chi-squared test on the left side ( $p = 0.48$ ) and the right side ( $p = 0.37$ ) was performed. The Shapiro-Wilk test revealed that the data were not normally distributed on the left and right sides. As a result of the abovementioned result, a Wilcoxon signed-rank test was performed, showing no

**Table 1.** Results of the bifurcating pattern of the anterior ramus of the L1 spinal nerve

Side	Anterior ramus of the first lumbar nerve bifurcation	Total	Male	Female
Left ( $n = 105$ )	After piercing transversus abdominis muscle	79 (75%)	41	38
	At the vertebral column	26 (25%)	18	8
Right ( $n = 105$ )	After piercing transversus abdominis muscle	90 (86%)	49	41
	At the vertebral column	15 (14%)	10	5
Combined ( $n = 210$ )	After piercing transversus abdominis muscle	169 (81%)	90	79
	At the vertebral column	41 (19%)	28	13



**Fig. 2.-** Anterior view of the left lower anterior abdominal wall with the external oblique muscle removed, indicating the anterior superior iliac spine (ASIS), ilioinguinal (blue) nerve, and iliohypogastric (yellow) nerve, in relation to each other. An accompanying schematic illustration demonstrates the spatial relationships.

**Table 2.** Location of the iliohypogastric and ilioinguinal nerves in relation to the anterior superior iliac spine (ASIS = Anterior Superior Iliac Spine; CI = Confidence Interval; SD = Standard Deviation)

Measurement	Side	Mean ± SD (mm)	CI (mm)	
			Lower	Upper
ASIS to the iliohypogastric nerve	Left (n = 33)	25.24 ± 11.61	21.12	29.35
	Right (n = 36)	23.60 ± 10.60	19.41	27.79
ASIS to the ilio-inguinal nerve	Left (n = 33)	18.79 ± 08.38	15.96	21.63
	Right (n = 36)	18.26 ± 09.77	14.74	21.78

statistically significant difference between the left and right sides ( $p = 0.88$ ). There was no statistically significant correlation observed between age, height, weight, BMI, and measurements from the anterior superior iliac spine to the iliohypogastric and ilioinguinal nerves ( $r < 0.30$ ).

## DISCUSSION

This study aimed to accurately describe the anatomy of the iliohypogastric and ilioinguinal nerves from their origin in the lumbar region to innervation in the groin. The spinal cord segmental origin of the iliohypogastric and ilioinguinal nerves was consistent throughout the entire study. Both nerves originated from the anterior ramus of the L1 spinal nerve and traversed the anterior surface of the quadratus lumborum muscle, coursing obliquely and laterally towards the transversus abdominis muscle. They then pierce it and further course anteriorly between the muscle and the internal oblique muscle (Barazanchi et al., 2016; Kale et al., 2019; Benes et al., 2024).

The iliohypogastric nerve terminates as the anterior and lateral branches, supplying the skin. The lateral branches pierce the internal oblique muscle, to further course between the muscle and the external oblique muscle. Cranial to the iliac crest, it pierces the external oblique muscle to course superficially and supplies the posterolateral surface of the skin over the gluteal region. In addition, this nerve gives motor innervation to the internal oblique and transversus abdominis muscles. The anterior cutaneous nerve courses similar to the lateral cutaneous nerves, piercing the internal oblique and external oblique muscles to give sensory innervation to the skin over the inguinal and pubic regions. Along its course, it also supplies the internal oblique and transversus abdominis muscles, together with the lateral

cutaneous nerve (Anloague and Huijbregts, 2009; Barazanchi et al., 2016; Kale et al., 2019; Benes et al., 2024).

At the level of the anterior superior iliac spine, the ilioinguinal nerve pierces the internal oblique muscle to enter the inguinal canal, accompanying the spermatic cord in males and the round ligament of the uterus in females. It exits the inguinal canal into the inguinal region through the superficial inguinal ring, to give sensory innervation to the medial thigh, base of the penis, and cranial surface of the scrotum in males and the mons pubis and labia majora in females. This sensory innervation is shared with that of the genitofemoral nerve. The ilioinguinal nerve also gives motor innervation to the internal oblique and transversus abdominis muscles (Anloague and Huijbregts, 2009; Barazanchi et al., 2016; Kale et al., 2019). Studies have reported variation in the course of the iliohypogastric and ilioinguinal nerves whereby they could be injured during inguinal hernia repairs (Al-dabbagh, 2002; Rab and Dellon, 2001; Fateh et al., 2018). Anloague and Huijbregts (2009) further reported instances of complete absence of the iliohypogastric nerve and no variation with the ilioinguinal nerve.

### *Spinal nerve values and location*

While the present study consistently found the iliohypogastric and ilioinguinal nerves originating from the anterior ramus of the L1 spinal nerve, the broader literature describes a much wider spectrum of variation (Table 3) (Amid, 2004a; Klaassen et al., 2011; Tagliafico et al., 2015; Amin et al., 2016; Nontasaen et al., 2016; Kale et al., 2019). Sources report that the ilioinguinal nerve, while typically from the anterior ramus of the L1 spinal nerve, can also be derived from the T12 to

**Table 3.** Comparison of the range of spinal nerve values for the iliohypogastric and ilio-inguinal nerves reported by different studies

Study	Country	n	Iliohypogastric spinal nerve segments	Ilio-inguinal spinal nerve segments
Amid (2004a)	USA	-*	T12-L1	T12-L1
Klaassen et al. (2011)	West Indies	200	T11-L1	T12-L3
Tagliafico et al. (2015)	Italy	-*	T12-L1	L1
Amin et al. (2016)	USA	-*	T12-L2	T12-L2
Nontasaen et al. (2016)	Thailand	131	T12-L1	T12-L1
Kale et al. (2019)	Turkey	-*	T12-L1	T12-L1
Current study	South Africa	210	L1	L1

\*Study reported the spinal nerve value based on surgical observations

L2 spinal nerves. The iliohypogastric nerve shows even greater variability, with potential origins from the T12, L2, or even a loop between the L2 and L3 spinal nerves. These variations were not observed in the current study's sample.

A study by Klaassen et al. (2011) was the most extensive, reporting on the contribution of the T11 and L2 spinal nerves in 200 body donations, respectively. They found that the ilioinguinal nerve originates from the T12-L1 spinal nerves in 14%, the L1 spinal nerve in 65%, the L1-L2 in 11%, and the L2-L3 spinal nerves in 10% of the cases. Klaassen et al. (2011) also found that the iliohypogastric nerve originates from the T12 spinal nerve in 7%, the T12-L1 spinal nerves in 14%, the L1 spinal nerve in 10%, and from the T11-T12 spinal nerves in 6%. The iliohypogastric nerve presented with an accessory branch to the subcostal (22%), ilioinguinal (55%) and lateral femoral cutaneous nerves (5%). These variations were not observed in this current study, which more closely relates to the findings from Nontasaen et al. (2016), who found the iliohypogastric and ilioinguinal nerves originated from L1 spinal nerve in 96.5% and 90.1%, respectively, in a 131 lumbar plexus sample.

Older descriptions of the spinal origins of the ilioinguinal and iliohypogastric nerves report similar ranges, with the majority originating solely from the L1 spinal nerve, with a range between T12 and L3 (Hollinshead, 1982; Apaydin, 2016). As well as reporting on similar ranges, Bardeen (1902) also reported on a very rare occurrence of the iliohypogastric nerve originating from the T11 and T12 spinal nerves. Acknowledging this wide range of potential origins, especially those from higher spinal

levels like T11, is rare but still clinically important to avoid iatrogenic injury.

#### ***The iliohypogastric and ilioinguinal nerves in relation to the anterior superior iliac spine.***

The location of the iliohypogastric and ilioinguinal nerves in the anterior abdominal wall is important to consider when performing inguinal hernia repairs, especially in reference to the ilioinguinal nerve, as it lies within the inguinal canal (Rab and Dellon, 2001; Amid, 2004b; Ferzli et al., 2008; Kale et al., 2019). On the left side, the iliohypogastric nerve was on average  $25.24 \pm 11.61$  mm from the anterior superior iliac spine, and on the right side,  $23.60 \pm 10.60$  mm from the anterior superior iliac spine. The ilioinguinal nerve was on average  $18.79 \pm 8.38$  mm from the anterior superior iliac spine on the left side, and on the right side,  $18.26 \pm 9.77$  mm from the anterior superior iliac spine. In a study of 11 fresh cadavers by Rahn et al. (2010), the iliohypogastric nerve was found to be 25 mm medial and 20 mm caudal to the anterior superior iliac spine. They reported the range to be between 0 and 46 mm for the measurement from the iliohypogastric nerve to the anterior superior iliac spine. In addition, they also found that the ilioinguinal nerve was 25 mm medial and 24 mm caudal to the anterior superior iliac spine, with ranges of 11 to 51 mm and 0 to 53 mm, respectively. These studies are compared in Table 4.

In a study by Whiteside et al. (2003), the iliohypogastric nerve was found  $21 \pm 18$  mm medi-

**Table 4.** Comparison of the iliohypogastric and ilioinguinal nerves in relation to the anterior superior iliac spine reported by different studies (ASIS = Anterior Superior Iliac Spine; SD = Standard Deviation)

Measurement Type	Nerve	Study (Year)	Combined (n)	Mean $\pm$ SD (mm)	Range (mm)
Direct distance from ASIS	Iliohypogastric	Current study	60	24.50 $\pm$ 11.10	10.03 to 72.37
	Ilioinguinal	Current study	68	18.54 $\pm$ 08.99	7.38 to 52.99
Offset from ASIS (Medial)	Iliohypogastric	Whiteside et al. (2003)	13	21 $\pm$ 18	-16 to 50
		Rahn et al. (2010)	11	25	0 to 46
	Ilioinguinal	Whiteside et al. (2003)	16	31 $\pm$ 15	9 to 63
		Rahn et al. (2010)	11	25	11 to 51
Offset from ASIS (Inferior)	Iliohypogastric	Whiteside et al. (2003)	13	9 $\pm$ 28	-54 to 55
		Rahn et al. (2010)	11	20	0 to 46
	Ilioinguinal	Whiteside et al. (2003)	16	37 $\pm$ 15	-5 to 59
		Rahn et al. (2010)	11	24	0 to 53

al and  $9 \pm 28$  mm caudal to the anterior superior iliac spine. The ilioinguinal nerve was on average  $31 \pm 15$  mm medial and  $37 \pm 15$  mm caudal to the anterior superior iliac spine. These results differ from the results obtained in the current study of a South African population. In this study, the ilioinguinal nerve was observed closer to the anterior superior iliac spine than the iliohypogastric nerve. In addition, the results of this study place both the iliohypogastric and ilioinguinal nerves closer to the anterior superior iliac spine than is documented in the literature. Rahn et al. (2010) observed the nerves equidistant from the anterior superior iliac spine medially, and Whiteside et al. (2003) observed the iliohypogastric nerve closer to the anterior superior iliac spine than the ilioinguinal nerve. Being cognizant of the differences in the observed distances in various populations from the anterior superior iliac spine to the iliohypogastric and ilioinguinal nerves is vital in the planning and performance of surgical and clinical procedures safely and successfully.

Additionally, recent studies have demonstrated that the iliohypogastric nerve is significantly absent in some populations. A study by Nontasaen et al. (2016) showed an absence of up to 34.35%, while an absence of 20.6% was noted by a study conducted by Anloague and Huijbregts (2009). In surgeries like inguinal hernia repairs, the lack of the nerve presents with special difficulties. The absence of this anatomical landmark makes surgical navigation more difficult, and may raise the possibility of complications post-surgery. These

results emphasize how important it is for surgeons to modify their methods and improve pre-operative planning in order to reduce risks and guarantee the best possible outcomes for their patients.

#### ***Clinical applications***

Several surgical procedures to repair these hernias have been introduced over the years, with varying success rates. A review of the literature indicated that surgeons are beginning to move towards the use of the Lichtenstein tension-free method (Lichtenstein et al., 1989; Amid, 2004b). To decrease the rate of complication incidence, an absolute understanding of the anatomy of the structures in, and in relation to, the inguinal canal, for placement of a mesh, specifically with regard to the iliohypogastric and ilioinguinal nerves, is required, as studies have reported the occurrence of nerve entrapment by the inserted mesh (Zwaans et al., 2017; Neogi et al., 2018). The entrapment of these nerves may be due to a lack of knowledge of the anatomy and variations of the nerves in the inguinal region.

Since its introduction, the Lichtenstein technique has been modified several times to what is best described in an article by Amid (2004b), stating the guidelines for the Lichtenstein tension-free hernioplasty procedure in males as a 50 mm skin incision from the pubic tubercle laterally towards the anterior superior iliac spine. This is followed by opening the inguinal canal by cutting through the external oblique muscle from the

floor of the inguinal canal and freeing it from the spermatic cord. The external oblique muscle is then reflected cranially for approximately 30 - 40 mm from the inguinal ligament, which forms the floor of the canal, also freeing it from the internal oblique muscle. This will allow visualization of the iliohypogastric nerve as it traverses the internal oblique muscle and the ilioinguinal nerve as it courses on the spermatic cord.

The results of this study found that the ilioinguinal nerve is closer to the anterior superior iliac spine than the iliohypogastric nerve in a South African population. This implies that the ilioinguinal nerve is most likely at risk during procedures done on or around the anterior superior iliac spine and the structures associated close to it, such as the inguinal ligament. Additionally, the results correspond to the described procedural guidelines for the Lichtenstein tension-free repair, where the external oblique muscle is reflected cranially for approximately 30 – 40 mm. This will allow for clear visualization of the iliohypogastric and ilioinguinal nerves, limiting the possibility of entrapment of the nerve when inserting the mesh, as both distances lie within the limits of the proposed muscle reflection distances.

It must be noted that, even though the Wilcoxon signed-rank test did not report a statistically significant difference in the distances on the opposite sides, the variability on the respective sides necessitates that each side be approached with caution. The finding that the data is not equally distributed on all sides for both the iliohypogastric and ilioinguinal nerves indicates the presence of variation in the location of the nerves in a South African population. This should be considered when undertaking inguinal hernia repairs. Knowledge of this variability will prevent the occurrence of nerve entrapment, which will require further surgical intervention.

The anatomy of the iliohypogastric and ilioinguinal nerves in a South African population was in line with previous descriptions in anatomical textbooks and literature. Further comparative studies could be performed in order to further investigate the presence of the T12 contribution that has been suggested by other studies. The L1 spinal nerve predominantly bifurcated into the

iliohypogastric and ilioinguinal nerves within the transversus abdominis muscle before coursing towards the anterior superior iliac spine. The distances of the iliohypogastric and ilioinguinal nerves lie within the recommended 30 - 40 mm muscle flap described for the Lichtenstein tension-free repair for visualization of the nerves. It is important to note the variability in the distances observed in the study on the left and right sides. It cannot be denied that the variability may be due to the limitation of a small sample size, as a result of exclusion criteria. It is recommended that the iliohypogastric and ilioinguinal nerves be further investigated on a larger cadaver sample with an equal distribution of males and females, including an extension of the study by mapping the nerves using modern medical imaging.

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#### **AUTHORS' CONTRIBUTIONS**

Dr Z.N. Tshabalala was primarily responsible for protocol development, data collection, data analysis, manuscript writing, and critical review of the final manuscript. Mr. T.H. Nadeem Hussain and Mr. D.J. van Tonder both participated in manuscript writing and the critical review of the final manuscript. Prof A. van Schoor supervised the design and execution of the study, participating in protocol development, data collection, data analysis, manuscript writing, and the critical review of the final manuscript.

#### **Ethics approval and consent to participate**

This study utilized body donations that were reviewed and approved (Ethics clearance number: 397/2017) by the Health Sciences Research Ethics Committee at the University of Pretoria, South Africa. All methods and observations were carried

out in accordance with the relevant requirements, guidelines, and regulations stipulated in the South African National Health Act (61 of 2003).

### Availability of data and materials

The original contributions presented in the study are included in the article, and any further inquiries can be directed to the corresponding author.

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