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REVIEW

Anatomical variations of the ilioinguinal, iliohypogastric, and genitofemoral nerves: a systematic scoping review of cadaver studies

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Abstract

Aim/background Nerve management during open inguinal hernia repair is thought to influence the incidence of postoperative chronic pain. Understanding nerve anatomy may assist surgeons in identifying and protecting nerves during surgery. In this study, we aimed to describe the anatomical variations and locations of the ilioinguinal, iliohypogastric, and genitofemoral nerves as reported in cadaver studies.

Methods We conducted a search in Pubmed, Embase, CNKI, and LILACS. Studies reporting on adult cadavers with detailed descriptions of the ilioinguinal, iliohypogastric, or genitofemoral nerves were included. Studies on cadavers that were previously operated on for inguinal hernia or anatomical areas not relevant to inguinal hernia surgery were excluded.

Results Out of 2,196 records, 115 articles were screened, and 47 articles met the inclusion criteria. The ilioinguinal nerve was typically found in the Lichtenstein operative field, running ventrally along the spermatic cord, parallel to the inguinal ligament. The iliohypogastric nerve was usually located cranial to the ilioinguinal nerve and spermatic cord, positioned between the internal and external oblique abdominal muscles. The genitofemoral nerve was generally found beneath the spermatic cord alongside the accompanying vessels. While the iliohypogastric nerve displayed the most consistent anatomical position, all nerves showed significant variations, with frequent occurrences of nerve fusion.

Conclusion The three major nerves involved in an open inguinal hernia repair exhibit considerable anatomic variability. Surgeons need to be cognizant of these variations to prevent nerve damage.

Keywords Inguinal hernia · Ilioinguinal · Iliohypogastric · Genitofemoral · Groin · Scoping review · Anatomy

Introduction

Open inguinal hernia repair remains a common surgical procedure worldwide [1]. However, patients may experience complications due to nerve damage during surgery. In recent years, recurrence rates after open inguinal hernia repair have decreased to between 2 and 5%, largely due to the introduction of mesh in hernia surgery [2–4]. Despite this improvement, chronic pain following open inguinal hernia repair remains an unresolved issue. It is estimated that 10% to 63% of patients experience some form of chronic pain post-surgery, with 1% to 18% suffering from moderate to severe chronic pain [5]. This pain is often linked to the damage or irritation of local nerves in the groin area [6, 7], where several key nerves are commonly encountered during the surgery, including the ilioinguinal, iliohypogastric, and genitofemoral nerves.

International guidelines currently recommend the routine identification of all three nerves during surgery [1, 8–11]. However, the evidence remains inconclusive regarding the protective effect of nerve identification [10, 12–15]. While it seems intuitive that identifying these nerves could prevent iatrogenic damage, some surgeons argue that the dissection process itself may cause harm [13]. Previous studies report identification rates of 73–82% for the ilioinguinal nerve [16, 17], 62–66% for the iliohypogastric nerve [16, 17], and 41% for the genitofemoral nerve [16]. Given these variable identification rates, it is important to understand the anatomical variations of these nerves to ensure accurate

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identification. Studies examining these variations may help clarify the upper limits of nerve identification observed in earlier research [16, 17].

This scoping review aimed to describe the anatomical variations and locations of the ilioinguinal-, iliohypogastric-, and genitofemoral nerves as reported in cadaver studies.

Methods

Protocol and registration

This scoping review was reported according to the PRISMA-ScR guideline [18]. A preregistered protocol can be found on OSF.io [19].

Eligibility criteria

We included studies that reported on adult cadavers dissected in the ventral inguinal region and described the ilioinguinal, iliohypogastric, or genitofemoral nerves. Cadavers that had previously undergone inguinal hernia surgery and studies focusing on anatomical areas unrelated to the open approach of inguinal hernia surgery were excluded. No language restrictions were enforced. Narrative reviews, systematic reviews, and conference abstracts were not included.

Information sources and search strategy

A comprehensive search was conducted across four databases to ensure a thorough identification of relevant studies. The searched databases included PubMed (1966 to present), Embase (1974 to present), Chinese National Knowledge Infrastructure (CNKI, 1999 to present), and Latin American and Caribbean Health Science Literature (LILACS, 1982 to present). Articles in languages other than English or Danish were translated using ChatGPT-4o (OpenAI. ChatGPT (GPT-4o). San Francisco, CA: OpenAI; 2023) [20]. For PubMed, the following search string was used: (inguinal OR groin OR"groin"[Mesh]) AND nerve AND (cadave* OR autopsy OR “anatomic* study” OR"Cadaver"[Mesh] OR"Autopsy"[Mesh] OR specimen* OR dissection*). This search string was adapted for CNKI and Embase. For the LILACS database, in addition to adapting the search string, we also translated each segment of the search string into Spanish. No search limits were applied during this literature search. All records, titles, and abstracts were independently screened by two reviewers. Any disagreements between reviewers during the screening process were resolved through discussion. Full-text screening and data extraction were carried out by the first author.

Data items and extraction

The data extraction form was tested and refined to ensure the inclusion of all relevant elements before full implementation. The extracted data included the author, year, country of origin, study aim, number of cadavers in the study, and the age of the cadavers. For more specific nerve-related data, we also collected descriptions of the ilioinguinal nerve location, the iliohypogastric nerve, the genitofemoral nerve, any outliers or variations of these nerves, and other pertinent information. Descriptions of nerve locations were reported in relation to common surgical landmarks. These landmarks were primarily determined by the included studies and included: the anterior superior iliac spine, the pubic symphysis and pubic tubercle, the spermatic cord, the transverse abdominal muscle, the internal oblique muscle, the external oblique abdominal muscle, and the inguinal ligament.

Synthesis of results

The descriptions of nerves were derived from the included literature, emphasizing the need to maintain relevance to the surgical field of open inguinal hernia repair. Both common and uncommon presentations of nerves were graphically charted with the help of an artist.

Results

Selection of sources of evidence

The search returned 2,186 titles and abstracts, from which 47 articles were selected for inclusion (Fig. 1) [21–67]. Six articles were identified as representing the same three studies [21, 22, 29, 30, 47, 51]. All six articles were utilized in this study, as they provided varied and valuable descriptions, resulting in a total of 44 included studies. More than 2,619 groins were dissected in these studies. Characteristics of the included studies are presented in Table 1. The common anatomy of the surgical site is depicted in Fig. 2.

The ilioinguinal nerve

The ilioinguinal nerve was referenced in 30 articles and identified in 73–100% of the groins (excluding the three included case reports [28, 57, 60]). However, this identification rate may be influenced by the fact that 16 articles

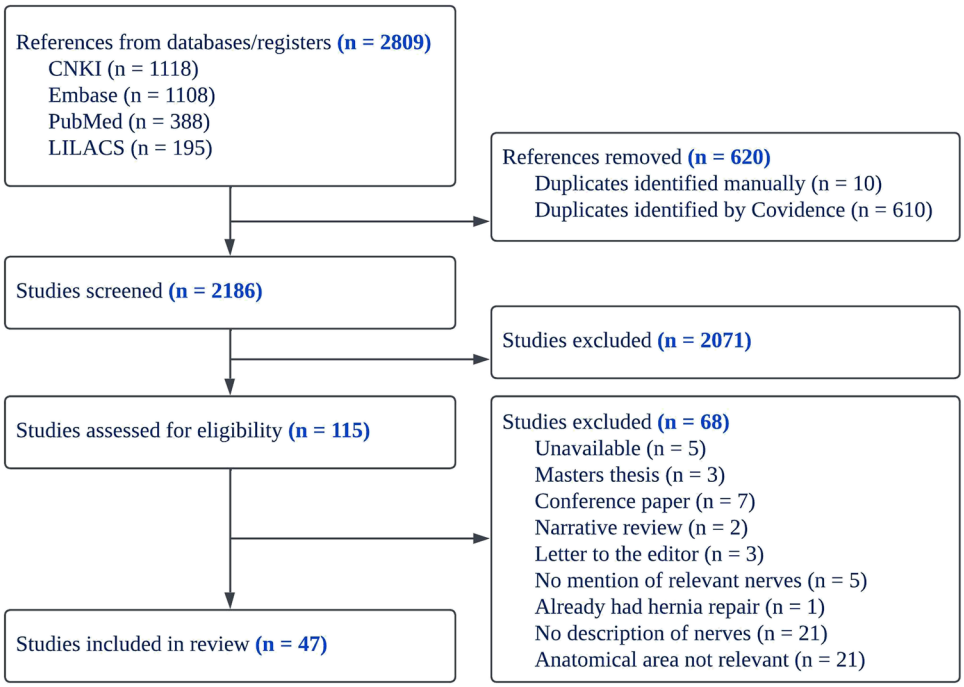

Fig. 1 PRISMA flowchart of included studies. n = number

mentioning the ilioinguinal nerve did not explicitly state an identification rate [22, 25, 26, 28, 29, 31, 33–35, 46, 52, 53, 55, 59, 63, 64].

Common presentation

Typically, the ilioinguinal nerve enters the surgical site laterally by piercing the internal oblique abdominal muscle. Several articles describe this emergence in relation to the anterior superior iliac spine [31, 40, 42, 43, 45, 50, 53, 56, 66]. Generally, it emerges 3–5 cm medial, 4 cm caudal to the anterior superior iliac spine [43], and 5 cm cranial to a horizontal line through the pubic tubercle [40, 50].

The course of the ilioinguinal nerve is generally described as running parallel to the inguinal ligament, between 1 and 3.5 cm cranial to this structure [29, 36, 47, 66]. It follows a relatively straight course along the ventral side of the spermatic cord, typically running anteromedially (50–100%), but is also described as running anterolaterally to the spermatic cord (10–50%). Along its path, the ilioinguinal nerve occasionally gives off branches to the genitofemoral nerve through the spermatic fascia.

The ilioinguinal nerve typically terminates after running along the spermatic cord through the superficial inguinal ring, 2 to 4 cm cranial to the symphysis and 3 cm lateral to the midline [31, 43, 50, 52, 53, 56, 59]. At this point, it innervates the skin of the inner thigh after dividing into two or three branches.

Variants

The following variations were identified: Two studies reported communication with the iliohypogastric nerve at the end of the ilioinguinal nerve's course in 5–30% of dissections (Fig. 3-A) [36, 45]. Multiple studies also indicated some degree of communication with the genitofemoral nerve (Fig. 3-B). Three studies noted a complete fusion of the ilioinguinal nerve and the genitofemoral nerve [22, 34, 38]. In these cases (10–44%), the fused nerves followed the typical path of the genitofemoral nerve. In one study, the ilioinguinal nerve exited the surgical field directly through the external oblique abdominal aponeurosis instead of penetrating the superficial inguinal ring (18%, Fig. 3-C) [25]. In these instances, the genitofemoral nerve appeared larger than usual, suggesting that some fibers of the ilioinguinal nerve had fused with it. In another study, the nerve was absent in up to 35% of the groins [22]. Additionally, the nerve may exit directly through the external oblique aponeurosis, lateral or cranial to the superficial inguinal ring, in 10–30% of the groins, as noted in six studies [21, 24, 25, 28, 36, 46].

The iliohypogastric nerve

Overall, 19 studies referenced the iliohypogastric nerve [23–25, 29, 34, 40, 42, 43, 46, 48–50, 52, 55–57, 60, 64, 65]. The iliohypogastric nerve was identified in 55–100% of the groins. Eleven studies that referenced the iliohypogastric nerve did not report any identification rate [23, 25, 29, 34,

Table 1 Characteristics of the included studies. n = number, IIN = Ilioinguinal Nerve, IHN = Iliohypogastric nerve, GFN = Genitofemoral nerve, ? = not explicitly stated, N/A = not applicable (nerve not mentioned)

Authors	Nationality	Groins (n)	Nerves identified (%)		
			IIN	IHN	GFN
Moosman 1977 [21]	US	424	?	N/A	N/A
Oelrich 1977 [22]	US	392	?	N/A	N/A
Wei 1982 [23]	China	50	N/A	?	?
Salama 1983 [24]	France	25	88	88	72
Mandelkow 1988 [25]	Germany	88	?	?	N/A
Ji 1991 [26]	China	24	?	N/A	N/A
van Mameren 1993 [27]	Netherlands	?	N/A	N/A	?
Yan 1995 [28]	China	2	100	100	N/A
Chen 1997 [29]	China	83	?	?	?
Chen 1997 [30]	China	87	?	?	?
Lou 1997 [31]	China	60	?	N/A	N/A
Rosen 1997 [32]	Israel	50	N/A	N/A	?
Wang 1998 [33]	China	100	?	N/A	N/A
Akita 1999 [34]	Japan	54	?	?	?
Yangwei 1999 [35]	China	30	87	N/A	?
Diop 2000 [36]	Senegal	40	93	N/A	N/A
Rosenberger 2000 [37]	Germany	106	N/A	N/A	?
Rab 2001 [38]	Austria, US	64	?	N/A	?
Yue Bing 2001 [39]	China	40	?	?	N/A
Avsar 2002 [40]	Turkiye	24	92	100	N/A
Liu 2002 [41]	Taiwan	116	N/A	N/A	100
Jacobs 2003 [42]	South Africa	33	100	55	N/A
Whiteside 2003 [43]	US	22	73	59	N/A
Ducic 2004 [44]	US	20	100	N/A	100
Peschaud 2005 [45]	France	33	?	?	N/A
Zhang 2005 [46]	China	50	?	?	42
Ndiaye 2007 [47]	Senegal	100	94	N/A	N/A
Wijsmuller 2007 [48]	Netherlands	18	78	100	100
Dong 2008 [49]	China	66	N/A	?	N/A
Okiemy 2008 [50]	Mali	74	91	86	N/A
Ndiaye 2010 [51]	Senegal	100	94	N/A	N/A
Xiao 2010 [52]	China	36	?	?	N/A
He 2011 [53]	China	60	?	N/A	N/A
Hebbard 2011 [54]	Australia	12	100	N/A	N/A
Jingzhi 2011 [55]	China	38	?	?	N/A
Klaassen 2011 [56]	Grenada	200	100	100	N/A
Liu 2012 [57]	China	2	N/A	100	100
Moazzam 2012 [58]	US	10	90	N/A	90
Wang 2012 [59]	China	76	?	N/A	N/A
Bachul 2013 [60]	Poland	2	50	100	100
Tagliafico 2014 [61]	Spain	5	?	?	?
Moreno-Egea 2018 [62]	Spain	80	N/A	N/A	100
Iwanaga 2019 [63]	US	24	N/A	N/A	100
Konschake 2020 [64]	Austria	4	?	?	75
Moreno-Egea 2021 [65]	Spain	100	?	99	?
Alshammari 2022 [66]	Sudan	154	100	N/A	N/A
O'Donnell 2023 [67]	US	16	?	N/A	N/A

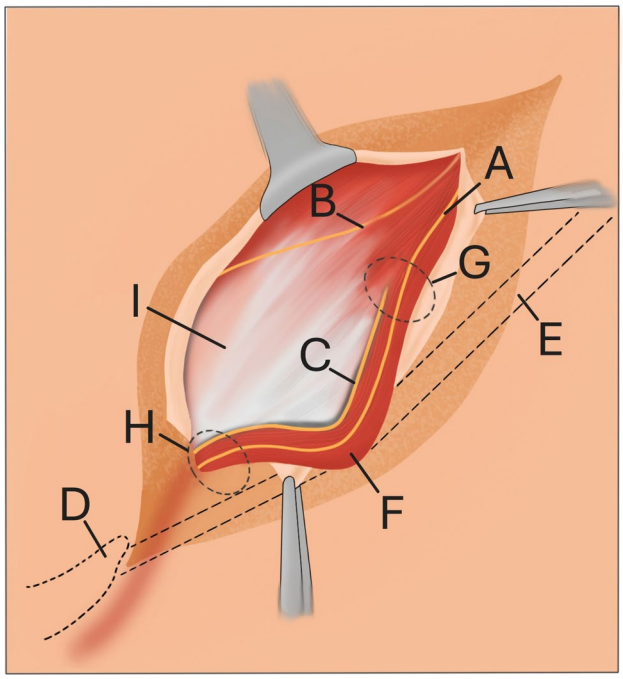

Fig. 2 Overview of the typical anatomy of the three nerves in the inguinal region: the ilioinguinal nerve (**A**), the iliohypogastric nerve (**B**), and the genitofemoral nerve (**C**). Also shown is the pubic tuberculum (**D**), to which the inguinal ligament (**E**) is attached. The spermatic cord (**F**) is mobilized laterally here, running from the deep inguinal ring (**G**) to the superficial inguinal ring (**H**). Dorsally located is the internal oblique abdominal muscle and aponeurosis (**I**)

43, 45, 46, 49, 52, 55, 64]. The iliohypogastric nerve was located between the internal oblique abdominal muscle and the external oblique abdominal muscle aponeurosis.

Common presentation

Generally, the nerve enters the surgical site laterally to the Lichtenstein incision. It pierces the internal oblique abdominal muscle 1–4 cm medially and 1–2 cm inferior to the anterior superior iliac spine [23, 25, 40, 43, 46, 49, 50, 52, 55,

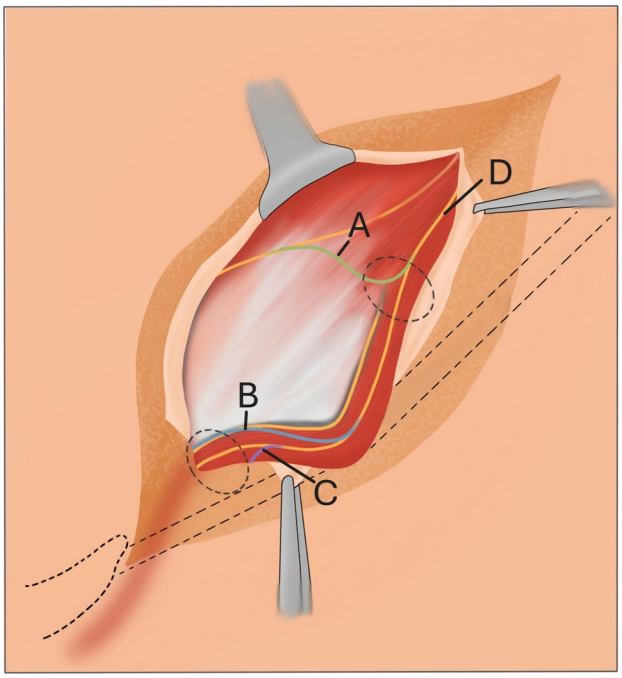

Fig. 3 The common variants of the ilioinguinal nerve identified in the literature. The ilioinguinal nerve may communicate with the iliohypogastric nerve (**A**). It may also communicate with, or completely fuse to, the genitofemoral nerve (**B**). Additionally, the ilioinguinal nerve may exit the spermatic cord directly through the external oblique abdominal muscle (**C**). The yellow line indicates the typical course of the nerve (**D**)

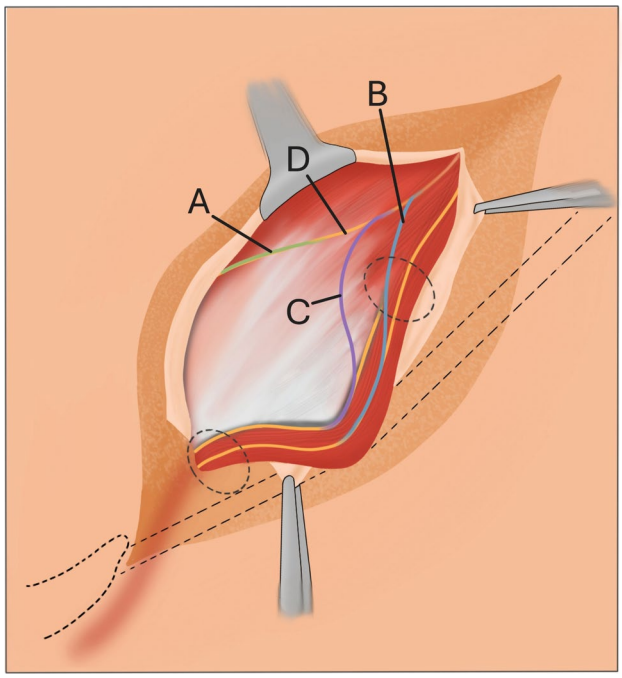

Fig. 4 The common variants of the iliohypogastric nerve as identified in the literature. The iliohypogastric nerve may enter the surgical field more medially, positioned cranial to the spermatic cord, resulting in a considerable intramuscular segment (**A**). It may also communicate with the ilioinguinal nerve (**B**) and the genitofemoral nerve (**C**). The yellow line represents the nerve's common course (**D**)

56]. One study also described the nerve as piercing the internal oblique abdominal muscle approximately 2–3 cm laterally to the deep inguinal ring. Seven studies used the anterior superior iliac spine as a reference point for its emergence.

The iliohypogastric nerve was generally described as running cranially and dorsally in the operative field, parallel to the inguinal ligament, and situated between the aponeurosis of the internal and external oblique abdominal muscles. It was typically found running caudally and medially toward its termination, embedded in the connective tissue of the external oblique abdominal muscle aponeurosis [52, 64].

The iliohypogastric nerve typically terminates about 4 cm cranial to the superficial inguinal ring, 1–4 cm from the midline, and approximately 5 cm cranial to the symphysis [25, 46, 48, 52, 53, 56]. At its termination, the nerve usually divides into several branches to innervate the lower part of the abdomen.

Variants

The following variations were identified: In one study, the iliohypogastric nerve pierced the internal oblique abdominal muscle at the midpoint of the Lichtenstein incision, cranial to the spermatic cord in 11% of the groins, resulting in a significant intramuscular segment (Fig. 4-A) [48]. In two additional studies, the iliohypogastric nerve fused with the ilioinguinal nerve prior to its termination in 20–36% of the groins (Fig. 4-B) [24, 45]. A single case report noted the fusion of the iliohypogastric nerve with the genitofemoral nerve (Fig. 4-C) [57]. Overall, only a few studies have addressed variations of the iliohypogastric nerve [24, 45, 48, 57].

The genitofemoral nerve

A total of 19 articles referenced the location of the genitofemoral nerve [23, 24, 27, 29, 32, 34, 35, 37, 38, 41, 44, 46, 48, 57, 58, 60, 62–64]. This nerve was identified in 42–100% of cases. Most studies that reported an identification rate identified the nerve 100% of the time.

Common presentation

Generally, the genital branch of the genitofemoral nerve enters the inguinal canal through the deep inguinal ring.

The course of the genitofemoral nerve usually runs on the dorsal side of the spermatic cord. It also generally runs within the spermatic fascia and is typically accompanied by the cremasteric vessels.

The genitofemoral nerve passes through the superficial inguinal ring in 85–100% of cases, moving toward the scrotum, where it innervates the skin.

Variants

The following variations were identified: Some studies described the genitofemoral nerve as emerging through the transversus abdominis and internal oblique abdominal muscles, lateral to the deep inguinal ring (19–44%, Fig. 5-A) [34, 37, 46, 62]. Two of these studies noted that in such cases, the nerve fuses with the ilioinguinal nerve in up to 80% of instances (Fig. 5-A) [34, 46]. These same studies also indicated the nerve emerging just below or through the inguinal ligament to enter the spermatic cord and inguinal canal (12–14%, Fig. 5-B) [34, 46]. Another study found that the genitofemoral nerve exhibited less variation proximally and greater variation distally [12]. This study also reported that the genitofemoral nerve accompanied its vessels in only 22% of cases. The nerve may also lie in different locations along its course through the spermatic cord, with some variants running along the lateral fibers (22–28%, Fig. 5-C) or the medial fibers (7–28%) of the spermatic cord [41, 48].

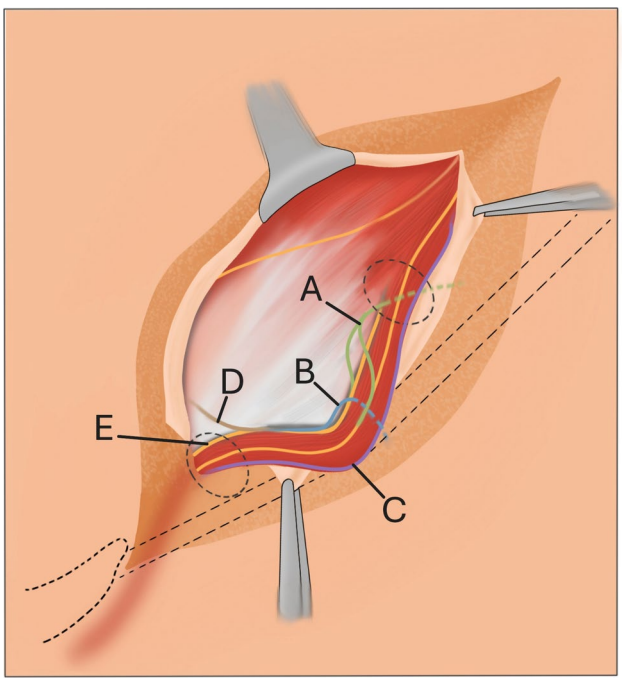

Fig. 5 The common variants of the genitofemoral nerve identified in the literature. The genitofemoral nerve may enter the spermatic cord lateral to the deep inguinal ring and may fuse with the ilioinguinal nerve (**A**). It may also enter the field caudal to the inguinal ligament or pass through it (**B**). The nerve may run laterally alongside the spermatic cord (**C**). Additionally, it may exit the spermatic cord directly through the external oblique aponeurosis (**D**). The yellow line represents the typical course of the nerve (**E**)

It was also noted to terminate directly through the external oblique aponeurosis before the superficial ring in 14–19% of cases (Fig. 5-D) [34, 44, 46].

Discussion

This study outlines the anatomical locations and variations of the ilioinguinal, iliohypogastric, and genitofemoral nerves in the ventral groin area. The ilioinguinal nerve is identified in 73–100% of groins, typically emerging near the anterior superior iliac spine. It then follows a caudo-medial trajectory, accompanying the spermatic cord toward the superficial inguinal ring. Notably, the ilioinguinal nerve can be absent in as many as one in three cases, likely because it fuses with the genitofemoral nerve and, on rare occasions, with the iliohypogastric nerve.

The iliohypogastric nerve was identified in 55–100% of the groins. The nerve typically entered the surgical field laterally through the internal oblique abdominal muscle. It then ran cranially to the spermatic cord, covered by connective tissue beneath the external oblique abdominal aponeurosis. In some cases, it may pierce the internal oblique abdominal muscle in a more medial position within the surgical area. The iliohypogastric nerve exhibited the least variation among the nerves examined.

The genitofemoral nerve was found in 42–100% of the dissected groins. It typically entered the inguinal canal through the deep inguinal ring, usually positioned within the cremasteric fascia and closely following the cremasteric vessels on the dorsal side of the spermatic cord. There is some variability in the anatomy of the genitofemoral nerve, particularly regarding its occasional fusion with the ilioinguinal nerve.

This study has several strengths. First, it involved an extensive literature search across diverse databases and geographic regions with no language restrictions, utilizing advancements in large language models such as ChatGPT for translations. This approach facilitated a better understanding across languages, particularly non-Latin scripts like Mandarin and Cyrillic. We also consider the scoping review design a significant advantage. By employing this method, we were able to systematically map the knowledge of anatomy in the inguinal region, enhancing its relevance for hernia surgeons. However, this study has certain limitations. While it is possible that some nuances may have been lost in translation, we believe this is unlikely, as ChatGPT has previously demonstrated reliability as a translation tool [68, 69]. Many studies did not report any identification rates for the nerves involved. Although a 100% identification rate might be implied in these studies, we could not assume this to determine how often the nerve was absent. Articles generally lacked unified language or

terminology to describe nerve locations, complicating our understanding of the intended meaning or measured distances. Additionally, many articles did not specify whether cadavers were selected based on nerve presence or if all nerves were examined in the included specimens, making it difficult to ascertain whether a nerve was genuinely absent or simply not identified. However, articles that traced nerves back to their spinal roots may have provided more certainty regarding the identification rate than those that did not.

This study aims to provide surgeons with a deeper understanding of their surgical field. Familiarity with the common and uncommon presentations of the nerves may help prevent unintended injuries, which can lead to chronic pain. Surgeons should pay special attention to the ilioinguinal and iliohypogastric nerves when making incisions, as well as the ilioinguinal and genitofemoral nerves when mobilizing the spermatic cord. While fixating the mesh, all three nerves can be at risk of entrapment, particularly the iliohypogastric nerve, which may be compromised by mesh placement. Consequently, it is advisable to secure the upper part of the mesh with absorbable sutures, only to the aponeurosis of the internal oblique abdominal muscle, but in the direction of the muscle fibers, to avoid permanent entrapment of this nerve in the suture [8, 70]. The variability in identification rates may reflect anatomical differences in the nerves themselves. Previous research indicates an upper limit for nerve identification, particularly around 80% for the ilioinguinal and iliohypogastric nerves, though this may be attributed to the fact that these nerves might only be present in no more than 80% of individuals [17]. Studies examining nerve variation during surgery on live patients might find different patterns, since two studies on live patients found that only 42–80% of patients had a nerve anatomy consistent with textbook examples [11, 71]. These found similar variants as described in the present study. One of these also found a common stem for the ilioinguinal and iliohypogastric nerves in 38% [71]. The fusion of the genitofemoral nerve and the ilioinguinal nerve in these studies was found to be rare [71].

International guidelines typically recommend a "nerve-recognizing" approach, where nerves are identified as they are encountered during inguinal hernia repair [8, 15]. The central idea is that a properly identified nerve is less likely to sustain injuries during surgery. However, it has also been argued that nerve identification could lead to unnecessary dissection, thereby increasing the trauma of the surgery [13]. Conversely, a proximal resection of "at risk" or damaged nerves is advised to alleviate postoperative chronic pain [1, 8, 12], and a nerve-identifying approach may more effectively highlight nerves in need of resection [11]. Nonetheless, this remains a topic of considerable debate among hernia surgeons, and extensive studies are necessary to further clarify the issue.

Conclusion

This scoping review highlights the anatomical locations and variations of the ilioinguinal, iliohypogastric, and genitofemoral nerves relevant to open inguinal hernia repair. Significant variability was observed, particularly for the ilioinguinal and genitofemoral nerves, which may fuse or even be absent in the surgical field. Surgeons should be cautious of these variations when making the initial incision, mobilizing the spermatic cord, and fixing the mesh.

Author contributions First author: conceptualization, data curation, formal analysis, writing – original draft. Second author: conceptualization, supervision and writing – review and editing. Third author: conceptualization, supervision and writing – review and editing.

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Data availability All data presented in this study are publicly available in the published articles.

Declarations

Informed consent This study is a scoping review based solely on previously published literature and does not involve human participants, patient data, or experimental interventions. Therefore, ethical approval and informed consent were not required.

Conflict of interests VBM, JJB and JR declare no conflicts of interest.

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