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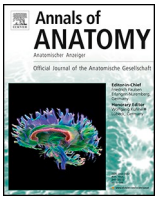

How to deal with the variability of peripheral nerve lesion patterns after inguinal herniotomy? A descriptive approach for a new terminology in clinical practice

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ABSTRACT

Background: Inguinal hernia is one of the most common visceral surgical conditions in industrialised countries. The aim of the present observational clinical study was to investigate the dermatome patterns after nerve injury following inguinal hernia surgery and to demonstrate the marked individual anatomical and topographical variability of peripheral nerves in the inguinal region.
Methods: 220 patients were followed up for one year after inguinal herniotomy. Surgical treatment was performed either with tension-free mesh techniques or open according (Lichtenstein).
Results: One year after inguinal herniotomy, 25 patients (11.4 %) reported postoperative symptoms. Of these, 15 patients showed evidence of a distinct nerve lesion. The results of the clinical neurological examination sometimes differed considerably from the subjective perceptions of the patients. In addition, a marked individual variability in the dermatomes of surgically lesioned nerves was found, with discrepancies to the classical and conventional dermatome data in textbooks.
Conclusions: This study has shown that it is hardly possible to assign a specific lesional inguinal dermatome to a specific nerve, as nerves show a large individual variability in their anatomical, topographical location and thus in their dermatome boundaries. Therefore, we propose a descriptive approach to the terminology of peripheral inguinal nerve lesions using common regional landmarks. This will avoid a potentially erroneous dermatome assignment to a certain nerve and facilitate the reproducibility of lesion descriptions between different observers, thus facilitating communication in clinical practice.

1. Introduction

Inguinal hernia is a common disease (Chung and O'Dwyer, 2007) and one of the most common visceral surgical conditions in industrialized countries (Wib and Ge, 2016). Possible complications of inguinal hernia surgery are injuries to cutaneous nerves (Stark et al., 1999) by cutting, stretching, electrodiathermy, crushing or entrapment in suture material and subsequent scarring (Al-Dabbagh, 2002). Intraoperative protection of these nerves is difficult because the anatomical, topographical and morphometric properties of nerves varies individually, as clinical studies have shown (Hirtler et al., 2018; Lange et al., 2009; Pandhare and Gaikwad, 2013). This individual variability of the topographical course and branching pattern of cutaneous nerves has rarely been described in anatomical textbooks (Palackic et al., 2023). However, these anatomical variants are important in clinical and surgical settings. The nerve identification during hernia repair is more difficult than in cadaver studies, and greatly depends on the preparedness, expertise and skills of the surgeon (Lorenz et al., 2017; Wang et al., 2016). The correct intraoperative identification of nerves helps to safeguard against their injury during the different steps of hernia repair (Al-Dabbagh, 2002).

In the present observational clinical study, the individual dermatome patterns following nerve lesions after inguinal hernia surgery were investigated in order to clarify the individual dermatome variability in

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the inguinal region.

2. Methods

From June 2014 to May 2017, 334 patients had underwent herniotomy in the HELIOS clinic of Sangerhausen, Germany. Surgical treatment was performed using tension-free mesh techniques or open according (Lichtenstein). The respective surgical procedure was determined by the surgeon on the basis of an individual clinical indication. The study presented here had no influence on this surgical decision. The patients received best surgical care. 220 of the 334 patients could be followed up for one year in a clinical observational study. Previous studies suggest that patients who were asymptomatic 3 months postoperatively are unlikely to develop sensory manifestations or neuralgic pain later in life (Al-Dabbagh, 2002). The remaining 114 patients had not completed one year follow-up (n=106), could no longer be reached (n=3) or were too ill to participate in this study (n=5).

The included patients had to fill a questionnaire about postoperative complaints (modified according to Melzack (Melzack, 1975) and Galer / Jensen (Galer and Jensen, 1997) and underwent a clinical investigation one year after herniotomy.

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3. Results

One year after surgery, 25 of 220 patients (11.4 %) had reported postoperative complaints in the questionnaire. 19 of these 25 patients could be retrieved for clinical investigation. In contrast to their reports to the questionnaire, 4 of the 19 patients were found to be asymptomatic on clinical investigation. Of the remaining 15 patients, each showed signs of a clear peripheral nerve lesion. Table 1 shows the sensory disturbances that occurred, several sensory disturbances can occur per patient. Dermatomes were located in the “peri-inguinal” region in 14 instances, while a lateral femoral cutaneous nerve lesion was detected once. Eight of the dermatomes among the inguinal nerve lesions showed margins around the inguinal ligament as illustrated in Fig. 1A. The further 7 dermatomes either extended down to the scrotum or showed margins extending more above and/or below the inguinal ligament (Fig. 1B).

4. Discussion

The dermatome is a fundamental concept in human anatomy and of major importance in clinical practice (Lee et al., 2008). A dermatome is typically defined as the cutaneous area supplied by one spinal nerve, through both rami (Standring et al., 2005). The study presented here demonstrates the individual variability of the dermatome distribution of peripheral cutaneous nerves in the inguinal region. The dermatome variability is due to the individual anatomical, topographical and morphometric properties of peripheral nerves, as previous studies have shown (Hirtler et al., 2018; Khadanovich et al., 2023). This individual variability of the topographical course and branching pattern of peripheral cutaneous nerves is important in clinical and surgical settings. However, this individual variability is hardly reflected in conventional

Table 1
Postoperative sensory disturbance after inguinal hernia surgery.

		Sensation		
		Touch	Temperature	Pain
Quality	Hypersensitive	2	5	3
	Less sensitive	12	8	10
	Insensitive	1	2	2

Investigation technique: touch: large head cotton swab; temperature: 2 stainless steel rollers (23 °C, 40°C); pain: wooden toothpick from Gastro®.

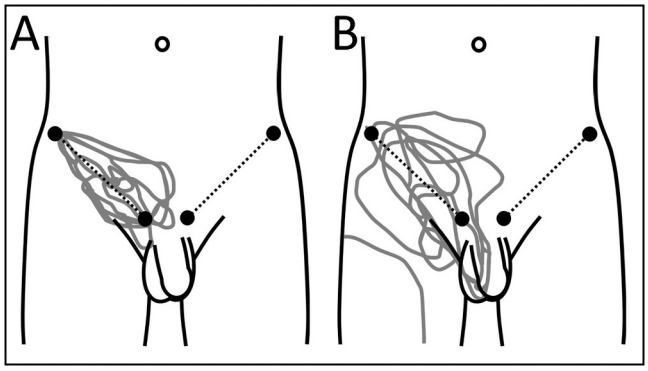

Fig. 1. A and B Variability of lesional patterns of peripheral nerves after inguinal herniotomy in 15 subjects. Dermatomes were identified by perception change to painful stimuli using a commercially available toothpick. Furthermore, the spina iliaca anterior superior and the left and right lateral ends of the christa pubica were used as landmarks. Finally, photodocumented margins of the examined areas were represented graphically. All dermatomes are shown superimposed on the right side. For this purpose, leftsided dermatomes were mirrored to the right. A: Eight of the dermatomes showed margins relatively closely around the inguinal ligament. B: Margins of the other 7 dermatomes extended more above and/or below the inguinal ligament or extended down to the scrotum, or corresponded to a cutaneus femoris lateralis nerve lesion.

textbooks (Palackic et al., 2023). In addition, the dermatome maps available in textbooks differ considerably from each other and may even be incorrect (Lee et al., 2008). Lee and colleagues (2008) provide a unique overview of the various dermatome maps in the textbooks and present an evidence-based dermatome map (Lee et al., 2008). Clinical studies have shown that the course of some nerves corresponds to less than half of the descriptions in anatomical textbooks (Al-Dabbagh, 2002). Furthermore, in the original literature, nerve courses (Feigl et al., 2020) and dermatomes (Iwanaga et al., 2022) exist, that are not represented in any textbook.

The embryological background to the development of such high variability has been only scarcely investigated (Cetkin et al., 2019; Uysal et al., 2003). From the very beginning, the fiber exchange starts with the formation of trunks, cords and finally the nerves, resulting in a high variability (Benes et al., 2021a, 2021b, 2022). Consequently, the distal skin innervation is mainly allocated to specific segments of the spinal cord. The main nerves of the limbs regularly have one or two main segments of the spinal cord supplying the nerve. Consequently, segmental nerve fibers can take different “nerve paths” to reach their dermatome or peripheral skin area (Palackic et al., 2023). Almost all skin areas are innervated by two or more spinal roots (Lee et al., 2008). Furthermore, there are intrathecal intersegmental anastomoses between dorsal spinal rootlets, enabling sensory neurones with a ganglion cell at one dorsal root ganglion to enter the spinal cord at a different level (Moriishi et al., 1989).

The presence of sensory variability of peripheral cutaneous nerves has e.g. already been described for arms (Akita et al., 2002), hands (Bozkurt et al., 2002; Hirtler et al., 2018; Keplinger et al., 2018), fingers (Démoulin et al., 2021; Windisch, 2006) or face (Iwanaga et al., 2022). Previous studies have also demonstrated a great anatomical variability in the inguinal region (Anson et al., 1960; Frassanito et al., 2018; Moosman and Oelrich, 1977; Salama et al., 1983), particularly in the operative repair of inguinal hernias (Al-Dabbagh, 2002; Rosenberger et al., 2000). The retroperitoneal and abdominal wall course of these nerves has been also described in several previous papers (Salama et al., 1983; Starling et al., 1987; Starling and Harms, 1989; Stulz and Pfeiffer, 1982).

In the present study, it was shown that the results of the clinical neurological investigation differed in part considerably from the subjective findings of the patients in the one year follow up questionnaire

after the surgical procedure. Postoperative symptomatic patients proved to show a distinct lesion of a peripheral peri-inguinal nerve in 14 instances and of the lateral femoral cutaneous nerve in one case. When the lateral scrotum is involved, the genital branch of the genitofemoral nerve is presumably lesioned. Such scrotal involvement was identified in 4 cases. Exact assignment of the dermatome was also possible in the case of the N. cutaneous femoris lateralis. In the remaining 10 cases with peri-inguinal nerve lesions, exact assignment of either ilioinguinal, iliohypogastric or genitofemoral nerve was arbitrary due to the variability of boundary lines (Fig. 1 A and B).

The impossibility to assign a given lesional inguinal dermatome to a certain nerve may be due to several reasons. Nerves usually display a large variability in their boundary lines in general (Hirtler et al., 2018). For inguinal nerves, it has been stated that "variations in the distribution pattern of inguinal nerves exist on several levels in the course of each nerve. Because of this logarithmic increase in different types of distribution patterns, a classic distribution pattern and its incidence cannot be determined" (Hernia Surge Group, 2018). Further, interconnections between all inguinal nerves have been described. Some studies note the absence of cutaneous innervation by the genital branch (GB) of the genitofemoral nerve (Karateke et al., 2014). One study found the GB in all dissections. However, in 18 of 64 of those branch dissections (28 %), no sensory fibers for cutaneous innervation could be identified (Karateke et al., 2014). In case of the scrotal involvement that is usually assigned to the GB, it has to be taken in mind that in a considerable part of persons, the GB does not contain sensory nerve fibers at all.

If it is arbitrary when not impossible to assign the lesional dermatome to a certain nerve in the inguinal region: How should then a lesional dermatome be reported? Already in 1970, Kirk and Denny-Brown suggested rethinking the artificial concept of a dermatome as an independent anatomical area (Kirk and Denny-Brown, 1970). We propose a descriptive approach using common regional landmarks: (1) purely above the inguinal ligament, (2) mainly over the inguinal ligament, (3) extending below the inguinal ligament adjacent to the scrotum, (4) extending below the inguinal ligament distant from the scrotum and (5) extending into the scrotum (Fig. 2). Such areas can be described as a single area or a combination of several areas. Thereby, a possibly erroneous attribution to a certain nerve is avoided and the reproducibility of lesional descriptions would be facilitated between different observers.

5. Conclusion

Understanding the exact anatomical topographical localization of peripheral nerves is of great relevance to clinical practice in many medical disciplines. In the different fields of surgery for operative procedures and transplantation medicine, in neurology for the assignment of a peripheral or central nervous lesion site, in medicine e.g. for referred pain from visceral disease or in anesthesia for regional anesthesia and peripheral nerve blocks (Davidovich and Nascimento, 2014; Hirtler et al., 2018; Iwanaga et al., 2022; Keplinger et al., 2018; Khadanovich et al., 2023; Lee et al., 2008; Palackic et al., 2023). Given the clinical importance of dermatomes, it is surprising that dermatome maps in standard anatomical and medical reference texts show a large variability (Lee et al., 2008). Fig. 3 shows a summary of the sensory innervation of the skin in the groin region by the dorsal spinal nerve roots and the peripheral cutaneous nerves (Fig. 3).

This study has shown that it is frequently hardly possible to assign a specific lesional inguinal dermatome to a certain nerve, as nerves display a large individual variability in their anatomical location and thus in their dermatome boundaries. Therefore, we propose a descriptive approach to the terminology of peripheral nerve lesions using common regional landmarks. This will avoid a potentially erroneous dermatome assignment to a certain nerve and facilitate the reproducibility of lesion descriptions between different observers, thus facilitating communication in clinical practice.

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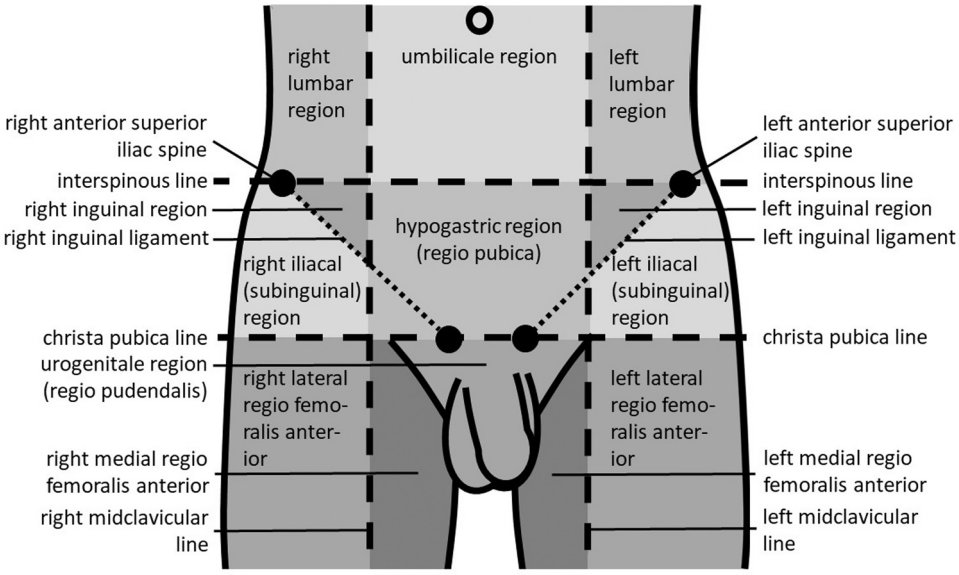

Fig. 2. A regional map of skin segments distributed over the ventral part the body extending from above the navel down to the upper third of the thigh separated by horizontal and vertical lines. Horizontal lines: interspinous line between either spina iliaca anterior superior, crista pubica line as a horizontal extension of the christa pubica. Vertical lines: Left and right midclavicular lines. Further, lines along the left and right inguinal ligaments were added as oblique lines. The resulting skin segments surrounded by these lines are illustrated in the figure.

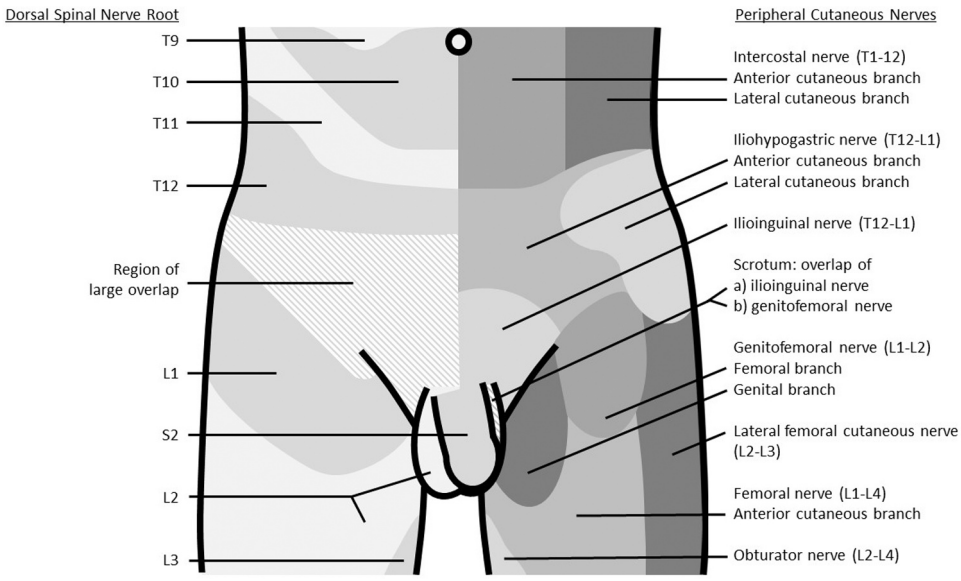

Fig. 3. Summary of sensory skin innervation in the groin region by dorsal spinal nerve roots and peripheral cutaneous nerves. Note: Adjacent dermatomes are not sharply and strictly demarcated. They overlap with a large and individual variability. This dermatome overlap is slightly less in the midline region. Section of the spinal cord: T - thoracic, L - lumbar, S - sacral.
(modified from Lee et al., 2008; Berlit and Stöhr, 2020; Rigoard, 2020; Trescot, 2016).

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Ethical statement

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CRediT authorship contribution statement

Andreas Posa: Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Conceptualization. **Christiane Barthel:** Writing – review & editing, Investigation, Formal analysis, Data curation. **Malte Kornhuber:** Writing – review & editing, Supervision, Project administration, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

None. On behalf of all authors, the corresponding author states that there is no conflict of interest.

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