Editor's key points

- Both the genitofemoral nerve (GFN) and lateral femoral cutaneous nerve (LFCN) may be adversely affected by lumbar sympathetic block (LSB).
- Thiel's cadavers were used to assess the anatomical distribution of these nerves relative to the lumbar sympathetic plexus.
- The anatomy of the GFN varied much more from that reported in the published literature than that of the LFCN.
- Complications affecting the GFN may be more likely with LSB carried out at the L3/4 and L4/5 levels than L2/3.

Background. Interference with the function of the genitofemoral nerve (GFN) and lateral femoral cutaneous nerve (LFCN) represents a significant complication of lumbar sympathetic blocks (LSBs). The nerve topography of the lumbar sympathetic trunk (LST) was investigated to find a possible morphological reason for this.

Methods. A total of 118 cadavers embalmed by Thiel's method were investigated. The nerves were dissected from their innervation area to their paravertebral origins. Distances of the GFN and the LFCN to the LST were measured at levels L2/3, L3/4, and L4/5, which are the most common levels for LSB.

Results. Two hundred and thirteen sides were assessable for the GFN and 151 sides for the LFCN. In 186 cases, the whole GFN (in 20 cases, its femoral branch only) approached the medial margin of the psoas major (PM) and passed the LST laterally at the level of L3/4 and a distance of 0–28 mm (mean distance 8.5 mm; SD 6.7 mm) and ran dorsally between the PM and the vertebral body of L3, reaching the intervertebral foramen L2/3. In three cases, the GFN fused with the LFCN. In 55 cases, the GFN–LST distance was 0–13 mm at L4/5 and in 19 cases, 9–19 mm at L2/3. The LFCN approached the lateral margin of the PM and entered the intervertebral foramen at L2/3 in 141 cases.

Conclusions. There is a higher risk of LSB affecting the GFN at L3/4 or L4/5 during neurolysis of the LST due to its topography. The LFCN rarely shows a strong relation to the LST and only when fused with the GFN.

Keywords: anaesthetic techniques; regional; anatomy; lumbosacral plexus; sympathetic nervous system

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Interference with the function of the genitofemoral nerve (GFN) during lumbar sympathetic block (LSB) or neurolysis of the lumbar sympathetic trunk (LST) is one of the reported complications. The incidence is reported to be between 5% and 40% depending on the level at which the block or neurolysis is performed. The use of alcohol might particularly affect the GFN permanently, resulting in a decreased sensation at the anteromedial subinguinal region and even neuralgia may result. The reason for this was assumed to be due to spread of the injectate to the GFN in the area of the nerve's course through the psoas major (PM), which would be in accordance with the described topography of the GFN. According to textbooks on topographic anatomy, the nerve arises from the spinal nerve of either L1 or L2, passing the PM with a laterally directed course to arrive at the ventral surface. At this area, the nerve is still covered by the psoas fascia and perforates this dense connective tissue layer to split into its femoral and genital branches. The femoral branch approaches the common or external iliac artery on its lateral side running parallel to the artery and the vein, passing the vascular space known as the ‘lacuna vasorum’ and innervating the proximal skin of the femoral triangle, or subinguinal region, respectively. The genital branch approaches the deep inguinal ring to pass the inguinal canal and to innervate the labia majora or the scrotum and the cremaster muscle. A second nerve might also cause problems: the lateral femoral cutaneous nerve (LFCN). This nerve arises from the
and runs between the superficial and deep portion of the PM, arriving at its lateral border. It then crosses the iliac muscle ventrally and approaches the anterior superior iliac spine running underneath the inguinal ligament most laterally in the muscular space, also known as the ‘lacuna musculorum’, to reach the anterior and the lateral parts of the thigh and its innervation area.3

However, although the injectate remains in the area of the LSB close to the medial margin of the PM, both the GFN and the LFCN might be affected in some cases.4 5 Moreover, if lateral spread along the ventral surface of the PM or a dorsal distribution along the vertebral body to the intervertebral foramen can be excluded, there is no plausible explanation as to why these nerves are affected. The only obvious remaining possibility is that the GFN might be located closer to the LST medial to the PM’s margin than initially assumed. An indication is given by Lanz,6 who mentions that the GFN arrives at this region in very rare cases. Unfortunately, Lanz6 does not provide any further information. Furthermore, rare cases cannot explain the already mentioned incidence rate of 40% at L4.1

We, therefore, investigated the course of the GFN and the LFCN on cadaveric specimens to search for possible explanations concerning this problem.

Methods
In total, 118 cadavers (44 females and 74 males; Table 1) embalmed by Thiel’s method were investigated.7 The cadavers were examined during two dissection courses in the year 2011/2012 and 2012/2013. All the cadavers had been donated to the Institute of Anatomy according to the Institute’s donation programme under the approval of the Medical University of Graz. Each donation includes a written consent of the donator that their cadaver can be used for research or teaching purposes.

The cadavers were investigated during the dissection course for advanced medical students (2nd to 5th year). The GFN and the LFCN of the lumbar plexus were marked with different coloured stitches in their peripheral area. This method of dissection was chosen to precisely determine the nerves according to their peripheral innervation area. Only nerves that were clearly determinable were included in the investigation. Assessments of nerves were performed by two experienced anatomists. The nerves were traced from their peripheral area of innervation to their exits at the intervertebral foramen. The topography of the two nerves to the PM, entrance points, and the way through the PM were documented and dissected. During the course of the dissection, the entire retroperitoneal dissection step was performed when the retroperitoneal space was still untouched. Specimens in which nerves could not be determined for sure or the retroperitoneal region had already been dissected were excluded directly because a precise allocation of nerves or a regular topography of the LST and therefore a precise distance measurement could not be assured anymore. High interest was given to nerves passing the levels of L2/3, L3/4, and L4/5 representing the regularly used levels in performing LSBs. The sympathetic trunk was identified and dissected without changing its topography by removing the psoas fascia. At the aforementioned levels, the distance of the LST from the lumbar plexus nerves was measured with special regard to the GFN and the LFCN. We used a calliper for distance measurements.

Data analysis
All data were analysed by descriptive statistics to evaluate the mean and SD of the mean by using SPSS 14.0 for windows statistical package (SPSS Inc., Chicago, IL, USA). Owing to the distance measurements with the use of a calliper, a margin of error was determined at 0.5 mm. Distances are provided in

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<th>Ranges of age (yr)</th>
<th>Height (cm)</th>
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periods and mean distances (MDs). Standard deviations of the mean (SD) are provided with one decimal, whereby the second decimal has been rounded up or down with regard to the margin of error. All MDs were provided with a confidence interval to a confidence level of 0.95.

Results

During dissection, we had to exclude several sides because of the impossibility of determination of allocation or already retroperitoneal dissection of the important structures. As a consequence, we could evaluate only 213 out of the 236 sides concerning the GFN, and 151 out of the 236 sides concerning the LFCN.

GFN topography: In only 27 out of the 213 cases did the nerve provide its topography according to the known literature (Fig. 1). In 186 of the 213 cases, the nerve ran along the ventral face of the PM, approaching its medial margin to pass medially and run dorsal to the PM in close relation to the LST. In 20 of these 186 cases, the femoral branch of the GFN showed this topography, whereas the genital branch perforated the PM more laterally. In 112 of the 186 cases, the GFN reached the L3/4 level and passed the tendinous arch of the PM at the L3 level medially, to reach the intervertebral foramen of L2/3 or L1/2 (Fig. 2A and B). In 55 of these 186 cases, the GFN already reached the medial margin of the PM at L4/5, ran cranially to L3/4 to pass the PM medially and ran dorsally to fuse with the second spinal nerve (Fig. 3). In 19 cases (out of 186), the GFN approached the medial margin of the PM at L3/4 and ran cranially to L2/3 to pass the PM medially and dorsally, in order to reach the spinal nerve L1 (Fig. 4). In three cases, the GFN fused with the LFCN on the ventral surface of the PM to approach its medial margin at L2/3 and pass medially and dorsally to fuse with the second lumbar spinal nerve.

Distance GFN–LST: at the L2/3 (Table 1 and Fig. 5; 19 cases) level, the distance was 9–19 mm (MD 8.8 mm; SD 5.2 mm), at L3/4 (Table 1, 3; 186 cases) 0–28 mm (MD 8.5 mm; SD 6.7 mm), and at level L4/5 (Table 1, 4; 55 cases) 0–30 mm (MD 6.1 mm; SD 3.6 mm). Most of the distances measured at L3/4 were below 5 mm (Fig. 5).

LFCN topography: the nerve provided topography in accordance with literature in 141 of 151 cases (Figs 1–3). In seven out of the 151 cases, the nerve ran on the ventral face of the PM and pierced the muscle at L3/4, reaching the spinal nerve roots at L2 or L3 (Fig. 4). Only in the aforementioned three cases did the LFCN fuse with the GFN.

Discussion

Adverse effects with damage to the GFN and LFCN are significant complications that might arise during LSB. Increased discomfort may occur particularly when using alcohol for neurolysis of the LST. Currently, as a consequence of the lack of randomized controlled trial, the neurolysis of the lumbar sympathetic chain is recommended only in the case of failure of other options for treatment of critical leg ischaemia and hyperhidrosis and in patients with complex regional pain syndrome (CRPS) or peripheral nerve injury of the lower limb after positive diagnostic block with local anaesthetic. There are no recently published surveys on how often LSB is performed currently in pain clinics that use interventional techniques. Some data are available from case reports: in two German pain clinics, 2000 lumbar neurolytic blocks were performed in patients with leg pain (most suffering from peripheral limb disease) in the 16 yr up to 2001; two decades later, the number of LSB for neuropathic pain was reduced to 5–10 yr. A Korean group reported on 82 patients with LSB within 3 yr for the treatment of plantar hyperhidrosis and another group included 82 patients within 6 months mostly suffering from CRPS, whereas Hatangdi and Boas list 508 included patients without precise information about the period. Despite the decreased frequency during the last decade, LSB remains an important part of interventional pain medicine, particularly in Europe and Asia.

Indeed, Hatangdi and Boas mention groin dysaesthesia with an occurrence of 5% when using a one-needle and 7% when using a two-needle technique. This dysaesthesia strongly indicates an adverse effect on the GFN due to the known innervation area. In accordance with Hantangdi and Boas, Ohno and Oshita mention GFN neuritis in 5–10% after neurolytic LSB. These authors assumed that the injectate has to spread into the PM after the needle path backwards to affect the GFN in its course in the PM. Another potential route of spread would have been dorsally along the vertebral body to
reach the nerve in the intervertebral foramen or a lateral spread along the ventral face of the PM affecting the nerve in its exit area.

Our paper clearly indicates that the most prevailing topography of the GFN seems to divert from that which is mentioned in the textbooks. The regularly known course, mentioned in frequently used and very specialized textbooks, is documented in a low frequency in this investigation, whereas the GFN showed a very high incidence being located at the medial margin of the PM with a very close distance to the LST at L3/4 and descending occurrences at L4/5 and L2/3. What is more, even focused anatomical investigations of the lumbar plexus nerves do not provide data for this particular anatomical region or mention this special topography of the GFN. This lack of information is of great importance and is provided by the current paper. As the GFN gets very close to the LST most
frequently at level L3/4, less frequently at L4/5 and least frequently at L2/3, there is a very high risk at L3/4 of affecting the GFN at a latter level during LSB. The close relation of the GFN not only to the LST but also to the medial border of the psoas muscle might cause a problem. As a consequence, the injected liquid does not need to spread along the needle path into the PM, dorsally to the intervertebral foramen or to the exit point at the ventral face of the PM, but can reach the GFN because the nerve showed a distance to the LST of smaller than 5 mm in most of these cases. This explains the observation of Sayson and colleagues\(^1\) that the incidence of an adverse effect on the GFN is 40% at level L4, whereas they had no GFN block at L2. At level L2, the GFN is not located close to the LST but distanced more dorsally. Therefore, the risk of the GFN being reached is much lower because of the aforementioned topography. As LSB is performed under either fluoroscopic or CT guidance, the needle can be placed in the area of the presumed location of the LST.\(^{21,22}\) With an ideal and predetermined spread, the LST was mainly reached at three different levels of the lumbar spine. As a consequence, a discussion concerning the preferable injection level started. Feigl and colleagues\(^23\) state that the LST has the most constant topography to the medial margin of the PM at the L2/3 and L3/4 levels, which results in the use of these two levels as the most effective LSB. Umeda and colleagues\(^24\) likewise determined the level L2/3 as the preferable injection site. This is supported by this manuscript because the L2/3 level shows the lowest risk of having the GFN in close relation to the LST, whereas the GFN is almost directly positioned lateral to the LST at L3/4 and is quite often close to the LST at L4/5. As a consequence, the risk of the GFN being affected still remains because the GFN has not yet been identified in MRI or CT images. This might change because Feigl and colleagues\(^25\) clearly state that the LST can be identified in MRI and in CT images. What is valid for the LST might also be applicable to the GFN. However, this must be investigated further in upcoming investigations.

In case of an affection of the LFCN, Racz and Stanton-Hicks\(^4\) assumed that only injection of large volumes in combination with a lateral distribution can cause this complication. A recently published paper by Pennekamp and colleagues\(^5\) describes the contrary. After a low-volume injection of 2 ml of 96% ethanol, the patient suffered long-lasting irritation of the LFCN due to a lateral distribution on the ventral surface of the PM. According to the description of the pathways of the LFCN found in anatomical textbooks, this should not be possible because the LFCN passes the PM to arrive at the lateral border. However, the current investigation shows that the LFCN can be fused with the GFN in some rare cases and arrives at the ventral surface of the psoas muscle. Consequently, this explains both cases of adverse effects described by Pennekamp and colleagues\(^5\) even when a low volume is injected.

Additionally, our investigation clearly explains the higher incidence rate of GFN block during LSB at the L3/4 and L4/5 levels compared with L2/3. Furthermore, it strongly supports the recommendation of level L2/3 as the most frequently used level of LSB.
Authors’ contributions

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Declaration of interest
None declared.

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Fig 5 Boxplots of the distance measurements GFN–LST at levels L2/3, L3/4, and L4/5.
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