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REVIEW

Unusual causes for meralgia paresthetica: systematic review of the literature and single center experience

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Abstract

Meralgia paresthetica is often idiopathic, but sometimes symptoms may be caused by traumatic injury to the lateral femoral cutaneous nerve (LFCN) or compression of this nerve by a mass lesion. In this article the literature is reviewed on unusual causes for meralgia paresthetica, including different types of traumatic injury and compression of the LFCN by mass lesions. In addition, the experience from our center with the surgical treatment of unusual causes of meralgia paresthetica is presented. A PubMed search was performed on unusual causes for meralgia paresthetica. Specific attention was paid to factors that may have predisposed to LFCN injury and clues that may have pointed at a mass lesion. Moreover, our own database on all surgically treated cases of meralgia paresthetica between April 2014 and September 2022 was reviewed to identify unusual causes for meralgia paresthetica. A total of 66 articles was identified that reported results on unusual causes for meralgia paresthetica: 37 on traumatic injuries of the LFCN and 29 on compression of the LFCN by mass lesions. Most frequent cause of traumatic injury in the literature was iatrogenic, including different procedures around the anterior superior iliac spine, intra-abdominal procedures and positioning for surgery. In our own surgical database of 187 cases, there were 14 cases of traumatic LFCN injury and 4 cases in which symptoms were related to a mass lesion. It is important to consider traumatic causes or compression by a mass lesion in patients that present with meralgia paresthetica.

Keywords Trauma · Traumatic · Mass lesion · Schwannoma · Lipoma · Endometriosis

Introduction

Meralgia paresthetica is a mononeuropathy of the lateral femoral cutaneous nerve (LFCN). The LFCN is a pure sensory nerve that is formed by the roots L2 and L3 (Fig. 1). In the retroperitoneal space the nerve runs posterior to the psoas muscle in a caudolateral direction and more distally runs on top of the iliac muscle. It frequently exits the pelvis just medial to the anterior superior iliac spine (ASIS) under the inguinal ligament, but anatomical variations have been described, where the nerve runs lateral to the ASIS or has a more medial course [1]. In thigh the LFCN runs on top of the sartorius muscle, and distally it pierces the fascia lata and splits into multiple branches that innervate the skin. The LFCN is a pure sensory nerve. Patients with meralgia paresthetica often experience a tingling or burning sensation in the anterolateral part of the thigh. Pressure on the skin may sometimes exacerbate symptoms (dysesthesia).

The term meralgia paresthetica in the literature is often used for idiopathic cases, in which there is no clear cause for the symptoms. It is questionable however if the term 'idiopathic' can be applied in meralgia paresthetica, because intra-operatively often a clear site of entrapment is found at the site where the LFCN pierces the inguinal ligament. Moreover, meralgia paresthetica has been reported to be associated with overweight, and sometimes symptoms have been reported to occur after strenuous exercise [2], accidents (seat-belt injury due to a car accident) [3] or positioning for surgery such as prone positioning for spine surgery [4]. In addition, meralgia paresthetica may be the result of iatrogenic injury to the LFCN, caused by surgical procedures around the anterior superior iliac spine (ASIS), including the anterior approach for placement of hip prosthesis [5],

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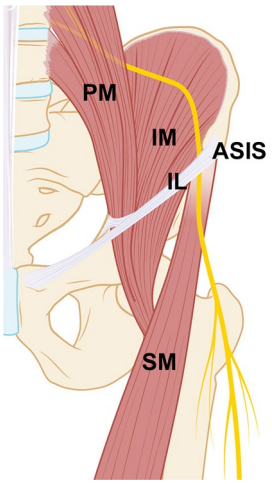

Fig. 1 Anatomical drawing of the course of the LFCN: The nerve originates from the nerve roots L2 and L3 runs posterior to the psoas muscle (PM) in the retroperitoneal space on top of the iliac muscle (IM) and exits the pelvis through the inguinal ligament (IL), just medial to the anterior superior iliac spine (ASIS), and in the upper leg runs on top of the sartorius muscles (SM). This anatomical drawing shows the type B variant, which is most frequently encountered in patients with idiopathic meralgia paresthetica [78]

the ilioinguinal approach for acetabular fractures [6], the harvest of iliac bone graft [7, 8] and inguinal hernia repair [9]. Moreover, several case reports have been published on unusual causes of traumatic injury and compression of the LFCN by mass lesions.

The goal of this study was to review the literature on unusual causes of meralgia paresthetica and investigate our own experience with the treatment of these cases from our surgical database.

Material and methods

Literature review

On September 7, 2022 a Pubmed search was performed using the search strategy provided in Appendix. Abstract was reviewed for unusual causes of meralgia paresthetica including traumatic injury and potential compression by a mass lesion. All selected articles were read by the first (GdR) and senior author (AK). Only articles in which the mechanism of injury or cause for compression for the cases was described were used for this review, and case series without description of the individual cases were excluded. In addition, case reports that were published in Journals that could not be accessed were excluded (a PRISMA Flow Diagram is provided in Appendix). The included cases were screened for factors that might have predisposed to the LFCN injury. Remarks were made on potential pathophysiologic mechanisms, onset of symptoms, additional work-up that was performed, intra-operative findings and anatomic variation in the course of the LFCN. For the latter we used the classification introduced by Aszmann et al. [1] that describes the course of the LFCN in relation to the ASIS in a coronal plane: type A: LFCN course lateral to the ASIS, type B and C: just medial to the ASIS (type C: between a split tendon of the sartorius muscle) type D: 1–3 cm medial to the ASIS and type E >3cm medial to the ASIS. For mass lesions, all potential clues that might have pointed to an unusual cause were noted.

Review of surgical series

Before start of the study, approval was obtained from the Medical Ethical Committee of our hospital to review the surgical database on meralgia paresthetica. A total of 187 cases were identified that had been operated in our Center between April 1, 2014 and September 1, 2022. All cases with potential traumatic injury to the LFCN or compression by a mass lesion were selected for review. Medical records were reviewed for cause of injury or compression by mass lesion. Results of surgical treatment were evaluated retrospectively. Remarks were made on the description of symptoms, interval between trauma and presentation, additional work-up and presence of anatomical variation in the course of the LFCN.

Results

Literature review

The PubMed search resulted in 757 hits. A total of 66 articles were selected, in which a clear mechanism of LFCN injury or cause of compression was described that caused the symptoms of meralgia paresthetica. An overview of these articles is provided separately in Table 1 for different traumatic causes and Table 2 for different mass lesions.

Traumatic causes

Iatrogenic injury is one the most frequently reported causes for traumatic injury of the LFCN. As already mentioned in the introduction complication rates have been described for the anterior approach for hip surgery, acetabular fractures, the harvest of iliac bone crest and inguinal hernia repair. In the literature search we found additional articles describing cases after iliac crest bone harvest with the coring technique [8], laparoscopic inguinal herniorrhaphy [10], and after different intra-abdominal surgical procedures [11, 12]. Most frequently reported cause was pressure or traction on the nerve due to retractor placement [11, 13] or manipulation [14, 15]. Other potential reported mechanisms of intraoperative injury were direct nerve injury due to retroperitoneal dissection [16], placement of a trocar [17] and placement and removal of a pelvic fixator [18].

Positioning of the patient also is a frequently reported cause for non-iatrogenic meralgia paresthetica, either by direct compression on the nerve by a fixture device [19], rotating tourniquet around the upper leg [20], positioning

Table 1 Literature review of traumatic causes of meralgia paresthetica: result from 37 articles

First author	Year of publication	Direct cause	Remarks on pathophysiologic mechanisms, onset symptoms, additional work-up and intra-operative findings
Massey	1977	Standing at attention for 2 h	Lumbar lordosis, increased pelvic inclination and extension of the hip
Cascells	1978	Rotating tourniquet on thigh	Malfunctioning tourniquet with inflation >20 min
Grace	1987	Gastroplasty for morbid obesity	3 cases, likely caused by Gomez retractor
Auriacombe	1991	Needle injury thigh	Accidental, drug needle
Parsonnet	1991	Coronary bypass surgery	Frog-leg position of legs during vein harvesting
Buch	1993	Fracture of ASIS	Acute onset
Andrew	1994	Laparoscopic inguinal herniorrhaphy	3 cases
Swezczyk	1994	Bodybuilder	Occurrence after training on leg press machine
Yamout	1994	Laparoscopic cholecystectomy	External compression by surgeons positioned around table, alternative compression in the inguinal ligament secondary to extension hip
Thanikachalam	1995	Fracture of ASIS	Sudden sharp pain, importance plain radiography
Broecke, van den	1998	Iliac bone crest harvest	3 cases, coring technique, potential anatomic variation
Hutchins	1998	Laparoscopic myomectomy	Injury probably due to retroperitoneal dissection
Schnatz	1999	Thigh injection with pain medication	Post-cesarean, but intraoperative damage unlikely
Butler	2002	Femoral artery cannulation for cardiac catheterization	Medial course LFCN
Polidori	2003	Laparoscopic appendectomy	LFCN damaged by insertion of trocar
Rajabally	2003	Repeated laparotomies	Bilateral case, scar tissue or due to retractors
Ulkar	2003	Direct trauma to anterolateral part thigh during soccer	Slightly decreased cutaneous sensation, provocative point on pressure distal to ASIS
Blake	2004	Seat-belt injury	Abrasion across chest extending to anterolateral region hip
Kavanagh	2005	Open appendicectomy	Anatomical variation in course LFCN
Kho	2005	Strenuous exercise	2 cases walking, 1 case cycling
Paul	2006	Cesarian section	Bilateral case, due to puling or manipulation
Peters	2006	One case after total abdominal hysterectomy and one case post-cesarian	Possible causes: lithotomy position and pressure from self-retaining retractors
Park	2007	Wear of hip-huggers for 2 years	Lateral course of the LFCN (Aszmann type A)
Otoshi	2008	Baseball	Occurrence during pitching practice, intra-operatively LFCN pushed upward by a hard rim of the iliac fascia
Stephenson	2008	Lateral positioning on a bean bag	No soft contact layer
Hayashi	2011	Avulsion fracture of ASIS	Sudden onset, positive Tinel's on percussing avulsed bony fragment of the ASIS
Yi	2012	Traumatic iliacus hematoma	Simultaneous femoral nerve compression
Hsu	2014	Avulsion fracture of ASIS and hematoma in sprinter	Diagnosed with US, confirmed with CT, treated conservatively
Satin	2014	Beach chair position for shoulder surgery	4 cases, compression by patient's abdominal pannus
Lagueny	2015	Injection of glatiramer acetate for MS	Lipoatrophy in proximal thigh and hyposensitivity in territory LFCN
Omichi	2015	Prone positioning	Distal entrapment underneath the fascia lata
Arends	2016	Subcutaneous interferon alpha treatment	Possible neurotoxic effect
Oh	2017	Femoral artery cannulation for cardiac catheterization	Bilateral meralgia paresthetica
Lee	2018	Sartorius muscle tear after jumping	Hematoma surrounding the LFCN on US
Marinelli	2020	Prone position ventilation	For COVID-19 infection, bilateral
Kot	2021	Placement and removal of pelvic fixator	Conservatively treated with US-guided injection of local anesthetics
Kokubo	2022	Park-bench position	Compression by fixture device

ASIS anterior superior iliac spine, *MS* multiple sclerosis, *US* ultrasound

Table 2 Literature review of mass lesions causing meralgia paresthetica: results from 29 articles

First author	Year publication	Mass lesion	Clue(s)
Flowers	1968	Retroperitoneal lipofibrosarcoma	Continuous pain in thigh and to a lesser degree in the lumbosacral region
Good	1981	Bone bar after iliac bone graft harvest	Bony bar formed 5 years after harvest with nerve passing through it
Suber	1979	Uterine fibroid tumor compressing superior lumbar plexus	Sensory disturbance extended outside distribution are LFCN
Rinkel	1990	Metastasis vertebral body L2	Compression nerve root L2
Rotenberg	1990	Pelvic inflammatory disease	Bilasterale case
Amoiridis	1993	Malignant tumor psoas	Walking impossible due to intolerable increase in pain
Brett	1997	Abdominal aortic aneurysm	Sudden onset, back pain
Tharion	1997	Metastasis in iliac crest	Hard mass
Trummer	2000	Lumbar disc herniation, extraforaminal L2–L3	Low back pain, advise MRI in all patients with meralgia
Yamamoto	2001	Hemangiomatosis	Diffuse swelling around ASIS
Yamamoto	2001	Heterotopic ossification	40 years after iliac bone graft harvesting
Gupta	2003	Hip-joint synovial cyst	Firm swelling in iliac fossa
Ahmed	2010	Femoral acetabular impingement	Discovered on MRI thigh
Rau	2010	Lipoma	Relief after excision lipoma
Yang	2010	L1 radiculopathy	probably root L2, because of suspect disc S1-S2 on MRI
Yi	2012	Iliacus hematoma	Both femoral neuropathy and meralgia paresthetica
Talwar	2012	Peritoneal dialysis	Increased intra-abdominal pressure
Lonkar	2012	Spinal hydatid	Swelling back
Ramirez Huaranga	2013	Renal tumor	Large abdomen, mass on CT
Noh	2015	Pancreatic pseudocyst	Abdominal pain, palpable mass
Nishimura	2015	Appendicitis	Prolonged fever, acute lymphoblastic leukemia
Arabi	2015	Schwannoma at level L2	Improvement after tumor resection
Magalhaes	2019	Pelvic osteochondroma	Thickening of iliac bone at palpation
Triplett	2019	Sartorius muscle fibrosis	Treated with cortisone injection
Gencer Atalay	2020	Inguinal lymphadenopathy	US-guided block with betamethasone and bupivacaine relieved pain
Makris	2020	Schwannoma LFCN	Improvement after tumor resection
Ganhao	2021	Lipomatosis	Small mass medial to ASIS
Seror	2021	Extraforaminal disc herniation L2-L3	L2 radiculopathy
Toscano	2021	Giant hemorrhagic trochanteric bursitis	Mobile mass lesion

of the surgeons around the patient [21], prone positioning of the patient [22, 23], flexion of the hips as in lithotomy positioning for gynecologic and obstetric procedures [15], frog-leg positioning for vein harvest during coronary bypass surgery [24] and compression by patient's abdominal pannus in beach chair position for shoulder surgery [25].

In addition, we found several cases of needle injury [26–29] and cases after femoral artery cannulation for cardiac catheterization [30, 31]. Reported potential mechanisms were direct needle injury, neurotoxic effect or from prolonged manual compression after cannulation [31].

Besides iatrogenic injury, several other traumatic causes have been reported including LFCN injury after seat-belt injury [32], avulsion fractures of the ASIS [33–36], sartorius muscle tear [37], traumatic iliacus hematoma [38], and several sports activities (including soccer [39], cycling [2], baseball [40]), long duration wear of hip-huggers [41] and standing at attention [42].

Mass lesions

Mass lesions causing symptoms of meralgia paresthetica were found along the entire course of the LFCN. Starting proximal, Rinkel et al. reported a case of meralgia paresthetica caused by compression of the nerve root L2 by a metastatic tumor of vertebral body L2 [43]. Other

causes of L2 root compression included (extraforaminal) disc herniation of L2–L3 [44–46] and a schwannoma of L2 [47]. More distal causes were a uterine fibroid tumor compressing the superior lumbar plexus [48], a malignant tumor in the psoas [49], a retroperitoneal lipofibrosarcoma [50], a renal tumor [51], a pancreatic pseudocyst [52], an abdominal aortic aneurysm [53], a metastasis of the iliac crest [54], a synovial cyst in the iliac fossa [55] and a hematoma of the iliac muscle [38]. In addition, multiple causes of LFCN compression have been reported around the SIAS, including hemangiomatosis [56], heterotopic ossification [57, 58] and a pelvic osteochondroma [59]. Finally, multiple distal sites of compression have been found to cause symptoms of meralgia paresthetica including lipoma/lipomatosis [60, 61], fibrosis of the sartorius muscle [62], inguinal lymphadenopathy [63], femoral acetabular impingement [64], giant hemorrhagic trochanteric bursitis [65] and a schwannoma inside the LFCN [66]. Besides cases with a cause of compression along the course of the LFCN, also cases have been reported on more diffuse compression by increased intra-abdominal pressure: one bilateral case due to pelvic inflammatory disease [67] and one case after peritoneal dialysis [68].

Signs that pointed at an unusual cause for meralgia paresthetica were sudden onset of symptoms, sensory disturbance outside distribution area of the LFCN, accompanying symptoms of back pain or fever or the presence of a swelling in the groin area. Other factors that raised suspicion were an oncologic history and continuous severe symptoms.

Single center experience with traumatic cases of the LFCN

Between April 1, 2014 and September 1, 2022 a total of 187 primary procedures were performed for meralgia paresthetica in our Center. Fourteen cases had a traumatic cause (Table 3).

The most frequent cause for iatrogenic injury in our series was the anterior approach for hip surgery (4), followed by seat-belt injury (2), bike accidents (2) and inguinal hernia repair (2). In addition, we surgically treated several other cases of iatrogenic injury caused by procedures around

Table 3 14 traumatic causes of meralgia paresthetica

Traumatic cause	Number of cases	Interval trauma-presentation	Remarks	Procedure	Outcome
Hip surgery	3 THP, 1 intramedullary rod femur	1.5–3 yrs	2 cases complete transection, 1 neuroma, 1 anatomical variant type E	Neurectomy (4)	Complete pain relief in 2 cases; other 2 cases no effect
Fixation acetabular fracture	1	5 yrs	Type D variant	Neurolysis	Temporary pain relief
Seat-belt injury	2	1 yr		Neurectomy (2)	Almost complete pain relief in both cases: one case recurrence 7 years after neurectomy, complete relief following suprainguinal re-resection
Bike accidents	2	5 yrs		Neurexeresis (1), neurolysis (1)	Partial pain relief after neurexeresis, no relief after neurolysis
Inguinal hernia repair	2	6 mo	1 open: 1 scopic, anatomical variant (type E)	Neurolysis (1), neurectomy (1)	1 good results after neurolysis, 1 recurrence of symptoms after neurolysis
Vascular surgery for false aneurysm iliac artery	1	1.5 yrs		Neurectomy	Almost complete pain relief
Abdominal uterus extirpation	1	1 yr		Neurolysis	Complete pain relief
Heparin injection	1	9 mo		Neurolysis followed by neurectomy	No pain relief after neurolysis, complete pain relief after neurectomy

Mo months, *THP* total hip procedure, anterior approach, *yrs* years

the ASIS. Most remarkable finding was the long interval between trauma and referral. Further, there was a relatively high number of cases with an anatomical variation in the course of the LFCN, most frequently a relatively medial course (type D and E according to the classification by Aszmann et al [1]).

Overall, outcome after surgery was variable: neurectomy for traumatic LFCN injury after hip surgery resulted in pain relief in half of the cases (2 out of 4).

Single center experience with mass lesion compressing the LFCN

In addition to the traumatic cases, four cases of meralgia paresthetica were identified caused by compression of the LFCN by a mass lesion. The separate cases are described below using the CARE guidelines [69]:

Case of a Schwannoma in the LFCN

A 41-year-old female was referred to our hospital, because of a tingling sensation in her right thigh to just below the knee that had lasted for half a year. In addition, she had noticed a swelling in the anterolateral part of her right upper leg for several months. She had no relevant medical history. During neurologic examination the swelling itself was not painful, but pressure given on top of the lesion exacerbated the symptoms of meralgia paresthetica. An MRI scan was made of her right upper leg, which showed an oval, well-circumscribed mass lesion of 10 mm inside the LFCN (Fig. 2A). She was operated in supine position. The lesion was localized with intraoperative ultrasound. A vertical incision was made over the localized lesion. The LFCN and the lesion inside the LFCN were exposed. After opening of the capsule, the tumor could be resected with sparing of the normal fascicles. Histopathologic analysis confirmed the diagnosis of a schwannoma. Three months after the surgery the patient had no more symptoms of meralgia paresthetica. She still had some numbness in the anterolateral part of her leg, but she was not bothered by this numbness. MRI showed no residual tumor.

Case of a lipoma in the tensor fascia

A 48-year-old male with a history of multiple lipomas was referred to our hospital, because of a burning sensation in the anterolateral part of his thigh. He had no relevant medical history and specifically no history of lipomatosis. An MRI scan was made, which showed a lipoma of 1-cm diameter inside the tensor fascia latae muscle (Fig. 3A). Intraoperatively the lipoma was localized with ultrasound. A vertical incision was made in the skin on top of the lesion, and the distal branches of the LFCN were identified (Fig. 3B). Subsequently the fascia of the underlying tensor fascia latae muscle was opened, the lipoma was identified and resected. Histopathologic analysis confirmed the diagnosis of a lipoma. Three months after the surgery the patient had complete relief of his pain symptoms.

Case of a Schwannoma of the L2 nerve root

A 37-year-old woman with an 8-year history of meralgia paresthetica on the right side was referred with a lesion in her right L2 nerve root. She had been diagnosed with meralgia paresthetica 8 years ago. Her pain symptoms had substantially increased over the last 2-3 years, which was the reason why the referring neurologist had ordered the MRI scan. This showed a lesion in the right L2 nerve root

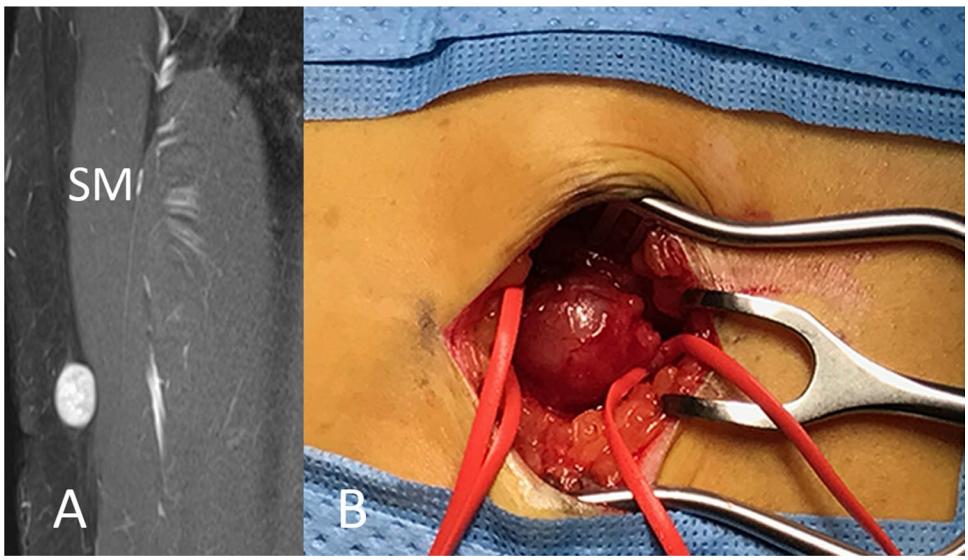

Fig. 2 Case of schwannoma inside the LFCN. **A**: Coronal T1-weighted MR image showing a well-circumscribed lesion inside the LFCN with homogenous gadolinium enhancement. The lesion was positioned on top of the sartorius muscle (SM). **B**: Intraoperative picture showing the schwannoma with bands placed around the LFCN proximal and distal to the lesion

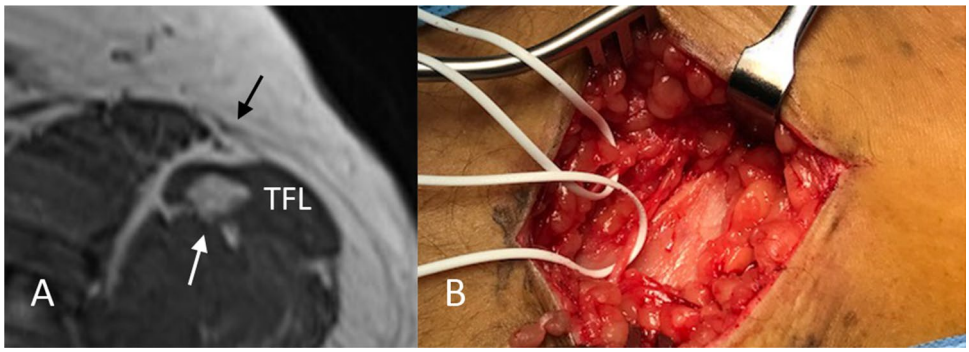

Fig. 3 Case of lipoma inside the tensor fascia latae muscle. **A**: Transverse T1-weighted MR image showing a lesion of 1cm in diameter in the tensor fascia latae muscle (TFL) with high signal intensity comparable to that of subcutaneous fat (white arrow). The black arrow points at the branches of the LFCN. **B**: Intra-operative image with white bands placed around the separate branches of the LFCN after opening of the fascia lata

(Fig. 4A). The patient had no relevant medical history. During neurologic examination no abnormalities were found. She was operated in prone position under general anesthesia. The lesion was exposed through a facetectomy L2–L3 on the right side (Fig. 4B). The sleeve of the nerve root and part of the dura was opened to expose the lesion and intradural filaments. The lesion could be resected totally by transecting the dorsal root filament with sparing of the ventral root filament. Pathologic analysis showed a Schwannoma. After the surgery she had no more pain symptoms in the anterolateral part of the thigh. She had decrease sensation in this area, but the numbness did not bother her. Postoperative MRI scans showed no residual or recurrent tumor up to 2 years after the surgery.

Case of endometriosis in the inguinal ligament

A 37-year-old woman with 5-year history of meralgia paresthetica on the left side was referred with a nodule on top of the left inguinal ligament suspect for endometriosis. She had continuous pain symptoms, but the severity substantially increased menstruation (numeric rating score increased during these periods from 5 to 8). She had a history of endometriosis. During neurologic examination, the lesion could be palpated in her left groin, and pressure on the lesion increased her pain symptoms. MRI scan (Fig. 5A) showed a nodule of 12-mm diameter. US showed a medial course of the LFCN with compression by the nodule. Patient was operated through a suprainguinal approach. The lesion was identified on top of the inguinal ligament. After mobilization of the lesion, the underlying LFCN could be identified (Fig. 5B). The nerve itself was not affected by the endometriosis. The lesion was totally removed (Fig. 5C). Patient experienced complete pain relief 3 months after surgical removal.

Discussion

Although surgery is most frequently performed for idiopathic meralgia paresthetica [70], it is important to consider the possibility of a previous trauma or compression by a mass lesion in the evaluation of patients with meralgia paresthetica and check for potential signs that may point at a traumatic cause or compression by a mass lesion. In this article we reviewed the literature and presented our own experience with the surgical treatment of traumatic cases of meralgia and cases caused by compression due to mass

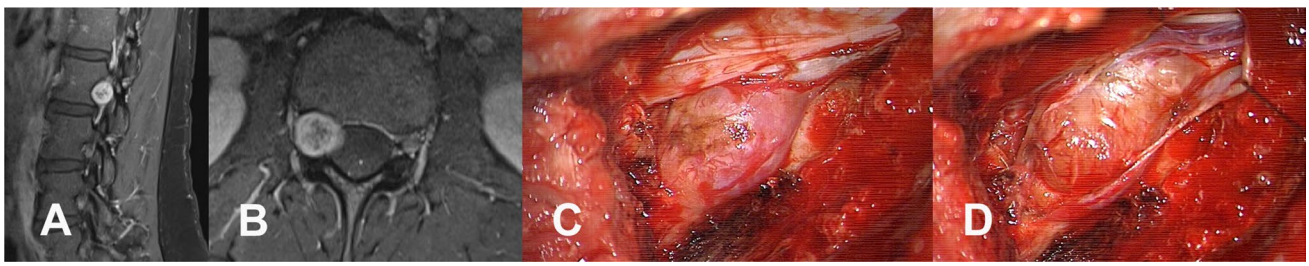

Fig. 4. L2 Case of L2 nerve root schwannoma: **A** and **B**: sagittal and transverse T1-weighted MR images after gadolinium showing the schwannoma inside the L2 nerve root on the right side. **C** and **D**: intra-operative pictures showing the schwannoma before and after opening of the dura

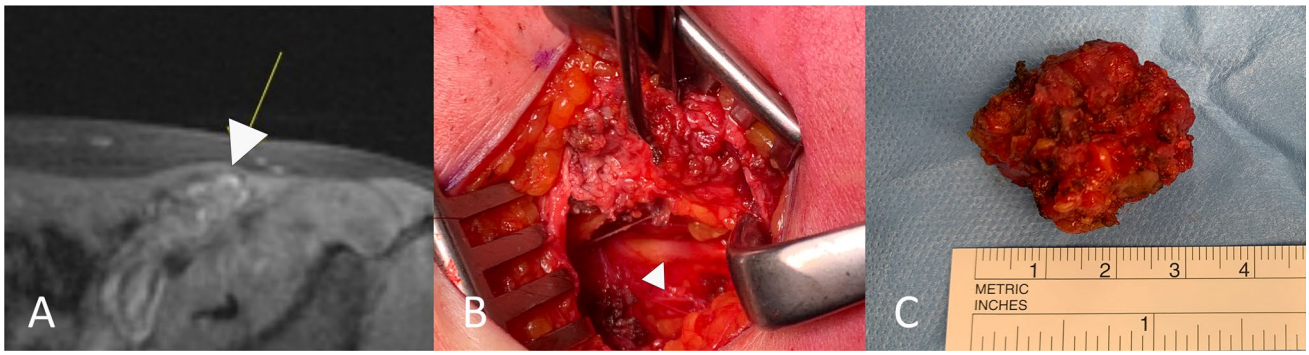

Fig. 5 Case of endometriosis in the groin area: **A**: Transverse T1-weighted image with gadolinium showing the endometriosis lesion (white arrow) inside the inguinal ligament. **B**: Intra-operative image showing the LFCN (arrow) after mobilization of the endometriosis lesion. **C**: Picture of endometriosis lesion

lesions. For clarity reasons we will discuss these two categories separately below.

Traumatic injury of the LFCN

As we expected, iatrogenic injury was the most frequently reported traumatic cause for LFCN injury in the literature. Besides the procedures that are well known for the potential of causing LFCN injury, we found several cases of meralgia after intra-abdominal procedures performed both through an open and laparoscopic approach. Several pathophysiologic mechanisms for injury have been reported including direct injury to the LFNC, for example during retroperitoneal dissection [16] or due to insertion of the trocar [17], or indirect injury due to manipulation or retraction by surgical blades [11]. The latter explanation is also supported by the finding of bilateral meralgia in 2 cases after laparotomy [13 14]. Other mechanisms that were mentioned included increased abdominal pressure (due to induced pneumoperitoneum [21]) and positioning of the patient, such as extreme lithotomy position [15].

In this study we did not include all studies on the effect of surgical positioning, because most studies concern series without description of the individual cases. Potential causes mentioned in these articles include pannicular traction at the inguinal ligament, extreme flexion of the hips or direct compression by a fixture device [19]. Unfortunately, the LFCN is not mentioned in the ASA Practice Advisory for the Prevention of Perioperative Peripheral Neuropathies [71], probably because of the low incidence and the fact that is often self-limiting (53% of the symptoms recover within first week after spine surgery, and every patient within 2 months [72]). Nevertheless, we feel that more awareness should be raised for the potential complication of meralgia paresthetica after positioning for different surgical procedures both for patient education and adequate conservative treatment.

Furthermore, our literature review showed several iatrogenic cases after femoral artery cannulation and needle injury either caused by direct injury of the needle, neurotoxic effect of the injected drug and/or compression after removal of the needle or cannula for hemostasis.

Finally, several cases have been reported of traumatic meralgia paresthetica after different sports activities. Although these cases are more difficult to distinguish from idiopathic meralgia paresthetica and the trauma may be regarded as predisposing rather than as direct cause, sometimes there was clear relation between the occurrence of symptoms and a certain activity. Otoshi et al. for example reported a case of meralgia paresthetica in baseball player and hypothesized that injury to the nerve was caused by contraction of the iliac muscles during pitching motion [40]. Other cases have been reported after training on a leg press [73], extensive walking and cycling [2] and long duration of standing at attention [42]. Direct impact on the anterolateral part of the thigh may also lead to symptoms of meralgia paresthetica, as for example shown by the case of Ulkar et al., who found symptoms after direct trauma in a soccer patient [39]. A lateral course of the LFCN (type A, where the nerve runs lateral to the ASIS) probably makes the nerve more vulnerable to injury (as seen in the case by Park et al [41]). Specific attention should be paid to a potential distal injury at the site where the branch(es) pierce the fascia lata to innervate the skin [23].

In our own series of 14 traumatic cases, we also observed the types of injury that are most frequently reported in the literature, including the anterior approach for hip surgery (4 cases), inguinal hernia repair (2 cases) and seat-belt injury (2 cases). Interestingly, we also operated two cases of injury after bicycle accidents, which can be explained by the frequent use of bicycles for transportation in the Netherlands [74]. Overall, outcome after surgery in our small series was variable. Neurectomy of the LFCN after traumatic injury for anterior hip surgery

resulted in pain relief in only half of the cases. This could be due to referral bias, because transection injury was most frequently observed in our cases, whereas Goulding et al. found that most injuries after the anterior approach for hip arthroplasty concern neurapraxia [75]. In the literature there are only a few articles in which surgical results for traumatic cases have been described and the series are heterogenous with often different traumatic causes [3, 76, 77]. More research is needed to investigate the role of surgery after traumatic LFCN injury. In any event, it is important to recognize the possibility of LFCN injury and preferably perform additional analysis with ultrasound pre-operatively, also to investigated potential hematoma, muscle tear and /or avulsion of a fragment of the ASIS. We suspect that traumatic injuries of the LFNC are frequently missed. In addition, we observed a substantial delay in the referral of these patients. After seat-belt injury for example (where the LFCN is vulnerable at the site where the seat belt runs just caudal to the ASIS and sudden deceleration of the car with tightening of the seatbelt might lead to compression injury of the nerve). As was shown in the case by Blake and Treble [32], abrasion across the chest extending to the anterolateral region of the hip may point at this, although these abrasions may not always be found and, as in our experience, patients are often referred years after the injury has occurred.

The most frequently reported finding from our series of traumatic cases was a relatively medial course of the LFCN. In the classification by Aszmann et al. this type is referred to as type D and E [1]. It could be that the more lateral course, where the nerve runs just medial to the ASIS (type B and C), protects the LFCN from injury or that surgeons are not aware of potential medial course of the nerve. More studies, as the one by Broin et al. [9], are needed to investigate safe margins for different procedures. Moreover, because medial variants may also be injured after femoral artery cannulation, it is important to realize that digital compression and the use compression devices [30] can lead to LFCN injury, and possibly, preventive measures such as the use of vascular closure device may prevent this complication [31].

Besides the more frequently reported traumatic causes of meralgia paresthetica, we also found several unusual causes, including nerve injury after heparin injection, vascular surgery for a false aneurysm of the iliac artery, abdominal uterus extirpation and fixation of an acetabular fracture. As expected for unusual cases, there was often a referral bias, and multiple scans had been performed before the patient was referred. In our experience it is helpful in these cases to perform analysis with ultrasound to investigate the possibility of a neuroma, hematoma or fibrosis. In addition, pressure with the probe of the US over the area of the injury may provoke symptoms (*sonopalpation*), which may also point at a traumatic mechanism of injury.

Compression by mass lesions

Our literature review shows that potential causes of compression can be found anywhere along the course of the LFCN. Proximally several lesions were found that presented with symptoms of meralgia paresthetica, often accompanied by back pain, which pointed at another potential cause than idiopathic meralgia paresthetica. Lumbar radiculopathy of L2 or L3 is probably the most important differential diagnosis of meralgia paresthetica. Yang et al. reported a case of L1 radiculopathy mimicking meralgia paresthetica caused by L1–L2 intervertebral disc herniation, but the MRI in their figure suggests a rudimentary disc S1–S2, and we question whether in that case the affected level was in fact L2–L3 [46]. Some authors recommend MRI to exclude a potential compression at the spinal level in all patients with meralgia paresthetica [44]. We would suggest to at least perform MRI in the presence of radicular pain symptoms (rather than dysesthesia which is often observed in meralgia), accompanying backpain, extension of the symptoms outside the distribution area of the LFCN and in case additional work-up for meralgia paresthetica is normal (no increased surface area of the LFCN on US or intraneural edema) and if there is no response to local nerve block.

Other clues that may point at another cause noted in the literature were an oncologic history, abnormal presentation (continuous severe symptoms or short duration), swelling around the ASIS or intra-abdominal swelling. Some articles have reported the occurrence of meralgia following pelvic inflammatory disease. The exact pathophysiologic mechanism in these cases remains unclear, but it may be explained by extension of the intra-abdominal contention and secondary compression of the LFCN. Another explanation could be inguinal lymphadenopathy [63]. In our experience ultrasound (US) is helpful to rule other mass lesions around the ASIS. Another advantage of US is that it can be used preoperatively to determine the anatomical variant in the course of the LFCN in relation to the ASIS [78].

In our surgical series we found 4 cases of compression of the LFCN, including two cases of schwannoma, one case of lipoma and one case of endometriosis. A few other cases of schwannoma involving the LFCN have been described in the literature: one case involving the LFCN [66] and one intradural case at the level L2 [47]. Also compression of the LFCN by a lipoma has been described previously [60 61]: one case was treated surgically [60] and one case by injection of triamcinolone and lidocaine [61]. To the best of our knowledge no other cases have been reported on cyclic symptoms of meralgia paresthetica related to menstruation due to endometriosis. In our case symptoms were caused by direct compression of the endometriosis lesion at the inguinal ligament. Although these causes are rare, in our opinion it is important to rule out a potential alternative

cause, especially when there are accompanying signs such back pain, swelling in the groin or the anterolateral part of the thigh or a history of schwannomatosis, lipomatosis or endometriosis.

Conclusion

As our literature review shows there are multiple iatrogenic and other traumatic causes for meralgia paresthetica. Sometimes the trauma mechanism is clear, but sometimes (especially in closed injury) the trauma mechanism is not recognized and patients are referred with a substantial delay. More awareness should be raised for potential occurrence of meralgia paresthetica after positioning for surgery, including prone-positioning for spine surgery.

Our literature review also shows that meralgia paresthetica can be caused by mass lesions all along the course of the LFCN, starting from the nerve root L2/L3 up to the distal branches of the LFCN to the skin. Accompanying signs such as atypical presentation (sudden onset, severe pain), accompanying symptoms (back pain), local swelling in the groin area and an oncologic history may point at an alternative cause. Ultrasound can be performed to investigate structural abnormalities around the ASIS. Additional work-up (including MRI of the lumbar spine) should be performed in case of suspicion of L2 or L3 nerve root compression.

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Availability of data and materials Details can be requested from the corresponding author, but restricted to the guidelines and only with permission from the Medical Ethical Committee South-West Netherlands.

Author contributions GdR selected and read all articles, wrote the manuscript (including the case descriptions), reviewed the final version and revised the manuscript according to the comments by the reviewers. JO reviewed the first and the revised version of the manuscript. TV participated in the literature search and reviewed the first and revised version of the manuscript. AK read all articles in the review and reviewed the revised version of the manuscript.

Declarations

Ethical approval Ethical approval was obtained from the Medical Ethical Committee from the South-West Netherlands and from the board of the Haaglanden Medical Center.

Competing interests The authors declare no competing interests.

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