ONLINE FIRST

This is a provisional PDF only. Copyedited and fully formatted version will be made available soon.

ISSN: 0015-5659

e-ISSN: 1644-3284

Genitofemoral nerve course and branching variations: what we see during laparoscopic extended pelvic lymph-node dissection in radical prostatectomy for prostate cancer and how to avoid intraoperative lesions? A retrospective analysis

Authors: Flavio Forte, Elena De Santis, Carlo Introini, Anastasios Asimakopoulos, Roberto Cirocchi, Mauro Palmieri, Alessandra Serraino, Luigi Cofone, Marco Artico, Francesco Maria Galassi

DOI: 10.5603/fm.102220

Article type: Original article

Submitted: 2024-08-24

Accepted: 2025-01-09

Published online: 2025-02-18

This article has been peer reviewed and published immediately upon acceptance.
It is an open access article, which means that it can be downloaded, printed, and distributed freely,

provided the work is properly cited.
Articles in "Folia Morphologica" are listed in PubMed.

Genitofemoral nerve course and branching variations: what we see during laparoscopic extended pelvic lymph-node dissection in radical prostatectomy for prostate cancer and how to avoid intraoperative lesions? A retrospective analysis

Flavio Forte[1, *], Elena De Santis[2, *], Carlo Introini[3], Anastasios Asimakopoulos[4], Roberto Cirocchi[5], Mauro Palmieri[6], Alessandra Serraino[6], Luigi Cofone[7], Marco Artico[7, *], Francesco Maria Galassi[8, *]

[1]Urology Department, M.G. Vannini Hospital, Rome and Science Department, Roma Tre University, Rome, Italy
[2]Department of Anatomical, Histological, Forensic Medicine and Orthopedic Sciences, La Sapienza University, Rome, Italy
[3]Urology Department, Enti Ospedalieri Galliera, Genova, Italy
[4]Urology Department, Policlinico Tor Vergata, Rome, Italy
[5]Department of Medicine and Surgery, University of Perugia, Perugia, Italy
[6]Department of Human Neurosciences, Sapienza University of Rome, Rome, Italy
[7]Department of Sensory Organs, Sapienza University of Rome, Rome, Italy
[8]Department of Anthropology, Faculty of Biology and Environmental Protection, University of Lodz, Łódź, Poland
*These authors contributed equally.

Address for correspondence: Prof. Marco Artico, MD PhD, Department of Sensory Organs, Sapienza University of Rome, V.le del Policlinico 155, 00161 Rome, Italy; e-mail: marco.artico@uniroma1.it

ABSTRACT

Background: The genitofemoral nerve is the most variable nerve of the lumbar plexus, in terms of its course and bifurcation, thus it must be taken into consideration during extended pelvic lymph node dissection. Its borders, during robotic, laparoscopic or open radical prostatectomy for intermediate or high-grade prostate cancer, have long been defined and must be usually respected; the genitofemoral nerve represents the extended pelvic lymph-node dissection lateral boundary and may vary from case to case putting its integrity at risk.

Materials and methods: For the first time, here the authors report genitofemoral nerve branching pattern data obtained extended pelvic lymph node dissection during videolaparoscopic radical prostatectomyand propose a further sub-classification to identify the exact genitofemoral nerve bifurcation point in correlation with the injury risk.

Results: The surgical results show the prevalence of a genitofemoral nerve originating as a single trunk which divides into two branches and highlight how this condition occurs at external iliac artery upper third in more than 75% of cases. Furthermore, at the femoral canal inlet the genitofemoral nerve two branches were mainly seen lying laterally sided and below the external iliac artery, or in the middle of external iliac artery and external iliac vein.

Conclusions: Knowledge and recognition of the genitofemoral nerve course and bifurcation points deduced from the extended pelvic lymph node dissection and, in any case, applicable to all major pelvic surgery, can prove helpful in avoiding iatrogenic nerve injuries during extended pelvic lymph node dissection.

Keywords: clinical anatomy, genitofemoral nerve, surgical anatomy, extended pelvic lymph node dissection, anatomical variations, videolaparoscopic radical prostatectomy

INTRODUCTION

The conventional pelvic lymph node dissection (henceforth PLND) remains at time the gold standard in the diagnosis of lymph node invasion (henceforth LNI) from PCa during robotic, laparoscopic or open radical prostatectomy (henceforth RARP, VLRP or ORP): current guidelines recommend performing PLND in intermediate and high-risk cases, based on different nomograms and cut-off levels [6]. The LNI diagnosis increases in percentage with ePLND which involves removal of obturator, external iliac, hypogastric with or without pre-sacral and common iliac nodes, compared PLND (obturator with or without external iliac nodes). The ePLND boundaries well described in Literature [7], are the ischio-pubic branch anteriorly, the IIA medially (included in the lymphadenectomy), the iliac bifurcation above, while the lateral edge is represented by the genitofemoral (henceforth GFN), which runs on the surface of the psoas muscle, medially to the intermediate psoas tendon and laterally to the external iliac artery (EIA). Since the ePLND involves a large peritoneal dissection to identify the iliac axis and bifurcation, the GFN iatrogenic injury risk increases, thus making it mandatory to know the GFN course and branching pattern.

Materials and methods

After obtaining the necessary approval from our Institutional Review Board, a retrospective analysis was conducted on all patients (69, aged 43–77) who had undergone videolaparoscopic radical prostatectomy (VLRP) with ePLND for intermediate and high-grade PCa between June 2022 and December 2023 at the Urology Department of the “MG Vannini” Hospital in Rome, Italy; all video recorded procedures were reviewed and the data of interest extrapolated from these. The ePLND technique starts on the body’s left side by opening the peritoneum laterally to the umbilical artery, cutting the *vas deferens* and entering the Bogros’ space [16] and the *obturator fossa*; extending the incision up to the iliac axis and left paracholic space, the Jonnesco inter-mesocholic space is reached, on whose bottom lies the iliac ureter, which represents the upper limit of the ePLND [14]. This wide peritoneal opening allows surgeons to perform external and internal iliac and the obturator lymphectomies on left side: on the right side, apart from the equal peritoneal opening, a partial Cattel-Braash maneuver is performed [1], with detachment of the caecum and the mesentery root and releasing of the main vascular axis, aided by the patient’s Trendelenburg position. VLRPs plus ePLNDs were performed by use bipolar forceps and monopolar scissors, avoiding any energy source device such as ultrasounds or radiofrequency and by the aid of the Air Seal Intelligent Flow System®, which allowed us to maintain a CO2 insufflation pressure at 10 mmHg, beside the continuous smoke extraction, avoiding any increase in $PaCO_2$ (Carbon Dyoxid Partial Pressure), which can lead to a pH decrease [10]. The two wide dissections free the surface of the psoas muscles on both sides, to identify the course of the GFNs and their variations; all our procedures were video recorded, making freeze frames on the GFN dissections bilaterally to highlight the course, presence of bifurcation and its level, entry point into the femoral canal and contiguity relationships with the EIA. We referred to Geh’s work [11] to classify the GFN branching patterns in three groups (Fig. 1): **Type I** (50% — single trunk that emerges from the psoas and divides itself into two branches at L5-S1 level); **Type II** (30% — complete single trunk); **Type III** (20% — two single branches, genital and femoral, which originate separately from the psoas). A further sub-group in the Type I was draw up relating to the GFN split point (sub-types A, B and C), as this represents the ePLND nodal point, the harbinger of nerve injury due to lack of knowledge or recognition.

RESULTS

The GFN branching pattern intraoperatively detected [14] showed type I in 55.07%, type II in 34.78% and type III in 10.14% on the right side (Fig. 2) while type I was detected in 59.42%, type II in 27.53% (Fig. 3) and type III in 13.04% on left side; on the right side the type I split point occurred close to the internal iliac artery (henceforth IIA) origin in 7.89% (sub-type A) (Fig. 4), at

the upper third of the EIA in 76.31% (sub-type B), and close to the femoral canal (henceforth FC) inlet in 15.78% (sub-type C); on left side sub-type A was 14.63%, type B 75.60% and type C 9.75% (Fig. 5). At the right FC entry point the sub-types A and B with their separate branches lie in close proximity to the EIA but still not stuck to it in all 32 cases (A + B), while the sub-type C-6 cases lie under the EIA, with the genital branch running between the external iliac vein (henceforth EIV) and the EIA and the femoral one stuck to the EIA lateral aspect; keeping to the right side type II lie about 1 cm laterally to the EIA in 94.73%, and in 5.27% it appears leaning against the EIA itself, while type III was found in between the EIA and EIV in all 7 cases. On left side the Type I — 6 sub-type A and 31 sub-type B lie very close to EIA, and the 4 sub-type C lie in between the EIA and the EIV: the 19 left Type II lie stuck to EIA in 12 subjects (Fig. 6) and less than 0,5 cm from the EIA in 7 cases (Fig. 7) and the 9 left Type III behave like those on the right.

DISCUSSION

The overall incidence of intra-operative and post-operative complications are similar for ePLND and conventional PLND, including blood loss, rectal and obturator nerve injuries [13]; among the less described complications (yet still present in daily surgery), the accidental GFN lesion during ePLND must be included, as this one, unlike the PLND, involves the wide opening of the peritoneum to free the psoas and carefully isolate the external iliac vessels. The GFN derives from the caudal branch of the L1 root and anterior division of L2 and is considered the most variable nerve of the lumbar plexus [12, 15]. It penetrates the psoas major muscle and splits itself into genital and femoral branches midway along the anterior psoas surface. Occasionally it can be absent, hence the ilioinguinal nerve replaces the genital branch, while the lateral cutaneous replaces the femoral one [3, 5]. A GFN early split, or in any case its subdivision at different levels, means that two nerve fibers would be identified to avoid injuries. Although it is more often described in inguinal hernioplasty injuries reports [9], cases deriving from open and laparoscopic pelvic surgery are also described; lesions may be due to compression, stretching, complete or partial transection, monopolar or bipolar electrocautery, and involve neuropathic symptoms described as burning, sharp, shooting or throbbing, felt in the abdomen, lower back or between the legs. It may come and go, or it may be more persistent, felt mainly in the upright position, but often also when seated and more rarely when lying down; patients suffering will often be forced into a bent-over position to alleviate some of the pain, that can lead to bulging of the anterior abdominal wall muscles [21]. GFN surgical lesions are more commonly described in gynaecological oncological surgery [4], and in the accurate and often very extensive dissection in deep pelvic endometriosis [8]; accidental GFN lesions during super-ePLND for radical cystectomy for bladder malignancies have been described,

due to non-recognition of nerve course, and manifested with scrotal pain and disappearance of the cremasteric reflex [19].

Furthermore, a characteristic alteration observed in the context of GNF pathology is genitofemoral neuralgia, which is represented by debilitating neuropathic pain localized in the groin following the distribution of the GNF [9]: besides pain, “paresthesias and a burning sensation spreading from the lower abdomen to the medial aspect of the thigh [9], can be present.

The retrospective works of Soares-Aquino and Muensterer [18, 20] on GFN injuries during laparoscopic varicocelectomies in paediatrics it might help in understanding: the authors hypothesize the use of electrocautery or energy devices to create the peritoneal window close to the internal inguinal ring plus the dissection between the internal spermatic artery and veins as the causes. However, it ought to be remembered that the GFN runs about 1 cm medially to the gonadal vessels into the iliac fossa, lies on the psoas muscle surface entering the FC and not the internal inguinal ring (IIR): the GFN runs very close to the gonadal vessels at the psoas middle-third, along its medial border. Laparoscopic varicocelectomy involves vessels ligation about 2 cm above the IIR, so if the wide peritoneal dissection, using or not energy devices, can be considered a cause of GFN injuries, the same cannot be said for the topographic relationships.

To avoid misunderstanding errors in dissection of the iliac fossa and extraperitoneal space, an in-depth knowledge of the nerves course and their variations is certainly appropriate, By the initial comparative studies of Zluska et al. [22], whose results have rather recently (2020) been re-confirmed by other authors from cadaveric and intraoperative studies [17], it is known that the GFN appears at its root as a single trunk in about 80% of cases and as two single branches in 20%. All these branches, formed by fibers deriving from the L1–L2 roots of the lumbar plexus, come out from the lateral edge of the great psoas muscle, with a considerable variability for the single trunk (80%) about the level in which it divides itself into two terminal branches. The greatest details were provided by Geh [11], who described GNF branching patterns as type I (50%) — single trunk that emerges from the psoas and divides itself into two branches at L5–S1 level; type II (30%) — complete single trunk; type III (20%) — two single branches which originate separately from the psoas.

With particular reference to avoiding nerve injuries during ePLND, the studies provided so far are not of much help: indeed, in ePLND reliable data for nerve identification must be provided in order to localize the point where it bifurcates (type I) and to identify proximity or contiguity relationship with the EIA (type I–II–III). Possible lesions of the GFN may occur during EIA lymphadenectomy, both with a retrograde and antegrade technique: the critical points are the LN package isolation from the EIA lateral aspect at its origin level (GFN generally runs below and to the side), the EIA

detachment from the psoas plane to free any underlying LN and the LN removal close to the deep inferior epigastric vessels origin to reach the FC inlet surrounded by Poupart's, Cooper's and Gimbernat's ligaments [2].

Our observational surgical data show the Types I, II and III, previously described only in cadaver dissection, are commonly applicable, yet the bifurcation point of Type I is not fixed. Therefore, we have defined three morphological sub-types, A, B and C, which correspond to the different GFN bifurcation levels: both on the right and on the left side, subtype B is the most represented one, and thus, potentially, the one most likely at risk of sustaining an injury during LN removal of EIA, whose close relationship with GFN appears truly remarkable.

CONCLUSIONS

To the best of our knowledge, the present work is the only one to provide intra-operative observations on the variability of the course of the GFN and the locations of its branching points, during ePLND in VLRP for PCa. The topographical data presented in this study not only confirm those present in the published biomedical literature but also provide more specific indications of the nerve's bifurcation points. This pivotal information can prove useful to medical practitioners and surgeons in order to avoid lesions during major pelvic surgery, which can include wide visceral mobilization and detachment of fascial planes to extend up to the vascular axes. Future multi-centric studies on the morphology and variations of the GFN in relations with surgical procedures and outcomes could significantly reduce errors and lesions detrimental to patients' wellbeing.

ARTICLE INFORMATION AND DECLARATIONS

Data availability statement

Data available from the corresponding author upon reasonable scientific request.

Ethics statement

Surgical data were collected after the involved patients had signed the relevant written informed consent forms.

Author contributions

Conceptualization, data analysis, investigation, imaging: FF, MA, FMG. Writing of the original draft: FF. Revision of the first draft: EDS, CI, AA, RC, MP, AS, LC, MA, FMG. Supervision: MA, FMG.

Funding

No grant associated with this manuscript.

Conflict of interest

The authors of this article have no conflict of interest to disclose.

REFERENCES

1. Akita M, Maeda E, Nishimura T, et al. Anatomical change of SMV branches after the Cattell Braasch maneuver facilitates safe resection around the uncinated process in pancreatoduodenectomy. BMC Surg. 2021; 21(1): 341, doi: 10.1186/s12893-021-01338-5, indexed in Pubmed: 34496813.
2. Albo G, Gallioli A, Ripa F, et al. Extended pelvic lymph node dissection during robotic prostatectomy: antegrade versus retrograde technique. BMC Urol. 2024; 24(1): 64, doi: 10.1186/s12894-024-01448-1, indexed in Pubmed: 38515053.
3. Anloague PA, Huijbregts P. Anatomical variations of the lumbar plexus: a descriptive anatomy study with proposed clinical implications. J Man Manip Ther. 2009; 17(4): e107–e114, doi: 10.1179/106698109791352201, indexed in Pubmed: 20140146.
4. Benito V, Romeu S, Esparza M, et al. Safety and feasibility analysis of laparoscopic lymphadenectomy in pelvic gynecologic malignancies: a prospective study. Int J Gynecol Cancer. 2015; 25(9): 1704–1710, doi: 10.1097/IGC.0000000000000555, indexed in Pubmed: 26397158.
5. Bergman RA, Tubbs RS, Shoja MM, Loukas M. Bergman's comprehensive encyclopedia of human anatomic variation. Wiley, Hoboken 2016: 669–673.
6. Briganti A, Blute ML, Eastham JH, et al. Pelvic lymph node dissection in prostate cancer. Eur Urol. 2009; 55(6): 1251–1265, doi: 10.1016/j.eururo.2009.03.012, indexed in Pubmed: 19297079.
7. Burkhard FC, Studer UE, Burkhard FC, et al. The role of lymphadenectomy in prostate cancer. Urol Oncol. 2004; 22(3): 198–202; discussion 202, doi: 10.1016/j.urolonc.2004.04.032, indexed in Pubmed: 15271316.
8. Ceccaroni M, Clarizia R, Roviglione G. Nerve-sparing surgery for deep infiltrating endometriosis: laparoscopic eradication of deep infiltrating endometriosis with rectal and parametrial resection according to the negrar method. J Minim Invasive Gynecol. 2020; 27(2): 263–264, doi: 10.1016/j.jmig.2019.09.002, indexed in Pubmed: 31518711.
9. Cesmebasi A, Yadav A, Gielecki J, et al. Genitofemoral neuralgia: a review. Clin Anat. 2015; 28(1): 128–135, doi: 10.1002/ca.22481, indexed in Pubmed: 25377757.

10. Forte F, Tripodi D, Pironi D, et al. Comparison of laparoscopic partial nephrectomy performed with AirSeal® system vs. standard insufflator: results from a referral center. Front Surg. 2023; 10: 1220332, doi: 10.3389/fsurg.2023.1220332, indexed in Pubmed: 37440928.
11. Geh N, Schultz M, Yang L, et al. Retroperitoneal course of iliohypogastric, ilioinguinal, and genitofemoral nerves: a study to improve identification and excision during triple neurectomy. Clin Anat. 2015; 28(7): 903–909, doi: 10.1002/ca.22592, indexed in Pubmed: 26149241.
12. Gupton M, Varacallo M. Anatomy, abdomen and pelvis: genitofemoral nerve. StatPearls [Internet], Treasure Island 2022.
13. Heidenreich A, Ohlmann CH, Polyakov S. Anatomical extent of pelvic lymphadenectomy in patients undergoing radical prostatectomy. Eur Urol. 2007; 52(1): 29–37, doi: 10.1016/j.eururo.2007.04.020, indexed in Pubmed: 17448592.
14. Hüscher CGS, Lirici MM, Marks JH, et al. Laparoscopic left colectomy: modern technique based on key anatomical landmarks reported by giants of the past. Minim Invasive Ther Allied Technol. 2021; 30(1): 1–11, doi: 10.1080/13645706.2019.1665072, indexed in Pubmed: 31524546.
15. Kostov S, Kornovski Y, Slavchev S, et al. Lateral transperitoneal accesses to the pelvic retroperitoneum in gynecology: surgical technique, anatomical landmarks and variations. Indian J Gynecol Oncol. 2021; 19(4), doi: 10.1007/s40944-021-00554-4.
16. Mirilas P, Colborn GL, McClusky DA, et al. The history of anatomy and surgery of the preperitoneal space. Arch Surg. 2005; 140(1): 90–94, doi: 10.1001/archsurg.140.1.90, indexed in Pubmed: 15655212.
17. Moreno-Egea A. A study to improve identification of the retroperitoneal course of iliohypogastric, ilioinguinal, femorocutaneous and genitofemoral nerves during laparoscopic triple neurectomy. Surg Endosc. 2021; 35(3): 1116–1125, doi: 10.1007/s00464-020-07476-w, indexed in Pubmed: 32430523.
18. Muensterer OJ. Genitofemoral nerve injury after laparoscopic varicocelectomy in adolescents. J Urol. 2008; 180(5): 2155–2157, doi: 10.1016/j.juro.2008.07.068, indexed in Pubmed: 18804242.
19. Sakai T, Murata H, Hara T. A case of scrotal pain associated with genitofemoral nerve injury following cystectomy. J Clin Anesth. 2016; 32: 150–152, doi: 10.1016/j.jclinane.2016.02.022, indexed in Pubmed: 27290965.

20. Soares-Aquino C, Vasconcelos-Castro S, Campos JM, et al. 15-Year varicocelectomy outcomes in pediatric age: Beware of genitofemoral nerve injury. J Pediatr Urol. 2021; 17(4): 537.e1–537.e5, doi: 10.1016/j.jpurol.2021.05.009, indexed in Pubmed: 34099399.
21. Tanaka T, Terai Y, Ono YJ, et al. Genitofemoral neuropathy after pelvic lymphadenectomy in patients with uterine corpus cancer. Int J Gynecol Cancer. 2015; 25(3): 533–536, doi: 10.1097/IGC.0000000000000335, indexed in Pubmed: 25486104.
22. Zaluska S, Urbanowicz Z. [The ilio-hypogastric, ilio-inguinal and genito-femoral nerves in man and in Macacus]. Ann Univ Mariae Curie Sklodowska Med. 1968; 23: 73–87, indexed in Pubmed: 4988560.

Table 1. Intraoperative findings of "Ndi Geh" classification of GFN branching.

	Right	**Left**
Type I	38/69 (55.07%)	41/69 (59.42%)
Type II	24/69 (34.78%)	19/69 (27.53%)
Type III	7/69 (10.14%)	9/69 (13.04%)

Table 2. Intraoperative findings of the presently discussed classification (sub-types A, B, C originate from Ndi Geh et al.'s Type I).

	Right	**Left**
Sub-type A	3/38 (7.89%)	6/41 (14.63%)
Sub-type B	29/38 (76.31%)	31/41 (75.60%)
Sub-type C	6/38 (15.78%)	4/41 (9.75%)

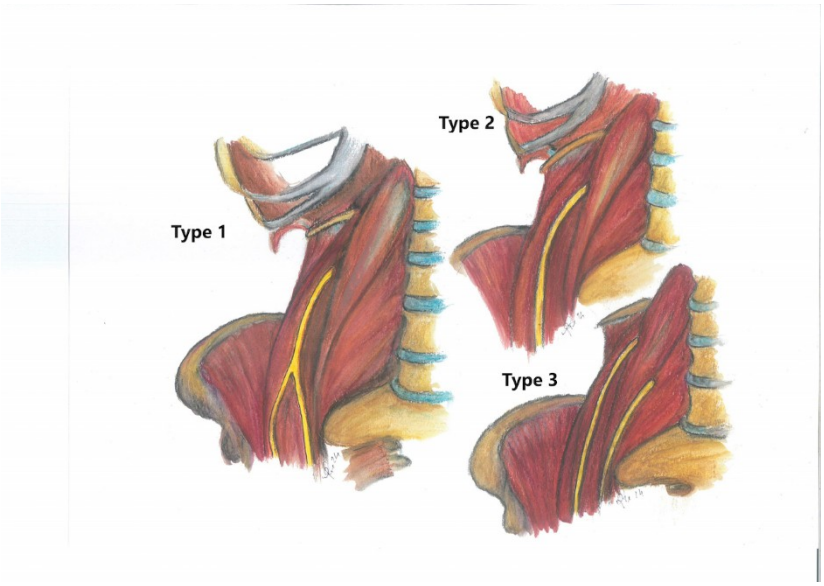

Figure 1. Drawning illustrating the classification of the genitofemoral nerve course branching patterns in three groups.

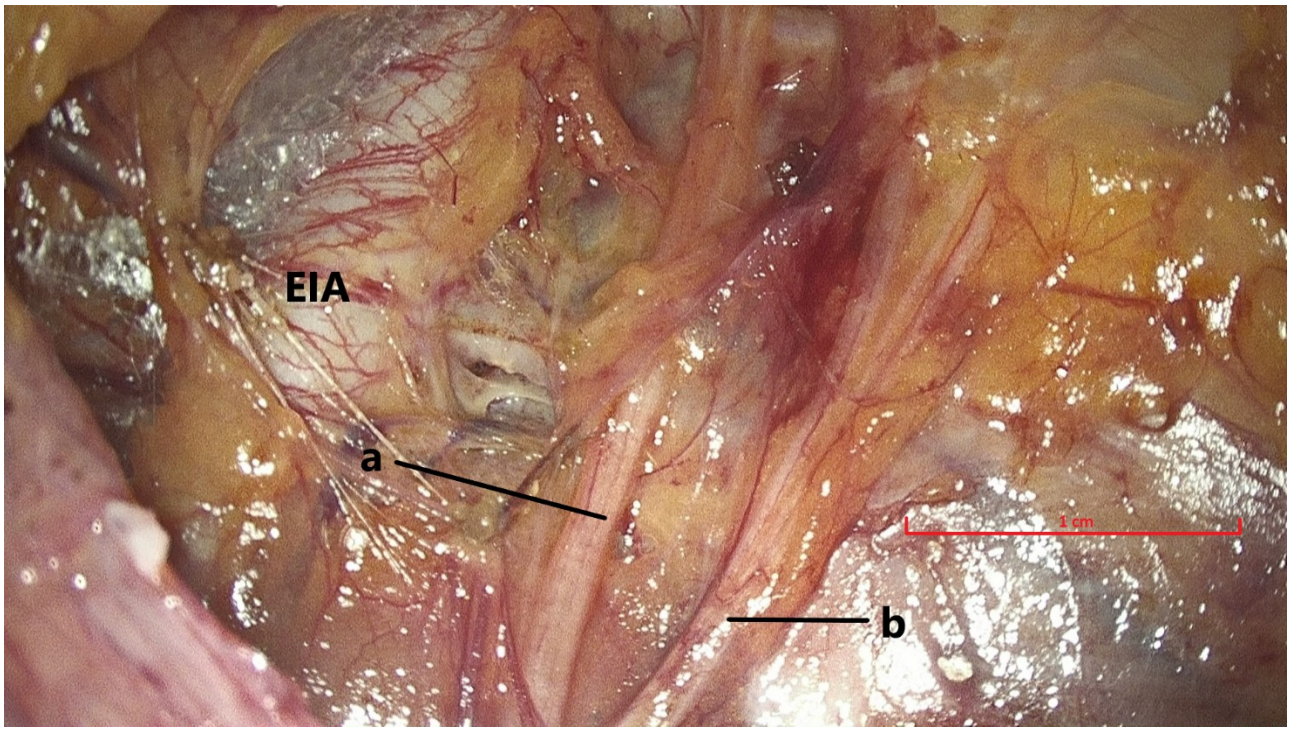

Figure 2. Type III two single branches; a — genital branch; b — femoral branch; EIA — external iliac artery.

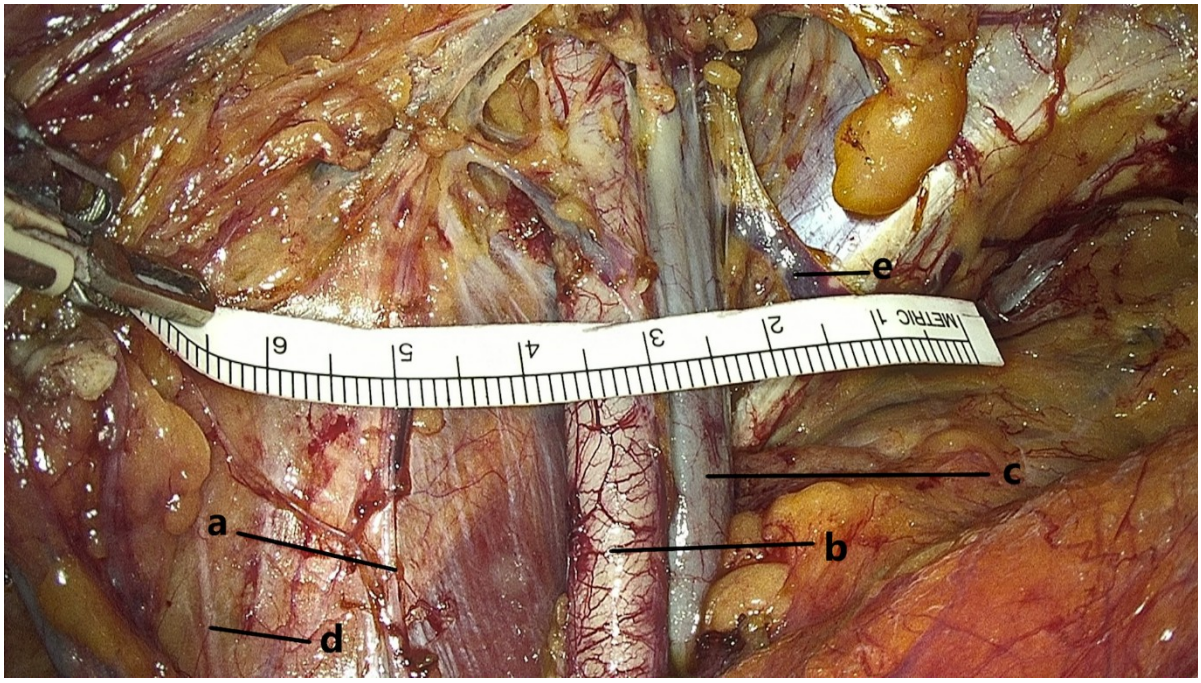

Figure 3. Left Type II genitofemoral nerve (GFN) — the variable distance between GFN and external iliac artery (EIA) performed during all laparoscopic procedures is shown: a — left GFN; a — EIA; c — external iliac vein; d — lateral cutaneous nerve of thigh; e — venous *corona mortis*.

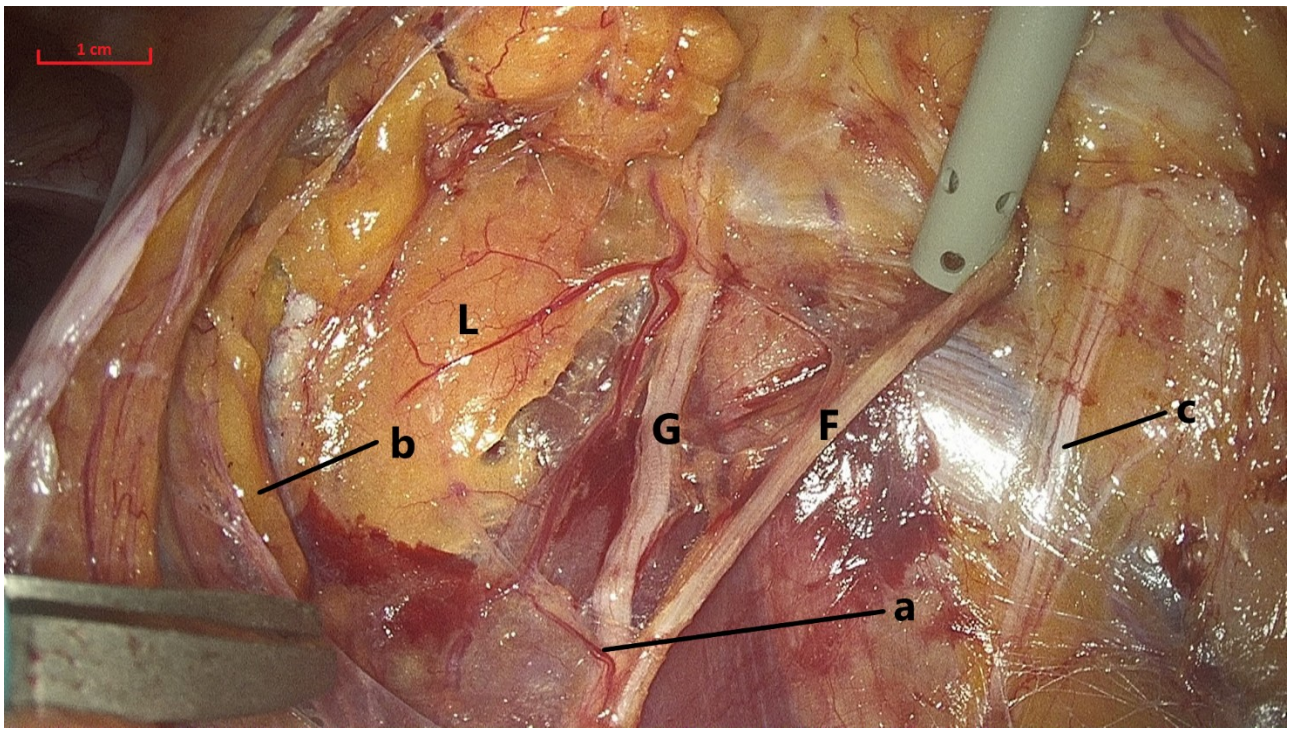

Figure 4. Right genitofemoral nerve (GFN) Sub-Type A; GFN branching occurs close to IIA bifurcation; a — branching point; b — IIA origin (lying under the lymph nodes); c — ; F — femoral branch; G — genital branch; L — external iliac lymph nodes.

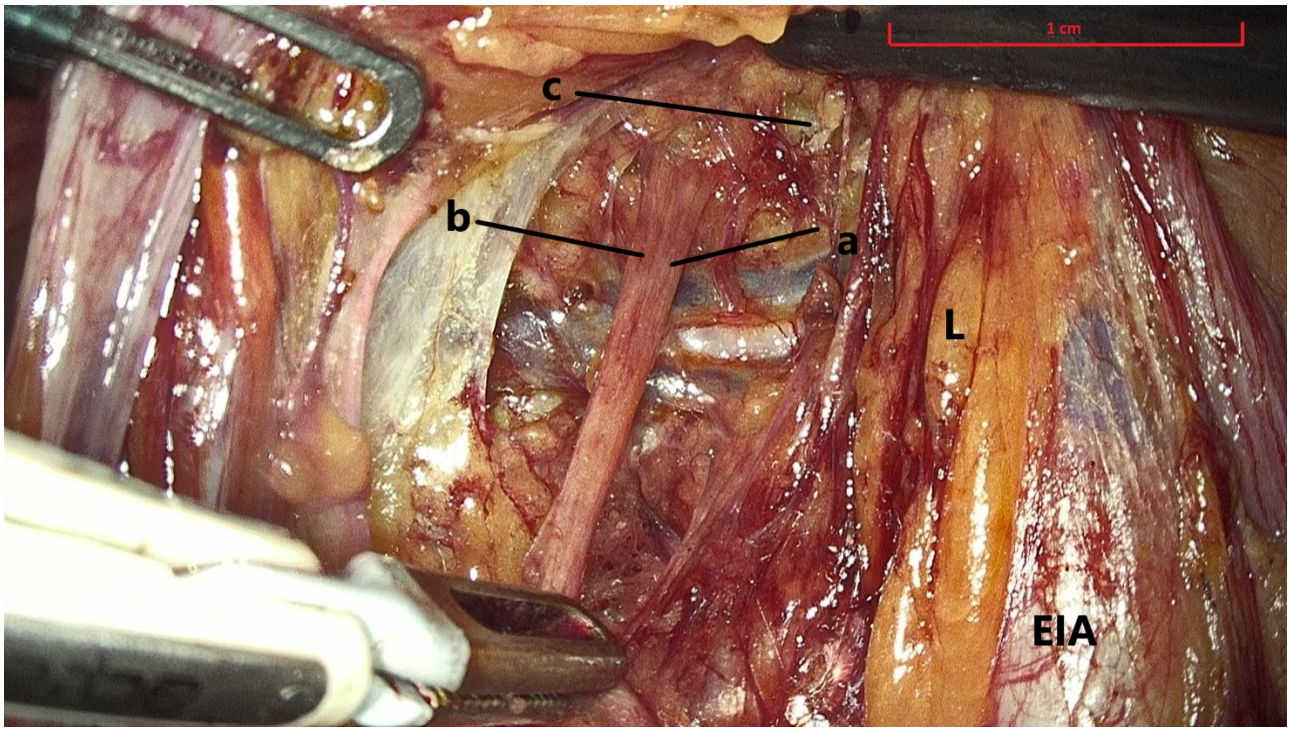

Figure 5. Sub-Type C; left genitofemoral nerve sub-type C runs across the external circumflex iliac artery and two veins; a — genital branch; b — femoral branch; c — femoral canal; EIA — external iliac artery; L — lymph nodes.

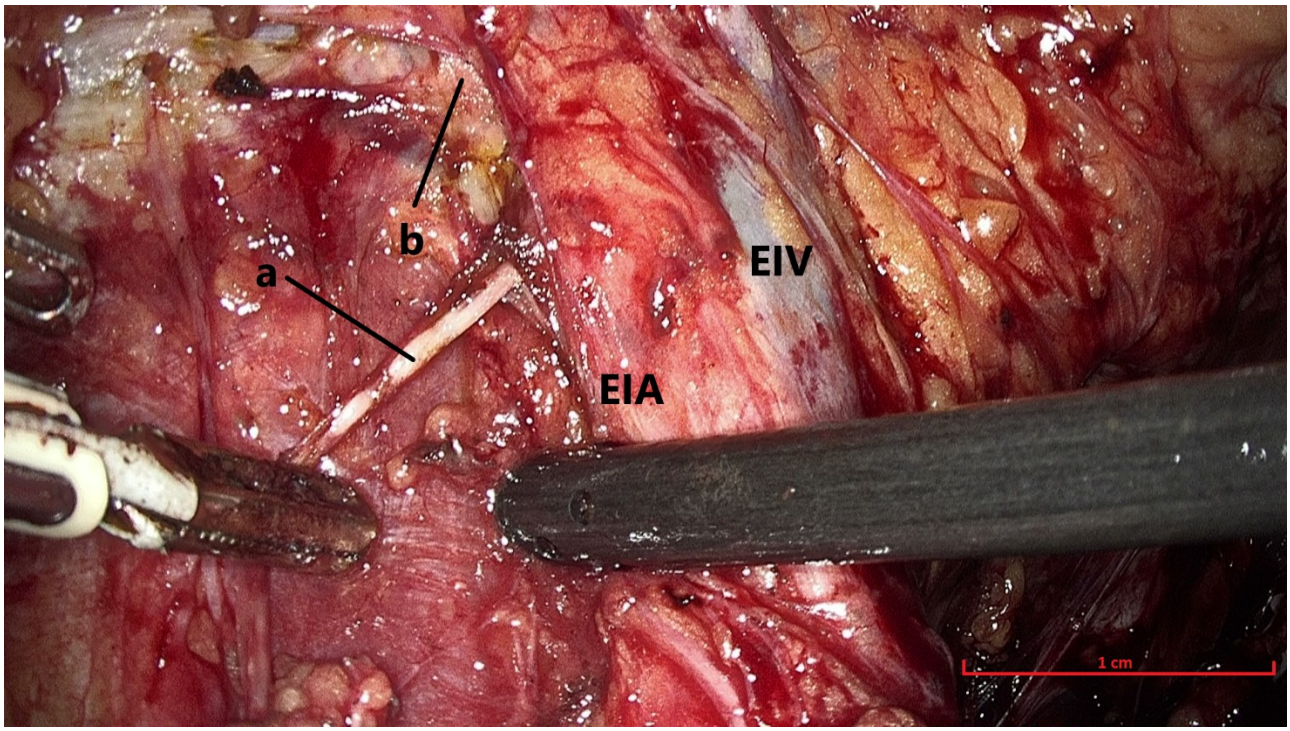

Figure 6. Left Type II — genitofemoral nerve (GFN) lies stuck to external iliac artery (EIA) at the femoral canal entry point; a — GFN; b — femoral canal; EIV — external iliac vein.

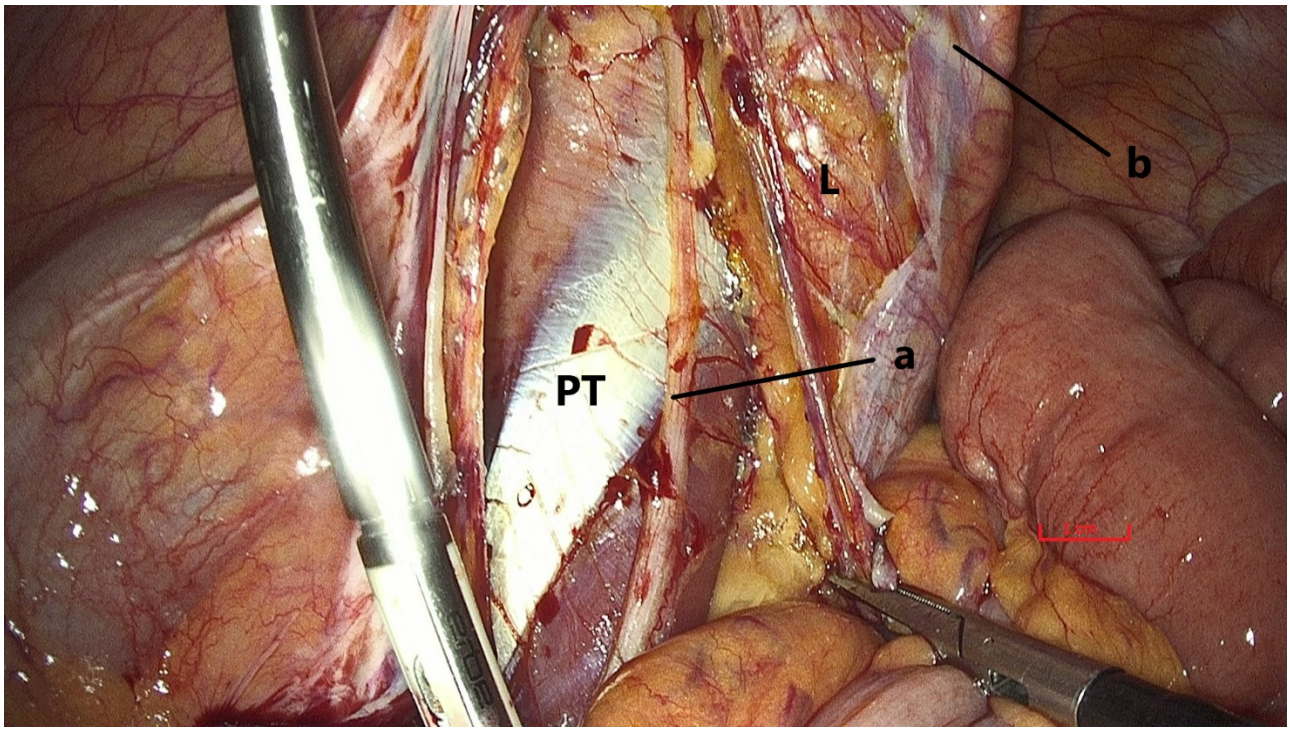

Figure 7. Left genitofemoral nerve Type II; a — GFN; b — *vas deferens*; L — lymph nodes; PT — psoas major tendon.