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ORIGINAL ARTICLE

Relationships between pelvic nerves and levator ani muscle for posterior sacrocolpopexy: an anatomic study

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Abstract

Background The placement of posterior mesh during pelvic organ prolapse laparoscopic surgery has been incriminated as responsible for postoperative adverse outcomes such as digestive symptoms, chronic pelvic pain, and sexual dysfunction. These complications may be related to neural injuries that occur during the fixation of the posterior mesh on the levator ani muscle.

Objectives The aim of our study was to describe the course of the autonomic nerves of the pararectal space and their anatomical relationship with the posterior mesh fixation zone on the levator ani muscle.

Study design Twenty hemi-pelvis specimens from 10 fresh female cadavers were dissected. We measured the distance between the posterior mesh fixation zone on the levator ani, and the nearest point of adjacent structures: the hypogastric nerve, inferior hypogastric plexus, uterosacral ligament, uterine artery, and ureter. Measurements were repeated starting from the inferior hypogastric plexus.

Results Nerve fibers of the inferior hypogastric plexus spread out systematically above the superior aspect of the levator ani muscle. Median distance from the posterior mesh fixation zone and the inferior hypogastric plexus was around 2.8 (range 2.1–3.5) cm.

Conclusions The inferior hypogastric plexus lies above the superior aspect of the levator ani muscle. A short distance between the posterior mesh fixation zone on the levator ani muscle and inferior hypogastric plexus could explain in part postoperative digestive symptoms. These observations support the development of nerve-sparing procedures for posterior mesh placement in the context of pelvic organ prolapse repair and suggest that postoperative complications could be improved by changing the fixation zone.

Keywords Inferior hypogastric plexus · Levator ani muscle · Mesh · Pararectal fossa · Pelvic organ prolapse · Laparoscopy · Sacrocolpopexy

Introduction

The prevalence of pelvic organ prolapse (POP) varies between 2.9 and 11.4% in the overall population by questionnaire evaluation, but is systematically above 30% in clinical situations using a POP quantification system: the POP-Q Classification [28]. Cumulative incidence of POP surgery of women after 70 years old can reach 11% [41].

Laparoscopic sacrocolpopexy has all the advantages of a minimally invasive approach in the field of POP management, and has become the gold standard for treatment [1, 6, 24]. In the case of a small posterior vaginal prolapse (rectocele), a posterior mesh, which is usually fixed on the levator ani muscle, may be indicated [24]. However, the following postoperative complications have been described: chronic pelvic pain, sexual dysfunction, and functional genito-urinary symptoms [6, 10]. These may be related to neural injuries that occur either during dissection of the pararectal space or during the fixation of the posterior mesh on the levator ani muscle.

While the anatomy of the pathway of the autonomic pelvic nerves within the pararectal fossa is well characterized [4, 15, 29], the exact relation between these nerves and the posterior mesh fixation zone on the levator ani muscle has

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been less well described in the literature. A better knowledge of this relationship could decrease postoperative adverse outcomes after sacrocolpopexy and therefore be of benefit to the patient. The aim of this study was to describe the anatomic relationship of the pelvic nerves with the posterior mesh fixation zone on the levator ani muscle.

Materials and methods

Twenty hemi-pelvis specimens from 10 fresh female cadavers were dissected at the School of Surgery (Ecole du Fer à Moulin, Paris, France) between March 2019 and June 2019.

The study complied with all French regulations on cadaver studies that authorize epidemiological surveys. Furthermore, it was exempt from the French law pertaining to biomedical research (Huriet-Serusclat Law, 20 December 1998, Jardé Law 16 November 2016) as no additional interventions were required. The local scientific committee of surgery ensured that written consent for body donation had been obtained and filed prior to death for each of the anatomic subjects.

All abbreviations are reported in Appendix Table 1. Practice dissections were performed by three gynecologists MD, PhD, (GC, HA and KNT) with residents (GR, AF), so that all the authors understood the anatomic structures and relationships to be examined and agreed on the measurements that would be taken.

The dissection protocol was as follow, after transecting the cadavers in the midsagittal plane:

- Removal of the abdominal wall, as well as the lower abdominal- and pelvic-parietal peritoneum
- Exposure of the superior hypogastric plexus (SHP) and the hypogastric nerves (HN). The retroperitoneal areolar connective tissue was gently dissected in a cranio-caudal way, starting from the origin of the inferior mesenteric artery where the aortic sympathetic fibers fuse. The origin, appearance (plexiform vs single nerve), position relative to the midline, length, and width of the SHP were recorded.
- Dissection of the presacral space to trace the HN through the pararectal space was followed by bilateral ureterolysis to define the medial pararectal space (Okabayashi's space) and the lateral pararectal space (Latzko's space) [17].
- The pubocervical fascia/anterior vaginal wall, rectovaginal fascia/posterior vaginal wall were identified as well as the pelvic parietal fascia covering the levator ani muscle.
- The course of the HNs was followed and their relationship to the rectum, uterus, and utero-sacral ligament (USL) were documented.
- The course of the uterine, vaginal, and middle rectal arteries (when observed) was followed and their position relative to the pelvic splanchnic nerves (PSN) or other components of the IHP was recorded.
- The connective tissue bundles, where the HN and the PSN converged within the paracervix below the cross of the uterine artery and ureter, were identified and labeled to be the IHP. The morphologic variations and positions of the IHP relative to the pelvic viscera, ligaments, and vessels were annotated.
- After opening the recto-vaginal space and deporting the dissection laterally into the pararectal fossa, the area above the superior face of the levator ani muscle was dissected.

During the sacrocolpopexy procedure the posterior mesh is fixed to the levator ani muscle laterally to the rectum. After a standardized dissection, simulating the placement of a posterior mesh, we defined the "posterior mesh fixation zone" within the levator ani muscle, which was delimited by the rectum medially, the piriform muscle laterally, the parametrium and paracervix anteriorly, and the middle rectal artery posteriorly [23, 26, 30].

All the following measurements (millimeters) were taken twice by the same examiner who used the same steel ruler:

(1) Distance between "posterior mesh fixation zone" and the nearest point of adjacent structures:
- the HN,
- the IHP,
- the USL (middle part),
- the uterine artery,
- the ureter,

(2) Distance between the IHP and the nearest point of adjacent structures:
- the USL (middle part)
- the uterine artery,
- the ureter,

The measurements were tabulated. Descriptive statistics (median and interquartile ranges) were proceeded with the use of Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA).

Results

The 10 subjects were European, and none had a history of altering pelvic anatomy disease or pelvic surgery.

The median age was 79.5 (range 65.2–93.8) years old. Parity and body mass index were not known.

Inferior hypogastric plexus (IHP) description

In all the specimens, the IHP was formed by the SHP via the HN and by the PSN coming from sacral nerves (Figs. 1, 2). From the distal part of the USL, the distal portion of the HN spreads out into a sheet of tissue containing thin nerve fibers. These fibers then embed in loose connective tissue.

After opening the rectovaginal space area, the HN was found lying on the levator ani muscle in all the specimens, easily separated from the rectum (Fig. 3). Therefore, this nerve fiber network always covers the posterior mesh fixation zone on the levator ani muscle (Fig. 2).

From the IHP, the nerve branches course toward the posterior and lateral walls of the bladder and were always found deep below the ureter.

Anatomic findings relative to the IHP and the "posterior mesh fixation zone" are presented in Table 1. The median distance between the mesh fixation zone on the levator ani muscle and the IHP above was 2.8 (range 2.1–3.5) cm (Fig. 4). The distal part of the IHP was at 2.6 (range 1.6–3.6) cm from the middle part of the USL, 3.3 (range 2.3–4.2) cm from the uterine artery, and 3.4 (range 2.2–4.5) cm from the ureter (measurement took place at the ureter crossing).

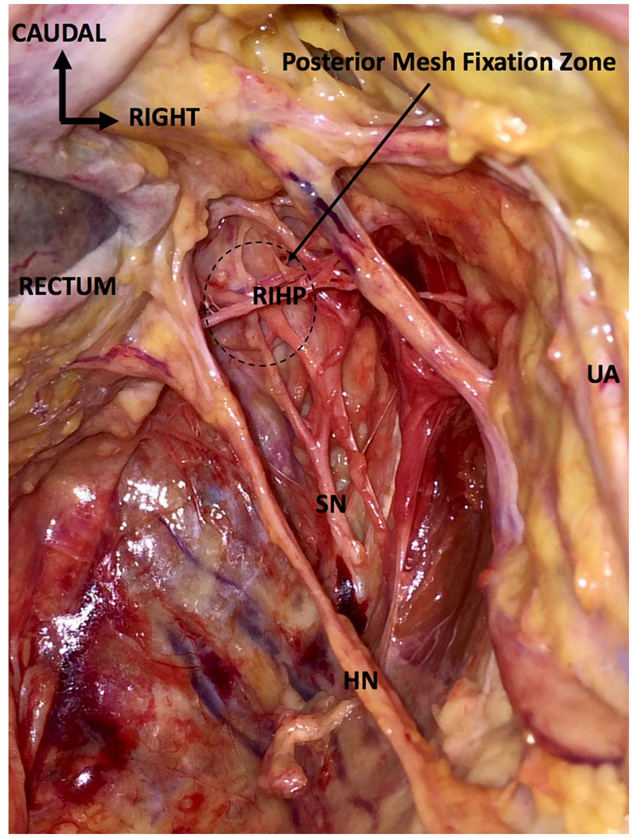

Fig. 2 Right pararectal fossa. Sacral afferences to the inferior hypogastric plexus are shown with the splanchnic nerve (SN). *UA* uterine artery, *RIHP* right inferior hypogastric plexus, *SN* splanchnic nerve, *HN* hypogastric nerve

Hypogastric nerves (HN) description

A right and left HN were identified in all cases. In all specimens, the HN began below the sacral promontory

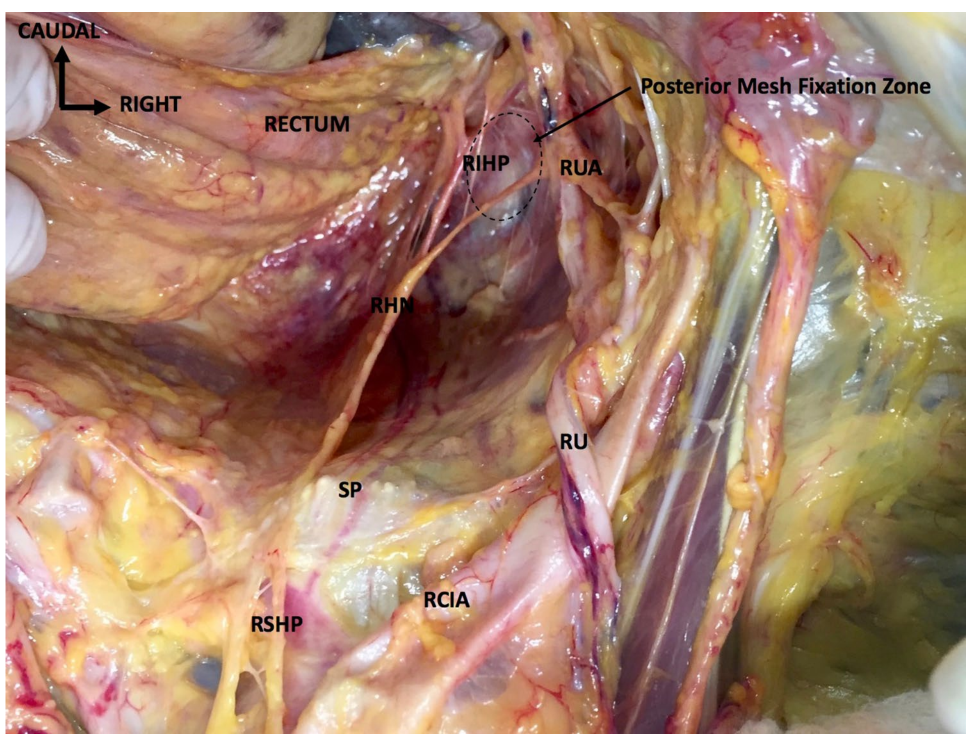

Fig. 1 Dissected presacral space shows the retroperitoneal structure's relationships. *RUA* right uterine artery, *RIHP* right inferior hypogastric plexus, *RHN* right hypogastric nerve, *RSHP* right superior hypogastric plexus, *RCIA* right common iliac artery, *RU* right ureter, *SP* sacral promontory

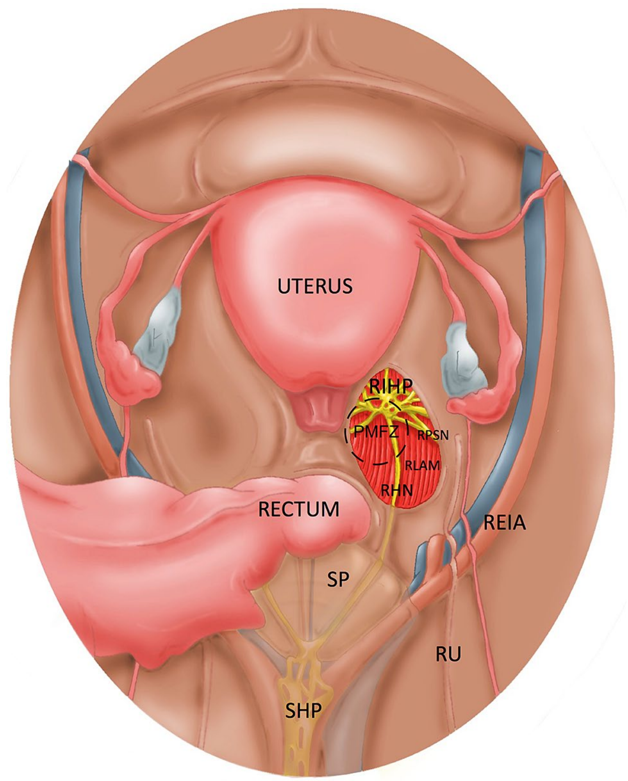

Fig. 3 Laparoscopic view of the pararectal fossa, posterior mesh fixation zone. *RUA* right uterine artery, *RIHP* right inferior hypogastric plexus, *RHN* right hypogastric nerve, *RLAM* right levator ani muscle, *SHP* superior hypogastric plexus, *REIA* right extern iliac artery, *RU* right ureter, *RUSL*, right utero-sacral ligament, *SP*, sacral promontory, *RPSN* right pelvic splanchnic nerve, *PMFZ* posterior mesh fixation zone

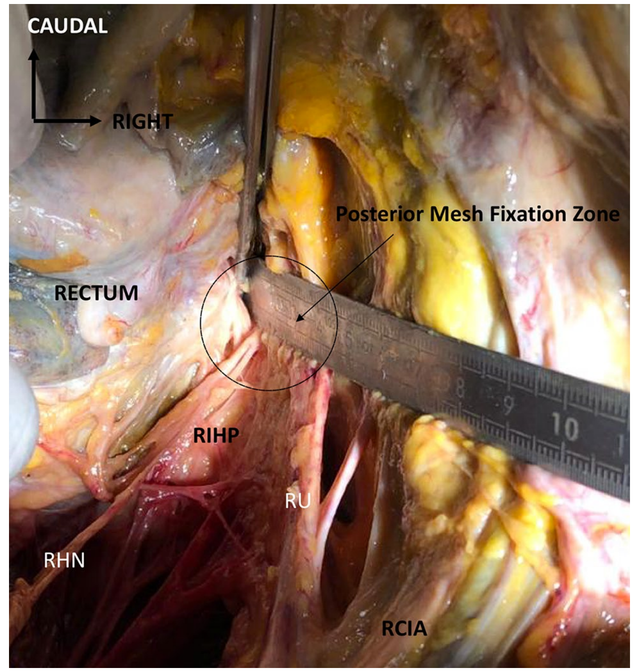

Fig. 4 Measurement of the distance between the mesh fixation zone and the inferior hypogastric plexus. *RCIA* right common iliac artery, *RHN* right hypogastric nerve, *RIHP* right inferior hypogastric plexus, *RU* right ureter

(Figs. 1, 2, 3) and was located in the tissue lateral to the rectum, which forms the medial wall of the pararectal space. These nerves course inferiorly and laterally within the presacral space toward the sides of the upper rectum. Communicating fibers between the right and left HN were sometimes found. The mean distance from the posterior mesh fixation zone on the levator ani muscle and the HN was 4.8 (range 3.8–5.8) cm.

Superior hypogastric plexus (SHP) description

In all the specimens, the SHP was embedded in a layer of connective tissue within the presacral space, just below the peritoneum. It was arranged into a plexus configuration in all cases and was predominantly located in the midline in front of the aortic bifurcation.

Discussion

The present study shows that the nerve fiber network constituting the IHP is systematically located above the levator ani muscle and they covers entirely the posterior mesh fixation zone on the levator ani. The median distance between the mesh fixation zone on the levator ani muscle and IHP above was 2.8 (range 2.1–3.5) cm.

Sacrocolpopexy is the surgical gold standard treatment for functional symptoms to improve quality of life. However, de novo post-operative functional sequelae can occur. We hypothesize than the proximity between pelvic nerves and levator ani muscle could explain these symptoms. Relationship between pelvic nerves and mesh fixation zone of the levator ani muscle during sacrocolpopexy in the pararectal fossa are rarely described. We realize dissection of anatomical subject in a view to precisely identify all fine pelvic nerves and the levator ani muscle. This is to our knowledge the first measurements taken between these two areas.

Bowel dysfunction after sacrocolpopexy has been poorly investigated with the use of non-validated questionnaires, without preoperative data. Main symptoms described are constipation, ODS and dyschezia. Coma et al. made a review that the rate of post-operative bowel dysfunction varied from 1.7 to 65.7% when posterior mesh was placed on the levator ani muscle[12]. Moreover, it has often been evaluated and sometimes even in the presence of concomitant confounding procedures. We reviewed the current literature on LSP, pooling studies that accurately reported functional outcomes, procedural steps, associated procedures, mesh types and placement, to accurately quantify this issue.

In the present study, we show that pelvic nerves are lying on levator ani muscle with a distance of 2.8 cm in surgery. These findings are in accordance with previous anatomic results. In deed Nyangoh Timoh et al. described an innervation situated below the levator ani muscle that they called supra-levator innervation pathway for the levator ani muscle via somatic nerves from the levator ani nerves and via the autonomic nerves from the IHP [34]. Furthermore, neurophysiological studies on POP and childbirth suggest that IHP lesions may be involved in pelvic functional symptoms [2, 14, 32]. According to our results, despite a good surgical technique during posterior sacrocolpopexy, approaching the levator ani muscle is at high risk of damaging these nerves which cross the region, and which are often too fine to be seen. It is important to note that the risk of nerve injury is more related to the position of the IHPs or somatic nerves covering the posterior mesh fixation zone on the levator ani, than to the proximity of the IHP to the fixation zone. Indeed, a distance of 2.8 cm in surgery, especially urogynecologic techniques, should not be considered as close proximity.

Interestingly, in our study, we found consistency in the anatomic location of the pelvic autonomic plexus, and branches of the IHP, despite variations in the vascular anatomy. The role and anatomical relationships of IHP with pelvic structures have been successively described in clinical anatomy [19, 25, 40]. The anterior portion of the IHP supplies innervation for the urogenital organs of the pelvic anterior compartment and the posterior portion supplies the rectum [3].

We can't exclude those functional sequelae could be secondary to muscular lesions of the levator ani muscle. In deed the levator ani muscle plays a role in urinary and digestive functions[13]. Complications occurring during dissection and the attachment of the mesh may also be related to the greater proximity of other structures (vessels, nerves, and ureters) according to other cadaveric studies [18, 22].

Knowledge of these risks of nerve injury supports the need to develop alternative techniques for the fixation of posterior meshes. One such alternative consists of fixing the mesh on the posterior vaginal surface with or without hysterectomy [21, 31]. This procedure may reduce disruption of the pelvic autonomic plexus, but not avoid it completely as autonomic fibers have been found within the USL coursing as neurovascular bundles on the posterior wall of the vagina [7, 8, 11, 36, 42]. According to Ercoli et al., rectovaginal space dissection could be at high risk of causing lesions of the rectal branches of the IHP [15]. Promising results have been found with this procedure and no post-operative digestive symptoms or recurrence of POP have been reported yet [21]. However, to date there is no randomized study showing any benefit for one special fixation technique over the other. Additionally, nerve preserving technics during sacrocolpopexy has been developed and seems to reduce post-operative bowel dysfunctions[12]. It is important to note that pelvic dysfunction described after sacrocolpopexy could also be explained by other mechanisms. First, the changed angulation and suspension of the rectosigmoid induced by mesh fixation may lead to de novo digestive symptoms. Secondly, exposure of the anterior surface of first sacral vertebra for mesh fixation may lead to injury of portions of the SHP, or of the right HN that is usually 1 cm from the median line on the promontory [20, 37].

The question of the placement of the posterior mesh is open to avoid post-operative symptoms for women suffering only anterior prolapse. Few data exist for abdominal sacrocolpopexy to recommend systematic double posterior placement at the same time.

In contrast to pelvic oncologic surgery (cervical cancer in particular) or endometriosis surgery, the para rectal space approach during sacrocolpopexy must be minimal in terms of exposure of nervous and arterial structures, with a small blunt pararectal dissection down to the levator ani muscle. Several authors have also described dissection techniques that can limit the risk of nerve or vascular damage. Shaub et al. [38] described a blunt dissection approach during laparoscopic sacrocolpopexy procedure, where the middle rectal vessels can be coagulated and cut, if needed, without increasing the risk of digestive disorders. Li L et al. [27] described in 2019 significative lower percentage of neural tissues of the IHP in nerve-sparing radical hysterectomy tissues, when the waterjet dissection technique was applied (vs. blunt dissection). This technique is known to reduce urodynamic complications. Nerve sparring colorectal cancer surgery refers regularly to the “holyplane” described by Heald [16] to preserve the autonomic pelvic nerves that comprise the SHP, HN and IHP. As this dissection plane is posterior to the rectum, the contribution for the procedure is moderate. Recently, robotic assisted laparoscopic procedures with 3D visualization have been developed to enhance the precision of the surgical gesture, and this positively contribute to identifying and sparing pelvic nerves [9, 33, 35]. But here again, no functional benefit of robotic-assisted POP surgery over a laparoscopic or open approach was demonstrated. Similarly, while augmented reality-assisted surgery is expected to be the next phase of surgical precision, it has not shown any clinical benefit to date [5, 39].

Some limitations of the present study deserve to be underlined. First, we did not know the parity or the prolapse history of the subjects and both components could be responsible for modifications of the nervous anatomy and its relationship with adjacent structures. This remains a common limitation of cadaveric studies. The second limitation comes from the surgical approach of the mesh fixation zone on the levator ani muscle: the dissections were performed in open surgery, while most sacrocolpopexies are now performed with a minimally invasive approach [1, 6, 24]. The open approach allowed us to have a better overview of the studied nervous system, but made us lose the quality of vision that a laparoscopic approach can provide. In laparoscopic posterior mesh fixation, the surgeon dissects a very small space almost bluntly to reach the puborectalis muscle, staying anteriorly to the middle rectal vessels and after having exposed the posterior vaginal wall. The laparoscopic dissection technique is completely different from the dissection technique of the cadavers, which is rather the oncologic way to reach the same space. Third, the potential damage of fine nerve fibers embedded in dense connective tissue during dissection, including the peritoneum of the pararectal fossa, was not evaluable. Nevertheless, the dissections were performed by senior surgeons with expertise in both nerve sparing techniques and in cadaveric dissections. Fourth, because of the peritoneal incision, which is extended inferiorly toward the posterior cul-de-sac and over the right USL, fibers of the IHP may be interrupted.

Conclusions

The IHP lies systematically above the levator ani muscle, and notably above the posterior mesh fixation zone. This promotes risk of injury during pararectal space dissection and the fixation of the mesh on the levator ani muscle and could explain in part the post-operative digestive symptoms observed after posterior sacrocolpopexy. Nerve-sparing procedures should be developed for posterior sacrocolpopexy as in pelvic oncology surgery and for the management of deep infiltrating endometriosis. Clinical studies are required to evaluate the patient benefit of such adjustments to the current technique.

Appendix

See Table 1.

Table 1 Distance between posterior mesh fixation zone, inferior hypogastric plexus and key anatomic structures

Measures from the posterior mesh fixation zone. Median, cm (inter-quartile ranges)	
To the hypogastric nerves	4.8 (3.8–5.8)
To the inferior hypogastric plexus	2.8 (2.1–3.5)
To the utero- sacral ligament (middle part)	4.3 (3.2–5.3)
To the uterine artery	5.2 (4.2–6.2)
To the ureter	5.2 (4.1–6.2)
Measures from inferior hypogastric plexus IHP. Median, cm (ranges)	
To the utero-sacral ligament (middle part)	2.6 (1.6–3.6)
To the uterine artery	3.3 (2.3–4.2)
To the ureter	3.4 (2.2–4.5)

For each parameter, 20 measurements were taken (20 hemi-pelvis specimens from 10 fresh female cadavers were dissected).

Author contributions Manuscript writing: RG, CG. Revisions: AH, UC, CM, MG, LV, MX, NTK, CG. Dissections work: RG, AH, FA, TK, CG. Figure 3: CM. All authors read and approved the final manuscript.

Declarations

Conflict of interests Pr Geoffroy Canlorbe, Pr Vincent Lavoué and Dr Gaby Moawad: Proctor for Intuitive Surgical.

Condensation We studied relationships between the inferior hypogastric plexus and the mesh fixation zone on the Levator ani muscle used for posterior sacrocolpopexy.

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