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Deep infiltrating endometriosis with sacral plexus involvement: improving knowledge
through human cadaver dissection

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Running title: deep infiltrating endometriosis anatomy

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Keywords: human cadaver dissection; deep infiltrating endometriosis; sacral roots; sciatic nerve.

Synopsis: A human cadaver model is a suitable means of improving a physician's level knowledge about this rare, complex type of deep infiltrating endometriosis.

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ABSTRACT

Introduction: The aim of this study was to assess a human cadaver model of sacral plexus dissection for learning about deep innervation in the female pelvis, and the latter's relationship with deep infiltrating endometriosis.

Methods: This was a prospective, observational study. Eight residents in obstetrics and gynecology were tested before and after a lecture on innervation of the female pelvis and a cadaver dissection class. Standardized cadaver dissection was used to identify the sacral nerve roots S2 to S4, superior and inferior hypogastric plexuses, hypogastric nerve, and splanchnic nerves.

Results: The residents' level of knowledge improved significantly after a one-hour lecture ($p=0.9 \cdot 10^{-5}$) and after a cadaver dissection class ($p=0.6 \cdot 10^{-6}$). The improvement was significantly greater for the dissection class ($p=0.0003$). All the pelvic nerve structures were identified in all but one of the cadavers and had similar measurements. A vascular anatomical variant was observed in one case.

Conclusion: A human cadaver model is of value for learning about deep pelvic innervation and the latter's relationship with deep infiltrating endometriosis. The reproducibility and safety of cadaver dissection might improve surgical skills.

Introduction

Although endometriosis is a concern for around 10% of women of childbearing age, deep infiltrating endometriosis (DIE) with sacral plexus involvement is rare [1–3]. The sacral plexus involvement results from the extension of endometriotic nodules deep into the retroperitoneal spaces, with entrapment of the sacral roots S2 to S4, the hypogastric nerve, the splanchnic nerves, and the inferior hypogastric plexus. In these specific locations, women can experience urinary symptoms (dysuria), bowel symptoms (constipation, dyschesia) and neurologic pain (sciatic nerve pain, pudendal nerve pain), for 51%, 45% and 71% of them [4]. Moreover, the surgical treatment of DIE with sacral plexus involvement can also be associated with a risk of nerve damage. Indeed, surgical injury to the sacral roots can lead to the sensory or motor impairments [5,6], and injury to the splanchnic nerves can result in the loss of urinary, defecatory or sexual function, as has been reported for radical surgery [7–9]. Hence the challenge of this surgery is to avoid worse or new symptoms, like for example self-urinary catheterization in the situation of a severe bladder atonia. In addition to these functional complications, dissection of the retroperitoneal spaces (in order to gain access to sacral roots) may result in vascular injury (especially for the internal iliac vein) and severe hemorrhage. Several studies have highlighted limitations in postgraduate surgeons' knowledge of surgical anatomy [10–12]. Gynecological surgeons are often unfamiliar with the anatomy of the pelvic nerves because the sacral roots are far from the surgical field in operations for benign gynecological diseases.

In view of (i) the rarity of DIE with sacral root involvement and (ii) the surgeons' lack of knowledge, we decided to assess these topics among residents in gynecology before and after a lecture and a cadaver dissection class.

The primary objective of the present study was to determine whether pelvic dissection of human cadavers improves a surgeon's level of knowledge about the deep pelvic anatomy and

about the functional relationship with nerve entrapment in DIE or nerve injury during surgery for DIE. The secondary objective was to describe the advantages and disadvantages of pelvic dissection in cadavers.

Materials and methods

We performed a prospective, observational study of participants in an anatomy course that included human cadaver dissection. The study participants were recruited from the pool of residents in the Department of Obstetrics and Gynecology at Amiens University Medical Center (Amiens, France) and gave their consent. The study procedure had been approved by the local investigational review board.

Eight junior residents (with less than four years of residency) agreed to participate in the study. Each course consisted of a one-hour lecture and a cadaver dissection class led by an expert in DIE, with assistance from a junior surgeon. The first part of the course consisted in a one-hour lecture, with a pre-test and post-test. The pre-test and post-test were respectively performed before the lecture and 1 week after the lecture. The tests assessed the candidate's knowledge of the disease and the related anatomical features. In each test, the study participant could score up to 16 points.

The second part of the course involved observing a human cadaver dissection focused on the pelvic nerves. The second post-test took place one week after the cadaver dissection class. Statistical analyses of continuous variables were performed using Student's t-test. The threshold for statistical significance was set to $p < 0.05$.

For the dissection procedure, four female cadavers (1 fresh non-preserved cadaver, and 3 embalmed cadavers; all Caucasian) were dissected in a university anatomy laboratory between January and June 2019. One cadaver had undergone a hysterectomy - probably via a

vaginal approach. None of the cadavers had laparotomic scars or pelvic endometriotic lesions. The senior surgeon and the junior surgeon on each cadaver performed measurements separately.

Dissection technique:

We dissected the cadavers by applying an open surgical technique for the treatment of DIE with sacral root involvement; a laparoscopic variant of the technique has been described previously [13–15] . Laparoscopic cadaver dissection was not technically feasible on our laboratory, so we applied an open approach with a cruciate incision. For each cadaver, only one hemipelvis was dissected. The same dissection steps were performed in all cases. All dissections were performed by a senior gynecological surgeon with expertise in DIE surgery (SS), and a resident in gynecology. Firstly, we inspected the pelvis and identified anatomic structures: the sacral promontory, the rectum, the uterus (which was then sutured attached to the anterior wall), and the uterosacral ligaments (USLs). Secondly, we opened up the retroperitoneal spaces in front of the sacral promontory, in order to identify the aortic bifurcation, the superior hypogastric plexus, the external and internal iliac vessels, the ureter, and the deep uterine vein and artery. Thirdly, we opened up the pararectal spaces: (i) Okabayashi's pararectal space between the ureter and the posterior layer of the broad ligament, and (ii) Latzko's pararectal space between the internal iliac vein and the ureter. Through these spaces, we identified the hypogastric nerve, the pelvic splanchnic nerves emerging from the sacral nerve roots S2 to S4, and the inferior hypogastric plexus. Lastly, the internal iliac vein was dissected medially from its origin, the parietal pelvic fascia was opened up, and the piriformis muscle and the sacral nerve root S1 were identified. Dissection was then performed caudally to successively reveal the sacral nerve roots S2 to S4, and the thin

nerve fibers leading to the pelvic splanchnic nerves that had been identified in the previous step (Figures 1, 2 and 3).

Any difficulties related to the dissection procedures or anatomical variants were fully documented. The duration of each dissection was noted. The following distances were measured by both the senior surgeon and the resident using a flexible ruler, and then averaged: the distance between the ureter and the hypogastric nerve, and the distances between the mid-portion of the USLs and the sacral nerve roots S2, S3 and S4, respectively.

Results

The test results are summarized in Table 1. Initial levels of knowledge about pelvic innervation and the impact of nerve damage in this region were low for all 8 students (mean (range) score in the pre-test: 2.5 (0-8)) but improved significantly after the lecture (mean score: 8.5, $p=0.9 \cdot 10^{-5}$ for pre- vs. post-) and after the dissection class (mean score: 14.25, $p=0.6 \cdot 10^{-6}$ for pre- vs. post-). The improvement was significantly greater for the dissection class ($p=0.0003$).

When considering the cadaver dissection, no technical difficulties were encountered in cases #1 and #3. In case #2, pelvic adhesions complicated the dissection. In case #4, a rectal fecaloma hindered correct exposure of the Douglas pouch and the USLs; the fecaloma was removed by transrectal incision and segmental resection.

We were able to dissect and identify the above-mentioned anatomic structures rapidly and unambiguously in three of the four cadavers. In case #3, a relevant anatomical variant was present: large inferior gluteal vessels were located in front of the sacral roots between S2 and S3 (Figure 4). These vessels were not observed in the other three cases.

The distances between the anatomic structures are given in Table 2. The median (range) dissection time was 145 min (130-180). There were no inter-observer differences in the

distances measured. The median (range) distance between the ureter and the hypogastric nerve was 2.25 cm (2 – 2.5). The median (range) distances between the mid-portion of the USLs and the sacral roots S2, S3 and S4 were respectively 5.5 cm (5.5 – 6), 5.0 cm (4.5 – 6), and 5.0 cm (4.5 – 6.5).

Discussion

A good understanding of pelvic anatomy is essential for gynecologic surgery and especially for difficult gynecologic surgery, such as the treatment of DIE with pelvic nerve involvement. A combination of risk factors in this kind of surgery can lead to irremediable functional consequences and (in the event of hemorrhage) severe complications. The first risk factor is the rarity of this pathology [1–3]. The second is the gynecologist's lack of knowledge of deep pelvic anatomy [10,12]. Our study confirmed this lack of knowledge in a selected population of residents in obstetrics and gynecology. Although practical anatomy can be learned in the operation room, the small number of cases and time and safety constraints during surgery prevent residents from learning properly about these topics.

Our results demonstrate that the human cadaver is a suitable model for teaching deep pelvic anatomy (and especially pelvic innervation) and the functional consequences in the event of injury. Furthermore, use of a cadaver model enables the surgeon to become familiar with vascular entrapments, anatomical variants, and the relationship between the pelvic nerves and surrounding anatomic structures.

Our results are in line with the literature data and also highlight the objectives of the French reform of the 3rd cycle of the medical studies in which surgical anatomical training is emphasized. It is well known that didactic session using cadaveric model after gaining surgical experience improves the anatomy comprehension and surgical skills [16]. For example, Corton et al. reported that cadaver dissection can increase the gynecologist's

proficiency in surgical anatomy [17]. In the UK, Barton et al. [11] developed a cadaver-based workshop and found that it improved the trainees' knowledge of pelvic anatomy. Improving the level of anatomical knowledge is one of the prerequisites for performing surgery – especially for difficult situations like DIE with plexus entrapment.

Three studies described a standardized laparoscopic approach for the treatment of DIE with sacral plexus entrapment [13–15]. In both cases, the researchers recommended that these cases should be managed in tertiary referral centers by skilled surgeons. Increasing the surgeon's level of skill in rare, complex procedures such as the surgical treatment of DIE requires a companionship approach, in line with Halstead's "see one, do one, teach one" principle [18].

Since the Renaissance, human cadavers have been used as models to teach anatomy to artists and physicians [19], and they are still used to teach medical students or residents. The main advantage of a cadaver training model for the identification of pelvic nerves and sacral roots is the high degree of reproducibility. Repetition of the multistep dissection makes it easier for the surgeon to understand anatomic features, and might improve his/her surgical skills [10,20]. Hence, cadaver dissection might reduce the operating time and increase the surgeon's level of confidence [20].

Our measurements of the main anatomical landmarks were similar for the four cadavers. Indeed, we found that the distance between the ureter and the hypogastric nerve and the distances between the sacral roots S2 to S4 and the ureter or the USLs were remarkably similar from one cadaver to another. Likewise, the anatomic locations of hypogastric nerve, splanchnic nerves and inferior hypogastric plexus did not differ from one cadaver to another.

Our present results show that these landmarks can be used during the surgery of deep pelvic spaces. Anatomical variants are nevertheless possible, and may particularly concern the deep pelvic vasculature. Overlooking these situations may lead to unexpected severe hemorrhages

and thus conversion to laparotomy. Awareness of anatomical variants may prepare the surgeon for unusual intraoperative findings that can complicate the surgical procedure in general and the dissection in particular.

Cadaver models nevertheless have a number of limitations. Firstly, the lack of intraoperative hemorrhages from hypogastric vessels and their branches means that young surgeons cannot learn to manage this severe complication. Secondly, female cadavers rarely present DIE, and the uterus and the adnexa tend to be atrophied in elderly cadavers. Thirdly, the open and laparoscopic approaches differ with regard to the angle of vision (influencing the view and the magnification) [21]. Fourthly, the surgical environment in the dissection of fresh or embalmed cadavers is very different from that encountered during laparoscopy in living patients. Fifthly, the dissection of only four cadavers in the present study limits the validity of our anatomic measurements. Lastly, cadaver dissection is expensive, and requires access to an anatomy laboratory and a sufficient supply of cadavers.

In order to reduce the cost of cadaver dissection (one of the main limitations of these training models), several in-house models of specific surgical techniques (such as inguinal hernia repair) have been developed [22]. It might well be possible to develop a similar model for the dissection of sacral roots. Recently, a French group developed a fresh cadaver perfusion/ventilation technique, which may mimic the *in vivo* environment [23]. As mentioned above, cost is not the only limitation of cadaver models; the variable availability of fresh cadavers, the time required to prepare the bodies, and the need for a cadaver-dedicated laparoscope are also problematic [23].

Lastly, the most modern approach to surgical training (three-dimensional laparoscopic computer simulators) is promising - particularly for younger surgeons [24,25]. However, simulators do not provide tactile feedback, and are still very expensive [25].

The present study presented several limitations. It will be necessary to confirm our results in a prospective study with a larger sample size of cadavers and participants. A larger cohort would allow for more robust statistical values.

Despite its limitations, a human cadaver model is useful for improving the level of knowledge of deep pelvic innervation and the functional consequences of injury to pelvic nerves - especially in cases of DIE with sacral plexus entrapment. Use of this model may also help to prepare surgeons for complex procedures, such as the surgical treatment of DIE with pelvic nerve and sacral plexus involvement. The reproducibility of cadaver dissection, the facilitated identification of anatomic landmarks, and the relatively invariant distances between anatomic landmarks can safely improve surgical skills and procedures.

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Table 1: pre- and post-test results

Participant	Pre-test	Post-test (after the lecture)	Post-test (after the cadaver dissection)
1	4	12	16
2	4	10	14
3	8	14	16
4	0	6	12
5	0	4	14
6	0	8	14
7	4	8	16
8	0	6	12
Mean	2.5	8.5	14.25

Table 2. Distances between pelvic anatomic structures, and the dissection time. (HN: hypogastric nerve, USLs: uterosacral ligaments)

	Case #1	Case #2	Case #3	Case #4	Median
Distance (cm)					
- Ureter to HN	2	2	2.5	2.5	2.25
- Mid-point of USLs to S2	5.5	6	5.5	-	5.67
- Mid-point of USLs to S3	5	6	4.5	-	5.17
- Mid-point of USLs to S4	5	6.5	4.5	-	5.33
Dissection time (min)	140	180	140	160	145

Figure 1. A fresh cadaver

OV: ovary; U: ureter; HN: hypogastric nerve; IHP: inferior hypogastric plexus; S2: sacral root 2; S3: sacral root 3; S4: sacral root 4

Figure 2. Exposure of the inferior hypogastric plexus

UT: uterus; OV: ovary; IHP: inferior hypogastric plexus; S3: sacral root 3

Figure 3. The pelvic vasculature and nerves

EIA: external iliac artery; IIA: internal iliac artery; IIV: internal iliac vein; U: ureter; UA: uterine artery; HN: hypogastric nerve; S2: sacral root 2; S3: sacral root 3; S4: sacral root 4

Figure 4. Inferior gluteal vessels crossing the sacral roots.

IGA: inferior gluteal artery; IGV: inferior gluteal vein; IIA: internal iliac vein; PM: piriformis muscle.

USL: utero-sacral ligament, S2: sacral root S2 S3: sacral root S3, S4: sacral root, S4 HN: hypogastric nerve.

Annexe

Test

Do you have knowledge about the possibility of sacral roots' entrapment by deep infiltrating endometriosis (DIE)?

- Yes = 1 point
- No = 0

How would you qualify your knowledge about female pelvic innervation?

- Very good = 3 points
- Good = 2 points
- Middle = 1 point
- Poor = 0

Cite anatomic areas where you find pelvic innervation?

- Sacral promontory = 1 point
- Para rectal fossa = 1 point
- Uterine parametria = 1 point
- Utero sacral ligaments = 1 point

What are the 2 main anatomical landmarks of the hypogastric nerve?

- External iliac vessels and ureter = 0
- Internal iliac vessels and ureter = 1 point
- Uterine artery and ureter = 0

The contributions of the inferior hypogastric plexus are:

- Hypogastric nerve + splanchnic nerves + sacral sympathetic nerves = 1 point
- Hypogastric nerve + superior hypogastric plexus = 0
- Superior hypogastric plexus + splanchnic nerves = 0
- Don't know = 0

From which sacral roots (S) are the origins of the splanchnic nerves and the sacral sympathetic nerves:

- S1 S2 S3=0
- S2 S3 S4=1
- S3 S4 S5=0
- Don't know =0

What are the consequences of inferior hypogastric plexus's injury or splanchnic nerves's injury?

- Motors defect =0
- Sensitive defects =0
- Sexual and urinary dysfunction =1 point
- Don't know =0

Do you know other kind of gynecologic surgery in which this pelvic innervation has its importance?

- Radical hysterectomy in cervical cancer = 1+1 points
- Promontofixation = 1 point

Have you ever heard about *nerve sparing*?

- Yes = 1 point
- No = 0

Score /16







