

Localisation of hypogastric nerves and pelvic plexus in relation to rectal cancer surgery

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SUMMARY

Urinary, bowel, and sexual dysfunction caused by iatrogenic lesions of the pelvic plexus remain a common complication of radical pelvic surgery. Preservation of these nerves during surgery is hampered by their poor visualisation within the pelvic cavity and their small size. Recently, increased awareness of the high incidence of post-operative autonomic dysfunction has led to the development of nerve-sparing surgical techniques. This study aims to expand our knowledge of the anatomy of the pelvic plexus, to contribute to further enhancement of nerve sparing surgical techniques. Dissections of the hypogastric nerves and pelvic plexuses were performed on 10 cadavers. We showed that nerves from the pelvic plexus that supply the rectum can be mobilised to a length of 10-15 mm and thus can be identified and safely divided, leaving the pelvic plexus intact following the extrafascial excision of the rectum. Likewise, the hypogastric nerves, which are enveloped in a layer of parietal fascia, also remain intact. The fascia containing the hypogastric nerves was separated from the fascia propria by a loose areolar layer. Pelvic plexuses measured about 30 by 30 mm in size. Radiological images showed the plexuses to be positioned about 5

mm below a line joining the upper surfaces of two acetabula. This study shows that extrafascial excision does not damage the hypogastric nerves or the pelvic plexuses and provides a way to radiologically assess the proximity of a tumour to the pelvic plexus. Such knowledge aids in preoperative planning to reduce the incidence of post-operative pelvic autonomic dysfunction.

Key words: Anatomy – Pelvic plexus – Colorectal surgery – Rectal neoplasms

INTRODUCTION

The importance of the hypogastric nerves and the pelvic plexuses has only become clear over the last few years, during which time many authors have reported a high incidence of urinary and sexual dysfunction following rectal excision (Balslev and Harling, 1983; Gerstenberg et al., 1980; Hjortrup et al., 1984; Hojo et al., 1989; Kinn and Ohman, 1986; La Monica et al., 1985; Neal et al., 1981; Santangelo et al., 1987; Williams and Slack, 1980). Lepor et al. (1985) identified the nerves responsible for potency and described their course in the pelvis based on serial giant sections of the pelvis of a cadaver. Other stud-

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ies of the pelvic nerves followed, leading to the development of several descriptions of surgical techniques aimed at preserving the nerves (Havenga et al., 1996; Heald, 1997; Maas et al., 1998; Moriya et al., 1995). Some studies involved microscopic dissection of foetal tissue where the nerves are thicker and are surrounded by a small amount of connective tissue (Fritsch, 1989). Baader and Herrmann (2003) investigated the pelvic autonomic nerves in adults and their implications in pelvic surgery. Despite advances in nerve-sparing surgery, the pelvic plexus remains liable to iatrogenic injury due to the small size of the individual nerve fibers, the depth and narrowness of the pelvis, which can hinder precise surgical access, and confusion relating to the anatomical description and surgical nomenclature of these structures. In addition, authors have often described the pelvic autonomic nerves as web-like in structure and as lying in different fascial planes. In particular, the relationship of the nerves to the fascia propria has profound implications in surgery for rectal cancer. Radiological identification of the position of the pelvic plexus would also allow preoperative assessment of tumour proximity to the plexuses, facilitating decision making and the planning of surgery.

The aims of this study are:

To confirm the integrity of the pelvic plexuses and hypogastric nerves after extrafascial excision (EFE) in rectal surgery

To identify the length and position of the nerves passing from the pelvic plexuses to the rectum during EFE

To identify the position of the pelvic plexuses in relation to a known radiological landmark

To clarify the site of the hypogastric nerves in the retrorectal fascial planes.

MATERIALS AND METHODS

Ethical approval for this study was granted by the Auckland Ethics Committee. The cadavers used in this study were bequeathed to the Department of Anatomy with Radiology under the terms of the New Zealand Human Tissue Act (1964) for teaching and research. Consent was obtained from the immediate relatives of the deceased. The present work conforms to the provision of the Declaration of Helsinki in 1995, as revised in Edinburgh 2000.

The study included 10 adult, unembalmed cadavers (9 male and 1 female) aged 52-85 years who required a post-mortem. Patients who had previously undergone pelvic surgery or who had been dead for more than 36 hours were excluded. The post-mortem was initially performed by the pathologist leaving the pelvic organs intact. Dissection of the pelvis was performed immediately following the pathologist's post-mortem examination. In addition, gross and microdissection using a surgical stereomicroscope was carried out on a further two formalin-preserved sagittally sectioned hemi- and whole male pelvises.

First, extrafascial dissection of the rectum was performed on all specimens. The dissection involved operating through the midline incision that had already been performed for the post-mortem. The dissection began at the aortic bifurcation and continued directly on the rectal fascia propria. The extrafascial dissection was continued up to the "lateral ligaments" of the rectum. In this study, the "lateral ligaments" refer to the condensation of endopelvic connective tissue encountered on the anterolateral aspect of the dissection in the extrafascial plane below the peritoneal reflection. They contain the autonomic nerves passing to the rectum from the pelvic plexuses (Rutegard et al., 1997).

Mobilization of the rectum anterior to these attachments was then carried out. The length of the nerves from their exit from the pelvic plexus on the parietal fascia to the point of their entry into the fascia propria after mobilization of the rectum was measured in millimeters using a calliper. The position of the uppermost nerve fibres in the "lateral ligament" was then determined in relation to the lateral peritoneal reflection, and a plane through the tip of the greater trochanter. The distance from the most superior nerve to the peritoneum on the lateral side of the rectum was measured in millimeters. The greater trochanter was then palpated through the skin on each side and a Kirschner wire inserted transversely immediately above it until the point was visible in the pelvic cavity. The distance in millimeters from the tip of the wire to the uppermost nerve of the "lateral ligament" was measured on each side.

Next, the pelvic plexuses were identified on the pelvic sidewall after extrafascial excision of the rectum. The vertical and horizontal dimensions of the plexuses were measured in millimeters with a calliper and recorded.

Radio-opaque skin staples were attached to the upper, lower, anterior and posterior borders of the pelvic plexuses. An AP X-ray of the pelvis was performed to demonstrate the position of the pelvic plexuses in the bony skeleton. The midpoints of the pelvic plexuses were plotted on the X-rays by finding the point of transection of lines drawn through the skin staples. A line was then drawn joining the upper surface of the acetabulum on both sides. The distance from the midpoint of the pelvic plexus to the upper acetabular line was then measured for each side on the X-ray films.

After removal of the rectum and measurement of the pelvic plexuses, the parietal fascia enveloping the superior hypogastric plexus immediately anterior to the aortic bifurcation was dissected off the underlying vessels. This dissection was continued down anterior to the sacrum and around to the lateral walls of the true pelvis. For each dissection the following details were recorded; the position of the hypogastric nerves and pelvic plexuses in relation to the parietal fascia dissected, the presence of a further layer of "presacral" fascia posterior to the dissected fascia, and the presence of any parietal fascia distal to the recto-sacral ligament. The data were then analyzed using mean and standard deviation for continuous, numerical measurements and percentages for the categorical descriptions of position.

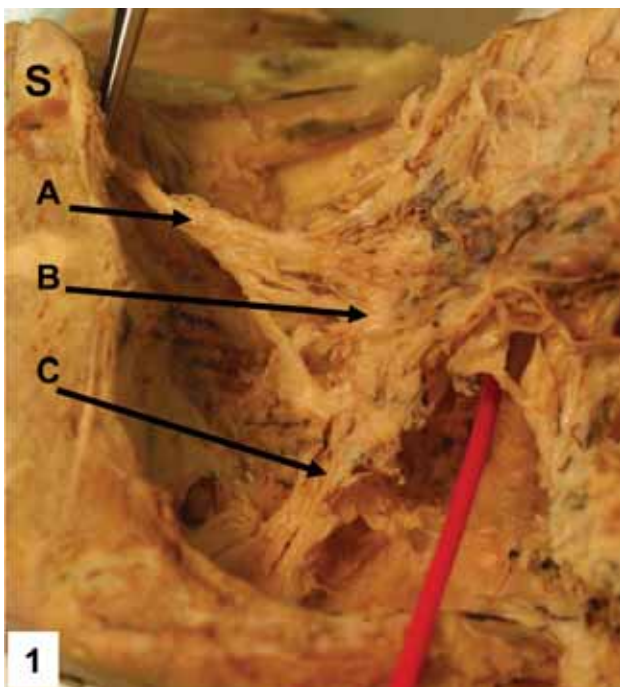


Fig. 1. Dissection of a male hemipelvis from the left side showing sagittally sectioned sacrum (S), left hypogastric nerve (A), fan-shaped pelvic plexus (inferior hypogastric plexus) or plate (B), and pelvic splanchnic nerve (C).

Dissection of the formalin-preserved male hemi-pelvis was commenced at the bifurcation of the common iliac vessels, where the hypogastric nerve was located descending in the retroperitoneal fascia. It was followed to its termination at the postero-superior surface of the pelvic plexus. A second contribution to the pelvic plexus was identified as pelvic splanchnic nerves contributing to the postero-inferior plexus. Further dissection of the formalin-preserved whole male pelvis involved cutting the pubic bones medial to the acetabula and removing the anterior border of the pelvic bowl. Following identification and gross dissection of the hypogastric nerves, the pelvic peritoneum was removed and the pelvic plexus microscopically dissected within the fascial plane.

RESULTS

Dissection study

In the formalin-preserved specimens, the pelvic plexus derived from hypogastric (sympathetic) and pelvic splanchnic (parasympathetic) sources, and was located deep to the peritoneal fold between the urinary bladder and rectum, immediately lateral to the pelvic organs. It comprised a web-like nerve plate, with numerous branches innervating the pelvic viscera (Figs. 1, 2, 3). The rectum was innervated by the posterior part of the pelvic plexus, with fibers travel-

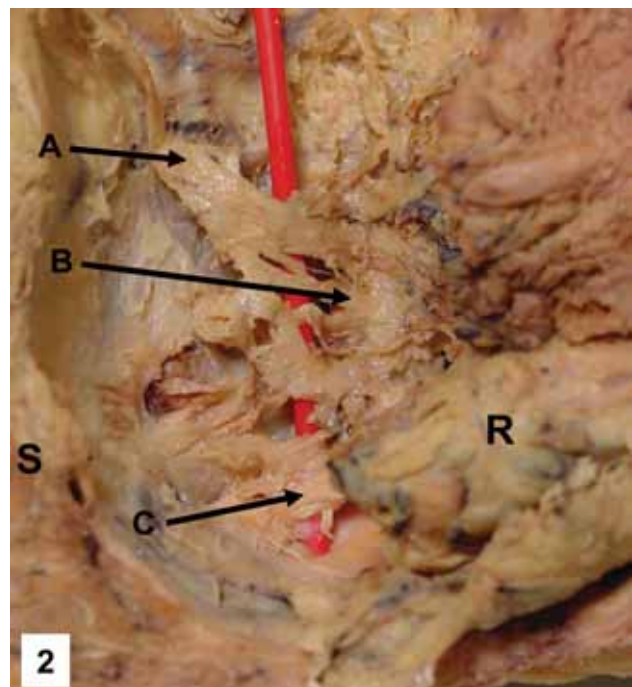


Fig. 2. Dissection of a male hemipelvis from the left side showing the left hypogastric nerve (A), the pelvic plexus (inferior hypogastric plexus) (B), pelvic splanchnic nerve (C), sacrum (S), and rectum (R). The pelvic plexus (inferior hypogastric plexus) is a web-like homogenous, flat, fibro-fatty nerve plate.

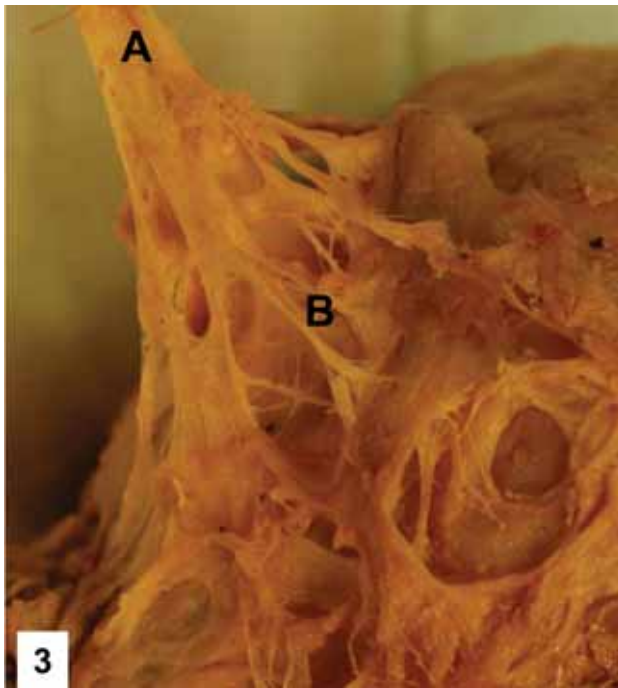


Fig. 3. Dissected specimen from a whole male pelvis showing the hypogastric nerve (A) terminating at the pelvic plexus (inferior hypogastric plexus) (B). The pelvic plexus is a web-like structure embedded in a fibro-fatty plate of tissue. This dissection demonstrates the detail of the intricate and complex spread of the pelvic plexus.

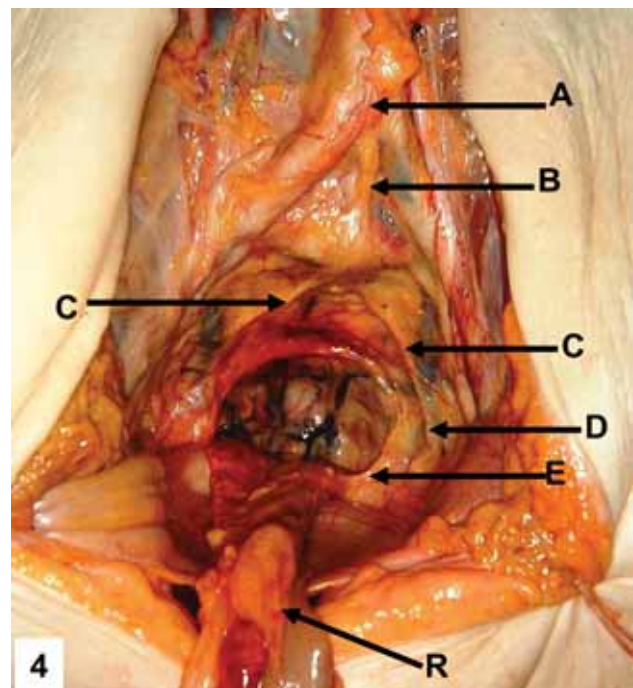


Fig. 4. Abdominopelvic dissection showing the bifurcation of the aorta (A), superior hypogastric plexus (B), right and left hypogastric nerves (C), left pelvic plexus (D), and left lateral ligament (E). Rectum and mesorectum (R) are retracted anteriorly (after extrafascial dissection).

ling in the “lateral ligaments” and thus innervating the rectum mostly from the lateral aspect (Figs. 2, 4). The bladder and the prostate gland were innervated from the anterior portion of pelvic plexus. No distinguishable sub-plexuses or ganglia within the pelvic plexus were observed during gross dissection (Fig. 3).

Nerve preservation

In all 10 subjects the right and left hypogastric nerves and pelvic plexuses remained preserved in the pelvis, embedded in a layer of the parietal fascia after EFE, as shown in Fig. 4.

The rectal branches of the pelvic plexus

The length and position of the nerves to the rectum from the pelvic plexus in relation to the peritoneum and the tip of the Kirschner wires (pins) after mobilisation of the rectum in the extrafascial plane are shown in Table 1.

The mean (\pm SD) of the lengths of the right and left nerves to the rectum from the pelvic plexuses were 13.7 (\pm 4.7) mm and 12.4 (\pm 4.0) mm respectively. The mean (\pm SD) of the distance from the lateral peritoneum to the uppermost nerves on the right and left was 18.7 (\pm 7.1) mm and 19.3 (\pm 5.1) mm respectively. In one patient it was not possible to

Table 1. Total data of each compartment for mitosis and apoptosis.

Age (yrs)	Sex	Right nerves			Left nerves		
		Length (mm)	distance below peritoneum	distance from pin (mm)	Length (mm)	distance below peritoneum	distance from pin (mm)
71	M	14	15	10	12	20	25
85	M	6	20	10	5	25	25
59	M	11	11	25	18	25	50
67	M	12	32		14	24	
78	M	11	25	31	10	23	29
64	F	15	25	41	8	14	41
80	M	24	10	40	13	16	36
74	M	12	20	40	13	16	28
52	M	16	12	29	13	10	37
58	M	16	17	20	18	20	34

insert the pins through the iliac bone above the greater trochanter because the bone was extremely dense and the pin was bent on attempted insertion. The mean (\pm SD) distances to the tip of the pin in the remaining 9 patients was 27.3 (\pm 12.1) mm and 38.9 (\pm 8.2) mm for the right and left nerves respectively. Although the pin was inserted immediately above the greater trochanter, the tip of the pin deviated markedly from the line joining the greater trochanter on each side and limited the use of this measurement in localising the rectal branches of the pelvic plexuses.

The pelvic plexuses

The size of the right and left pelvic plexuses measured in millimetres after excision of the rectum are shown in Table 2.

Table 2. Dimensions of the pelvic plexuses in mm.

Age	Sex	Right PP		Left PP	
		height	width	height	width
59	M	35	35	35	45
67	M	20	40	30	35
78	M	26	32	29	34
64	F	30	32	31	22
80	M	31	34	29	37
74	M	23	31	28	26
52	M	34	28	23	25
58	M	30	30	33	35

PP, pelvic plexus

In the 8 subjects in whom the pelvic plexuses were measured the vertical dimen-

sions, mean (\pm SD), were 28.6 (\pm 5.2) mm and 29.8 (\pm 3.6) mm and the horizontal dimensions were 32.8 (\pm 3.7) mm and 32.4 (\pm 7.6) mm for right and left sides respectively.

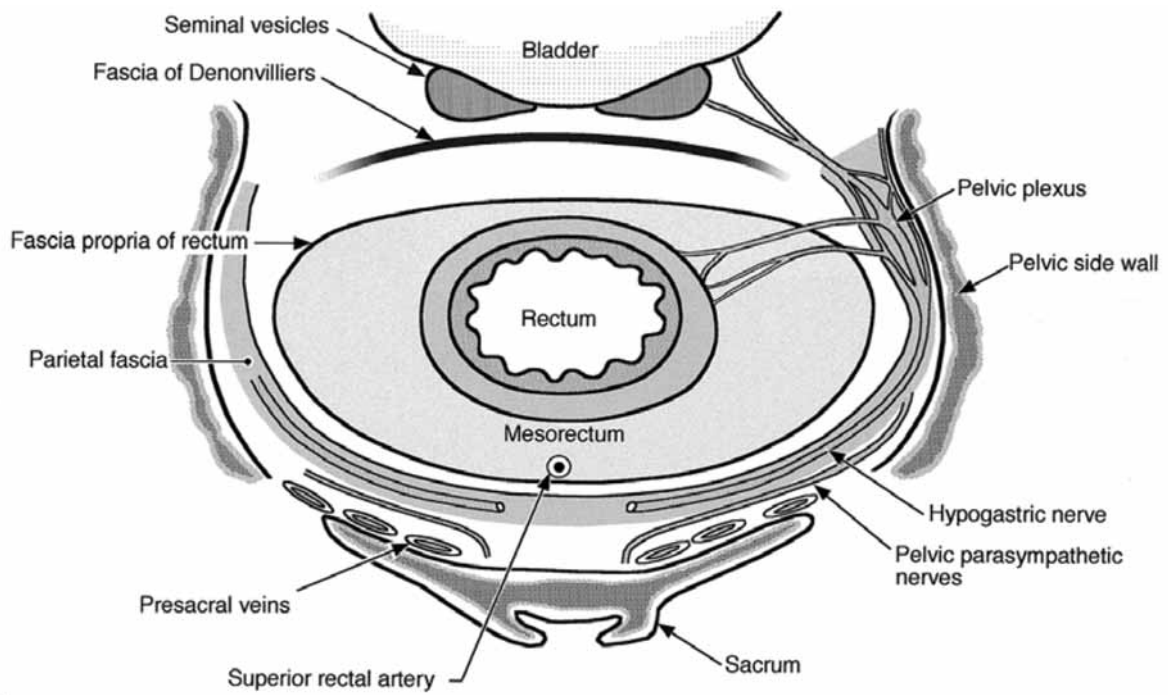
Figure 5 shows an X-ray of the pelvis of one of the patients with the pelvic plexus marked with staples. In the 7 patients in whom it was marked, the mean distance to midpoint of the pelvic plexus below a line drawn joining the superior border of the acetabulum on each side was 4.6 mm (SD 15.0 mm) and 6.4 mm (SD 12.1 mm) for the right and left side respectively.

The fascial planes

Dissection of the hypogastric nerves and pelvic plexuses was carried out in all 10 cadavers. The thin layer of fascia that covers the aortic bifurcation and common iliac vessels was found to hold both hypogastric nerves, which became more visible just inferior to the sacral promontory. Dissection followed the hypogastric nerves as they joined the pelvic plexuses. No distinct layers that could be distinguished during surgery were observed within the pelvic plexus and nor could any ganglia be seen. It was noted that the fascia containing the hypogastric nerve was the same layer of fascia that contained the pelvic plexus and from which the "lateral ligaments" were formed (Fig. 6). The recto-sacral ligament was inconsistent in appearance, sometimes form-



Fig. 5. Radiographic estimation of the position of the pelvic plexus in relation to the acetabulum. An AP radiograph of the pelvis showing the position of the staples marking the outline of the pelvic plexuses and the line joining the superior acetabular surfaces. A double headed arrow shows the distance between the center of the left plexus and this line.



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Fig. 6. Schematic representation of a transverse section through the male pelvis showing the relationship of the rectum to the surrounding fasciae, blood vessels and nerves (produced with the assistance of Mr A. Ellis, medical illustrator).

ing a thick layer of fascia and sometimes found in the form of multiple discrete connective tissue fibers covering a wide area.

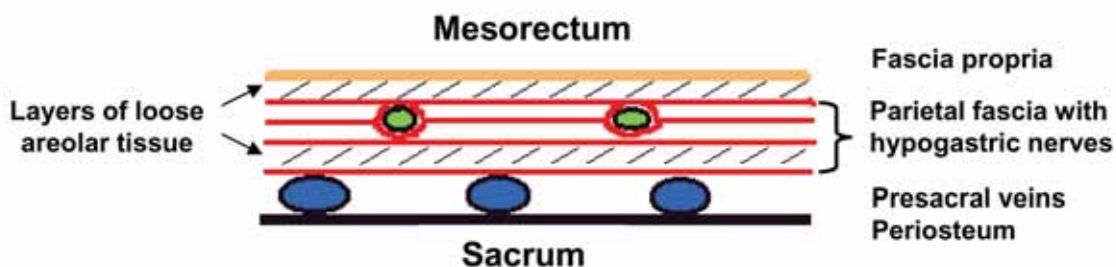
The parietal fascia was still present distal to the recto-sacral ligament after dissection of the rectum in the extrafascial plane in all 10 subjects but was noted to be very thin in one.

After dissection of the hypogastric nerves with their enclosing fascia off the underlying structures there was still discernible presacral fascia present posterior to the nerves in 7 of the 10 subjects, although in 2 of these it was very thin. The commonest arrangement of the fascial planes in the retrorectal area above the

recto-sacral attachment is shown diagrammatically in Fig. 7. (adapted from: Bissett and Hill, 2000) This arrangement was present in 7 of the 10 dissections. In the other 3 dissections the parietal fascia containing the hypogastric nerves lay immediately anterior to the presacral veins without a further layer of parietal fascia intervening between them.

DISCUSSION

This study has shown that following EFE the hypogastric nerves remain undisturbed in



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Fig. 7. The conceptualized arrangement of the fascial planes in the retrorectal area. The fascia propria is separated from the parietal fascia by a plane of loose areolar tissue. The parietal fascia contains several layers and encloses the hypogastric nerves. There is often a further loose areolar plane anterior to the hypogastric nerves and anterior to a further leaf of the parietal fascia. The pelvic splanchnic nerves are not shown in this figure.

the parietal fascia of the pelvis. The nerves from the pelvic plexus to the rectum can be mobilised to a length of 10-15 mm by dissecting in the extrafascial plane and they are found about 2 cm below the point where the peritoneum reflects lateral to the rectum. The pelvic plexuses are about 30 by 30 mm in size and are encountered in the parietal fascia, centred about 5 mm below a line joining the upper surface of the two acetabula. In the retrorectal area there is a loose areolar layer between the fascia propria and that layer of the parietal fascia containing the hypogastric nerves. In the majority of subjects there was a further loose areolar layer posterior to the hypogastric nerves within the parietal fascial layers.

The "lateral ligaments" of the rectum have recently been shown to be composed of the nerves running to the rectum from the pelvic plexus ensheathed in a loose bundle of collagen fibres (Rutegard et al., 1997). Sato and Sato (1991) included the whole of the pelvic plexus and the middle rectal vessels as part of the lateral ligaments, but other investigators (Boxal et al., 1963; Church et al., 1987) recognise the lateral ligament as lying medial to the pelvic plexus. No additional routes of innervation of the rectum were recorded in this study. Long and Bernstein (1959) reported that nerves from the pelvic plexus to the rectum follow the course of the middle rectal artery, whereas Fritsch (1989) reported a direct innervation from an anterolateral direction, presumably via lateral ligaments. The observations of Baader and Herrmanns (2003) support both of these pathways. The surgical importance of the lateral ligaments relates to the fact that medial traction on the rectum can "tent" the pelvic plexus and allow it to be damaged during rectal excision (Mundy, 1982). Dissection in the extrafascial plane both anterior and posterior to the nerves allows a 10-15 mm portion of these nerves to be exposed. This can be safely divided without damage to the pelvic plexus.

Yamakoshi et al. (1997) carried out en bloc dissections of the pelvic organs in cadavers and then performed transverse sections at 10 mm intervals to identify the distance from the rectal wall to the pelvic plexuses. They found that in surgical specimens removed for rectal cancer the mean distance to the pelvic plexus from the rectal muscularis propria was 14.7 ± 4.5 mm. This short distance, they argued, mitigated against preserving the pelvic plexus during rectal excision. They did not, however, dissect the planes between the pelvic plexus and the rectum to identify whether there was

a safe dissection plane inside the pelvic plexus. Our approach differed from this in that we developed the extrafascial plane before measuring the nerves passing to the rectum from the pelvic plexuses.

The dimensions of the pelvic plexus were described as 2 x 3 x 1 cm by Ashley and Anson (1946) and 25-30 mm in height and 40 mm in length by Sato and Sato (1997). The mean size in our dissections was 29 mm vertically and 32 mm horizontally, comparable to the findings of those authors. The thickness of the plexus was not measured in the present study. Contrary to the postulations by Ashley and Anson (1946), and in agreement with Lee et al. (1973) and Baader and Herrmann (2003), there were no distinct plexus layers or ganglia visible at macroscopic level.

Although the position of the lumbosacral plexus has been described on cross-sectional imaging (Taylor et al., 1997), the position of the pelvic plexus on such imaging has not been previously reported. Lepor et al. (1985) described the anatomy of the nerves from the pelvic plexus to the corpora cavernosa based on histological cross-sections of the pelvis. He demonstrated the position of the pelvic plexuses on these sections. Baader and Herrmann (2003) localised the pelvic plexus in the horizontal plane at the level of S4 and S5. This present study's identification of the associated bony landmarks opens the way for assessment of the spread of rectal cancer in relation to the pelvic plexus using preoperative cross-sectional imaging. This would provide more preoperative information to aid in the planning of surgery.

The three most dangerous sites for nerve injury during rectal surgery are at the superior hypogastric plexus where the formation of the two hypogastric nerves takes place; at the pelvic plexus, and posterior to seminal vesicles (Keating, 2004). The identification of multiple layers in the parietal fascia with the presence of intervening loose areolar tissue illuminates the underlying reason for differing anatomical descriptions and highlights the need for caution when dissecting the fascial layers. It is possible to dissect outside the hypogastric nerves in a separate layer of the parietal fascia while considering that the plane is the "holy plane" (Heald, 1997) between the visceral and parietal fascia. This will lead to inadvertent removal of the hypogastric nerves, with associated ejaculatory dysfunction in men. It also risks the severe complication of bleeding from the venous plexuses in the presacral area in those patients in whom there is no further layer of the parietal fascia posterior to the hypogastric

nerves (as was the case in 3 of the 10 subjects in the present study). The pelvic plexus could potentially be endangered during division of the lateral ligaments due to medial tenting of the plexus as the rectum is pulled laterally. Knowledge of the length of the fibers within the lateral ligament would lead to safer manipulation of the rectum during surgery.

The findings of this study confirm that EFE allows the removal of the rectum and mesorectum without damage to the hypogastric nerves or pelvic plexuses, as illustrated clearly in figure 6. Here, the anatomy of the retrorectal fascia in relation to the hypogastric nerves is described and the ease with which the wrong plane can be entered posterior to the mesorectum is highlighted. Our study also offers clarification of the site and dimensions of the nerves passing from the pelvic plexuses to the rectum in the lateral ligaments. Preoperative identification of the position of the pelvic plexuses is made possible. This offers the potential for the clinician to assess the proximity of the tumour to the pelvic plexuses in preoperative axial imaging. Such information would assist in surgical planning and allow more accurate patient counselling before surgery.

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