GENERAL GYNECOLOGY

Anterior abdominal wall nerve and vessel anatomy: clinical implications for gynecologic surgery

David D. Rahn, MD; John N. Phelan, PhD; Shayzreen M. Roshanravan, MD; Amanda B. White, MD; Marlene M. Corton, MD

OBJECTIVE: We sought to describe relationships of clinically relevant nerves and vessels of the anterior abdominal wall.

STUDY DESIGN: The ilioinguinal and iliohypogastric nerves and inferior epigastric vessels were dissected in 11 unembalmed female cadavers. Distances from surface landmarks and common incision sites were recorded. Additional surface measurements were taken in 7 other specimens with and without insufflation.

RESULTS: The ilioinguinal nerve emerged through the internal oblique: mean (range), 2.5 (1.1–5.1) cm medial and 2.4 (0–5.3) cm inferior to the anterior superior iliac spine (ASIS). The iliohypogastric emerged 2.5 (0–4.6) cm medial and 2.0 (0–4.6) cm inferior. Inferior epigastric vessels were 3.7 (2.6–5.5) cm from midline at the level of the ASIS and always lateral to the rectus muscles at a level 2 cm superior to the pubic symphysis.

CONCLUSION: Risk of anterior abdominal wall nerve and vessel injury is minimized when lateral trocars are placed superior to the ASISs and >6 cm from midline and low transverse fascial incisions are not extended beyond the lateral borders of the rectus muscles.

Key words: iliohypogastric, ilioinguinal, inferior epigastric, nerve injury, vascular injury

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Injuries to the nerves and vessels of the anterior abdominal wall are well-recognized and significant complications of laparoscopic and open gynecologic surgeries. Ilioinguinal and iliohypogastric nerve injury has been reported in up to 3.7% of gynecologic procedures performed through Pfannenstiel incisions, and these nerves may also be damaged during operative laparoscopic procedures with placement of lateral trocars.[1,2] General surgery literature for laparoscopic repair of inguinal hernias using similar port sites quotes an overall nerve entrapment rate of 4.2% and of 1.1% for the ilioinguinal nerve, in particular.[3] Injury to the inferior epigastric vessels occurs in 0.2-2% of operative laparoscopic procedures using lateral trocars and can lead to transfusion, hematoma or abscess formation, and reoperation to control bleeding.[4-6]

A classic manifestation of ilioinguinal/iliohypogastric neuropathies includes lancinating or burning pain in the groin region that radiates to the vulva.[1] This pain may present immediately postoperatively or weeks to months later and may require management with prolonged use of opiates, repeated nerve blocks, or surgical exploration for neurolysis, neuroma resection, or nerve resection.[1,7,8] Proposed mechanisms for these neuropathies involve direct nerve trauma and neuroma formation from transection or entrapment of these nerves. Neural constriction is thought to persist months to years postoperatively as a consequence of the normal scarring/healing process.[9] Ilioinguinal and iliohypogastric nerve injury may also contribute to subsequent formation of direct inguinal hernias.[10] Given that the consequences of these neuropathies can be debilitating, strategies for prevention should prove advantageous.

The ideal approach to avoid inferior epigastric vessel injury during laparoscopic accessory trocar placement is to directly visualize the vessels transperitoneally. However, when unable to visualize the vessels directly, surface landmarks are often employed. One such landmark is the point 5 cm superior to the pubic symphysis (PS) and 8 cm from the midline, which was recommended by Hurd et al[11] after they evaluated normative data of inferior epigastric vessel location relative to superficial anatomic landmarks using computed tomography scans. Their findings have been subsequently replicated.[5]

Although ilioinguinal and iliohypogastric nerve injuries are most commonly associated with Pfannenstiel incisions, injuries have also been described following accessory trocar placement.[1] The relationship of these nerves to the point 5 cm superior to the PS and 8 cm from the midline has not been specifically evaluated. Given that these nerves cannot be directly visualized transperitoneally, precise knowledge of the relative position of the nerves to the inferior epigastric vessels and to commonly used landmarks employed to avoid vessel injury is essential. Thus, the objectives of this study were to: (1) further characterize the relationships of the ilioinguinal/iliohypogastric nerves and inferior epi-

From the Division of Female Pelvic Medicine and Reconstructive Surgery, Department of Obstetrics and Gynecology (Drs Rahn, Roshanravan, White, and Corton), and the Department of Cell Biology (Dr Phelan), University of Texas Southwestern Medical Center, Dallas, TX.

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gastric vessels to each other and to surface landmarks commonly used for gynecologic incisions; and (2) identify optimal locations for accessory trocar entry and laparotomy incisions that would minimize the risk of both nerve and vessel injury.

MATERIALS AND METHODS

Detailed dissections of the anterior and posterior abdominal walls were performed on 11 unembalmed female cadavers obtained from the Willed Body Program at the University of Texas Southwestern Medical Center in Dallas. Further surface anatomy measurements before and after insufflation for laparoscopy were made in an additional 7 unembalmed specimens. This study was exempt from review by the institutional review board. Age, height, weight, and cause of death of the body donors at the time of death were recorded. These specimens had no evidence of prior laparotomy or other anterior abdominal wall incisions.

All measurements were taken twice using a digital caliper sensitive to 0.01 mm (General Tools, New York, NY), and the average value was recorded. Descriptive statistics including means, SD, and ranges were performed.

Surface landmarks

Common placement sites of laparoscopy and laparotomy incisions used in gynecologic surgery were marked with straight metal pins placed through the anterior abdominal wall. These sites were measured from 2 clinically identifiable bony landmarks: the upper surface of the mid-PS and the most anterior surface of the anterior superior iliac spines (ASISs). The midline of the abdomen was defined as the vertical line connecting the PS to the umbilicus. Other sites marked included (1) a point 5 cm superior to the mid-upper surface of the PS and 8 cm lateral from the midline of the abdomen, a point often used as a landmark for insertion of accessory trocars;[11] and (2) a point 2 cm superior to the mid-upper surface of the PS, a typical starting site for Pfannenstiel incisions.[12] Additional annotations included the distance from the PS to the midpoint between the right and left ASISs, distances from the PS to the umbilicus, and from ASIS to ASIS.

In an attempt to account for the variability of measurements on the skin with abdominal insufflation relative to the landmarks above, in 7 additional specimens, the abdominal skin was marked over 3 sites bilaterally: (1) the point 5 cm superior and 8 cm lateral from the midline PS; (2) McBurney point, or the point one-third of the distance from the ASIS to the umbilicus, bilaterally; and (3) the ASIS. After insufflation with carbon-dioxide gas to 15-20 mm Hg, the skin was again marked at these 3 sites, and the distances medial/lateral and superior/inferior between corresponding points before and after insufflation were measured.

Ilioinguinal and iliohypogastric nerve dissection-anterior abdominal wall

Bilateral incisions were made parallel and approximately 1 cm inferior to the inguinal ligaments, from the level of the ASISs to the pubic tubercles. The skin and subcutaneous tissue of the anterior abdominal wall were reflected superiorly, the superficial inguinal ring was identified, and the structures that emerged from this ring were isolated en-block and held with a suture for further characterization at subsequent steps of the dissection. The aponeurosis of the external oblique muscle was incised just superior and parallel to the inguinal ligament and sharply dissected upward. The iliohypogastric and ilioinguinal nerves were identified as they emerged through the anterior surface of the abdominal wall muscles and the distance and relationship of each nerve at this point to the ASIS was recorded. The course of the nerves was then followed and the distances and anatomic relationships of these nerves to the previously marked sites were documented. Nerve widths nearest the ASIS and the midline were also recorded.

Inferior epigastric vessels

The rectus sheath was incised vertically just lateral to the midline. The anterior abdominal wall muscles were reflected laterally to identify the inferior epigastric vessels. Care was taken that the peritoneal cavity was not entered at this time. The inferior epigastrics were traced from the external iliac vessels to a level just superior to the umbilicus. The closest distance of the vessels to the initially marked and above-mentioned points was documented.

Ilioinguinal and iliohypogastric nerve dissection–posterior abdominal wall

The abdominal cavity was opened. The small bowel and a portion of the large bowel to the rectosigmoid were tied, transected, and removed. The peritoneum overlying either side of the aorta was sharply transected and reflected laterally to a level just inferior to the iliac crest. The ilioinguinal and iliohypogastric nerves were identified on the posterior abdominal wall and their course traced through the anterior abdominal wall layers. The relationship of the nerves to the muscle layers was documented.

RESULTS

Demographic data were available on all cadavers. Mean age at time of death (SD; range) was 88 years (9.5; 65–101 years); height was 162 cm (6.4; 152–170 cm); weight was 47 kg (9.9; 32–64 kg); and body mass index was 18.1 kg/m^2 (3.9; 13.7–26.5 kg/m^2). All cadavers were white.

Main findings of the study are shown in Figure 1.

Ilioinguinal and iliohypogastric nerves

In the posterior abdominal wall, the ilioinguinal and iliohypogastric nerves were identified as they emerged from the upper part of the lateral border of the psoas muscles. They coursed laterally over the anterior surface of the quadratus lumborum toward the iliac crest. In 50% of the specimens, a common trunk perforated the psoas muscle and divided into the 2 nerves near the iliac crest. In the remaining specimens, the ilioinguinal nerve coursed through the posterior abdominal wall just inferior to the iliohypogastric nerve. Near the iliac crest, both nerves pierced the deep or posterior surface of the transversus abdominis muscle and then coursed in the plane between the transversus abdominis and internal

oblique muscles, where small nerve branches were noted to perforate the muscles. Next, the nerves coursed medially and inferiorly, pierced the internal oblique muscles, and traveled between the aponeuroses of the internal and external obliques (Figure 2).

The ilioinguinal nerve pierced the superficial or anterior surface of the internal oblique muscle: mean (range), 2.5 (1.1–5.1) cm medial and 2.4 (0–5.3) cm inferior to the ASIS. It then coursed medially and inferiorly and entered the inguinal canal at variable distances from the pubic tubercles. Along with the round ligament, the ilioinguinal nerve was identified as one of the structures emerging from the superficial inguinal ring in all specimens. The course of this nerve was traced to the subcutaneous tissue of the labia majora and/or mons pubis.

The hypogastric (anterior cutaneous) branch of the iliohypogastric nerve pierced the anterior surface of the internal oblique muscles 2.5 (0–4.6) cm medial and 2.0 (0–4.6) cm inferior to the ASIS. It then coursed medially and inferiorly and terminated in the subcutaneous tissue after piercing the aponeurosis of the external oblique.

The closest distance of the ilioinguinal nerve to a point 5 cm superior to the PS and 8 cm from midline was 0.6 (0–1.6) cm and that of the iliohypogastric nerve was 1.3 (0–3.7) cm. In the majority of specimens, the nerves were just superior to this point. At a point 2 cm superior to the PS (typical starting point for transverse incisions), the ilioinguinal and iliohypogastric nerves were 5.9 (4.0–8.3) cm and 3.8 (1.3–5.7) cm lateral from the midline, respectively. In 3 of 11 (27%) of specimens, the iliohypogastric nerve terminated above the level 2 cm superior to the PS. In all specimens, the width of the nerves in the anterior abdominal wall was ≤2 mm.

Inferior epigastric vessels

From their point of junction with the external iliacs, the inferior epigastric vessels coursed obliquely superiorly toward the umbilicus. Near the external iliacs, the inferior epigastrics were noted just medial to the round ligament, as the ligament passed through the deep inguinal ring into the inguinal canal.

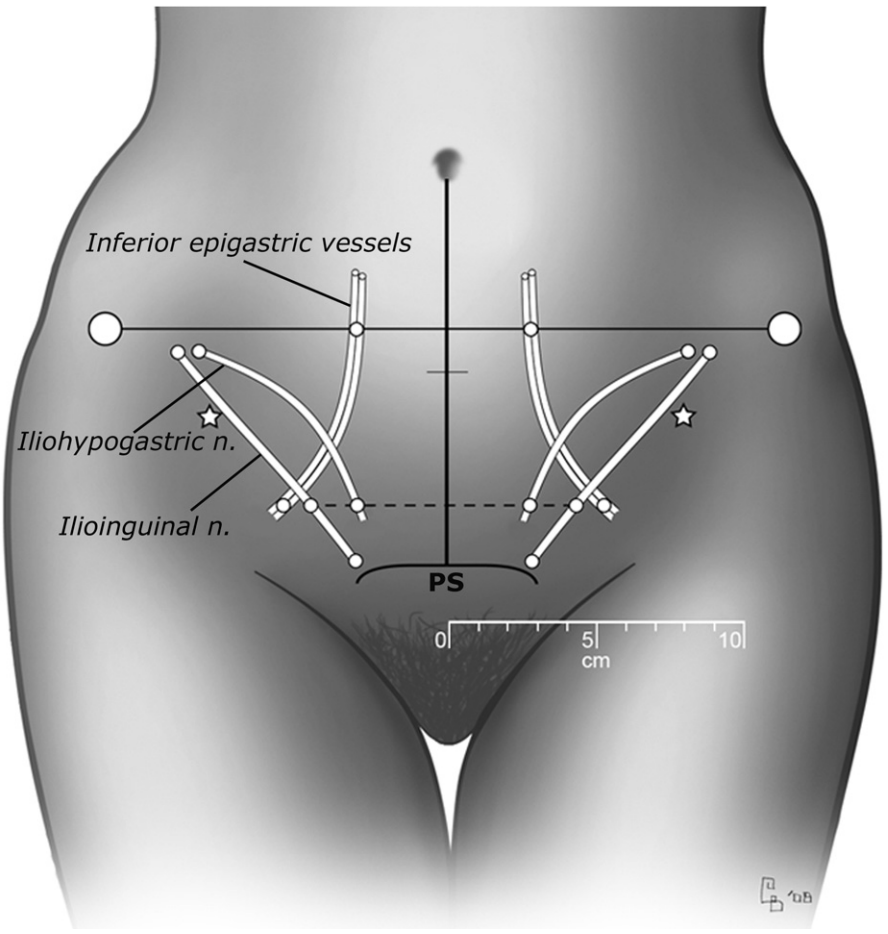
The closest distance of the vessels to the midline of the lower abdomen at the point 2 cm superior to the PS was 6.1 (4.8–7.9) cm. At this level, the inferior epigastrics were lateral to the lateral margins of the rectus abdominis muscles in all specimens.

The closest distance of the vessels to the point 5 cm superior to the PS and 8 cm from midline was 3.2 (1.2–5.2) cm. The vessels were medial to this point in all specimens. The line connecting the left and right ASIS crossed the midline ≥9 (9.2–10.5) cm superior to the mid-upper surface of the PS. At the level of the ASIS, the vessels were 3.7 (2.6–5.5) cm from the midline of the abdomen.

Surface measurements

With insufflation of the abdominal cavity, the distances moved by points on the skin overlying landmarks of interest were highly variable. The mean (SD) distance moved by the point 5 cm superior and 8 cm lateral to the midline PS with insufflation was 4.4 (8.8) mm medial and 8.2 (11.3) mm superior. McBurney point moved 8.2 (9.3) mm laterally and 3.1 (9.4) mm inferiorly, and the point on the skin overlying the ASIS moved 10.5

FIGURE 1
Nerve and vessel locations on anterior abdominal wall



Mean location of ilioinguinal and iliohypogastric nerves and inferior epigastric vessels are shown relative to anterior superior iliac spine (*large open circles*); pubic symphysis (PS); point 2 cm superior to PS, common starting site for Pfannenstiel incisions (*dashed line*); and point 5 cm superior to PS and 8 cm from midline (*stars*), common landmark for accessory trocar placement.

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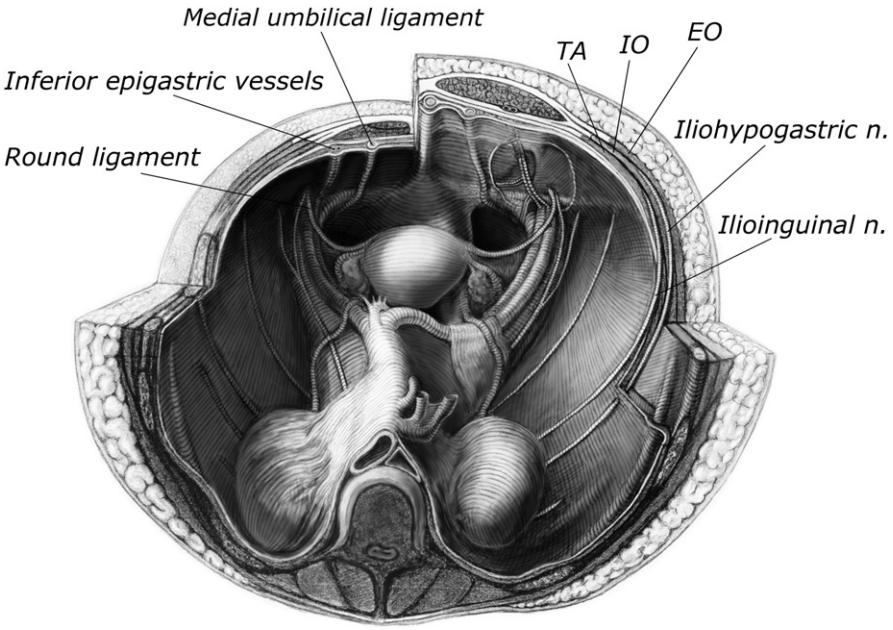
FIGURE 2
Course of ilioinguinal and iliohypogastric nerves (n.) in anterior abdominal wall



Near iliac crest, both nerves pierce deep or posterior surface of transversus abdominis muscle (TA). They then course in plane between TA and internal oblique muscles (IO) and then move medially and inferiorly, piercing IO, and travel between aponeuroses of IO and external oblique (EO). Inferior epigastric vessels are observed lateral to medial umbilical ligaments and just medial to round ligaments as these enter inguinal canal.

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(14.2) mm laterally and 8.8 (8.5) mm inferiorly. Most importantly, for this final measurement of the position on the skin relative to the palpable ASIS, the skin always moved in an inferior direction with insufflation, ranging 1–26 mm.

Comment

Based on the findings of this unembalmed female cadaver study, a reasonable region for accessory trocar placement in the infraumbilical portion of the anterior abdominal wall is >6 cm from the midline at the level of or superior to the ASIS. Placement of trocars in this area minimizes risk of injury to both the ilioinguinal/iliohypogastric nerves and inferior epigastric vessels. This cadaver study substantiates the recommendations of other studies using computed tomography to guide lateral trocar placement for the avoidance of the inferior epigastrics: Sriprasad et al[13] also advocates lateral trocars be placed >6 cm from midline at the level of the ASISs. While our study confirms that placement of accessory trocars 5 cm superior to the PS and 8 cm lateral to the midline should prevent inferior epigastric vessel injury,[11] this may increase the likelihood of ilioinguinal and/or iliohypogastric nerve injury, as both nerves coursed in close proximity to this surface landmark.

In a previous study by Whiteside et al,[14] the ilioinguinal nerve was found to enter the anterior abdominal wall, on average, 3.1 cm medial and 3.7 cm inferior to the ASIS, and the iliohypogastric entered 2.1 cm medial and 0.9 cm inferior to the ASIS. In our study, we found the ilioinguinal emerged through the internal oblique 2.5 cm medial and 2.4 cm inferior to the ASIS, and the iliohypogastric emerged 2.5 cm medial and 2.0 cm inferior to the ASIS. The greatest discrepancy between our findings and those ot Whiteside et al[14] was the inferior entry point relative to the ASIS. Part of this discrepancy may be due to the exact location on the ASIS from which measurements were taken. However, in both studies the nerves were consistently shown to emerge at or inferior to the level of the ASIS. As the ilioinguinal and iliohypogastrics coursed medially and inferiorly from their entry point in the anterior abdominal wall, low transverse incisions and laparoscopy trocars placed inferior to the level of the ASIS can result in laceration or entrapment of these nerves.

Transverse fascial incisions that begin 2 cm superior to the PS may compromise the medial portion of the iliohypogastric nerves if they extend >3.5 cm from the midline. The ilioinguinal nerve and inferior epigastric vessels, however, should be spared if these fascial incisions remain within 5.5 cm from the midline. One should take care not to place fascial closure stitches lateral to the angle/apex of the fascia incision so as to minimize the likelihood of entrapping these nerves.[1,9] Care should also be taken when the lateral extents of low transverse fascial incisions are directed or "curved" upward. While this practice may prevent injury to the medial segment of the iliohypogastric nerves, it may place the inferior epigastric vessels at risk as they course medially toward the umbilical region.

In order to avoid inferior epigastric vessel injury during laparotomies, low transverse fascial incisions ideally will not extend beyond the lateral borders of the rectus muscles. At a point 2 cm above the PS, the inferior epigastrics were always found lateral to the lateral border of the rectus muscles. This is the region known as Hesselbach triangle, bounded medially by the lateral border of the rectus abdominis muscles, laterally by the inferior epigastric vessels, and inferiorly by the medial half of the inguinal ligament. The locations of the deep inferior epigastric vessels identified in this study closely mirrored those reported in a computed tomography–based report by Saber et al.[5]

It should be emphasized that during accessory trocar placement, injury to the vessels of the anterior abdominal wall is best avoided by placing the trocars under direct visualization. In contrast to the su-

perficial epigastrics, which can often be transilluminated with the laparoscope,[15,16] the inferior epigastrics course deep to the fascia and muscles of the anterior abdominal wall and cannot be identified by transillumination.[16] They can, however, be directly identified transperitoneally in most women. These vessels can be found lateral to the medial umbilical ligaments and just medial to the round ligaments as these enter the inguinal canal, ie, "the round wraps around" the inferior epigastric vessels (Figure 2). When the inferior epigastrics cannot be directly visualized, placement of trocars >6 cm from the midline at a level superior to the ASIS minimizes risk of injury to these vessels and to the ilioinguinal and iliohypogastric nerves.

One limitation of this study is that direct measurements between neurovascular structures and surface landmarks could not be made with an insufflated abdomen, which would have reflected intraoperative conditions more accurately. Once the inferior epigastric vessels had been dissected, inevitably the abdominal cavity had been breached, making it difficult to create a pneumoperitoneum for remeasurements. It is possible that the distance and relative location of neurovascular structures to the surface landmarks chosen for this study would have changed with intraabdominal insufflation. However, despite the marked variability in distances moved by points on the skin relative to landmarks of interest, perhaps the most important change is the superior/inferior movement of the skin relative to the ASIS with insufflation. For this measurement, we found the skin reliably moved inferiorly with insufflation, suggesting that placement of lateral trocars at or above the level of the palpable ASISs with the abdomen insufflated would still avoid the ilioinguinal and iliohypogastric nerves as they emerge on the anterior wall at (or below/inferior to) the level of the ASISs.

Other limitations of this study are those inherent to most cadaver studies. Findings from a limited number of dissections cannot reflect the spectrum of anatomic variation that is likely to be encountered in clinical practice. The cadavers in this study are likely thinner and older than the average woman undergoing operative laparotomy or laparoscopic procedures. To avoid other potential limitations of a cadaveric study, we used only unembalmed specimens, as findings from these dissections are more likely to reflect those in living subjects than findings from embalmed specimens. We also excluded specimens with evidence of any abdominal wall incisions, as these may have altered the anatomic path of the nerves and vessels of interest. Lastly, a study of this type cannot address why there is such variability in the clinical presentation of anterior abdominal wall neuropathies, ie, some women may be asymptomatic or have painless paresthesia of the lower anterior abdominal wall while others have debilitating pain that worsens with time and severely limits daily activities. Given the proximity of the distal portion of the iliohypogastric nerves to the midline 2 cm superior to the PS, it is likely that paresthesia or anesthesia in this region is common after Pfannenstiel incisions but patients either underreport or physicians do not query for this finding.

Vascular and neurologic injuries are important complications of common gynecologic incisions. While the deep inferior epigastric and superficial epigastric vessels can frequently be visualized directly within the lateral umbilical folds of peritoneum or via transillumination, respectively, the nerves of the anterior abdominal wall are virtually never observed upon entry into the abdominal cavity. As a greater number of procedures are performed laparoscopically, it remains increasingly important to define approximate locations of both vessels and nerves and to adjust operative trocar sites accordingly to minimize risk of neurovascular injury. ■

REFERENCES

1. Cardosi RJ, Cox CS, Hoffman MS. Postoperative neuropathies after major pelvic surgery. Obstet Gynecol 2002;100:240-4.

2. Luijendijk RW, Jeekel J, Storm RK, et al. The low transverse Pfannenstiel incision and the prevalence of incisional hernia and nerve entrapment. Ann Surg 1997;225:365-9.

3. Stark E, Oestreich K, Wendl K, Rumstadt B, Hagmüller E. Nerve irritation after laparoscopic hernia repair. Surg Endosc 1999;13:878-81.

4. Bergqvist D, Bergqvist A. Vascular Injuries during gynecological surgery. Acta Obstet Gynaecol Scand 1987;66:19-23.

5. Saber AA, Meslemani AM, Davis R, Pimentel R. Safety zones for anterior abdominal wall entry during laparoscopy: a CT scan mapping of epigastric vessels. Ann Surg 2004;239:182-5.

6. Hurd WW, Pearl ML, DeLancey JO, Quint EH, Garnett B, Bude RO. Laparoscopic injury of abdominal wall blood vessels: a report of three cases. Obstet Gynecol 1993;82:673-6.

7. Nahabedian MY, Dellon AL. Outcome of the operative management of nerve injuries in the ilioinguinal region. J Am Coll Surg 1997;194:265-8.

8. Whiteside JL, Barber MD. Ilioinguinal/iliohypogastric neurectomy for management of intractable right lower quadrant pain after cesarean section: a case report. J Reprod Med 2005;50:857-9.

9. Gross CR. Iliohypogastric nerve injury. Am J Surg 1981;142:628.

10. Tobin G, Clark S, Peacock EE. A neuromuscular basis for the development of indirect inguinal hernia. Arch Surg 1976;111:464.

11. Hurd WW, Bude RO, DeLancey JOL, Newman JS. The location of abdominal wall blood vessels in relationship to abdominal landmarks apparent at laparoscopy. Am J Obstet Gynecol 1994;171:642-6.

12. Nichols DH. Incisions. In: Nichols DH, Clarke-Pearson DL, eds. Gynecologic, obstetric, and related surgery. St Louis: Mosby; 2000:197-226.

13. Sriprasad S, Yu DF, Muir GH, Poulsen J, Sidhu PS. Positional anatomy of vessels that may be damaged at laparoscopy: new access criteria based on CT and ultrasonography to avoid vascular injury. J Endourol 2006;20:498-503.

14. Whiteside JL, Barber MD, Walters MD, Falcone T. Anatomy of ilioinguinal and iliohypogastric nerves in relation to trocar placement and low transverse incisions. Am J Obstet Gynecol 2003;189:1574-8.

15. Quint EH, Wang FL, Hurd WW. Laparoscopic transillumination for the location of anterior abdominal wall blood vessels. J Laparoendosc Surg 1996;6:167-9.

16. Hurd WW, Amesse LS, Gruber JS, Horowitz GM, Cha GM, Hurteau JA. Visualization of the epigastric vessels and bladder before laparoscopic trocar placement. Fertil Steril 2003;80:209-12.