Review

Anatomy Journal of Africa 1 (1): 2-10 (2012)

ENDOSCOPIC ANATOMY OF THE GROIN; IMPLICATION FOR TRANSABDMOMINAL PREPERITOTONEAL HERNIORRHAPHY

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SUMMARY

Hernia surgery is in many ways the quintessential case for demonstrating anatomy in action. Laparoscopic hernia surgery has a more recent history compared to open surgery. The demand for the procedure is increasing. The indications for laparoscopic herniorrhaphy include bilateral disease, recurrence following anterior repairs and patient preference. Anatomy of the lower anterolateral abdominal wall appreciated from a posterior profile compounds the challenge of a steep learning curve for the procedure. The iliopubic tract and Cooper's ligaments, less obvious to anterior surgeons, are important sites for mesh fixation for laparoscopic surgeons. Their neural and vascular relations continue to receive plenty of mention in hernia literature as explanations for troublesome procedure-related morbidities. The one 'rectangle' (trapezoid of disaster), one 'circle' (of death) and two 'triangles' (of doom, of pain) geometric concepts denote application of anatomy in mapping the danger areas of the groin where dissection and staples for fixation should be minimized.

INTRODUCTION

Groin hernia surgery is common globally with around twenty million hernias repaired worldwide annually (Heuvel et al., 2011). Although open anterior approaches suffice for most unilateral hernias, the advantages of shorter convalescence, lower pain scores, cosmetic incisions and recurrence rates similar to open surgery have persuaded patients to demand laparoscopic approaches (Filipi et al., 1996; Leim et al., 1997, Wellwood et al., 1998; Eklund et al., 2007). Further, laparoscopic procedures are recommended for bilateral and recurrent hernia (Krahenbuhl et al., 1998; Memon et al., 2003; MacCormarck et al., 2003). Hernia treatment requires both an excellent understanding of the regional anatomy and requisite skills (Brick et al., 1995,;Bhatia, 2012). As an example, the myopectineal orifice presents to both the anterior and posterior surgeon but the anatomical borders and relations are different (Spaw et al., 1992; Skandalakis et al., 1989; Skandalakis et al., 2000). Inadequate mastery of the details of the posterior anatomy is a recipe for avoidable complications including damage to concealed nerves and aberrant vessels. The experience with laparoscopic hernia procedures in Africa is limited (Ohene-Yeboah, 2011) by the associated costs and learning curve. However, patients who desire faster return to work and cosmetic wounds are demanding the procedure from local surgeons. This review reconstructs the pertinent anatomy as a prerequisite and reminder for safe Transabdominal Preperitoneal (TAPPP) repair of groin hernia.

The anatomy in anterior open approach

Most surgeons are fairly well versed with the anatomy when the groin is exposed from an anterior approach (Skandalakis et al., 1993; Marks et al., 1996; Skandalakis et al., 2000). The external oblique aponeuroses, conjoint tendon, spermatic cord, pubic tubercle, inguinal ligament and lacunar ligaments, transversalis fascia and ilioinguinal, genitofemoral and iliohypogastric nerves are easily identified. The aponeurotic transformation, the inguinal ligament at its free lower border and the position and form of the external inguinal ring are anatomical features of the external oblique muscle thankfully appreciated by surgeons. At its insertion at the pubic tubercle, fibers of the inguinal ligament are reflected onto the superior pubic ramus forming the lacunar ligament encountered when the problem is one of femoral herniation (Fig. 1).

Received 5 September 2012; Revised 9 September 2012; Accepted 14 September 2012 . Published online 15 September 2012 . To cite: Saidi H. 2012. Endoscopic Anatomy Of The Groin; Implication For Transabdmominal Preperitoneal Herniorrhaphy Anatomy Journal of Africa 1(1): 2 –10.

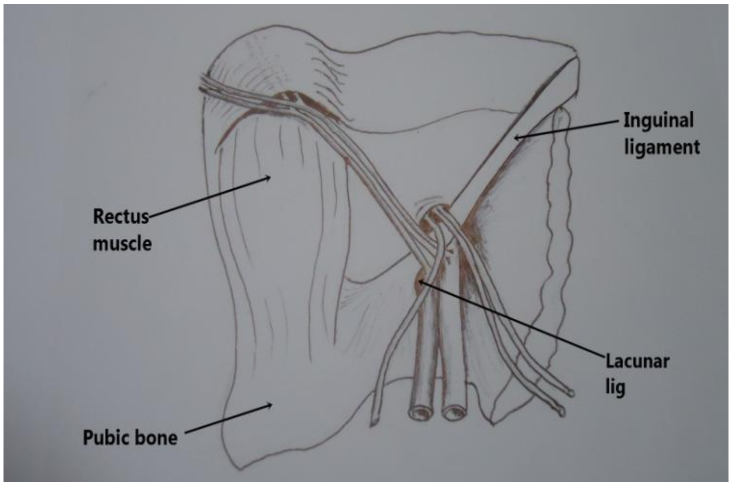

Figure 1: Illustration of the inguinal ligament and its reflection, the lacunar ligament.

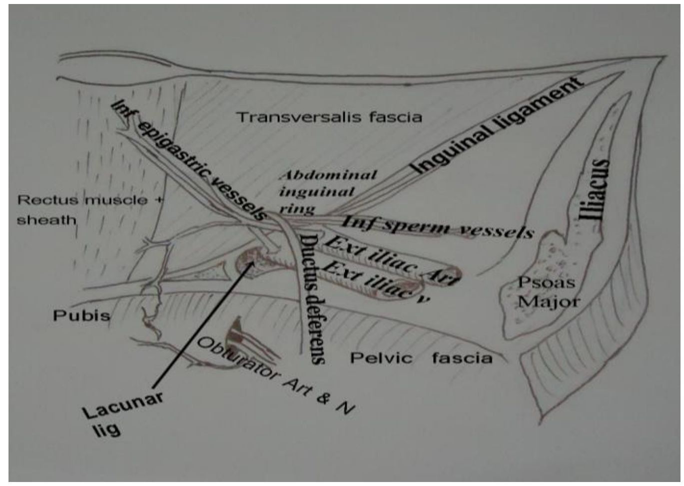

Figure 2: Schematic view of a transverse view of the infraumbilical region to demonstrate umbilical fossae.

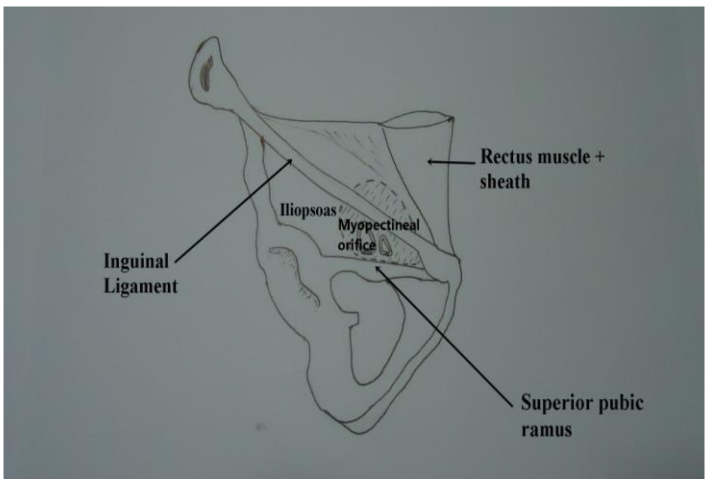

Figure 3: Diagram illustrating the boundaries and divisions of the myopectineal orifice: medially-rectus abdominis in its sheath; laterally-iliopsoas muscle; inferiorly-superior pubic ramus and superiorly-fascia transversalis and internal oblique muscle. The inguinal ligament divides this space.

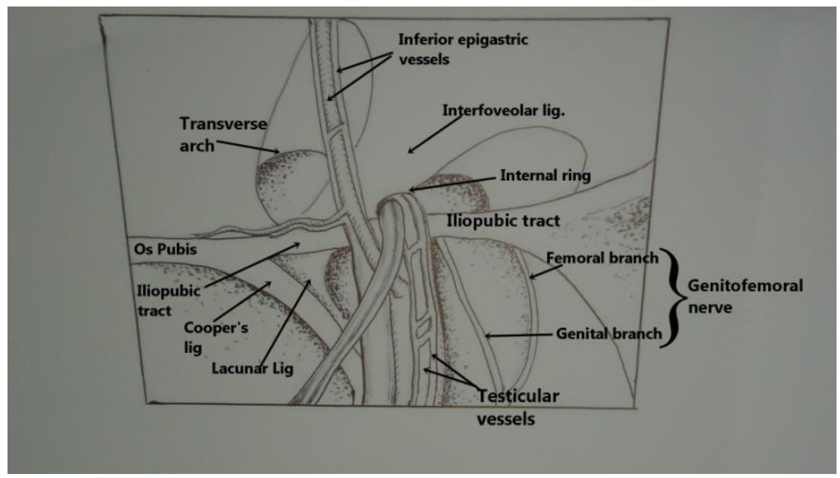

Figure 4: Laparascopic view of the internal ring and its relations.

The inguinal ligament forms a key landmark in anterior surgeries. The anterolateral abdominal muscles attach to it in a formation that leaves an interval between them. Below the ligament is subinguinal space through which muscles, nerves and blood vessels traverse. An area above and below the ligament limited by the internal oblique and tranversus abdominis muscles (superior), superior pubic ramus (inferior), rectus muscle sheath (medial) and iliopsoas muscle (lateral) has been described (Fig. 2). This myopectineal orifice (of Furchaud) is single weak area through which hernias occur (Bhatia, 2012). Practitioners attempt to reinforce this area of weakness when treating hernias.

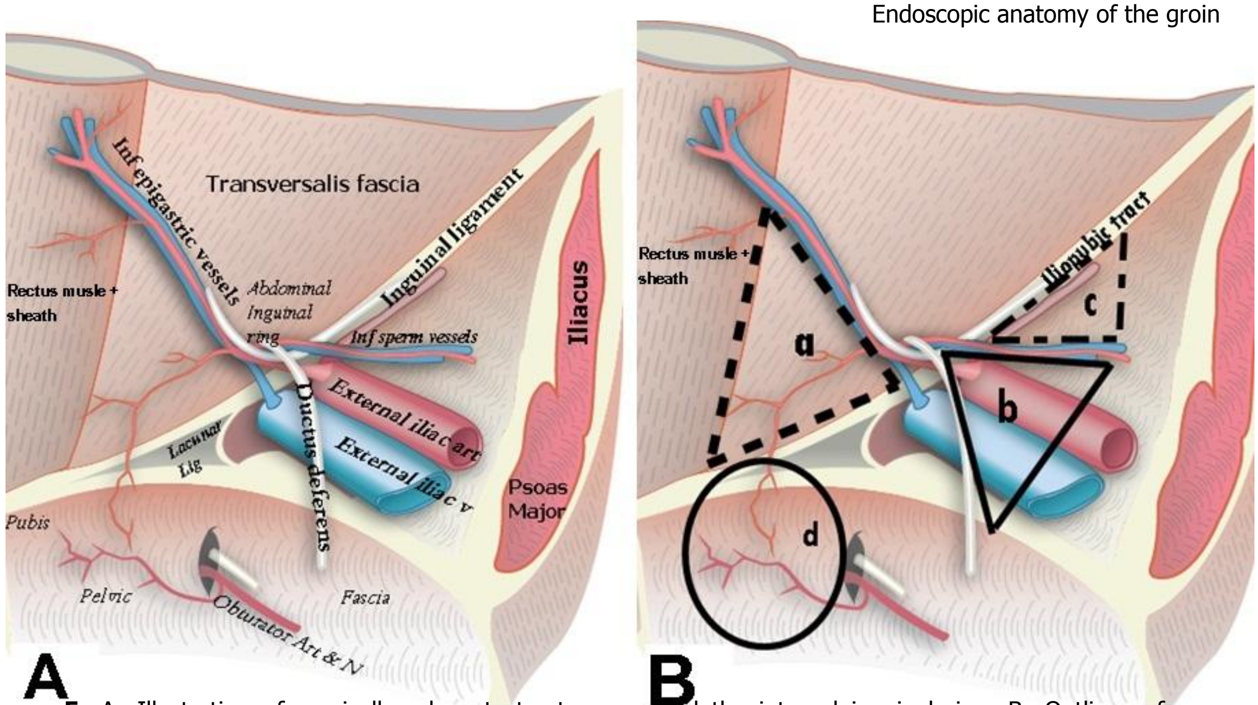

Figure 5: A- Illustration of surgically relevant structures around the internal inguinal ring. B- Outlines of Hasselbach's triangle (**a**) and the triangle of doom (**b**) and pain (**c**). The latter two triangles constitute the trapezoid of disaster (square of doom). The circle of death (**d**) is also demonstrated. Image adapted from Laparascopic Hernia Repair: A step by step approach.

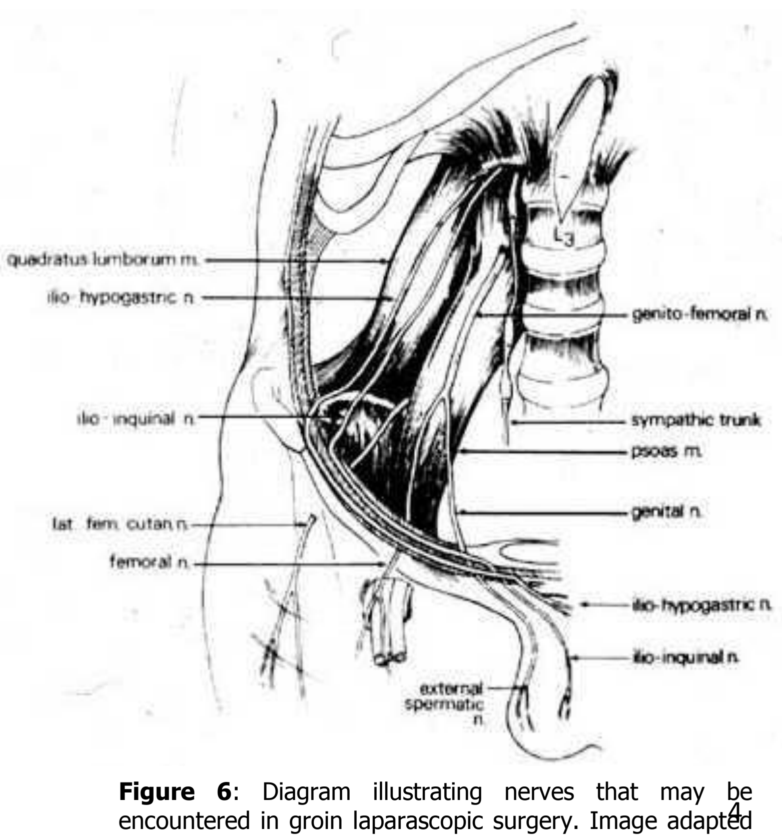

Figure 6: Diagram illustrating nerves that may be encountered in groin laparascopic surgery. Image adapted from Gray H. 1918. Anatomy of the human Body. Philadelphia: Lea & Febiger. 20th Edition.

On the floor of the myopectineal orifice is the equally important transversalis fascia. Bilaminar its anatomical organization (Skandalakis et al., 1989; Skandalakis et al., 2000; Bendavid, 1992), it bridges the crucial space between the conjoined arch and the inguinal ligament. Termed the "Achilles heel of the groin", it is here that direct hernias occur (Bhatia, 2012). There are several anterior procedures that reinforce the weak area. These are either tissue based repairs without the use prostheses or non-tension repairs using meshes. In the Shouldice operation which is the gold standard for prosthesis free repair, inguinal floor dissection is performed and a four-layered reconstruction involving fascia transversalis, the transversus arch and inguinal ligaments done (Chan et al., 2006). Lichtenstein procedure is a tension-free repair that places a flat mesh over the myopectineal orifice and secured to the inguinal ligament and conjoined muscles (Fig.2). In this way, potential sites of herniation below the ligament are not covered. This is addressed when bilayer meshes (Sanjay et al., 2006), are used. The onlay portion is placed as in Lichtenstein procedure while the sublay component is placed behind the fascia transversalis to cover all three hernia sites envisioned by Fruchaud (Fig 3).

The deep inguinal ring is a defect in the fascia transversalis through which structures enter and leave the inguinal canal. Other anatomical features of the fascia include modifications into ligamentous structures (interfoveolar ligament, iliopubic tract, Cooper's ligament) better appreciated from the posterior aspect (Skandalakis et al., 1993; Bhatia, 2012). The surgical anatomy of the groin is incomplete without mention of neurovascular structures. The main structures encountered in open anterior herniorrhaphy include the inferior epigastric artery, its accompanying veins and superficial nerves earlier mentioned. The inferior epigastric vessels mark the lateral boundary of the inguinal (Hasselbach) triangle where direct hernias pass (Fig 4).

The ilioinguinal and iliohypogastric nerves arise from the twelfth thoracic and the first lumbar roots and descend on lateral aspect of psoas major muscle. The nerves run over posterior abdominal wall muscles and then pierce transversus abdominis (superomedial to anterior superior iliac spine) to travel between internal oblique and external oblique muscles (Fig 5). The ilioinguinal nerve supplies and pierces the internal oblique and is encountered at surgery as a content of the inguinal canal and travels with the cord to supply skin near the external genitalia (root of penis, anterior scrotal skin, labia majora). The iliohypogastric nerve supplies skin in the suprapubic region and provide afferent and efferent paths for abdominal reflex. The two nerves communicate frequently. Their relational anatomy to the anterior superior iliac spine is important for ilioinguinal and iliohypogastric blocks for open hernia surgery (Harrison et al., 1994). The genitofemoral nerve descends in a more medial position in relation to the psoas muscle. It gives to branches which present to the anterior and posterior surgeon differently. The genital branch enters the inguinal canal through the deep inguinal ring and encountered at open surgery as it supplies the coverings of the spermatic cord. It is also the efferent arm for cremasteric reflex.

Endoscopic anatomy for TAPP

A view of the anterior abdominal wall from posterior presents key anatomical landmarks both with peritoneum intact and when the latter has been reflected (Fig 6). Three peritoneal ligaments are distinctive in the lower abdominal wall, two of embryologic interest (Skandalakis et al., 1989; Skandalakis et al., 2000). The median ligament represents the obliterated urachus, the medial ligament the obliterated umbilical artery while the lateral ligament is a peritoneal fold containing the inferior epigastric vessels. The inferior epigastric artery is a branch of from external iliac artery given off medial to the internal. It is identified by a superomedial course from the internal ring to the rectus sheath.

Three infra-umbilical fossae are clearly delineated and bounded by the ligaments- supravesical, medial and lateral umbilical fossae (Fig 6). The vas deferens and the spermatic vessels are seen to converge at the internal ring (Bhatia 2012, Fig 7). On their way to the deep ring the two structures border an interval termed 'triangle of doom' within which lie the external iliac vessels (Fig. 7).

It is important to note that in this view, the spermatic vessels course lateral to the external iliac vessels before entering the internal ring. In the same region is the lateral placed femoral nerve. The ring is more obvious when the peritoneum is reflected or when an indirect hernia is present, otherwise it is inconspicuous landmarked by the meeting point of the two structures. In the presence of a hernia the boundaries of the ring become more easily more easily appreciated-transversalis fascia and inferior epigastric artery medially, iliopubic tract inferiorly, transversus abdominis arch anteriorly. With the peritoneum removed, further landmarks are revealed including the iliopubic tract, Coopers ligament and when a femoral hernia is present, the femoral canal (Skandalakis et al., 1989; Spaw et al., 1993; Brick et al., 1995; Teoh et al., 1999; Skandalakis et al., 2000). The iliopubic tract is a thickened part of transversalis fascia that originates from the anterior superior iliac spine laterally, stretches medially over the iliac muscles (iliopectineal arch) and attaches to the superior ramus of the pubis (Skandalakis et al., 2000). This fibroelastic structure runs deep and parallel to the inguinal ligament with which it is only loosely connected (Gilroy et al., 1992; Teoh et al., 1999). As stated before, it forms the inferior margin of the internal inguinal ring and from an endoscopic perspective, the boundary between inguinal hernia (above) and femoral hernia (below)- a role for the inguinal ligament more superficially. Near the medial attachment, fibers of iliopubic tract form the medial margin of the femoral canal and related intimately with anteriorly placed lacunar ligament. The canal's other borders (pectineal fascia posteriorly and femoral sheath and vein laterally) may also be appreciated (Fig.7).

Cooper's ligament is an extension of lacunar ligament that runs over the pectineal line of the pubic bone. It is also described as a condensation of transversalis fascia and periosteum of the superior pubic ramus. The structure is immediately visible as a glistening white structure after reflection of the peritoneum unless obscured by adipose tissue. The iliopubic tract fibers merge with those of Cooper's ligament in the medial inguinal area (Gilroy et al., 1992). Reconstructing the interval of Fruchaud from posterior, fascia transversalis fills the space between the arch of tranversus abdominis above and the iliopubic tract and Coopers ligament below. Termed the 'Achiles heel' of the groin, this is the point of direct herniation. Descriptive anatomy relates to two parts of fascia - an anterior and posterior lamina (Skandalakis et al., 2000). The anterior lamina is intimately adherent to abdominal wall muscles while the posterior is free and divides the preperitoneal space into two. The space between the anterior and posterior laminae is the vascular space while the interval between the posterior lamina and the peritoneum is the true preperitoneal space

– the avascular space of Bogros (Skandalakis et al., 2000). This is the space developed for prosthesis placement in both anterior and posterior approaches (Bendavid, 1992; Bendavid et al., 2000). The space extends medially into the space of Retzius which may be developed for placement of larger meshes.

The nerves of the inguinal region

The area lateral to the external iliac vessels contains several nerves which the hernia operator needs to respect (Rosen et al., 1993; Seid et al., 1994; Marks et al., 1996). The femoral nerve lies lateral to the iliac vessels in the iliopsoas groove while the genitofemoral nerve descends on psoas before dividing into two branches (Fig 5). Its genital branch as indicted earlier enters the deep ring and is usually not injured in laparoscopic approaches. The femoral branch on the other hand, descends lateral to the external iliac vessels and passes inferior to the iliopubic tract to enter the femoral sheath. It is at great risk during laparoscopy. It supplies the skin over the femoral triangle and is the afferent arm of the cremasteric reflex.

The lateral cutaneous nerve of the thigh is a commonly injured L2, L3 nerve (Grothaus et al., 2005; Bhatia, 2012). It emerges from the lateral end of the psoas, descends on iliacus muscle and lies in a superficial position 3 cm below the anterior superior iliac spine. It supplies the front and lateral aspect of the thigh. Its relationship to various anatomical landmarks has been studied (Aszmann et al., 1997; Grothaus et al., 2005). The nerve passes deep or through the inguinal ligament about 1cm medial to anterior superior iliac spine (range of 6-73mm medial to the spine) (Grothaus et al., 2005).

Blood vessels of the groin

The external iliac artery runs within the triangle of doom on the medial aspect of the psoas muscle and deep to the iliopubic tract to form the femoral vessels. The vein is posteromedial. As mentioned, its inferior epigastric artery is a key endoscopic landmark. Laterally, it gives off the deep circumflex artery. The dissection in the true preperitoneal space is posterior to the vessels. The inferior epigastric artey gives off two branches along its course- a cremasteric branch and a pubic branch. The pubic branch courses and crosses the Coopers's ligament to anastomose with a pubic branch of obturator artery, a branch of the internal iliac artery (Bhatia, 2012). The testicular vessels have been described above. The other vessels of note in this area include the networks of veins in the preperitoneal space (deep inferior epigastic vein, suprapubic vein, retropubic vein and recusial veins) (Bendavid et al., 1992).

Applied anatomy

The focus of this review was to highlight the anatomical details the endoscopic surgeon needs to master to allow a joyful surgery. The prominent peritoneal folds described above can at times be confused. The need to delineate both the medial and lateral umbilical ligament is informed by the disastrous consequence of confusing one for the other. The inferior epigastric artery can bleed briskly when injured while dissection medial to the medial fold may injure the bladder (MacFayden et al., 1993).

The most important step after the initial recognition of landmarks is dissection of the preperitoneal space of Bogros after the peritoneal incision in the TAPP procedure. To do this the peritoneum is incised superior to the hernia sac with incision running from the medial umbilical ligament towards the anterior superior iliac spine. A direct hernia presents at the medial umbilical fossa while the indirect hernia goes through the internal ring, the point of convergence of the vas deferens and spermatic vessels as highlighted above.

Dissection medial to the medial umbilical ligament, when a large mesh needs to be placed, should be meticulous or avoided altogether as this step may endanger the urinary bladder. This medial extension of the space of Bogros (space of Retzius), is also surgically relevant for the vascular structures it may contain (Skandalakis et al., 2000). It contains venous networks that may bleed if dissection is rough (Bendavid, 1992; Bendavid et al., 2000).

The concept of anatomical triangles described above are modeled to invite caution during laparoscopic procures. Placement of staples or tacks in the triangle of doom jeopardizes the external iliac vessels with a consequence of troublesome bleeding. Laterally placed triangle of pain and trapezoid of disaster are nerve areas where tacking of the mesh is to be avoided (Rosen et al., 1993; Marks et al., 1996). As indicated the risk of disabling neuropathies due to injury to the femoral branch of the genitofemoral nerve, lateral femoral cutaneous nerve or the femoral nerve itself is real if staples are applied inferior to the iliopubic tract.

To securely anchor meshes in place, surgeons take advantage of tough fibrous tissues that are exposed at laparoscopic surgery. The iliopubic tract, Cooper's ligament and region around the anterior superior iliac spine are the main anchoring sites for prostheses. Cooper's ligament is often the initial point of mesh fixation in TAPP. It has been highlighted that a pubic branch of inferior epigastric artery crosses this structure and anastomoses with the pubic branch of obturator artery. Dissection in this area may be complicated by aberrant anatomy. A large pubic branch may replace the obturator artery and cause massive bleeding that may force a conversion to open surgery. This aberrant situation is a common reported finding. In a recent paper the obturator artery was aberrant in > 50% of patients (Requarth et al., 2011). There are many accounts of this large pubic branch existing with a 'normal' obturator artery with the two forming variable anastomoses around the obturator canal. The resultant vascular network has been aptly termed (crown/circle of death). Several accounts of venous and arterial corona mortis exist in pelvic and hernia surgery literature (Lokmon, 2002; Pungpapong, 2005; Sakthivelavan et al., 2010; Berberoglu et al., 2011). The iliopubic tract borders the triangle of pain and the quadrangle of disaster (Gilroy et al., 1992; Seid et al., 1994). Most accounts suggest that dissection and placement of staples inferior and lateral to the iliopubic tract will protect the nerves in the trapezoid of disaster. But studies evaluating the nerve relationship of iliopubic tract indicate that this is not always the case. In one account > 13% of the lateral cutaneous nerve of the thigh were in the vicinity of iliopubic tract (5% within 1mm of the tract) and liable to injury during staple application. Eleven percent of nerves run within 1cm of anterior superior iliac spine which is another site for anchorage (Marks et al., 1996).This is thought to explain at least in part, the neuropathy that may follow mesh placement even when staples are applied lateral to the spermatic vessels and not inferior to iliopubic tract. While the lateral cutaneous nerve is the most commonly injured, ilioinguinal and iliohypogastric are not unless the staples are placed very deep.

Comment

A deep understanding of the endoscopic anatomy of the inguinal region is a requisite for safe groin surgery (Seid et al., 1994). Vascular complications can be avoided if the anatomy described is respected. Groin pain following groin surgery is a more persistent problem with a debatable point whether frequencies are higher in laparoscopic hernia surgery. In the account by Eklund et al., (2010), the laparoscopic group had a lower incidence (1.9%) of pain than the open surgery group (3.5%) five years after surgery. Patterns that may suggest nerve injury include persistence and distribution of pain and numbness to the scrotum and thigh. The causes of this pain include nerve entrapment with mesh, fixation devises or adhesions. An appreciation of the anatomical details above would be key in interpreting and reducing the incidence of chronic groin pain after surgery. Recurrence of hernia after laparoscopy is similar to open surgery but higher for the inexperienced (Memon et al., 2003; McCormack et al., 2003). Inadequate appreciation of the anatomical landmarks is tied to this experience. While a thorough appreciation of the normal anatomy guarantees safety at surgery, anatomical variations also claim a niche in understanding complications. The traditional 'danger zone' for nerves may be wider than the 'rectangle of disaster'.

In conclusion, during transperitoneal surgery for groin hernia, the umbilical ligaments unearth the type of hernia and the limits of dissection. A meticulous dissection of the space of Bogros exposes further landmarks that guide the dissection. Identification of Cooper's ligament and iliopubic tract presents safe areas for staple placement Dissection and anchorage within the triangle of doom and inferolateral to iliopubic tract are fraught with danger. Aberrant courses of nerves and vessels should be kept for seamless procedures.

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