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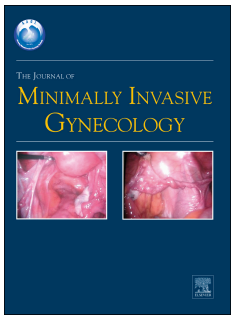

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Nerve Injuries in Gynecologic laparoscopy

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Precis

The aim of this review is to discuss the common neurologic injuries associated with gynecologic laparoscopic surgery

Abstract

Nerve injuries during gynecologic endoscopy are infrequent but distressing complication. In benign gynecologic surgery most of these injuries are associated with patient positioning although some are related to port placement. Most are potentially preventable with attention to patient placement on the operating room bed and knowledge of the relative anatomy of the nerves. The highest risk group vulnerable to these injuries includes women who have extreme body mass index and those with longer surgical times in Trendelenburg position. Upper and lower limb peripheral nerves are the most common nerves injured during gynecologic endoscopy. These injuries can result in transient or permanent sensory and motor disabilities that can interrupt patient recovery in an otherwise successful surgery. Numerous strategies are suggested to reduce the frequency of nerve injuries during gynecologic endoscopies. Proper patient positioning and proper padding of the pressure areas are mandatory to prevent malposition related nerve injuries. Anatomic knowledge of the course of nerves especially ilioinguinal and iliohypogastric nerves can minimize injury.

Keywords:

Gynecologic endoscopy;

Laparoscopy complications;

Nerve injury;

47 Lithotomy;

48 Trendelenburg;

49 Brachial plexus;

50 Lumbosacral plexus

51

Introduction:

Iatrogenic nerve injuries following gynecologic laparoscopic procedures are not common but do occur. The main causes are poor patient positioning during anesthesia, improper use of stirrups, inadequate padding protecting nerve-exposed areas, lengthy operations, and closure of lower lateral port trocar insertion sites [1, 2]. The most common nerves susceptible to injury originate from the lumbar, lumbosacral and brachial plexus but any nerves in the in the upper and lower limbs as well as the lower anterior abdominal wall can be affected. The majority of injuries has a good prognosis and is self-limited with spontaneous recovery or physical therapy. However, some patients will need long-term treatment, medical therapy for treatment of chronic pain and may need surgical intervention [2].

Being able to identify patients who are vulnerable to neurological complications is important in the prevention and early identification of nerve injuries related to gynecologic laparoscopies. Surgeon awareness of the anatomy of these nerves and injury mechanisms can help avoid most injuries. Therefore, this paper reviews the anatomy of the female pelvis and the risks and mechanisms of nerve injury associated with gynecologic laparoscopic surgeries. It will also review preventive strategies to reduce perioperative neuropathies.

Incidence:

The exact incidence of nerve injuries caused by gynecologic laparoscopic surgery is not well documented, possibly because such injuries are uncommon and usually resolve on their own. Bohrer et al. (2009) [3] conducted a prospective cohort trial of 616 female patients who

underwent elective gynecologic surgeries to evaluate the incidence and the prognosis of postoperative neuropathies related to vaginal surgeries. They found that the overall incidence of nerve injuries was 1.8% and that the most frequently injured nerves were the lateral femoral cutaneous nerve of the thigh and the femoral nerve [3]. A retrospective study of the medical records of 1210 patients who underwent major pelvic surgeries estimated the incidence of postoperative neuropathy to be 1.9% [4].

Risk Factors

Risk factors for peripheral nerve injuries during gynecologic laparoscopy surgeries are summarized in table 1.

Patient positioning. Early reports suggested that the most common causes of peripheral nerve injuries could be attributed to improper patient positioning [5]. The estimated incidence of nerve injuries associated with malposition under anesthesia during gynecologic laparoscopy ranges between 0.02 and 0.16% in the upper limbs [6, 7] and 1.5 to 1.8% in the lower limbs [3, 8]. In a large retrospective chart review of 198,461 patients who underwent surgeries in the lithotomy position, the incidence of severe motor disabilities was 1:3608 [9]. A more recent retrospective study that included 831 cases of robotic-assisted gynecologic surgeries reported that the malposition risk of nerve injuries was less than 1% [10].

Compression and stretching are the most commonly identified etiologies with patient positioning while entrapment of a nerve may occur with fascial closure. The brachial plexus and the lumbosacral plexus are the most vulnerable to injury during gynecologic laparoscopy due to their superficial, long course and the attachment of the nerves to the bones or the fascia in

many points along their course [8, 11]. High lithotomy with extreme flexion at the hip and steep Trendelenburg positions can contribute to perioperative nerve injuries during gynecologic laparoscopies (Figure 1, 2). Anesthetized patient malposition can result in neuropathies because of the wide range of positioning required during surgery that can cause nerve stretching, or compression with vascular ischemia [12]. Lateral port placement can lead to entrapment of ilioinguinal or iliohypogastric nerves during the fascial wound closure of port sites [2]. Figure 3 demonstrates the distribution of ilioinguinal and iliohypogastric nerve in the lower abdomen.

Several studies reported that increased surgical time spent in the lithotomy position is associated with an increased frequency of nerve injuries [8, 9, 13, 14]. In a large retrospective review that included 198,461 patients, the authors demonstrated that each hour in the lithotomy position enhanced the likelihood of nerve injuries by 100 fold [9]. A more recent prospective study found that extended positioning in lithotomy particularly for more than 2 hours was associated with an increased risk of nerve injuries.[8] Similarly, a positive correlation was observed between brachial plexus injuries and extended operative duration [11, 15]. However, Winfree et al. (2005) did not find the duration to be an important risk factor for postoperative peripheral neuropathy. Winfree et al. suggested that nerve injuries can occur during long and short operations. The introduction of robotic assisted laparoscopic surgeries may require patient positioning in the steepest degree (head down tilt 30- 40 degrees) of Trendelenburg position, which is associated with patient sliding and possible brachial plexus injuries [16]. Robotic-assisted laparoscopy can increase the risk of perioperative neuropathies

due to its heavy arms, its positioning near to the lower extremities, and the need to place the patient in an extreme position [17].

Support devices. Some types of leg supports increase the risk of nerve injuries because of inadequate support (eg, candy cane leg supports). Shoulder braces can lead to nerve compression as well.

Port placement. Lateral port placement and lateral port fascial closure in the lower abdomen can result in iliohypogastric and ilioinguinal nerve injuries if the ports are placed low in the abdomen [17].

Patient Specific Predisposing Factors. Some patients are more susceptible to nerve injuries due to the presence of predisposing factors [5] such as pre-existing generalized peripheral neuropathy [18]. The underlying cause of peripheral neuropathy can be diabetes mellitus or peripheral vascular disease; in rare cases, it is hereditary [19-22]. Patients with controlled or uncontrolled disease are at an increased risk for perioperative neuropathies [23]. Although there are no comparative data, we assume that since uncontrolled diabetics are at greater risk for diabetic neuropathy that they would also be at higher risk for perioperative neuropathies that are due to ischemia.

The presence of a cervical rib is a risk factor for brachial plexus entrapment during surgery [24]. Studies have shown that patients with an extreme high or low body mass index (BMI), particularly when BMI is less than 20 kg/m^2, and those who are older than 60 years of age are more susceptible to nerve pressure injuries. In these patients, the peripheral nerves seem to be

less protected and more sensitive to pressure [17, 23, 25-27]. A history of smoking or alcohol intake is considered a risk factor for perioperative peripheral nerve injuries [28].

Other patient-related conditions that can increase the risk of postoperative peripheral neuropathy include hypovolemia, hypotension, electrolyte disturbance and malnutrition [5].

Pathophysiology and Classification

The peripheral nerves consist of bundles of nerve fibers that conduct signals from and to the central nervous system. The axon is surrounded by a myelin sheath and Schwann cells. Each nerve is walled with triple layers of connective tissue; deep endoneurium, superficial epineurium, and perineurium in between. The vasa nervorum are minute arteries responsible for the blood supply of the interior of the nerves and their coverings.

Postoperative neuropathy after gynecologic laparoscopy surgeries can be the consequence of pressure, stretching, entrapment or laceration of the nerves [29]. Although lower lateral trocar placement and fascial wound closure during gynecologic laparoscopy can be associated with direct partial or complete nerve laceration, it is usually a result of entrapment [1]. The degree of nerve trauma can be classified according to its severity by Seddon's or Sunderland's classifications as shown in Table 2 [30, 31]. The use of classification systems can help the surgeon anticipate the patient's prognosis and treatment options.

Perioperative peripheral neuropathy can cause a variety of signs and symptoms such as loss of sensation, pain, numbness, and muscle weakness with motor disabilities, inability to move a limb and loss of reflexes [26]. The severity of nerve damage is proportional to the degree and

duration of nerve compression [32]. Nerve injuries caused by pressure can occur within 15 to 30 minutes from the start of the procedure although it is possible that motor nerve fibers can be affected within 60 seconds [33]. These are not associated with axonal damage.

Conduction block (Neuropraxia)

Neuropraxia is the mildest type of nerve injury and is not associated with axonal damage (no Wallerian degeneration). Nerve stretching and compression usually result in temporary nerve ischemia that leads to transient focal axonal conduction block (neurapraxia) across the affected portion of the nerve [31, 34, 35]. This transient conduction block usually resolves in few minutes. However, if it is associated with elevated venous pressure and edema, it may lead to sustained dysfunction that requires weeks to months to completely resolve [36, 37]. Consistent and chronic nerve compression will result in Schwan cell damage and demyelination, which can interrupt impulse conduction down the nerve [38]. Motor nerve fibers seem to more affected by slight nerve injury [39].The average time for recovery of neurapraxia is four to six weeks[40].

Axonal damage (Axonotmesis)

Profound nerve compression or traction can lead to physical axonal disruption and result in Wallerian degeneration; the supporting Schwan cells are usually not affected. Axonal damage affects motor, sensory as well as autonomic function [39]. This incomplete nerve injury can lead to prolonged dysfunction that requires weeks to months to completely resolve. [35, 41] The proximal axon grows at rate 2-3 mm per day.[42] However, recovery is usually complete in most cases because the Schwan cell layer is intact [43].

Nerve damage (Neurotmesis)

Neurotmesis is the most severe form of nerve injury and is caused by nerve compression, stretching or complete nerve transection or ligation. This type of nerve injury is associated with complete neural separation (neurotmesis) including disruption of both the axon and Schwan cells. This type of injury has the worst prognosis and will not resolve without surgical intervention.[24, 35]

Upper extremity nerve injuries

The nerve supply of the upper extremities originates from the spinal nerve roots in C5- T1; it is integrated to form the brachial plexus and its peripheral nerves. The brachial plexus is a somatic network of nerve fibers that provides motor and sensory innevation to the upper limbs as well as to the shoulder girdle. The peripheral nerves of the upper limbs include five main nerves: Ulnar, Radial, Median, Axillary and Musculocutaneous. Upper extremity nerve injuries can be attributed to poor positioning of the anesthetized patient as well as to direct compression of the superficial nerves against hard surfaces.

Brachial plexus nerve injuries:

Brachial plexus injuries are uncommon in gynecologic laparoscopy surgeries but represent the most serious complication due to improper positioning of anesthetized patient [7, 24]. Table 3 illustrates summary of brachial plexus major nerve injuries with the common clinical features. Extensive arm abduction (Figure 4), external rotation and posterior shoulder displacement can result in brachial plexus stretching and ischemia [5]. Direct compression of the brachial plexus can also occur if braces are placed too medially. According to a cadaver study that investigated

the mechanism of brachial plexus stretching, the medially adjusted shoulder brace seems to downwardly displace both the clavicle and the humeral head, which work as a fulcrum upon which the nerves can be stretched [44].

Romanowski et al. retrospectively reviewed 3200 records of advanced laparoscopic surgeries to assess the frequency of brachial plexus injuries. They found that the incidence of brachial plexus injuries associated with advanced laparoscopic surgeries was 0.16% [7]. They suggested that modifying the position of the patient can reduce the incidence of brachial plexus injuries during advanced laparoscopic surgeries [7].

Applied Anatomy:

The brachial plexus as shown in Figure 4 originates from five spinal nerve roots C5 - T1. The nerve roots pass out from the vertebral canal through the vertebral transfer process and merge to form the superior trunk (C5,C6), middle trunk (C7), and inferior trunk (C8,T1). Then, each trunk divides into two parts; the anterior one supplies the flexors muscles while the posterior one supplies the extensors. These divisions pass from the neck area into the axilla and merge to form the three cords of the brachial plexus posterior, lateral, and medial. The cords of the brachial plexus terminate at the bottom of the axilla and form five main nerves: Ulnar, Radial, Median, Axillary and Musculocutaneous.

The brachial plexus is at risk to injury during laparoscopic procedures due to several anatomical factors. The anatomical factors that increase the risks of brachial plexus injuries include a long superficial course, firm attachment to the prevertebral and axillary fascia and its close relation to movable bony structures such as the clavicle, first rib, humeral head and coracoid process.

The existence of associated anatomical factors as cervical rib or deformities caused by a previous neck or shoulder fracture can increase the risk of positional nerve injuries.[45] Due to the sensitive position of the brachial plexus, it is especially vulnerable to malposition injuries.

Mechanism of injury:

Patient malposition during gynecologic laparoscopy can stretch or compress the brachial plexus. Irvin et al found that stretch trauma is the most common cause of brachial plexus nerve injury during laparoscopy.[25] The most common mechanisms of brachial plexus nerve injuries are shown in table 4.

Hyper-abduction of the arms (figure 4) can stretch the upper roots (C5, C6) of the brachial plexus during laparoscopic surgeries [11, 46, 47]. Abducting the arm more than 90 degrees stretches the brachial plexus between the first rib and the clavicle. This stretching is magnified by the arm's pronation and head rotation away from the extended arm. This may result in Erb's Palsy where the arm hangs by the side with medial rotation and pronation.

[11, 48]. The Steep Trendelenburg position can stretch the lower brachial plexus roots (C8, T1), particularly when the arms are extended (Figure 1). Injury to the lower roots results in Claw hand (Klumpk's hand). This stretching is due to cephalad movement of the body in relation to the arms, especially when wristlets are used to secure the arms [11, 49]. Shoulder braces, which are used to protect the patient from sliding while in Steep Trendelenburg position, seem to increase brachial plexus traumas particularly when the arms are extended [7, 11]. Braces should not be placed too medial or too lateral to avoid brachial plexus roots and division

injuries [24]. The use of wristlet supports can lead to nerve compression injury of the brachial plexus [11].

Sequelae of injury

Brachial plexus neuropathies can lead to sensory and motor deficits. Minor brachial plexus injury can cause transient sensory impairment on the medial side of the upper limb. The more severe affection of the upper roots (C5 and C6) classically leads to Erb's palsy syndrome (Waiter's tip hand). Injury of the lower roots (C8 and T1) classically causes Klumpke's paralysis syndrome (Claw hand) [11, 17]. Horner's syndrome (ipsilateral ptosis, miosis and anhydrosis) may accompany brachial plexus injuries particularly when the (T1) nerve root is injured--due to involvement of the nearby cervical chain [11].

Upper extremities peripheral nerve injuries

The peripheral nerves supplying the upper extremities are derived from the brachial plexus. The most commonly injured nerves in the upper limbs are the radial nerve and the ulnar nerve because of their course (Table 3). The radial nerve can be compressed while passing through the spiral groove while the ulnar nerve is the most vulnerable to injury where **it** is related to the olecranon fossa of the humerus.

Applied Anatomy:

The radial nerve passes directly along the spiral groove of the humerus. The motor component of the radial nerve innervates the extensor muscles of the wrist and the fingers while its sensory component supplies the posterior aspect of the lateral 3.5 fingers.

The ulnar nerve **passes** ~~leaves the arm~~ close to the medial epicondyle (passing through the olecranon groove) of the humerus. At this point, the superficial ulnar nerve is more susceptible to compression against the operating table or the arm boards [5, 19]. The ulnar nerve sensory component supplies the medial 1.5 fingers and its motor component supplies the small muscles of the hand [39]. Extreme or prolonged flexion of the elbow across the chest can cause ulnar nerve stretching around the medial epicondyle and its subsequent injury [50]. When the arms are tucked on the side of the patient, extra padding should be placed at the elbow.

Mechanism of injury:

Persistent pressure on the humerus or the medial epicondyle of the elbow during arm positioning can damage the radial or the ulnar nerves (53). The radial nerve can be compressed between the edge of the operating table and the humerus while passing over the spiral grove, particularly with inadequate padding of the arm. The ulnar nerve can be compressed if the patient forearm is pronated on the arm board or when the arm is supinated and tucked at the patient side, particularly with inadequate padding to the elbow joint (table 4) [39].

Sequelae of injury:

Radial nerve neuropathy can lead to paresthesia in the lateral 3.5 fingers and loss of function in the extensor muscles in the wrist and the fingers (wrist drop) [51] while ulnar nerve neuropathy can cause sensory loss or paresthesia in the medial 1.5 fingers, which may result in claw hand [52].

Lumbosacral plexus nerve injuries

The lumbosacral plexus originates from the 3rd, 4th and 5th lumbar nerve roots and from the 1st, 2nd and 3rd sacral nerve roots with minimal contribution from the 2nd lumbar and the 4th sacral nerve root. The most common neuropathies reported with surgeries in the lithotomy position are summarized in table 5, involve the femoral, ilioinguinal, iliohypogastric, lateral femoral cutaneous nerve of the thigh, the sciatic, obturator and the common peroneal and saphenous nerves. Table 6 summarizes the most common mechanisms of lumbosacral nerve injuries during laparoscopic surgeries.

Femoral nerve injury

The frequency of femoral nerve injury recorded in gynecologic surgeries has recently decreased because of the reduction of the use of self-retaining retractors which their lateral plates can compress the nerve. A retrospective review estimated that femoral nerve motor injuries related to the lithotomy position occur in approximately 1 of every 50,000 surgeries [9].

Applied Anatomy:

The femoral nerve starts as the largest branch of the lumbar plexus and is composed of nerve roots L2-L4. It exits the psoas muscle from its lateral border within the abdomen. It descends in the interval between the psoas muscle and the iliacus. The femoral nerve leaves the pelvis below the inguinal ligament to end in the upper third of the thigh where it branches into anterior and posterior divisions.

Mechanism of injury:

Inappropriate lithotomy position can be associated with femoral nerve injury. Prolonged hip flexion, extreme abduction, and external rotation can be associated with stretching and entrapment of the femoral nerve under the inguinal ligament with subsequent interruption of the nerve blood supply and femoral neuropathy [53]. A surgical assistant leaning on the patient's inner thigh during surgery can result in femoral nerve compression [54].

Sequelae of femoral nerve injury:

Femoral nerve injury can lead to paresthesias of the anteromedial aspect of the thigh and the medial aspect of the calf. If the motor fibers of the femoral nerve are involved, the patient may find it difficult to walk due to weakness in hip flexion, adduction, and knee extension. Femoral nerve neuropathy results in weakness in the quadriceps muscle with a weak or absent patellar reflex. The classic postoperative presentation of femoral nerve injury is falling when trying to get out of bed and difficulty in climbing stairs [54].

Lateral femoral cutaneous nerve of the thigh injury

The lateral femoral cutaneous nerve of the thigh provides sensory supply to the lateral surface. A prolonged lithotomy position can result in lateral femoral cutaneous nerve compression with an estimated incidence of 0.4% [17].

Applied Anatomy:

The lateral femoral cutaneous nerve of the thigh orgiantes from nerve roots L2-L4 and exits the spinal cord between the L2 and L3 vertebrae. It passes along the outer edge of the psoas muscle and then below or within the lateral aspect of the inguinal ligament near its insertion to

the anterior superior iliac spine (ASIS). However, in rare cases, the lateral cutaneous nerve may enter the thigh lateral to the ASIS or medially near the insertion of the inguinal ligament to the pubis.[55]

Mechanism of injury:

As with the femoral nerve, the lateral femoral cutaneous nerve of the thigh can be injured during gynecologic laparoscopy by entrapment below the inguinal ligament due to excessive hip flexion, abduction and external rotation. According to Littwiller et al. (2004), hip external rotation during lithotomy results in increased strain on the lateral femoral cutaneous nerve of the thigh [56].

Sequelae of lateral cutaneous nerve of the thigh injury:

Meralgia paresthetica results from lateral femoral cutaneous nerve compression. The classic presentation is burning pain, paresthesia (numbness and tingling), and hypoesthesia over the anterior and the lateral aspects of the thigh down to the knee [57]. In most affected patients, meralgia paresthetica is a benign self-limited condition that does not require any intervention.[58]

Obturator nerve

The obturator nerve originates from the lumbar plexus and emerges in the abdomen from the medial border of the psoas muscle.

Applied Anatomy:

The obturator nerve begins from the anterior division of L2-L4 and travels in the substance of the psoas muscle to appear from its medial border. It then runs in front of the sacroiliac joint to the lesser pelvis. The obturator nerve travels down to the obturator notch to exit the pelvis through the obturator foramen where it splits into anterior and posterior branches. Both divisions innervate the thigh adductor muscles. The anterior branch gives sensory innervation to the medial surface of the mid thigh and the hip joint while the posterior branch innervates the knee joint.

Mechanism of injury:

This nerve is most commonly injured during endometriosis excision, retroperitoneal surgeries, transobturator tape insertion and paravaginal defect repair.[59]

It is suggested that prolonged hip flexion leads to obturator nerve stretching at the bony obturator foramen.[60] A cadaver-based study demonstrated that the most important factor in obturator nerve injury is a hip abduction [56].

Sequelae of obturator nerve injury:

Unilateral obturator nerve neuropathy leads to sensory loss or paresthesia in the upper inner thigh and weak adduction with minor ambulatory problems.[60] Pressure and stretching injury rarely lead to motor affection [61].

Sciatic nerve injury

The sciatic nerve is the largest and longest nerve in the human body. It is located in the back of the leg and provides motor and sensor innervation to the lower limbs. Sciatic nerve neuropathy

related to the lithotomy position is relatively uncommon. Sciatic nerve injuries result in sensory symptoms in 0.4% [62] of cases and severe motor sequelae in 1:25000 surgeries [17].

Applied Anatomy:

The sciatic nerve originates from the anterior division roots of the lumbosacral trunk (L4-S3). It runs posteriorly down the thigh to exit the pelvis through the sciatic foramen to enter the gluteal region. It descends on the posterior aspect of the thigh to the apex the popliteal fossa where it forms two branches: the tibial and common peroneal nerves. The sciatic nerve supplies the thigh flexor muscles and provides both motor and sensory supply to the lower extremities below the knee.

Mechanism of injury:

Patients with a low body mass index are more vulnerable to sciatic nerve neuropathy especially if placed in the lithotomy position for a long duration [63]. Hip flexion, especially if combined with knee extension (high lithotomy position), can cause sciatic nerve stretch injury [17]. Hip abduction and external rotation can stretch the sciatic nerve particularly when the knee is flexed [64, 65].

The Sequelae of sciatic nerve injury:

Sciatic nerve injury can cause hypoesthesia or paresthesia over the posterior aspect of the thigh, calf and sole of the foot [66]. Severe damage may cause weakness with hip extension and knee flexion. It may also lead to foot drop associated with paresthesia over the calf and the

dorsum of the foot due to weakness in the dorsiflexion foot muscles (anterior and lateral compartment) [67].

Common peroneal nerve injury:

The common peroneal nerve is a branch of the sciatic nerve and is the most frequently injured nerve during surgeries that involve the lithotomy position. Motor disabilities caused by common peroneal nerve injuriess is estimated to occur in 1 of every 4500 lithotomy operations [9].

Applied Anatomy:

The common peroneal nerve (also named as the common fibular nerve or external popliteal nerve) starts as a branch of the sciatic nerve at the apex of the popliteal fossa. It winds along the lateral side of the popliteal fossa and around the fibula neck. At this point, the common peroneal nerve is subcutaneous and can be entraped against the head of the fibula. The common fibular nerve ends within the peroneal longus muscle by branching into two divisions: the superficial and deep fibular nerves. The motor component of the superficial and the deep fibular nerves are responsible for foot eversion and dorsiflexion by supplying the muscles of the lateral and posterior compartment while the sensory component of the common peroneal nerve gives cutaneous innervation to the posterolateral aspect of the leg.

Mechanism of injury:

The common peroneal nerve can be injured during surgeries that use the lithotomy position due to direct pressure and stretching. The use of hanging candy cane stirrups is a recognized

risk factor for pressure injury (Figure 1). Stretch trauma of the common peroneal nerve is related to prolonged knee flexion and can be exacerbated by excessive hip external rotation. The use of boot stirrups helps protect against this type of injury [17]. Extra padding should be used in this area during surgery.

Sequelae of common peroneal nerve injury:

Common peroneal nerve injury can be associated with hyposthesia or paresthesia affecting the dorsum of the foot and the lateral surface of the leg. Severe damage can lead to “foot drop” that manifests with the loss of foot dorsiflexion, loss of toes extension and loss of lateral rotation of the ankle.

Other lithotomy position related nerve injuries:

Both the tibial and saphenous nerves can be compressed against a hard surface while the patient is in the lithotomy position. Adequate padding minimizes the risk of these injuries.[68]

Iliohypogastric and ilioinguinal nerve injury:

Injury to the ilioinguinal and iliohypogastric nerves typically occurs as a result of nerve ligation during closure of the lateral port-fascial defects in the lower abdomen [69]. In a retrospective study, the estimated incidence of abdominal wall nerve injury during laparoscopic gynecologic surgeries was 4.9%.[2] The course of ilioinguinal and iliohypogastric nerves makes them vulnerable to trauma during gynecologic laparoscopy surgery [2, 69].

Applied Anatomy:

The ilioinguinal and iliohypogastric nerves are composed of the T12-L1 nerve roots. Both nerves run along the abdominal oblique muscles to supply the area between the ASIS and iliac crest. Whiteside et al. conducted a cadaver-based study and demonstrated the relationship of the ilioinguinal and iliohypogastric nerves to lateral trocar placement sites in laparoscopy. Whiteside's study also found that the ilioinguinal nerve should be 3.1 cm medial and 3.7 cm inferior to the ASIS while the iliohypogastric nerve should be 2.1 cm medial and 0.9 cm inferior to the ASIS (Figure 3) [1]. Rahn et al. (2010) conducted a similar cadaver-based study and found that the ilioinguinal nerve should be 2.5 cm medial and 2.4 cm inferior to the ASIS and the iliohypogastric nerve should be 2.5 cm medial and 2 cm inferior to the ASIS [70]. Both the ilioinguinal and the iliohypogastric nerves are pure sensory. The iliohypogastric nerve innervates the skin over the gluteal and hypogastric regions while the ilioinguinal nerve innervates the skin of the groin, inner thigh, and labia majora.

Mechanisms of injury:

A retrospective study of the risk factors for abdominal wall nerve injury during gynecologic laparoscopy found that neuropathy is mainly caused by entrapment of the ilioinguinal and iliohypogastric nerves during fascial closure of the lateral port site. In the same study, unrepaired fascial wounds were not associated with postoperative neuropathies [2].

Sequelae of iliohypogastric and ilioinguinal nerve injury:

The most common presentation of ilioinguinal/iliohypogastric neuropathies includes sharp, burning, lancinating pain radiating from the incision site to the suprapubic area or the vulva with paresthesia over the nerve distribution area.[4, 71] This neurological pain can occur

immediately or weeks to months after surgery [72]. The neurological pain may persist for months or years due to persistent neural constriction caused by scarring [70] and can be relieved with a local anesthetic.[71]

Prevention of nerve injury during gynecologic laparoscopy:

Safe and proper positioning of the patient on the operative room table is a joint responsibility of the surgeon and anesthesiologist [26]. Proper positioning with adequate padding of all of the pressure points can minimize the possibility of nerve injury [73, 74].

Ghomi et al. performed a descriptive study to explore the importance of patient positioning when using the Trendelenburg in robotic-assisted gynecologic surgery for benign lesions and found that these surgeries could be performed efficiently without the use of the steep position [75].

Prevention of brachial plexus injuries:

Table 4 summarizes the common strategies to prevent nerve upper extremities nerve injuries during gynecologic laparoscopy surgeries. The brachial plexus is commonly injured during gynecologic laparoscopy. To avoid brachial plexus injuries, the patient's arms should be tucked carefully at his or her sides. If it is necessary to extend the arms, the trunk arm angle should preferably be limited to 90 degrees to prevent hyper- abduction nerve injury [17]. The best position for the head is the central position; posterior displacement of the shoulder should be avoided to decrease stretching and pressure on the brachial plexus. Shoulder braces and wrist restraints should also be avoided [24] . Gel pads, egg crate or foam mattress pads can replace shoulder braces to prevent patient sliding from the Trendelenburg position. If it is necessary to

use shoulder braces, they should be adjusted to the acromiovlavicular joint directly [39, 61]. Even with correct placement of shoulder braces directly over the acromioclavicular joint, the risk of brachial plexus injury is still present.

A number of measures can be taken to minimize postoperative ulnar nerve neuropathy: using elbow pads, avoiding arm abduction, pronation of the forearm and avoiding prolonged or extreme elbow flexion[50, 76]. Both arms must be tucked at the patient's side pronated with adequate padding (foam padding) over the posteromedial elbow to protect the ulnar nerve from pressure against a hard surface [76]. If the arms are placed on boards, the forearm should be placed in a supine position with padding to help protect the ulnar nerve from compression [39]. George et al. (2009) suggested placing the arms in a comfortable sling position with elbow flexion angle > 90 degrees to minimize injuries to the brachial plexus [77]. The angle of the bed head tilt used for the Trendelenburg position should be limited to 30 degrees especially if the arms are extended [78]. Figures 5, 6 and 7 demonstrate the proper patient positioning for gynecologic laparoscopy surgeries.

Prevention of lower extremities nerve injuries

The recommended strategies to minimize lower extremities nerve injuries during gynecologic laparoscopy are summarized in table 6.

Proper leg placement in lithotomy position:

Correct placement of the patient in a lithotomy position is critical for the prevention of position-related nerve injuries. The surgeon should limit the hip flexion, abduction, and external rotation to minimize nerve injuries [39, 65].

A proper lithotomy position depends on the type of the surgery performed. The ideal position for laparoscopy is the low lithotomy position; with the thigh-trunk angle about 170 degrees. A trunk-thigh angle of less than 170 degrees may cause obturator nerve strain and an angle more than 180 degrees may cause lumbar spine stress.[17] Vaginal surgeries may necessitate a high lithotomy position to improve exposure. The trunk-thigh angle should be greater than 60 degrees to minimize the strain on the sciatic and femoral nerves. The angle of the knee should be kept between 90 and 120 degrees to avoid pressure on the sciatic nerve and to allow a better venous return.

The angle of hip abduction should be 90 degrees or less to minimize strain on the obturator nerve. The extent of external hip rotation should be minimized so as not to increase the pressure on the femoral, obturator or sciatic nerves. It is believed that candy cane stirrups enhance the risk of the external hip rotation. The legs must be padded around the knee to protect the common peroneal nerve from trauma [39].

Leg support:

Traditional candy cane stirrups give little support to the legs during laparoscopy. They are considered a risk factor for uncontrolled hip abduction and external rotation. When the leg comes in contact with the support pole, it can place pressure on the common peroneal nerve and cause injury. Adequate padding should be placed between the lateral fibular head and the stirrups or the supporting pole to prevent common peroneal nerve compression.[47] Figures 5, 6 and 7 demonstrate the proper patient positioning for gynecologic laparoscopy surgeries.

Prevention of ilioinguinal and iliohypogastric nerve injuries:

The best way to avoid ilioinguinal and iliohypogastric nerve injuries is to place side ports above the ASIS. Other stratigies to prevent ilioinguinal and iliohypogastric nerve injuries include using a side-port trocar that is no larger than 5mm, which avoids the need to close the fascial defect in the lower abdomen and, if necessary, avoiding a tight closure by accurately approximating the fascial edges [2].

Conclusion

Neurologic injuries after gynecologic surgery are relatively uncommon. However, when they occur they are very distressing to the patient and delay convalescence time and decrease quality of life. Most are self-limited or respond to conservative treatment such as physical therapy. There are several critical factors that can decrease the frequency of occurrence. First is knowledge of the anatomy of the peripheral nerves of the upper and lower limbs and the anterior abdominal wall. Second is for the entire surgical team to pay close attention to the patient positioning step. The entire team is responsible and all should participate. Finally a discussion with the patient of the risk factors that predispose her to this complication.

Figure legends

Figure 1: High lithotomy position coupled with Trendelenburg (head down) with the usage of shoulder braces. Both brachial plexus and lumbosacral plexus are at risk for nerve stretching and injury.

Figure 2: High lithotomy position. Excessive hip abduction (> 90 degrees) and external rotation are associated with femoral nerve injuries.

Figure 3: The shaded areas demonstrate the distribution of ilioinguinal and iliohypogastric nerves which should be avoided during lateral port insertion in gynecologic laparoscopy. The main anatomic landmark is the anterior superior iliac spine (ASIS). Avoid placing trocars, especially those requiring fascial closure, below this level.

Figure 4: The brachial plexus. The origin and the impact of arm abduction when the arm trunk angle exceeds 90 degrees.

Figures 5- proper patient positioning with appropriate relative angles and padding of upper and lower limb sensitive areas- side view

Figure 6-- proper patient positioning with appropriate relative angles and padding of upper and lower limb sensitive areas- perineal view

Figure 7: -- proper patient positioning with appropriate relative angles and padding of upper and lower limb sensitive areas- top view

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Table 1:

Risk factors for peripheral nerve injuries during gynecologic laparoscopy surgeries:

Patient specific risk factors:

- Preexisting peripheral neuropathy (due to preexisting diabetes mellitus, peripheral vascular disease or rare hereditary).
- Preexisting diabetes mellitus or peripheral vascular disease.
- Congenital cervical rib.
- Extreme body mass index (e.g. Low BMI < 20 kg/m^2).
- History of smoking.
- History of alcohol intake.

Surgical risk factors:

- Improper patient positioning with nerve stretch or compression.
- Prolonged operative time.
- Use of candy cane stirrups for leg support in lithotomy position.

Table 2
Classification of nerve injury according to the degree severity (1, 2)

Classification		Nerve pathology	Pathophysiology	Prognosis
Sunderland's Classification	**Seddon's Classification**			
I	**Neurapraxia (Class I)**	-Possible demyelination at the site of injury -No Wallerian degeneration	Focal Conduction block	Full recovery within (one day up to 12 weeks)
II	**Axonotmesis (Class II)**	-Some axon injury with Wallerian degeneration. - Intact Endoneurium, Perineurium and Epineurium	Complete loss of nerve function at the site of injury and distally.	Full recovery (slow/ up to 4 months)
III		-Axon and Endoneurium disruption with Wallerain degeneration. - Intact epineurium and Epineurium.	Complete loss of nerve function at the site of injury and distally.	Variable (Full to incomplete within weeks to months)
IV		-Axonal, Endoneurium and Perineurium disruption. -Intact Epineurium	Complete loss of nerve function at the site of injury and distally.	Unlikely for recover without surgical intervention
V	**Neurotmesis (Class III)**	Complete transection or tearing of the nerve (disruption in all the nerve layers)	Complete loss of nerve function at the site of injury and distally.	No recovery without surgical intervention.

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Table 3:

Summary of brachial plexus major nerve injuries:

Nerve	Origin	Clinical identification of nerve injury	
		Sensory presentation	**Motor presentation**
Upper brachial plexus nerve roots	C5-C6	Lateral aspect of the upper limb. (rare presentation)	Shoulder adduction, elbow extension, and arm medial rotation. (Erb's Palsy).
Lower brachial plexus nerve roots	C8-T1	Sensory loss of the lateral aspect of the upper limb	Paralysis of the intrinsic muscles of the hand. (Klumpke's Palsy)
Ulnar nerve	C8-T1	Sensory loss in the dorsal tips of the lateral 3.5 fingers.	Paralysis of the small muscles of the hand (Claw hand)
Radial nerve	C5-T1	Sensory loss in the medial 1.5 fingers	Loss of wrist and finger extension (drop hand)

Table 4:

Brachial plexus nerve injuries and preventive strategies:

Nerve	Mechanisms of injury	Preventive strategies
Upper brachial plexus nerve roots (C5-C6)	Hyperextension of the arms more than 90 degrees (magnified by arm pronation and head rotation away from the arm)	Tuck the pronated arms to the sides of the patient, Centralize the head, and Keep the extended arms in supination
Lower brachial plexus nerve roots (C8-T1)	Steep Trendelenburg position 30 to 40 degrees (magnified by extended arms and the use of shoulder braces)	Try to minimize the angle of inclination in Trendelenburg position and avoid the use of shoulder braces. If the braces used, apply them to the acromioclavicular joint and use gel pads, egg crate or foam mattress pads.
Ulnar nerve (C8-T1)	Compression of the ulnar nerve at the point of the medial epicondyle against hard surface or extreme prolonged flexion of the elbow.	Adequate padding over the posteromedial elbow. Keep the arms supinated if extended on boards. Keep the arms pronated if the arms tucked at the patient's sides.
Radial nerve (C5-T1)	Pressure of the radial nerve against the humerus	Avoid the position of the arm at the edge of the arm board.

Table 5:

Summary of lumbosacral major nerve injuries:

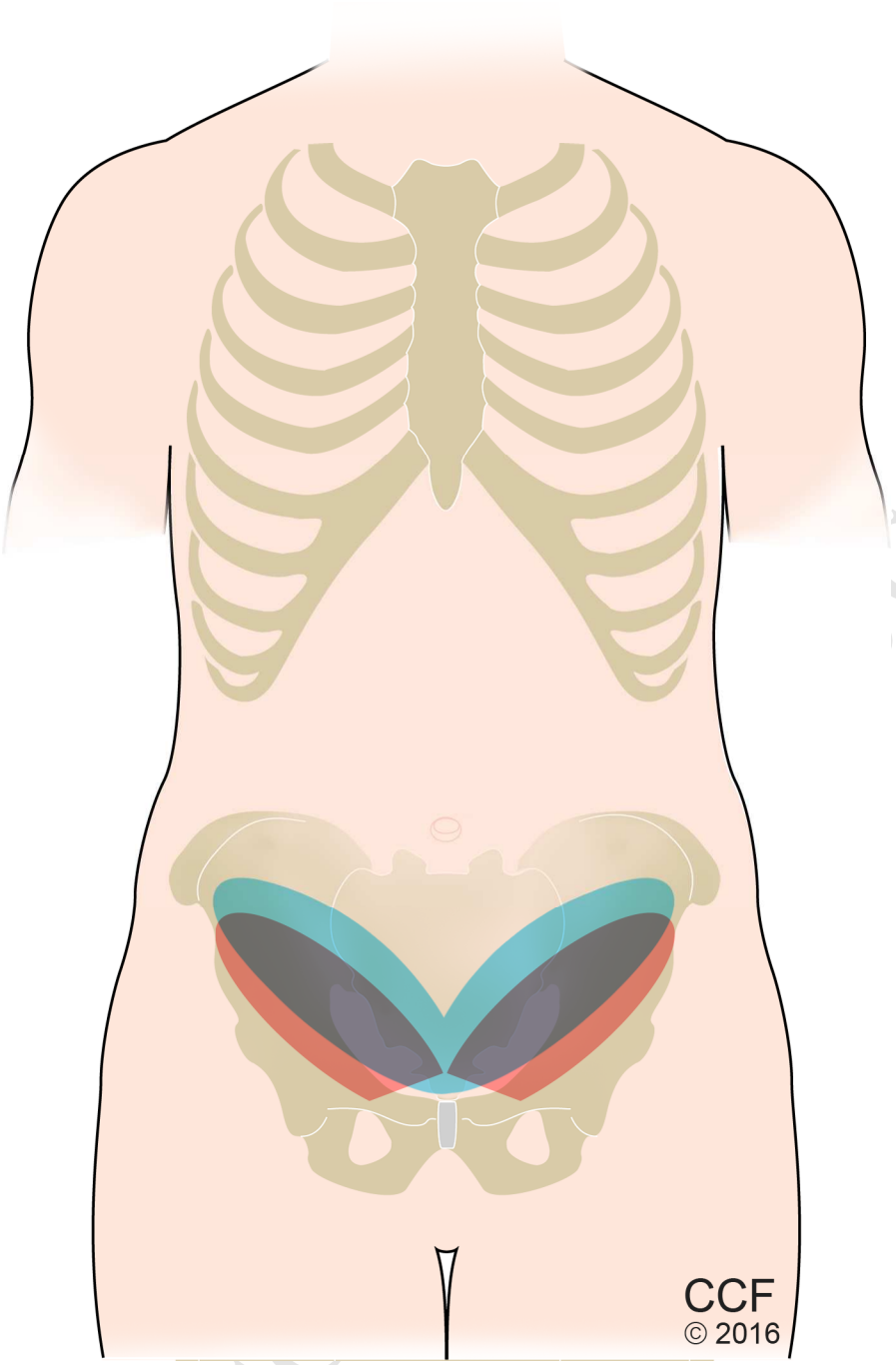
Nerve	Origin	Clinical identification of nerve injury	
		Sensory presentation	**Motor presentation**
Femoral nerve	L2-L4	Numbness over the thigh.	Weakness in hip flexion. (difficult climbing stairs)
Obturator nerve	L2-L4	Numbness over the upper medial thigh	Weakness in hip adduction. (minor ambulatory problem)
Sciatic nerve	L4-S3	Numbness below the knee. (sciatica)	Weakness in the ankle dorsiflexion and plantar flexion, and weakness in knee flexion
Common peroneal nerve	L4-S3	Numbness over the lateral calf and dorsum of the foot	Weakness in dorsiflexion of the ankle and toes. (foot drop)
Tibial nerve	L4-S3	Numbness of the toes and foot plantar surface.	Weakness of the plantar flexion of the ankle and toes (Cavus deformity foot)
Lateral femoral cutaneous nerve	L2-L3	Pain or paresthesia of anterio-posterior lateral thigh (Meralgia paresthetica)	None

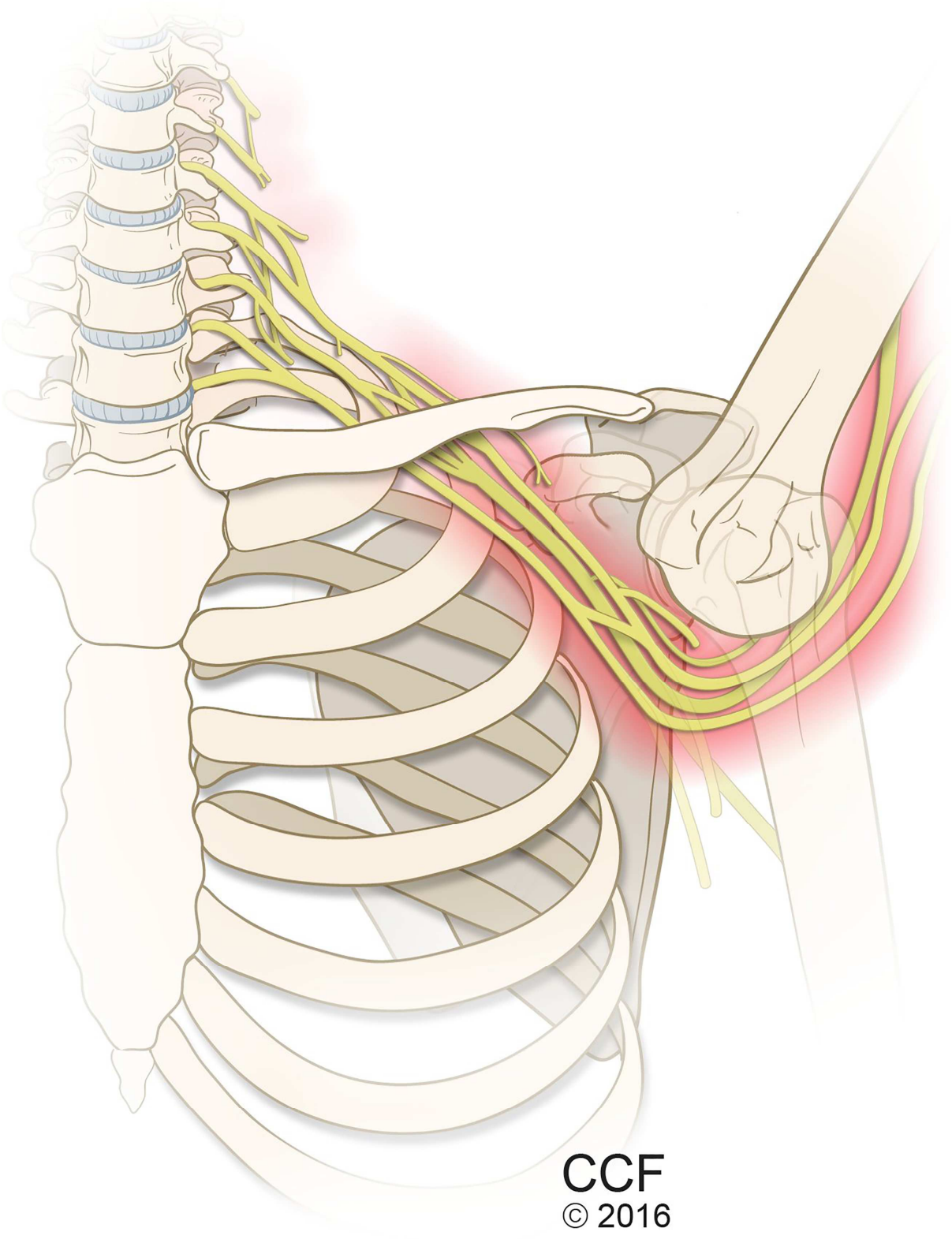
Ilioinguinal and iliohypogastric nerves	T12-L1	Sharp burning pain radiating from incision site to mons, libia or thigh.	None

Table 6:

Lumbosacral plexus nerve injuries and preventive strategies:

Nerve	Mechanisms of injury	Preventive strategies
Femoral nerve (L2-L4)	Prolonged hip flexion, extreme abduction and external rotation. Surgical assistant leaning on the inner thigh of the patient.	Proper positioning of the patient in lithotomy position with limitation of hip flexion, abduction and external rotation.
Obturator nerve (L2-L4)	Prolonged excessive hip flexion.	
Sciatic nerve (L4-S3)	Hip flexion with extension of the knee. Hip abduction and external rotation with flexed knee	
Lateral femoral cutaneous nerve (L2-L4)	Excessive flexion, abduction and external rotation of the hip.	
Common peroneal nerve	Compression between the head of the fibula and the candy cane stirrups. Prolonged knee flexion with excessive hip external rotation.	Avoid the use of candy cane stirrups. Avoid excessive knee flexion and external rotation of the hip. Adequate padding of the knee area.
Ilioinguinal and iliohypogastric nerves (T12-L1)	Insertion of the lateral side port at the site of nerves course of the lower abdomen with stitch closure of the fascial defects	Avoid the nerve course sites. Avoid the use of stitch closure of the fascial defect If the fascial defects were closed, do not tight the stitching

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