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Review article

Intraoperative Peripheral Nerve Injury in Colorectal Surgery. An Update☆

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ABSTRACT

Intraoperative peripheral nerve injury during colorectal surgery procedures is a potentially serious complication that is often underestimated.

The Trendelenburg position, use of inappropriately padded armboards and excessive shoulder abduction may encourage the development of brachial plexopathy during laparoscopic procedures.

In open colorectal surgery, nerve injuries are less common. It usually involves the femoral plexus associated with lithotomy position and self-retaining retractor systems.

Although in most cases the recovery is mostly complete, treatment consists of physical therapy to prevent muscular atrophy, protection of hypoesthetic skin areas, and analgesics for neuropathic pain. The aim of the present study is to review the incidence, prevention and management of intraoperative peripheral nerve injury.

Lesión intraoperatoria de nervio periférico en cirugía colorrectal. Revisión de conjunto

Palabras clave:
Lesión del plexo braquial
Neuropatía femoral
Lesión de nervio periférico
Cirugía colorrectal

RESUMEN

La lesión de nervio periférico durante procedimientos de cirugía colorrectal constituye una complicación potencialmente grave a menudo infravalorada durante el postoperatorio.

La posición de Trendelenburg, la colocación de topes y las abducciones de los brazos han demostrado favorecer el desarrollo de plexopatía braquial durante los procedimientos laparoscópicos.

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En cirugía colorrectal abierta las lesiones nerviosas son menos frecuentes, afectan preferentemente al plexo femoral y se asocian a la posición de litotomía y al uso de autorretractores.

Aunque en la mayoría de los casos la recuperación es completa, el tratamiento consiste en fisioterapia para prevenir la atrofia muscular, protección de las zonas con hipoestesia y analgésicos frente al dolor neuropático. El objetivo del presente artículo es realizar una revisión de la literatura existente sobre incidencia, prevención y manejo de la lesión intraoperatoria de nervio periférico.

Introduction

Intraoperative peripheral nerve injury (IPNI) is an important complication that has not been mentioned very often in the context of perioperative morbidity. Although some papers cite an incidence of from 0.3%[1] to 1.5%,[2] its actual incidence is unknown due, on the one hand, to the fact that it may vary depending on its position and the surgical speciality, and on the other, that it is rarely mentioned in the literature, where it is limited to a heterogeneous series of cases. In spite of this, it is a potentially serious complication with the risk of chronic neurological damage[1,3–5] and major medical-legal costs.[2,5–12] In colorectal surgery the range of approaches and surgical positions mean that knowledge and publication of the mechanisms that cause neurological damage is especially important. The purpose of this paper is to revise the current evidence for IPNI in colorectal surgery using an open or laparoscopic approach. To this end we analyse the factors associated with IPNI as described in the literature, as well as its diagnosis, and evolution.

Method

The literature was searched in MEDLINE, PubMed, and EMBASE using the following keywords: Peripheral Nerve Injury, Positioning Colorectal Surgery, Laparoscopic Colorectal Surgery, Brachial Plexus Injury, and Femoral Neuropathy. Papers in English and Spanish were selected which included adult patients operated on using open or laparoscopic colorectal surgery from 1993 to 2014. Of a total of 78 papers, 19 were selected for this revision. These include 3 systematic revisions, 12 case series, and 4 original papers. Case data and aspects in connection with their diagnosis, treatment, and prevention were extracted from all of these papers. 59 studies were excluded because they covered patients operated on for other specialities, had different subjects or dealt with direct injuries to the nerves during surgery.

Results

Aetiology

Since Herbert Seddon systematised damage to the peripheral nerves in 1942,[13,14] these injuries have been classified into 3 types according to their morphological characteristics. Neuropraxy is the blockage of the nerve connection without structural damage, and it usually recovers in 4–6 weeks. Axonotmesis consists of the breakage of the axon, while the perineuronal conjunctive tissue remains intact. Although in the majority of cases spontaneous regeneration occurs within a few weeks, surgical treatment may be required.[15] Neurotmesis involves the complete sectioning of the axon and elements of conjunctive tissue, preventing it from regenerating spontaneously. These patients lose the nerve function (motor or sensitive) and require surgical repair for their recovery.[16,17]

The chief mechanisms which cause IPNI are the position of the patient and the duration of the surgery.[17,18] The duration of surgery is a time during which muscle relaxation and the absence of pain facilitate injuries due to stretching and slackening.[19] Although the peripheral nerves are elastic[20,21] and can withstand stretching to 6%–10% of their length,[22–25] greater traction causes dysfunction due to blockage of axon transmission, reduction of the intraneural blood flow, and histological damage.[22,26–30] Nevertheless, IPNI may even occur in patients who have been subjected to the necessary postural measures during the intervention. Previous diabetic neuropathy, peripheral vascular disease[11,17,31,32] and malnutrition with the absence of subcutaneous fat cushioning are preoperative factors that make patients more liable to IPNI due to compression or stretching.[31,33] Other contributing factors are nicotinism, alcoholism, and vitamin B12 deficit,[4,11,34] or intraoperative factors such as hypotension, hypothermia,[11,31] and heparinization.[1,35]

Laparoscopic Surgery

Laparoscopic colorectal surgery has been associated with a higher risk of IPNI than open surgery (3.2% vs 0.2%).[1] The main reason is that the use of laparoscopy in inframesocolic surgery often requires the Trendelenburg position during a long time to facilitate the descent of the small bowel loops into the supramesocolic compartment.

In left colon and rectal surgery the patient is placed with the hips semi-extended, the knees flexed at about 45° and with the calf on leg supports to prevent compression of the popliteal fossa.[35] Due to the lateral inclination and the Trendelenburg position, head and side restraints are required at shoulder level to prevent the patient from descending down the operating table. Some published cases refer to the injurious effect due to compression of the restraint on the brachial plexus.[36] The arms

are held to the trunk by cloth bands on the right side and in abduction on the left side. During the perineal time of an abdominoperineal amputation, this position is modified by flexing the hips in lithotomy (the Lloyd-Davies position)[37] to permit the perineal approach to the rectum.

In right colon surgery the patient is placed in a supine position with the legs separated and slightly flexed on leg supports, left lateral anti-Trendelenburg inclination. The left arm is held to the trunk while the right arm is placed on an arm support in abduction. Injuries to the nerve branches have been described with abductions greater than 90° or with the neck turned contralaterally.[38] Lateral restraints must be put into place at shoulder level to prevent excessive compression; the leg supports function as the caudal stop.

A revision of the bibliography from 1993 to date shows 20 described cases of neural injuries in colorectal laparoscopic surgery (Table 1). Of all these, 17 occurred in the brachial plexus[4,7] while the others refer to specific damage in its terminal nerves: the median, musculocutaneous and axillary nerves.[1,39] No IPNI in the lower limbs has been described during a laparoscopic approach. The average age of the patients is 50 years (range 21–77 years) with an average BMI of 24.2 kg/m^2 (range 19–28). The duration of the operation for development of plexopathy varied from 90 min to 335 min. The different colorectal operations in which this is described are shown in Fig. 1. In all cases the patient was kept in the Trendelenburg position; with the arms in abduction at 80° in 7 cases and held to the trunk in 3 cases. The injuries are usually to the left plexus, coinciding with the arm in abduction.

Open Surgery

The incidence of IPNI after laparotomy varies according to different studies from 0.2%[1] to 0.17%.[35] Although neuropathy

Table 1 – List of the Laparoscopic Colorectal Operations Associated With Injury to the Peripheral Nerves.

Reference	Injury	Side	BMI	Age	Intervention	Position	Duration	Alteration	State
Gagnon and Poulin[73] 1993	Brachial plexus+Horner's syndrome	Left	–	48	Sigmoid colon	Arms in abduction Head in neutral position Shoulder restraints	180 min	Sensitive-motor+ Horner's syndrome	Resolved in 5 months
Milsom et al.[91] 1997	Brachial plexus	–	–	–	Total colectomy	Arms held to the trunk Head in neutral position	–	–	Resolved
Chin and Garth[51] 2003	Brachial plexus	Bilateral	–	39	Sigmoid colon	Arms held to the trunk Head in neutral position No shoulder restraints	175 min	Sensitive-motor	Resolved in 6 months, although pain persists
Craig[92] 2004	Brachial plexus	Right	28	55	Anterior resection converted into open	Arms held to the trunk Head in neutral position Shoulder restraints	90 min	Sensitive-motor	Resolved in 5 days
Brill and Walfish[3] 2005	Brachial plexus	Right	–	72	Anterior resection	Head in neutral position	140 min	Sensitive-motor	Resolved in 2 months
	Brachial plexus	Right	–	43			150 min		Resolved in 2 months
	Brachial plexus	Right	–	62	Anterior resection		135 min		Resolved in 3 months
					Anterior resection				
Auguste et al.[93] 2006	Brachial plexus	Left	–	–	Rectopexy	–	–	Motor	Resolved in a few days
	Brachial plexus	Right	–	–	Rectopexy	–	–	Motor	Partially resolved in 2 years
Kent and Cheney[74] 2007	Brachial plexus	Bilateral	–	32	Sigmoid colon	Arms in abduction Shoulder restraints	90 min	Sensitive-motor	Permanent injury
Mizuno et al.[39] 2008	Median nerve	Right	–	61	Sigmoid colon	Arms in abduction Head in neutral position	160 min	Sensitive	Resolved in one week
Navarro-Vicente et al.[1] 2012	Brachial plexus	Left	24.7	–	Sigmoid colon and total and subtotal colectomies	Arms held to the trunk	165 min	–	Resolved
	Musculocutaneous	Left	20.4	–		Arms held to the trunk	240 min	–	Permanent injury
	Musculocutaneous+ axillary	Left	26.1	–		Arms held to the trunk	150 min	–	Resolved
Eteuati et al.[50] 2013	Brachial	Left	22	32	Rectopexy	Left arm in abduction	135 min	Sensitive-motor	Resolved in 5 months
	Brachial	Left	19	21	Rectopexy	Left arm in abduction	185 min		Resolved in 48 h
	Brachial	Left	22	77	Anterior resection	Left arm in abduction	335 min	Sensitive	Resolved in 3 months
	Brachial	Left	28	62		Left arm in abduction	285 min	Sensitive-motor	Resolved in 7 months
	Brachial	Left	28	41	Anterior resection Anterior resection	Left arm in abduction	315 min	Sensitive-motor Sensitive	Resolved in 6 months

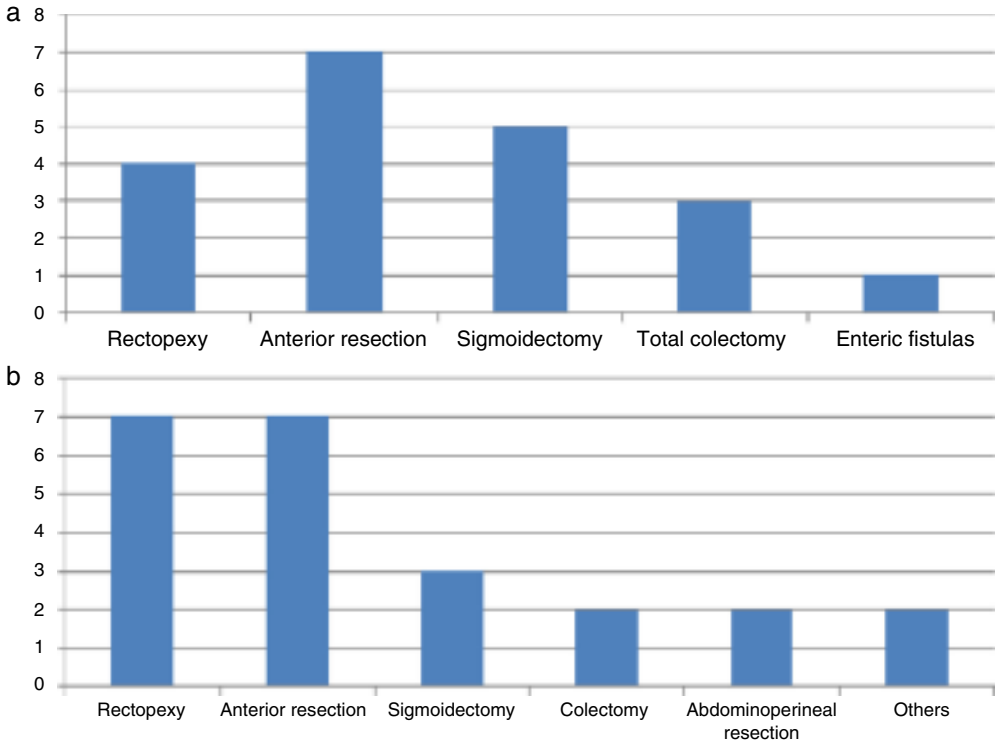

Fig. 1 – Colorectal operations described in the literature that caused IPNI in laparoscopic surgery (a) and in open surgery (b).

of the brachial plexus may occur, the associated injuries usually affect the lower limbs, and they derive from the use of self-retracting instruments and the lithotomy position.

Self-retaining separators are essential instruments for facilitating exposure in open colorectal surgery. They are composed of a stable frame on which interchangeable valves are affixed that retracts the wall and viscera. The positioning of the side valves of the self-retaining separator may injure the femoral nerve,[40–43] causing ischemia[44] by compressing the psoas muscle on the nerve.[45,46] Goldman et al.[41] state that the self-retaining separator increases the incidence of postoperative femoral neuropathy by more than 10 times.

The lithotomy position facilitates the exposure of the perineum, so that it is commonly used in proctology. It is useful in access to the rear face of the rectum during endorectal and combined approaches in abdominoperineal amputation.[35] This position is a recognised cause of neuropathy of the lower limbs,[47] due to stretching of the nerves with the abduction and forced external rotation of the hips or compression at the level of the inguinal ligament.[48]

Although it is a controversial question, bodily constitution, the duration of surgery and transversal incisions[45,49] have all been said to be possible factors associated with IPNI in open surgery. Table 2 shows a revision of the cases published since 1994. It can be seen that of the 31 cases described, 29 refer to lower limb neuropathy, of which 23 are of the femoral plexus and the others of the sciatic, popliteal, peroneal and tibial nerves. Average patient age is 50 years old (range 21–76 years old) with an average BMI of 26.2 kg/m^2 (range 16.7–36.5 kg/m^2). The duration of the operation for the development of plexopathy varies from 90 min to 684 min. The different colorectal interventions described are shown in Fig. 1.

Neuropathy of an Upper Limb

Neuropathy of the brachial plexus C5-D1 has a published incidence that varies from 0.9%[50] to 6.7% according to Brill and Walfisch,[3] and it is the second most common perioperative nerve injury.[8,9]

The long trajectory of the plexus from the neck to the arm, as well as its position proximal to the cervical vertebra and distal to the axillary fascia, make it especially vulnerable to traction and stretching injuries.[16–18,51–53] From its origin the plexus passes through the supraclavicular fossa between the middle and anterior scalene muscles, then it passes under the clavicle to reach the subclavicular fossa where the 3 trunks into which the plexus is divided accompany the subclavicular vascular bundle (Fig. 2).

Brachial plexopathy is characterised by alteration of the sensitivity which with varying degrees of intensity may affect the different trunk territories of the upper limb (Fig. 3). Although the complete loss of sensitivity is possible, patients often describe from numbness and paresthesias to intense pain (Table 3). The osteotendinous reflexes of the C5-D1 (bicipital [C5-C6], tricipital [C7], and styloradial [C6]) roots may be lost. The motor sign will take the form of varying degrees of muscular weakness.

Upper trunk (Erb's) palsy: this is caused by involvement of roots C5-C6 and sometimes C7. The patient presents with their arm straight in adduction and in internal rotation, with their wrist flexed showing the palm of the hand. The resulting posture is the characteristic "beggars" position.[54] The sensory deficit presents along the lateral face of the whole upper limb.[55]

Table 2 – List of the Open Colorectal Operations Associated With Injury to the Peripheral Nerves.

Reference	Injury	Side	BMI	Age	Intervention	Position	Duration	Alteration	State
Infantino et al.[94]	Femoral	Right	–	50	Ripstein's	Self-retractor	–	Sensitive-motor	Improved
1994	Femoral	Left	–	22	rectopexy	Holzbach	–	Sensitive-motor	Resolved
	Femoral	Bilateral	–	33	Ripstein's	Self-retractor	–	Sensitive-motor	Resolved
	Femoral	Bilateral	–	65	rectopexy	Holzbach	–	Sensitive-motor	Residual left
	Femoral	Right	–	21	Ripstein's	Self-retractor	–	Sensitive-motor	hypoesthesia
	Femoral	Right	–	24	rectopexy	Holzbach	–	Sensitive-motor	Residual
					Ripstein's	Self-retractor			right
					rectopexy	Holzbach			hypoesthesia
					Ripstein's	Self-retractor			Resolved
					rectopexy	Holzbach			
					Ripstein's	Self-retractor			
					rectopexy	Holzbach			
Brasch et al.[42]	Femoral	Left	–	54	Sigmoid	Self-retractor	120 min	Motor	Partially
1995	Femoral	Left	–	60	colon	Bookwalter	150 min	Sensitive	resolved
	Femoral	Left	–	35	Anterior	Self-retractor	90 min	Sensitive-motor	in one year
					resection	Bookwalter			Resolved
					Right	Self-retractor			in 6 months
					hemicolectomy	Bookwalter			Resolved
									in 3 months
Dillavou et al.[35]	Sciatic	–	–	–	–	Ring-type	300 min	Sensitive-motor	Resolved
1997	Sciatic	–	–	–	–	self-retractor	684 min	Sensitive-motor	in 6 months
	Femoral	–	–	–	–	Ring-type	Average	–	Resolved
	Femoral	–	–	–	–	self-retractor	258 min	–	in 6 months
	Femoral	–	–	–	Anterior	Ring-type	Average	–	Resolved
	Femoral	–	–	–	resection	self-retractor	258 min	–	in 6 months
					Anterior	Ring-type	Average		Permanent
					resection	self-retractor	258 min		deficit
						Ring-type	Average		Permanent
						self-retractor	258 min		deficit
						Ring-type			Contact lost
						self-retractor			
Vasilevsky et al.[95]	Fibula	–	–	–	Fistula surgery due	–	–	–	–
1998					to diverticulitis				
Kell and O'Connell[96]	Femoral	Left	–	30	Abdominoperineal	Assistant's	–	–	Resolved
2000					resection	elbow rested			in 6 weeks
						during the			
						perineal			
						dissection			
Celebrezze et al.[43]	Femoral	Left	–	76	Abdominoperineal	Ring-type	180 min	Sensitive-motor	Resolved
2000	Femoral	Left	–	60	resection	self-retractor	270 min	Sensitive-motor	in 2 months
	Femoral	Left	–	72	Anterior resection	Ring-type	210 min	Sensitive-motor	Partially
	Femoral	Right	–	68	Reconstruction	self-retractor	–	Motor	resolved
					of transit	Ring-type			in 6 months
					Sigmoid colon+	self-retractor			Partial
					uterus	Ring-type			resolution
						self-retractor			Partial
									resolution
									in 6 months
Brown and	Femoral	Left	–	52	Abdominal	Self-retractor	120 min	Sensitive-motor	Neurolysis
Shorthouse[97]					rectopexy	de Balfour			resolved
2002									
Huang et al.[61]	Femoral	Left	31.5	68	Anterior resection	Self-retractor	240 min	Sensitive-motor	Residual
2007	Femoral	Bilateral	30.8	76	Anterior resection	Bookwalter	120 min	Sensitive-motor	right
	Femoral	Left	36.5	58	Reconstruction	Self-retractor	180 min	Sensitive-motor	hypoesthesia
	Femoral	Left	17.5	37	of transit	Bookwalter	120 min	Sensitive-motor	Resolved
					Anterior resection	Self-retractor			in 15 months
						Bookwalter			Resolved
						Self-retractor			in 9 months
						ookwalter			Resolved
									in 6 months
Navarro-	Popliteal	Bilateral	26	–	Sigmoid colon and	Flexed hip,	220 min	–	Resolved
Vicente et al. [1]	Popliteal	Right	24.1	–	total and subtotal	lithotomy	240 min	–	Resolved
2012	Tibial	Bilateral	26.8	–	colectomies	Flexed hip,	120 min	–	Equine foot
	Cubital	Left	26.4	–		lithotomy	105 min	–	Resolved
	Interosseus	Right	16.7	–		–	270 min	–	Resolved
						–			

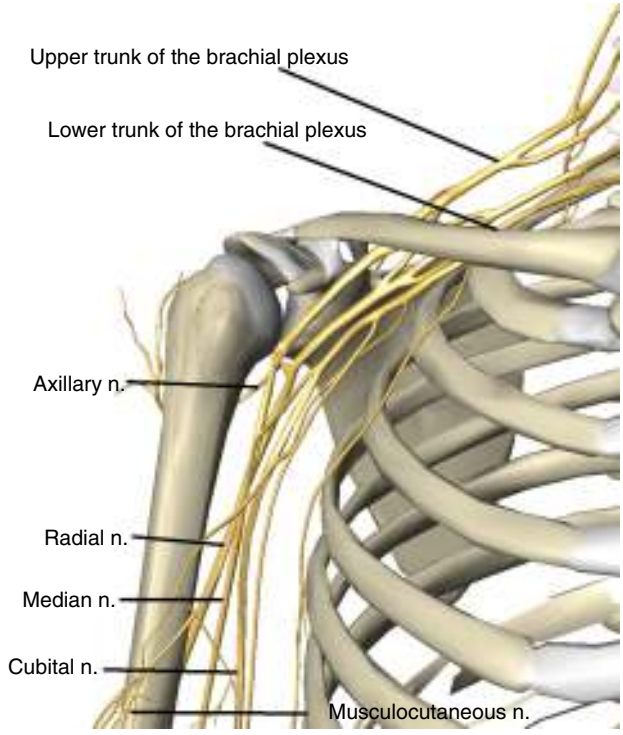

Fig. 2 – Anatomical representations of upper limb nerves.

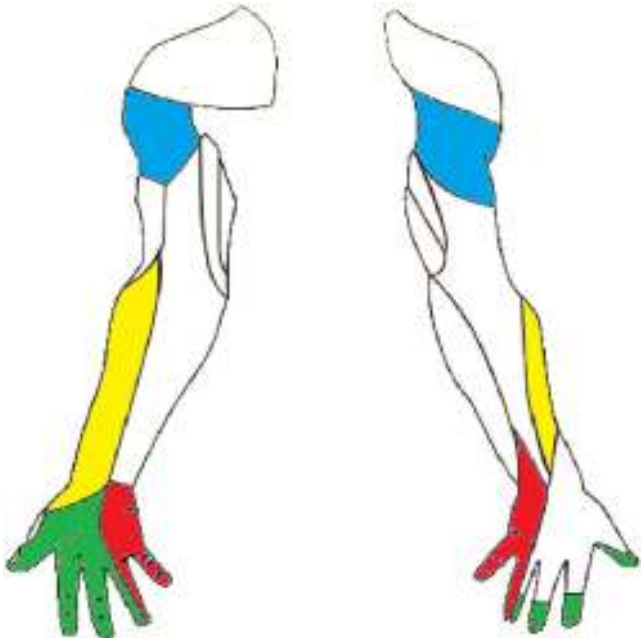

Fig. 3 – Sensitive innervation of the upper limbs. The nerve trunks have been marked to show the injuries mentioned in the literature. The musculocutaneous nerve (the side of the forearm), the axillary nerve (shoulder area), the median nerve (side of palm) and the cubital nerve (palm and medial dorsal).

Injury of the lower trunk (Klumpke's palsy): this is less common than upper trunk injury, and it occurs due to damage to roots C8-D1, causing paralysis of the hand and fingers that is sometimes accompanied by palm hypoesthesia.[56] If root D1 is affected close to the cervical sympathetic trunk, this may be associated with Horner's syndrome with ptosis, myosis, and facial anhydrosis.[55,57]

Given the compressive origin of the injuries to the brachial plexus, several terminals are often injured simultaneously, although clinical signs may predominate for one of them. Differential diagnosis with pure IPNI of the brachial plexus is important as the prognosis for the latter is generally better.[58]

Navarro-Vicente et al.[1] describe 2 cases of IPNI caused by damage to the musculocutaneous and axillary nerves. Involvement of the musculocutaneous nerve usually present as weakness in flexing the elbow, paresthesias in the radial side of the arm and loss of the bicipital reflex. When damage is caused to the axillary nerve atrophy and numbness are usually detected in the region of the deltoids, sometimes accompanied by weakness of the arm in abduction.

Mizuno et al.[39] refer to a median nerve injury during laparoscopic sigmoidectomy. The injury to this branch of the brachial plexus started with paresthesias in the region of the thenar eminence (Fig. 3) and weakness in making the pincer movement between the first and second fingers of the hand.

Although no references have been described in colorectal surgery, injury to the *cubital nerve* is, nevertheless, one of the most frequent in a laparoscopic approach.[59] It usually presents clinically as numbness of the cubital half of the hand, accompanied by weakness in flexion between the 4th and 5th fingers. On the other hand, *radial neuropathy* manifests as a ''hanging hand'', with weakness in extending the wrist and fingers (Table 3).

Brachial plexopathy generally gives rise to a neuropraxy with symptoms that remit in 2–7 months,[3,31,32,51] with gradual recovery, first sensory and then motor.[3] Ben-David and Stahl have suggested that diabetic patients require a longer recovery time.[32]

Lower Limb Neuropathy

The *crural or femoral nerve (L2–L4)* originates in the lumbar plexus. It emerges from the lower third of the larger psoas muscle before descending in the pelvis between the iliac and psoas muscles. It enters the thigh behind the inguinal ligament, covered by the psoas fascia. At this level the nerve, as it is superficial with precarious vascularisation,[60] is vulnerable to compression (Fig. 4).

It innervates the quadriceps muscle and receives sensitivity from the anteromedial face of the thigh and leg. Injury to the femoral nerve has a described incidence of 0.12%.[35] When it is injured, the first sign is usually that the patient falls when commencing to walk[61] (Table 4). If the injury was caused by compression at a proximal level in the lumbar plexus or pelvis (flexion of the hip or self-retainers), the symptoms will be weakness in extending the knee, flexing the thigh, hypoesthesia, and weak patella reflex.[62] If the injury is caused where the nerve emerges from the pelvis under the inguinal ligament,[43] this will only be differentiated from a pelvic injury by conservation of hip flexion.[63] Injuries in the thigh may present as a motor deficit or isolated sensory deficit.[43]

The femoral nerve is especially vulnerable to injury in its path through the pelvis[64]; in this it is vascularised from the

Table 3 – Injury Mechanisms and IPNI Symptoms in the Upper Limbs.

Injury	Surgical position of patient	Injury mechanism	Symptoms
Brachial plexus C5-D1 Upper trunk C5-C7 Lower trunk C8-D1	Hyperabduction of the arm Abduction of the arm with contralateral rotation of the head Shoulder restraints with Trendelenburg position	Compression of the plexus between the clavicle and first rib Pressure of the head of the humerus on the brachial plexus	Straight arm in adduction and internal rotation with the wrist flexed showing the palm of the hand Paralysis of the hand and fingers
Musculocutaneous no. C5-C7	Hyperabduction of the arm, with extension and internal rotation[81]	Pressure of the head of the humerus on brachial plexus[31] Compression at the level of the pass through the coracobrachial muscle	Weakness in flexing the forearm, paresthesias in the side of the arm and loss of the bicipital reflex
Axillary no. C5-C6	Isolated injury described prone[82] Armpit restraints	Pressure of the head of the humerus on the brachial plexus	Weakness in arm abduction, alteration of shoulder sensitivity
Median no. C5-D1	Hyperabduction of the arm[83] Arm pronated over uncushioned support[84]	Pressure on the nerve at the level of the arm	No thumb opposition, paresthesias in the thenar eminence area
No. cubital C7-D1	Arm pronated over uncushioned support[85]	Pressure of the nerve at the level of the cubital tunnel, in the elbow[86]	Weakness in flexing the 4th and 5th fingers, numbness of the cubital half of the hand
No. radial C5-D1	Arm supinated over uncushioned support	Pressure of the nerve in the spiral groove of the humerus[87]	Weakness in extending the wrist and fingers, and the hand is left hanging

iliolumbar artery and the deep circumflex iliac artery. However, there is a notable difference in vascularisation between the left and right nerves. Thus the right femoral nerve receives more vascularisation from the deep circumflex iliac artery, as well as branches of the fourth and fifth lumbar arteries, making the left nerve more vulnerable to injury.[64]

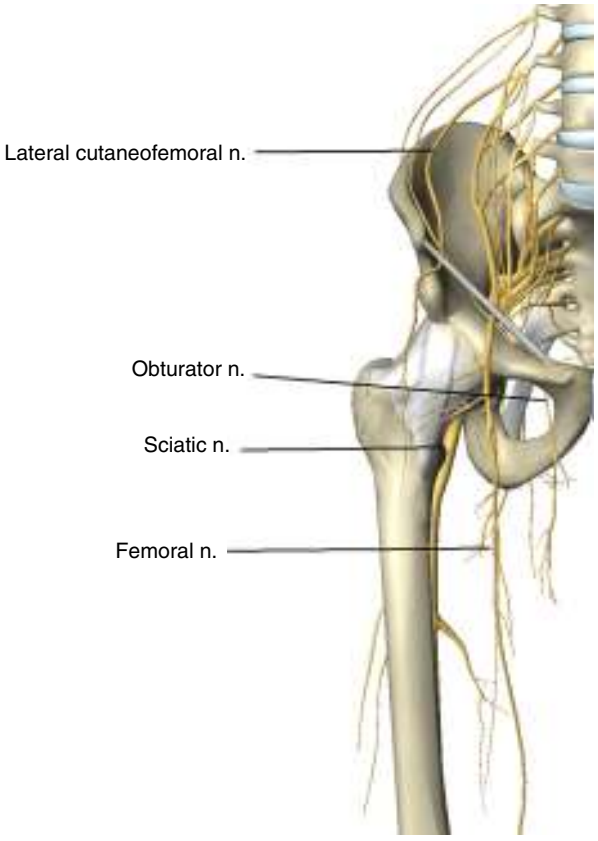

Fig. 4 – Anatomical representation of the lower limb nerves.

The *lateral cutaneofemoral or femorocutaneous nerve (L2–L3)* runs along the side of the psoas muscle before entering the thigh. This nerve is entirely sensitive, so that if it is compressed in the abdomen or inguinal region this causes burning pain, numbness, and paresthesias in the region of the thigh which it innervates (Fig. 5). These symptoms, which are termed meralgia paresthetica, worsen when walking, and usually disappear spontaneously.[65]

The *obturator nerve (L2–L4)* collects the sensitivity of the inner part of the thigh and innervates the leg adductors. Obturator nerve neuropathy is characterised by weakness and atrophy of the thigh adductor muscles accompanied by hypoesthesia and paresthesias in the medial face of the thigh (Fig. 5). It may be injured bilaterally when the nerve is stretched due to abduction with prolonged external rotation of the hip.[66] To reduce the risk of this it is recommended to simultaneously flex the hip when positioning the patient.[20] Other possible mechanisms which cause injuries are pelvic tumour surgery[67,68] or the presence of an obturator hernia (Table 4).

The *sciatic nerve (L4–S3)* can be compressed by a pelvic haemorrhage as a complication of laparotomy[68] or direct crushing of the nerve in the gluteal region during anaesthesia or when lying down for a long time on a hard surface,[19,69] or due to severe flexion of the hip which stretches the nerve when the patient is positioned in lithotomy (Fig. 5).

As a result of sciatic neuropathy hypoesthesia occurs on the external face of the leg and foot except for the malleolus. This also causes paresthesia and atrophy of the knee flexor (posterior thigh) muscles and all of the muscles below the knee (eversion and inversion, plantar, and dorsal flexion of the foot) together with reduction of the Achilles reflex.

Table 4 – Injury Mechanisms and Symptoms of IPNI in the Lower Limbs.

Injury	Surgical position of the patient	Injury mechanism	Symptoms
Femoral no. (L2-L4) In the lumbar plexus Under inguinal ligament	Self-restraining separators in open abdominal surgery Lithotomy position with hips in abduction and external rotation	Compression of the psoas muscle on the nerve by the side valves of the self-restraining retractor[40] Compression of the nerve under the inguinal ligament	- Weakness in extending the knee, flexing the thigh. Hypoesthesia of eh medial face of the thigh and anteromedial face of the calf. Loss of patella reflex - Weakness in extending the knee. Hypoesthesia of the medial face of the thigh and anteromedial face of the calf. Loss of patella reflex
Lateral cutaneofemoral no. (L2-L3)	Lithotomy position Prone	Side holding bars on the leg stirrups[15] Compression of the nerve due to position of the thigh[31]	- Meralgia paresthetica: burning pain, numbness and paresthesias in the medial face of the thigh[64]
Obturator no. (L2-L4)	Lithotomy position with hips in abduction and external rotation	Compression of the nerve against the lower face of the branch of the pubis at the level of the obturator orifice[88]	- Weakness in thigh adduction. Hypoesthesia or paresthesias in the medial face of the thigh.
Sciatic no. (L4-S3)	Lithotomy position with hips in extreme flexion, especially if combined with extension of the knee[89]	Excessive stretching of the nerve	- Weakness in flexing the knee, eversion, inversion, plantar and dorsal flexure of the foot. Hypoesthesia in the external face of the leg and foot. Loss of the Achilles reflex
Common peroneal no. (L4-S2)	Lithotomy position with hips in extreme flexion, especially if combined with extension of the knee[89] Supine position with leg supports that compress at the level of the popliteal fossa[90]	Excessive stretching of the nerve Compression of the nerve laterally to the head of the fibula	- Weakness of dorsal flexure and ankle eversion, equine foot and steppage gait. Hypoesthesia in the back of the foot and side of the leg

The *common peroneal or external sciatic popliteal nerve (L4-S2)*. This originates laterally at the head of the fibula, as a branch of the sciatic nerve. It may be injured at this level as a result of compression by leg supports.[19] This injury causes hypoesthesia in the back of the foot and the distal side of the leg. It also causes paresis in dorsal flexion and eversion of the ankle, giving rise to an equine foot and steppage gait.

Diagnosis

The postoperative diagnosis of IPNI requires a high degree of suspicion from the surgeon. Shoulder pain caused by brachial plexopathy may often be mistakenly attributed to residual pneumoperitoneum or musculotendinous injuries; the first sign of injury to the femoral nerve may be that the patient falls when starting to walk.[70] Due to all of these reasons special attention must be paid during the postoperative period to symptoms of numbness and weakness in the limbs, especially if they are asymmetrical.

The neurological examination must include a detailed history and an evaluation of the motor and sensory functions of the nerve roots.[17,71] To confirm the injury, locate its level and evaluate its intensity. This examination may be complemented by an electroneurogram and an electromyogram.[72] Nerve conduction characteristics (latency, amplitude, and velocity) are used to diagnose IPNI and to determine its prognosis and severity. It is also useful to differentiate IPNI due to stretching of the nerve from acute plexitis (the Parsonage-Turner syndrome).[31] The typical changes of de-innervation do not appear until 2–3 weeks after the injury, so that determination before this time will detect the pre-existing physiological state of the nerve.[54]

Complementary imaging studies may be necessary to exclude organic disease such as perineural haematomas (cranial CT or spinal magnetic resonance).

Prevention

To prevent IPNI during laparoscopic surgical procedures, the duration of surgery should be reduced and the position of the patient should be optimised. Arm abduction greater than 80° should be avoided, keeping the arm on the trunk whenever possible. The elbows should be slightly flexed to discharge the tension in the brachial plexus and median nerve, and supination of the forearm must also be avoided.[18,73] The head should be kept in a neutral position so that the neck is not

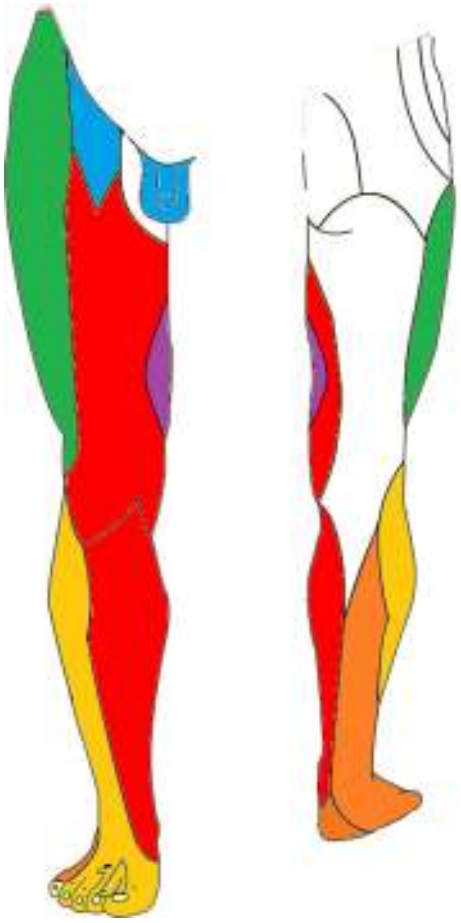

Fig. 5 – Sensitive innervation of the lower limbs. The nerve trunks with injuries mentioned in the literature have been marked. The genitofemoral nerve (genital and upper medial area of the thigh), the obturator nerve (medial thigh), the femoral nerve (anteromedial thigh and calf) and the sciatic nerve (side of calf and foot).

turned or hyperextended,[50] and restraints should not be used at the shoulders, as they may compress the head of the humerus and the acromioclavicular joint against the brachial plexus.[17,33,51–53,74]

New restraining devices have been coming into use recently. ''Allen'' type leg supports fulfil a dual purpose. On the one hand they contribute to the caudal support of the foot so that the weight of the legs rests on the heel and sole of the foot, not on the popliteal fossa. This prevents compression of the peroneal nerve and compression of the venous return. On the other hand, at any time during surgery these leg supports allow the surgeon to freely modify the state of hip flexoabduction.[35] Vacuum ''bean bags'' are restraining devices that adapt to patient anatomy, making it possible to hold the shoulders while keeping the arm held to the body and supporting the trunk and abdomen in lateral movements.

Some authors described the measures which are necessary to prevent lumbar and sacral nerve root injuries during open abdominal operations. The self-retaining retractor valves must be as short as possible to ensure correct retraction of the abdominal wall[45] without also pulling on the psoas muscle.[46] Pads can be placed under the valves to cushion the pressure they exert,[75] checking the femoral pulse after putting them into place[43,44] and regularly checking the positions of the valves during the operation. When using the lithotomy position the hip should not be flexed, abducted or rotated externally, to prevent compressing the nerves under the inguinal ligament.[61] When the surgeon and assistant are both working on the same side of the patient, they must avoid resting on the abducted upper limb as this could increase the abduction.

Treatment

Treatment of IPNI must start as soon as possible to ensure optimum recovery.[43,76,77] These patients have to be treated with physiotherapy, including passive muscular exercises, stretching and galvanic stimulation to prevent muscular atrophy. Hypoesthetic zones must be protected to prevent injuries which the patient does not notice. Neuropathic pain requires specific drugs such as gabapentin, pregabalin, amitriptyline and topiramate.[74,76]

During the postoperative period regular neurological checks must take place; if there is no recovery 3 or 4 months after the injury, a surgical exploration will be performed[9,42,44,49,62,78] to evaluate the possibility of repair, graft or neurolysis.[9] Intraoperative evaluation of nerve action potentials in the injured limbs may help to decide whether neurolysis or resection with a graft should be used.[9,78]

The prognosis for IPNI depends on the injured nerve, the intensity of pressure and its duration.[43] In the majority of cases recovery is complete, especially in muscular deficit,[41–43,79,80] although symptoms of pain or residual paresthesia may persist, especially in diabetic subjects.[32] Goldman et al.[41] reported a total recovery rate of 94% in a large series of 282 patients, as opposed to 6% of patients in whom symptoms persisted 116 days after surgery.

Conclusions

While surgery is being carried out, the absence of pain and muscular relaxation facilitate the creation of nerve injuries due to stretching and distension.

A revision of the literature on IPNI showed that in colorectal surgery neuropathy occurs the most often when a laparoscopic approach is used, fundamentally of the brachial plexus. In open colorectal surgery the cases described refer to sciatic and femoral neuropathy which is generally attributed to the use of self-retracting separators and the lithotomy position.

A high level of diagnostic suspicion is required for the early detection of this postoperative complication so that the appropriate rehabilitation treatment can be started.

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Conflict of Interests

The authors have no conflict of interests to declare.

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