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Factors Associated With Peripheral Nerve Injury After Pelvic Laparoscopy: The Importance of Surgical Positioning

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ABSTRACT

Background: Nerve damage after abdominal and pelvic surgery is rare but potentially serious. The incidence of peripheral nerve injury is difficult to assess, and rates of between 0.02% and 21% have been cited in the literature. Signs and symptoms of this type of injury may appear immediately after surgery or a few days later.

Purpose: This study was developed to assess the rate of peripheral nerve injury after pelvic laparoscopy and to identify associated risk factors.

Methods: A pilot prospective cohort study was conducted between March 2018 and April 2019 on 101 patients with a 1-month follow-up using two semistructured clinical interviews. We carried out a descriptive analysis followed by univariable and multivariable logistic regression analyses.

Results: Thirteen patients were found to have peripheral nerve injuries, representing a rate of 12.9%. Overall, 14 injuries (five severe and nine mild) were detected. One patient had two mild injuries. In this study, the risk of injury was found to increase 1.77-fold (OR = 1.77, 95% CI [1.13, 2.76], p = .007) for each hour the patient was in the Trendelenburg position.

Conclusions/Implications for Practice: The longer the patient is in the Trendelenburg position, the greater the risk of peripheral nerve damage. Patients aged 60 years or less also face a higher risk of nerve injury.

Key Words:
peripheral nerve injury, patient positioning, laparoscopy, nerve injury, Trendelenburg.

Introduction

Peripheral nerve injury (PNI) represents a rare but potentially serious risk after abdominal and pelvic surgery. The incidence of this type of injury is difficult to assess, with prior studies reporting rates ranging between 0.02% and 21% (Bouyer-Ferullo, 2012; Navarro-Vicente et al., 2011). Such injuries occur after a peripheral motor nerve is torn, cut, or compressed and muscles are subsequently denervated when the distal branches of that nerve become weak or paralyzed and motor function distal to the level of the injury is impaired or lost.

Such injuries may become evident as soon as a patient regains consciousness or a few days after surgery and may have serious functional consequences. In addition to the significant social and health impacts, these types of injury have potential medicolegal implications (Akhavan et al., 2010), as they show a failure to ensure the safety of patients undergoing surgery. Nerve injuries accounted for 22% of the malpractice claims in the American Society of Anesthesiologists Closed Claims Database between 1990 and 2007 (Welch, 2017).

A recent systematic review of the literature confirmed two types of risk factors for PNI: individual patient-related factors and perioperative surgery-related factors (Abdalmageed et al., 2017). The former includes diabetes mellitus, a low body mass index (BMI), and age, whereas the latter include surgical time, the use of compression stockings (Güzelküçük et al., 2014), factors related to patient positioning, and certain intraoperative events such as hypoxia, hypotension, and significant blood loss. Furthermore, laparoscopic surgery often entails longer surgical times, more difficult surgical positions (Agostini et al., 2010), and more fixation systems to perform the surgery, which are factors that may exacerbate PNI risk.

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The main objectives of this study were to assess the incidence of PNI and identify associated risk factors.

Methods

We conducted a pilot observational prospective cohort study after receiving approval for this research from the Ethics Committee of Galdakao-Usansolo University Hospital (Reference Number 05/18). We recruited patients undergoing pelvic laparoscopy under the care of general, urological, or gynecological surgery teams between February 2018 and April 2019. The common element in all of these procedures was the use of Trendelenburg position. The types of procedures conducted by the general surgery team included left hemicolectomy, sigmoidectomy, total colectomy, low and ultralow anterior resection, and abdominoperineal resection (i.e., coloproctological procedures), whereas total and radical hysterectomy procedures were conducted by the gynecology team, and radical prostatectomy and radical cystectomy procedures were conducted by the urology team.

Because previous studies have identified prolonged surgical time as a risk factor (Abdalmageed et al., 2017; Al-Temimi et al., 2017; Ellebrecht et al., 2015), all patients aged 18 years old and above who had undergone surgery lasting over 2 hours (from the start to the closure of the surgical incision) were recruited as participants. We excluded patients with spinal cord injury, neurodegenerative disease, preexisting nerve damage in a limb, and/or dementia. Patients were informed verbally that participation was voluntary, and written informed consent was obtained from them or their legal representatives before inclusion.

Data were gathered preoperatively on patient-related variables (Abdalmageed et al., 2017; Al-Temimi et al., 2017; Welch, 2017), including age, gender, perioperative American Society of Anesthesiologists risk, BMI, specialty in charge, and category of diagnosis. Data were gathered intraoperatively on perioperative variables, including type of intervention, the use of conventional compression stockings or intermittent pneumatic compression (Güzelküçük et al., 2014; Kim et al., 2016), the use of Allen shoulder supports, total duration of the surgical intervention, and time in minutes (Bohrer et al., 2009) spent in the Trendelenburg position (Treszezamsky et al., 2017) and in the left or right lateral positions.

We assessed each patient 48 hours after the surgery using a semistructured clinical interview for the following symptoms: weakness, tingling, loss of strength, cramps, pain, and abnormal limb movements. Patients were considered to have clinically suspected PNI if they gave a positive response to any questionnaire item (Kumar et al., 2019), and this suspicion was notified to the doctor in charge. The injuries were confirmed by medical diagnosis and were classified as mild or severe. Cases in which the injury was self-limiting, that is, which resolved spontaneously or with pharmacological treatment, were considered to be mild, whereas injuries requiring surgical and/or rehabilitation treatment or took longer than 60 days to resolve were considered to be severe.

A second semistructured interview was carried out over the phone 1 month after the initial surgery to assess the presence or absence of the symptoms identified in the first interview as well as the onset of new symptoms and the need for medical or rehabilitation treatment.

Statistical Analysis

The descriptive analysis constructed frequency and percentage tables for the categorical variables and calculated means, standard deviations, medians, and interquartile ranges for the continuous variables. Next, univariable analyses were performed to identify (a) differences between surgical specialties and (b) risk factors related to the development of PNI. Categorical variables were compared using chi-squared or Fisher's exact tests, whereas continuous variables were compared using Student's *t* test or nonparametric Wilcoxon and Kruskal–Wallis tests.

To identify the risk factors for PNI, variables that were significant at the .2 level in the univariable analysis were considered as potential independent variables to fit the multivariable logistic regression model. In all cases, the final predictive factors were those that were significant at the .05 level. Odds ratios (*OR*s) and 95% confidence intervals (CIs) were calculated. The goodness of fit of the model was assessed using the Hosmer–Lemeshow test. The predictive power of the model was analyzed by calculating the area under the receiver operating characteristic curve (AUC) and the corresponding CI using the bootstrap resampling method with 2,000 samples.

Finally, the results obtained in the clinical interviews at 48 hours and 1 month after surgery were compared using McNemar's test. All of the statistical analyses were performed using SAS for Windows Version 9.4 (SAS Institute, Cary, NC, USA) and R Version 4.0.0.

Results

One hundred one patients were enrolled as participants during the study period, with a mean age of 66.3 (SD = 10.4) years. Thirty-four (33.6%) were women. Regarding the distribution by surgical specialty, 50 (49.5%) were coloproctology patients, 41 (40.6%) were urology patients, and 10 (9.9%) were gynecology patients. Mean age and BMI were similar in participants across the three surgical specialties. Urology patients had the highest injury rate (n = 10, 24.4%; p = .015). In this subgroup (urology), the participants had longer total times both in surgery and in the Trendelenburg position (p < .001 in both cases; Table 1).

Patients with PNI had longer times in surgery overall (335 [300–440] vs. 275 [210–350] minutes, p = .002) and in the Trendelenburg position (285 [220–385] vs. 218 [145–270] minutes, p = .011). Being 60 years old or less was positively associated with having PNI (p = .018). However, no differences were identified between patients who did and did not develop PNI in terms of gender, BMI, use of shoulder supports, or use of lateral positioning (either right or left; Table 2).

Table 1
Descriptive Analysis and Comparison of the Main Variables, by Specialty

Variable	*n*	%	Specialty						*p*
			Coloproctology (General Surgery)		Urology		Gynecology		
			n	%	*n*	%	*n*	%	
Total participants	101		50	49.5	41	40.6	10	9.9	
Patient characteristics									
Gender									< .001
Male	67	66.4	29	58.0	38	92.7	0	0	
Female	34	33.6	21	42.0	3	7.3	10	100.0	
Age (years; *M* and *SD*)	66.3	10.4	67.1	12.5	65.7	5.8	64.6	13.7	.563
Age (years), categorized									.552
≤ 60	30	29.7	16	32.0	10	24.4	4	40.0	
> 60	71	70.3	34	68.0	31	75.6	6	60.0	
Personal history									
ASA classification									.193
I	12	11.9	5	10.0	5	12.2	2	20.0	
II	64	63.4	27	54.0	29	70.7	8	80.0	
III	23	22.8	17	34.0	6	14.6	0	0	
IV	2	2.0	1	2.0	1	2.4	0	0	
Nutritional status									
BMI (kg/m^2; *M* and *SD*)	27.1	4.5	26.5	5.0	27.4	3.9	29.0	4.2	.171
BMI > 30 kg/m^2	19	18.8	9	18.0	6	14.6	4	40.0	.184
Intraoperative data									
Injuries in the limbs	13	12.9	3	6.0	10	24.4	0	0	.015
Surgical time [a]	285	210–360	280	210–345	310	250–390	180	150–245	< .001
Shoulder supports	76	75.3	25	50.0	41	100.0	10	100.0	< .001
Compression									.006
No	2	2.0	0	0	2	4.9	0	0	
Conventional stockings	57	56.4	33	66.0	15	36.6	9	90.0	
Pneumatic	42	41.6	17	34.0	24	58.5	1	10.0	
Trendelenburg position used	100	99.0	49	98.0	41	100.0	10	100.0	.597
Trendelenburg right lateral position	46	45.5	46	92.0	0	0	0	0	< .001
Trendelenburg left lateral position	4	4.0	4	8.0	0	0	0	0	.119
Time in Trendelenburg position [a]	220	155–278	180	135–245	275	220–350	140	75–180	< .001

Note. ASA = American Society of Anesthesiologists; BMI = body mass index.
[a] Variables measured in minutes. Results are expressed as median [interquartile range].

Combining the significant variables in the logistic regression model for predicting the risk of PNI, time in the Trendelenburg position was positively correlated with developing PNI, with each additional hour spent in this position associated with a 77% increase in the probability of developing PNI ($OR = 1.77$, 95% CI [1.13, 2.76], $p = .007$). In addition, being 60 years old or less was associated with a 4.16 times higher risk of developing PNI ($OR = 4.16$, 95% CI [1.16, 14.92], $p = .026$). We concluded the fit of the model to be good ($p = .23$ in the Hosmer–Lemeshow test). The AUC obtained for this model was 0.8 (95% CI [0.69, 0.91]).

The results of the descriptive analysis of the symptoms in the participants with PNI at 48 hours and 1 month after surgery are summarized in Table 3. At 48 hours after surgery, 5.0% reported weakness, 11.9% reported tingling, 5.0% reported loss of strength, 4.0% reported cramps, and 6.9% reported pain. Nonetheless, 94.1% reported having the same level of limb mobility as they had before surgery. One month later, slight improvements were observed, but most of the participants with PNI continued to experience the same symptoms as reported 48 hours postoperatively.

Thirteen of the 101 participants developed PNI (incidence = 12.9%) during the first 48 hours after surgery. Overall, 14 injuries were detected, with nine mild cases and five severe cases. Moreover, one participant developed two mild injuries. Regarding the injury site, the upper limbs were involved in only four cases, with all of the others involving the lower limbs. Ten of these participants had undergone urological surgery, and the other three were general surgery patients. Most of the mild injuries involved paresthesia (six cases),

Table 2

Comparisons of the Main Variables by Whether Patients Had Limb Nerve Injury

Variable	Upper or Lower Limb Nerve Injury				*p*
	Yes (*n* = 13)		No (*n* = 88)		
	n	%	*n*	%	
Specialty					.015
Coloproctology	3	23.1	47	53.4	
Urology	10	76.9	31	35.2	
Gynecology	0	0.0	10	11.3	
Patient characteristics					
Gender					.055
Male	12	92.3	55	62.5	
Female	1	7.7	33	37.5	
Age (years; *M* and *SD*)	58.6	8.0	67.4	10.2	.004
Age (years), categorized					.018
≤ 60	8	61.5	22	25.0	
> 60	5	38.5	66	75.0	
Personal history					
ASA classification					.828
I	2	15.4	10	11.4	
II	9	69.2	55	62.5	
III	2	15.4	21	23.9	
IV	0	0.0	2	2.3	
Nutritional status					
BMI (kg/m^2; *M* and *SD*)	26.4	4.3	27.2	4.6	.927
BMI > 30 (kg/m^2)	1	7.7	18	20.7	.452
Intraoperative data					
Surgical time [a]	335	300–440	275	210–350	.002
Shoulder supports	11	84.6	65	73.9	.510
Compression					.229
No	1	7.7	1	1.1	
Conventional stockings	8	61.5	49	55.7	
Pneumatic	4	30.8	38	43.2	
Trendelenburg position used	13	100.0	87	98.9	1
Trendelenburg right lateral position	3	23.1	43	48.9	.081
Trendelenburg left lateral position	1	7.7	3	3.4	.429
Time in Trendelenburg position [a]	285	220–385	218	145–270	.011

Note. ASA = American Society of Anesthesiologists; BMI = body mass index.
[a] Variables measured in minutes. Results are expressed as median [interquartile range].

with only one case each of external popliteal nerve neuropathy, ulnar nerve neuropraxia, and brachial plexus palsy, which were all caused by compression. Regarding injury course, in six cases, no treatment was required and the condition resolved spontaneously. The remaining cases required pharmacological treatment. All of the severe injuries involved the lower limbs. Three of the participants had muscle ischemia attributable to compartment syndrome that required emergency fasciotomy, with two further requiring graft reconstruction as well as rehabilitation and pharmacological treatment. One other participant had edema associated with orthostatic hypoperfusion, which was treated using medication and compression stockings. The last patient with a severe lesion had external popliteal neuropathy that required rehabilitation (see Supplemental Material, Appendix 1, available at http://links.lww.com/JNR/A3).

Discussion

In this study, we found a positive association between time in the Trendelenburg position and risk of PNI, with each additional hour in this position increasing the risk of nerve injury by 77%. The Trendelenburg position is a specific position used for all of the surgical interventions requiring pelvic laparoscopy in this study. The participants who experienced severe PNI were those who spent the longest time in this position. In addition, longer time in the Trendelenburg position was associated with a longer total time in surgery. The results

Table 3

Descriptive Analysis: Interviews Conducted at 48 Hours and 1 Month After Surgery

Symptom	Interview at 48 Hours (*n* = 101)		Interview at 1 Month (*n* = 101)		*p*
	n	%	*n*	%	
Weakness	5	5.0	6	5.9	.757
Tingling	12	11.9	12	11.9	1
Loss of strength	5	5.0	6	5.9	.757
Cramps	4	4.0	2	2.0	.407
Pain in at least one limb	7	6.9	6	5.9	.774
Able to move all limbs spontaneously/ in response to instructions	95	94.1	96	95.1	.757
Similar to before surgery	94	94.0	96	95.1	.744

support prolonged Trendelenburg positioning as a more accurate predictor of PNI. This relationship has not been shown in the predictive models reported in previous studies, although some authors have concluded that the Trendelenburg position promotes the development of PNI. Specifically, in a 2017 review, Colsa Gutiérrez et al. (2016) commented that the Trendelenburg position together with the use of arm boards and shoulder abduction may encourage the development of PNI during laparoscopic procedures. Al-Temimi et al. (2017) mentioned that the Trendelenburg position may increase the risk of upper limb neuropathy. In our review of the literature, only two studies were found that measured the time spent in this position (Klauschie et al., 2010; Treszezamsky et al., 2017). Both studies concluded that patient displacement on the surgical table was not influenced by the time in the Trendelenburg position and that this factor was not identified as a risk factor for the development of PNI. On the other hand, prolonged total surgery time has been shown to increase this risk (Al-Temimi et al., 2017; Wallis et al., 2017).

Our findings are in line with those of previous studies, which have found patients under 60 years old to be at a greater risk of developing PNI (e.g., Al-Temimi et al., 2017). However, the results in the scientific literature are very heterogenous. For example, Navarro-Vicente et al. (2011) did not observe any relationship between age and PNI, whereas both Abdalmageed et al. (2017) and Welch (2017)identified being over 60 years old as a risk factor for developing PNI.

A strength of this study was the use of predictive models for predicting risk of developing nerve injuries. Few studies in the literature reported conducting this type of analysis (Al-Temimi et al., 2017; Wallis et al., 2017). The predictive model used in this study has an AUC of 0.80 and a good calibration ability, indicating its robust discrimination and calibration in the prediction of PNI.

Despite the findings of a systematic review by Codd et al. (2013) indicating that the brachial plexus is particularly vulnerable to nerve injury during colorectal laparoscopy and the claim by Abdalmageed et al. (2017) that brachial plexus injuries represent the most serious complication caused by incorrect positioning, this study found lower limb injuries to be more common and more severe than upper limb injuries. The findings of this study are in line with those of the systematic review by Das et al. (2019), which did not find an association between the development of neuropathy and the use of shoulder supports. However, other authors (Abdalmageed et al., 2017) have suggested that their use may be a relevant factor. In another study, placing patients on a vacuum bean-bag positioner to avoid the use of shoulder supports was found to reduce the incidence of brachial plexus injuries to zero (Navarro-Vicente et al., 2011). On the other hand, Harada et al. (2019) used a protocol under which patients were rotated from a lateral to a supine position every 120 minutes such that the pressure at the shoulder would be reduced for 5 minutes, thereby avoiding injury to the brachial plexus.

In this study, we found no significant differences between the use of conventional compression stockings and intermittent pneumatic compression, although the latter approach has been recommended (Kim et al., 2016). In a book chapter, Filler et al. (2016) indicated that both conventional stockings and intermittent compression may cause damage by compressing the peroneal nerve. Güzelküçük et al. (2014) emphasized the need to use the correct stocking size to reduce the risk of nerve injury.

According to Al-Temimi et al. (2017), patients with a BMI greater than 30 kg/m^2 are at a greater risk of developing nerve injury. Similarly, Ellebrecht et al. (2015) related the risk of nerve injury to obesity. In this study, we failed to identify a greater vulnerability to PNI among the participants with a high BMI (> 30 kg/m^2).

Urological surgery was associated with a higher rate of nerve injuries in this study, likely because of the longer surgical times and the steeper Trendelenburg position used rather than of the characteristics of the specialty itself. Bjøro et al. (2019) concluded that the lithotomy position with a steep Trendelenburg position may lead to PNI but that comparisons between different surgical procedures are hindered by a lack of valid instruments to identify a PNI, making it difficult to assess the incidence.

It is likely that, as noted by other authors (Filler et al., 2016; Welch, 2017), PNI will continue to occur despite efforts to adopt preventive measures. The data collected in this study did not allow our identification of the optimal patient position for nerve injury avoidance. Nevertheless, we consider it essential to train surgical teams and raise awareness of the risk and consequences of these types of injury. Recording a patient's positioning is an important step in increasing awareness of how to prevent PNI, as shown in the pilot study of Bouyer-Ferullo et al. (2015). One of our future priorities is thus to develop a form to facilitate the recording of patient positioning during surgery for use in future research.

Limitations

The limitations of this study include the small number of gynecological patients included because of human resource management problems and the overall sample size because of the framing of this research as pilot study.

In the future, the degree of Trendelenburg tilt should be measured and positions may be changed intermittently to avoid tilting patients when not necessary to reduce the time patients spend in this constrained position and allow blood flow to be restored to the lower limbs to reduce the risk of ischemia.

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Author Contributions

Study conception and design: AZDC, NHM, VPP
Data collection: AZDC, NHM, AMBB, LRO, ATM
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