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ORIGINAL ARTICLE

Lower extremity pain and/or numbness after laparoscopic surgery and robot-assisted surgery in the lithotomy position combined with the Trendelenburg position

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Abstract

Purpose The purpose of this study was to investigate the incidence and risk factors of lower extremity pain and/or numbness after laparoscopic colorectal surgery and robot-assisted laparoscopic radical prostatectomy in the lithotomy position combined with the Trendelenburg position. The relationship between creatine kinase (CK) levels and lower extremity pain and/or numbness was also investigated.

Methods We retrospectively reviewed adult patients who underwent laparoscopic colorectal surgery and robot-assisted laparoscopic radical prostatectomy in the lithotomy position combined with the Trendelenburg position between May 2015 and April 2020. Logistic regression analysis was used to identify risk factors of lower extremity pain and/or numbness. Preoperative and postoperative CK levels were compared in patients with and those without lower extremity pain and/or numbness.

Results Among 940 patients, 1.9% experienced lower extremity pain and/or numbness postoperatively. The incidences of lower extremity pain and/or numbness after laparoscopic colorectal surgery and after robot-assisted laparoscopic radical prostatectomy were 1.7% and 2.1%, respectively. Multivariate logistic regression analysis revealed that only duration of surgery > 4 h (odds ratio = 3.144, 95% CI: 1.102–8.969, $p = 0.032$) was a significant predictor of lower extremity pain and/or numbness. Postoperative median CK level in patients with lower extremity pain and/or numbness was significantly higher than that in patients without lower extremity pain and/or numbness.

Conclusion The incidence of lower extremity pain and/or numbness after laparoscopic colorectal surgery was comparable to that after robot-assisted laparoscopic radical prostatectomy. Prolonged duration of surgery contributed to lower extremity pain and/or numbness. Significantly elevated CK levels in patients with lower extremity pain and/or numbness suggest the involvement of muscle injury in these symptoms.

Keywords Lower extremity pain · Lithotomy position · Trendelenburg position · Compartment syndrome

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Introduction

Laparoscopic surgery and robot-assisted surgery have become increasingly common as minimally invasive procedures. These procedures necessitate the lithotomy position combined with the Trendelenburg position to achieve optimal visibility of the surgical field. Unfortunately, this combined position often leads to lower extremity pain and/or numbness probably due to peripheral neuropathy [1]. While previous studies have shown that the incidence of lower extremity neuropathy in robot-assisted laparoscopic radical prostatectomy ranges from 1.7% to 6.6% [2, 3], the incidence in laparoscopic colorectal surgery remains unknown. The possible mechanisms underlying neuropathy induced by the lithotomy position combined with the Trendelenburg position are direct compression or stretching of nerves as well as nerve ischemia resulting from blood flow obstruction to nerves [4]. Vulnerability of the peroneal nerve to compression between the head of the fibula and the levitator stirrup is a well-documented phenomenon [5]. In terms of ischemia, obstruction of blood flow to nerves can arise from vessel compression, diminished perfusion due to hypotension, and positioning of the lower extremities higher than the heart. Additionally, although rare, the lithotomy position combined with the Trendelenburg position can lead to well-leg compartment syndrome [6], characterized by muscle necrosis. This condition likely results from direct external compression and/or reduced perfusion of the calf muscles, subsequently increasing compartment pressure [7]. Consequently, patients afflicted with well-leg compartment syndrome typically exhibit a significant elevation in serum creatine kinase (CK) levels [8]. Lower extremity neuropathy and well-leg compartment syndrome induced by the lithotomy position combined with the Trendelenburg positions may be argued to represent a sequential pathological condition. If this is the case, both muscle injury and neuropathy may contribute to the development of pain and/or numbness in the lower extremities after robot-assisted laparoscopic radical prostatectomy and laparoscopic colorectal surgery. However, it has not been clarified whether serum CK levels are increased in patients with lower extremity pain and/or numbness.

In this study, we investigated the incidences of lower extremity pain and/or numbness after laparoscopic colorectal surgery and robot-assisted laparoscopic radical prostatectomy in the lithotomy position combined with the Trendelenburg position. We also investigated the risk factors associated with lower extremity pain and/or numbness. Additionally, we examined the relationship between lower extremity pain and/or numbness and plasma concentration of CK.

Methods

The protocol for this study was approved by the ethics committee of our institution (approval number 3157).

Patients

We retrospectively reviewed adult patients who underwent laparoscopic colorectal surgery or robot-assisted laparoscopic radical prostatectomy in the lithotomy position combined with the Trendelenburg position in our hospital during a 5-year period from May 2015 to April 2020 using the electronic medical records of our hospital. Patients who already had lower extremity pain and/or numbness before surgery, patients with numbness that improved with discontinuation of the epidural block, and patients with pain or numbness in the lower extremities due to obvious causes were excluded.

The protocol of our hospital for the lithotomy position combined with the Trendelenburg position was as follows: intraoperative positioning was performed in a lithotomy position with the use of a bilateral bracing device (Levitator™, MIZUHO, Japan). The hip abduction angle was less than 45 degrees, knee flexion angle was less than 50 degrees, and hip flexion angle was less than 45 degrees, and the lower limbs were fixed at symmetrical angles, heights, and positions. The Trendelenburg position was 30 degrees for robot-assisted laparoscopic radical prostatectomy and 10–15 degrees for laparoscopic colorectal surgery. If the lithotomy position combined with the Trendelenburg position exceeded 4 h, the lower extremities were temporarily returned to a horizon position every 4 h. Elastic stockings covering both knees to toes and an intermittent pneumatic compression device (Kendall SCD 700series™, Cardinal Health K.K., Japan) were applied.

Assessment

Our medical records include a checklist for documenting the presence of pain and/or numbness after surgery. In our hospital, nurses are required to interview patients at least three times a day and complete this checklist. We assessed the presence or absence of postoperative pain and/or numbness on the day of surgery and the following day using the checklist. Additionally, we reviewed physicians' notes for relevant information. Firstly, the incidence of postoperative lower extremity pain and/or numbness after laparoscopic colorectal surgery and that after robot-assisted laparoscopic radical prostatectomy were compared. Secondly, we clarified the factors associated with postoperative lower extremity pain and/or numbness. Prospective factors were selected from previous studies [9–13] in which risk factors of lower leg compartment syndrome or lower extremity neuropathies after the lithotomy position were investigated. The prospective factors included patient's age, preoperative body mass index (BMI) > 25, intraoperative vasoconstrictor use, intraoperative hypotension (mean arterial pressure less than 50 mmHg), and duration of surgery > 4 h. Diabetes, hypertension, and lymph node dissection were also included in the prospective factors. Thirdly, preoperative and postoperative CK levels were compared in patients with and those without postoperative lower extremity pain and/or numbness. Postoperative CK levels were measured on the day of surgery or the following morning.

Statistical analysis

Continuous variables were presented as means ± standard deviations and categorical variables as numbers (with a percentage, n%). When the values were not normally distributed, data were presented as the median [interquartile range]. The incidence of lower extremity pain and/or numbness and CK were analyzed by Fisher's exact test and the t test. To identify factors associated with lower extremity pain and/or numbness, all variables were compared in a univariate logistic regression analysis. The factors from the univariate regression analysis with p values < 0.05 were included in multivariate logistic regression models. To confirm the robustness of the results, sensitivity analyses were performed by altering the combination of explanatory variables. Spearman's rank correlation coefficients were calculated to measure the degree of multicollinearity. A p value < 0.05 was considered statistically significant. Statistical analyses were performed using JMP statistical software package version 13 (SAS Institute, Cary, NC).

Results

A total of 940 patients received laparoscopic colorectal surgery (465 patients) or robot-assisted laparoscopic radical prostatectomy (475 patients) during the study period. The patient's characteristics are summarized in Table 1. We did not find any occurrence of obturator nerve injury during surgery in the medical records. Among the 940 patients, 18 patients (1.9%) had lower extremity pain and/or numbness that met our criteria after surgery: 8 patients in laparoscopic colorectal surgery and 10 patients in robot-assisted laparoscopic radical prostatectomy. There was no significant difference between the incidence of lower extremity pain and/or numbness after laparoscopic colorectal surgery and that after robot-assisted laparoscopic radical prostatectomy (1.7% vs 2.1%, $p = 0.812$) (Table 2).

Next, we investigated the risk factors associated with lower extremity pain and/or numbness after combining the data from laparoscopic colorectal surgery and robot-assisted laparoscopic radical prostatectomy. Univariate logistic regression analysis for factors that influence pain and/or numbness indicated that BMI > 25 ($p = 0.015$), hypertension ($p = 0.019$), and duration of surgery > 4 h ($p = 0.015$) were statistically significant (Table 3). Multivariate logistic regression analysis revealed that only duration of surgery > 4 h (odds ratio = 3.144, 95% CI: 1.102–8.969, $p = 0.032$) was a significant factor for lower extremity pain and/or numbness (Table 4). Sensitivity analyses using different

Table 1 Patient characteristics

	All patients (n = 940)	Laparoscopic colorectal surgery (n = 465)	Robot-assisted laparoscopic radical prostatectomy (n = 475)
Age, years	68 ± 9	67 ± 12	68 ± 6
Sex, *n* (%)			
Male	764 (81.3)	289 (62.2)	475 (100.0)
Female	176 (18.7)	176 (37.8)	0 (0.0)
BMI, kg/m^2	23.2 ± 3.4	22.5 ± 3.6	23.9 ± 3.1
Diabetes, *n* (%)	156 (16.6)	88 (18.9)	68 (14.3)
Hypertension, *n* (%)	483 (51.4)	222 (47.7)	261 (54.9)
ASA physical status, *n* (%)			
ASA 1	43 (4.6)	27 (5.8)	16 (3.4)
ASA 2	833 (88.6)	392 (84.3)	441 (92.8)
ASA 3	63 (6.7)	45 (9.7)	18 (3.8)
ASA 3E	1 (0.1)	1 (0.2)	0 (0.0)
Duration of surgery, min	248 ± 86	263 ± 106	233 ± 56
Duration of surgery > 4 h, *n* (%)	416 (44.3)	221 (47.5)	195 (41.1)
Preoperative Hb, g/dL	13.7 ± 1.8	12.9 ± 1.9	14.6 ± 1.2
Preoperative CK, U/L	92 [66,132]	79 [56,112.5]	105 [77,148]
Intraoperative blood loss, mL	55 [15,200]	20 [15,47.5]	155 [65,350]
Intraoperative infusion volume, mL	1510 [1200,1887.5]	1550 [1200,1950]	1500 [1220,1800]
Intraoperative vasoconstrictor use, *n* (%)	523 (55.6)	299 (64.3)	224 (47.2)
Intraoperative hypotension, minutes	0 [0,1]	0 [0,1]	0 [0,0]

BMI body mass index, *ASA* American Society of Anesthesiologists, *E* emergency

Data are expressed as number (%) or mean ± standard deviation or median [interquartile range]

Table 2 Incidence of lower extremity pain and/or numbness

	Laparoscopic colorectal surgery ($n=465$)	Robot-assisted laparoscopic radical prostatectomy ($n=475$)	*p* value
With pain and/or numbness, *n* (%)	8 (1.7)	10 (2.1)	0.812
Without pain and/or numbness, *n* (%)	457 (98.3)	465 (97.9)	

Data are expressed as number (%)

combinations of explanatory variables without multicollinearity (Table 5) showed that not only duration of surgery > 4 h (odds ratio = 3.352, 95% CI: 1.185–9.482, $p=0.023$), but also hypertension and BMI > 25 (odds ratio = 3.382, 95% CI: 1.105–10.353, $p=0.033$ and odds ratio = 3.200, 95% CI: 1.249–8.197, $p=0.015$, respectively) were independently associated with the risk of lower extremity pain and/or numbness (Supplemental Tables 1–3).

Next, we compared the plasma concentrations of CK in individuals with and those without lower extremity pain and/or numbness (Table 6). Although there was no significant difference in the preoperative median CK levels in patients with and those without lower extremity pain and/or numbness (81 [70.5,113.5] U/L vs 92 [66,133] U/L, $p=0.822$), the postoperative median CK level in patients with lower extremity pain and/or numbness was significantly higher than that in patients without lower extremity pain and/or numbness (994.5 [214.5,4488.75] U/L vs 208 [136,328] U/L, $p<0.001$), suggesting that muscle injury is involved in the symptoms. Next, due to the wide range of postoperative CK levels observed, we examined the relationship between CK levels and the symptoms by dividing the patients into two groups: high and low postoperative CK levels (Supplemental Tables 4 and 5, respectively). According to a previous study [14], low and high postoperative CK levels were defined as below 2000 U/L and above 2000 U/L, respectively. In both groups, there was a significant difference in CK levels between patients with and those without symptoms.

Two patients were diagnosed with well-leg compartment syndrome, and fasciotomy was performed. One patient reported intense pain immediately after surgery, with serum CK level measured at 1257 U/L and compartment pressure exceeding 80 mmHg, prompting fasciotomy. The other patient complained of severe lower extremity pain on the day following surgery, with CK level rising to 22,449 U/L and compartment pressure of 35–45 mmHg. Fasciotomy was

Table 4 Multivariate logistic regression analysis for factors that influence pain and/or numbness

	Odds ratio (95%CI)	*p* value
Hypertension	2.945 (0.944–9.193)	0.062
Duration of surgery > 4 h	3.144 (1.102–8.969)	0.032*
BMI > 25	2.407 (0.919–6.300)	0.073

CI confidence interval, *BMI* body mass index

*$p<0.05$

Table 3 Univariate logistic regression analysis for factors that influence pain and/or numbness

	All patients ($n=940$)	With pain and/or numbness ($n=18$)	Without pain and/or numbness ($n=922$)	Odds ratio (95%CI)	*p* value
Type of surgery, *n* (%)				1.228 (0.481–3.141)	0.666
Laparoscopic colorectal surgery	465 (49.5)	8 (44.4)	457 (49.6)		
Robot-assisted laparoscopic radical prostatectomy	475 (50.5)	10 (55.6)	465 (50.4)		
Lymph node dissection, *n* (%)	619 (65.9)	13 (72.2)	606 (65.7)	1.356 (0.479–3.837)	0.558
Age, years	68 ± 9	66 ± 10	68 ± 9	1.020 (0.972–1.071)	0.421
BMI > 25, *n* (%)	269 (28.6)	10 (55.6)	259 (28.1)	3.200 (1.249–8.197)	0.015*
Diabetes, *n* (%)	156 (16.6)	4 (22.2)	152 (16.5)	1.445 (0.469–4.451)	0.534
Hypertension, *n* (%)	483 (51.4)	14 (77.8)	469 (50.9)	3.381 (1.104–10.347)	0.019*
Intraoperative vasoconstrictor use, *n* (%)	523 (55.6)	10 (55.6)	513 (55.6)	0.997 (0.390–2.548)	0.994
Intraoperative hypotension, minutes	0 [0,1]	0 [0,0.25]	0 [0,1]	0.981 (0.947–1.017)	0.379
Duration of surgery > 4 h, *n* (%)	416 (44.3)	13 (72.2)	403 (43.7)	3.348 (1.184–9.469)	0.015*

CI confidence interval, *BMI* body mass index

Data are expressed as number (%) or mean ± standard deviation or median [interquartile range]

*$p<0.05$

Table 5 Spearman's rank correlation coefficients for explanatory variables used in the primary and sensitivity analyses

Variables	Hypertension	Duration of surgery > 4 h	BMI > 25	Intraoperative vasoconstrictor use
Hypertension	1			
Duration of surgery > 4 h	− 0.016	1		
BMI > 25	0.173	0.090	1	
Intraoperative vasoconstrictor use	0.018	0.028	− 0.003	1

BMI body mass index

Table 6 Pre- and postoperative plasma concentrations of creatine kinase

	All patients (n = 940)	With pain and/or numbness (n = 18)	Without pain and/or numbness (n = 922)	p value
Preoperative CK, U/L	92 [66,132]	81 [70.5,113.5]	92 [66,133]	0.822
Postoperative CK, U/L	210 [137,332]	994.5 [214.5,4488.75]	208 [136,328]	< 0.001*

CK creatine kinase

Data are expressed as median [interquartile range]

*$p < 0.05$

performed due to severe swelling in the patient's lower leg accompanied by a change in skin color to dark red.

Discussion

There ###were two new findings in this study. First, the incidence of lower extremity pain and/or numbness after laparoscopic colorectal surgery (1.7%) was comparable to that after robot-assisted laparoscopic radical prostatectomy (2.1%). Second, the postoperative median CK level in patients with lower extremity pain and/or numbness was significantly higher than that in patients without lower extremity pain and/or numbness.

Since the incidence of lower extremity pain and/or numbness after robot-assisted laparoscopic radical prostatectomy in our patients (2.1%) was similar to the incidences of lower extremity neuropathies reported previously (1.7%–6.6%) [2, 3], we judged our results to be appropriate for further analysis. Comparable incidences of lower extremity pain and/or numbness after the two types of surgery suggest that lower extremity pain and/or numbness are due to the lithotomy position combined with the Trendelenburg position during surgery rather than the surgery itself. It is well known that the lithotomy position is a risk factor for lower extremity neuropathy. On the other hand, there has been no report, as far as we know, showing that the Trendelenburg position itself is involved in lower extremity neuropathy, but when the Trendelenburg position is added to the lithotomy position, the risk for lower extremity neuropathy may be increased. Lower extremity neuropathy can be caused by direct compression or stretching of nerves and ischemia [4]. Previous studies showed that blood flow to the lower extremities was not compromised by the low lithotomy position but was compromised by a combination of leg elevation and the Trendelenburg position [15–17]. Recently, Yamada et al. showed that the lithotomy position combined with the Trendelenburg position (15-degree head-down tilt) significantly increased the contract pressure between the leg and the leg holder of the levitator stirrup compared to that with the lithotomy position alone, also suggesting that the lithotomy position combined with the Trendelenburg position might cause significant lower extremity ischemia [18]. Our study showed that the postoperative mean CK level in patients with lower extremity pain and/or numbness was significantly higher than that in patients without lower extremity pain and/or numbness. Two patients developed well-leg compartment syndrome. These results suggest that muscle injury is involved in lower extremity pain and/or numbness after the lithotomy position combined with the Trendelenburg position. Our results also suggest that lower extremity neuropathy and well-leg compartment syndrome induced by the lithotomy position combined with the Trendelenburg position have a sequential pathological condition, and lower extremity neuropathy is likely to be pre-compartment syndrome.

Multivariate logistic regression analysis showed that only duration of surgery > 4 h was a significant predictor of lower extremity pain and/or numbness after laparoscopic colorectal surgery or robot-assisted laparoscopic radical prostatectomy in the lithotomy position combined with the Trendelenburg position. The rule of having a minimum of ten events per variable can be relaxed, especially for sensitivity analysis that aims to demonstrate adequate control of confounding [19]. The primary analysis and sensitivity analysis showed similar results for duration of surgery > 4 h, indicating a robust association with lower extremity pain and/or numbness (Tables 4 and Supplemental Tables 1). In contrast, the results of primary analysis for hypertension and BMI > 25 differed from the results of sensitivity analysis (Table 4 and Supplemental Tables 2 and 3). Therefore, it is difficult to conclude from this study whether hypertension and BMI > 25 are independent risk factors for lower extremity pain and/or numbness. Previous studies have also shown that duration of surgery is a risk factor of lower extremity neuropathies. Since a longer duration of surgery leads to a longer duration of lower extremity elevation, the duration of lower extremity elevation rather than the duration of surgery would be important for lower extremity neuropathies. Previous studies showed that duration of lithotomy > 5 h or duration of surgery > 4 h is a risk factor for lower extremity neuropathies. Based on those findings, if the lithotomy position combined with the Trendelenburg position exceeded 4 h, elevation of the lower extremities was temporarily stopped in our hospital as described in "Methods". Despite our care, 1.9% of the patients developed lower extremity neuropathies in our hospital. Thus, it may be necessary to reconsider the acceptable duration of lower extremity elevation.

Our study's limitation lies in its retrospective nature, which prevents identification of the specific area of pain and/or numbness and may have caused underestimation of the incidence of lower extremity pain and/or numbness. If the location of pain and/or numbness corresponds to a particular nerve territory, neuropathy would likely be the main cause of pain and/or numbness. However, if this is not the case, pain and/or numbness may precede compartment syndrome. Regarding the incidence of lower extremity pain and/or numbness, a prospective study showed an incidence of 37% [13], which is higher than the incidences in retrospective studies including our study. The observation period in that prospective study was 7–10 days, whereas observation was conducted only on the day of surgery and the following day in our study. Therefore, the observation period might have influenced the results. Additionally, the retrospective nature of our study may have led to an underestimation of the incidence of the event. Additionally, multivariate logistic regression analysis was performed in this study using three explanatory variables and 18 patients developed pain and/or numbness in the lower extremity. The results were interpreted objectively, with sensitivity analyses conducted and ensuring no multicollinearity among the explanatory variables.

Conclusion

The incidence of lower extremity pain and/or numbness in patients who received laparoscopic colorectal surgery or robot-assisted laparoscopic radical prostatectomy in the lithotomy position combined with the Trendelenburg position was 1.9%. The only significant predictor of lower extremity pain and/or numbness was duration of surgery > 4 h. Muscle injury as well as neuropathy may contribute to lower extremity pain and/or numbness.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00540-024-03399-1.

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Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare that they have no competing interests.

Ethical approval This study was approved by the ethics committee of Wakayama Medical University, in Wakayama, Japan.

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