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ORIGINAL ARTICLE

Impact of the combination of abdominal peripheral nerve block and neuromuscular blockade on the surgical space during robot-assisted laparoscopic surgery: a prospective randomized controlled study

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Abstract

Purpose The impact of the combination of abdominal peripheral nerve block (PNB) and the depth of neuromuscular blockade on the surgical field were assessed.

Methods Thirty-eight patients undergoing elective robot-assisted laparoscopic radical prostatectomy (RARP) were randomized into two groups: a PNB group (moderate neuromuscular block [train-of-four 1–3 twitches] with abdominal PNB) and a non-PNB group (deep neuromuscular block [post-tetanic count 0–2 twitches] without abdominal PNB). The primary outcome was the change in the depth of the abdominal cavity relaxation assessed by the change in the distance (*Δdistance)* between the umbilicus port and peritoneum upon pneumoperitoneal pressure increase from 8 to 12 mmHg. The secondary outcomes were the CO_2 usage for the pneumoperitoneal pressure increase and the subjective differences in the Surgical Rating Score (SRS) during surgery.

Results The *Δdistance* and the CO_2 usage from 8 to 12 mmHg did not differ significantly between the non-PNB and PNB groups (1.34 ± 0.65 vs. 1.28 ± 0.61 cm, $p = 0.763$ and 3.64 ± 1.68 vs. 4.34 ± 1.44 L, $p = 0.180$, respectively). There was also no significant difference in SRS. Comparisons of the *Δdistance* values for pressure increases from 6 to 8 mmHg, 6 to 10 mmHg and 6 to 12 mmHg between the non-PNB and PNB groups also showed no between-group differences, despite significant intra-group differences ($p < 0.001$) by pressure increment.

Conclusions Our findings indicate that moderate neuromuscular block with abdominal PNB maintained an adequate surgical space for RARP, with no significant difference from the space achieved by deep neuromuscular block.

Keywords Peripheral nerve block · Muscle relaxant · Robotic surgery

Introduction

Robot-assisted laparoscopic surgeries have the benefits of minimal invasiveness and earlier recovery compared to conventional open abdominal surgeries [1]. However, a sufficient view and sufficient space in the abdominal cavity are essential for these surgeries to be successful. Deep muscle relaxation has been reported to improve the surgical space and surgeons' satisfaction [2] and to shorten operation times [3]. However, it has been difficult to objectively evaluate the surgical space conditions in relation to the degree of peripheral nerve block (PNB)-induced muscle relaxation during robot-assisted laparoscopic surgery.

Abdominal PNB has been used in abdominal surgeries to produce both good abdominal muscle relaxation and postoperative analgesia [4]. An abdominal PNB may thus provide sufficient muscle relaxation with a lesser amount of muscle relaxant in the surgical field during robot-assisted laparoscopic surgeries. A retrospective analysis showed that perioperative opioid and neuromuscular blockade use were significantly reduced in the abdominal PNB group undergoing a robot-assisted laparoscopic radical prostatectomy

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(RARP) [5], suggesting that abdominal PNBs may assist in muscle relaxation. However, the beneficial effects of abdominal PNBs on the surgical field during robotic surgery have not been elucidated. Previous studies showed that deep muscle relaxation provided better surgical field conditions than moderate muscle relaxation [2, 3]. However, our pilot study revealed that the Surgical Rating Score (SRS) of the operative field by surgeons was not significantly different according to the degree of muscle relaxation and the presence or absence of abdominal peripheral nerve block (PNB). Furthermore, when the pneumoperitoneal pressure was increased from 8 to 12 mmHg, the change in distance between the outer edge of the umbilicus port and the peritoneum tended to be greater in the group that underwent deep muscle relaxation, but not significantly (unpublished). Therefore, this study investigated whether changes in the distance from the umbilicus port to the peritoneum would be similar between the group using deep muscle relaxation (non-PNB group) and the group using moderate muscle relaxation with abdominal peripheral nerve block (PNB group).

Methods

Study design and patient selection

This prospective, single-blinded, randomized controlled study was conducted from February 2019 to August 2019 at Hirosaki University Graduate School of Medicine, Japan. The study complied with the Declaration of Helsinki and was approved by the local ethics committee (the Ethics Committee of Hirosaki University Graduate School of Medicine, Japan; approval no. 16H28004). The study was registered on the University Hospital Medical Information Network (https://upload.umin.ac.jp/cgi-open-bin/ctr_e/ctr_view.cgi?recptno=R000028586; registration no. UMIN000024840) on February 1, 2017. Written informed consent was obtained from all study participants. We included patients with an American Society of Anesthesiologists (ASA) physical status of I or II, an age of 40–80 years and a body mass index (BMI) of < 30 kg/m^2 who were scheduled for elective RARP at our hospital. The exclusion criteria were impaired liver or kidney function, any difficulty regarding the use of abdominal PNB, and allergy to local anesthetics, neuromuscular blockades, or their antagonists.

The patients were randomly assigned to one of the two groups using a computer-generated table by a researcher who was not responsible for performing anesthesia. The non-PNB group received only deep muscle relaxation (post-tetanic count of 0–2) while the PNB group received abdominal PNB and moderate muscle relaxation (train-of-four count [TOF] of 1–3).

Anesthesia and PNB management

All of the patients received general anesthesia with total intravenous anesthesia. Standard monitoring was used upon the patient's arrival in the operation room. Anesthesia was induced with propofol (0.5–1 mg/kg), remifentanil (0.2–0.5 μg/kg/min), ketamine (0.5–1 mg/kg), and rocuronium (0.6–1 mg/kg) and maintained with propofol (2–8 mg/kg/h) and remifentanil (0.025–0.5 μg/kg/min) with a target bispectral index (BIS) of 40–60 (monitored with a BIS-XP® system; Aspect Medical Systems, Leiden, The Netherlands). Vasoactive agents such as ephedrine, phenylephrine, and atropine were intermittently given to maintain the mean arterial pressure at > 60 mmHg and the heart rate between 40 and 100 beats/min. The patient's lungs were mechanically ventilated to maintain the end-tidal carbon dioxide ($EtCO_2$) at 30–40 mmHg using the pressure-controlled mode with peak inspiratory pressure < 25 cmH_2O.

During the surgery, continuous intravenous rocuronium at 5–10 μg/kg/min was administered to manage the patient's muscle relaxation until the prostatectomy. An additional 5 mg of rocuronium was given if there was poor visibility or body movement, or at the request of the surgeon. After the surgery, sugammadex was administered when the TOF ratio was < 0.9. The dosage of sugammadex was 2 mg/kg if the TOF count was greater than 4, followed by additional doses until the TOF ratio was 0.9 or higher.

A subcostal transversus abdominis plane block and a lower abdominal rectus sheath block were performed with a mixture of 40 mL of 0.25% levobupivacaine and 20 mL of 1% lidocaine after the induction of general anesthesia with a 22-G needle. Bilateral lower abdominal rectus sheath blocks in the umbilical port region and bilateral lateral subcostal transversus abdominis plane block were performed using 16 mL and 44 mL of the same anesthetics, respectively. These methods were chosen because the port locations were all above the umbilical region. The thickness of the rectus abdominis muscle and subcutaneous fat in the umbilical region was also measured in all patients by sonography after anesthesia induction.

Fentanyl and/or morphine was given intravenously for postoperative pain during surgery. If patients complained of pain in the postanesthesia care unit (PACU), fentanyl, acetaminophen or flurbiprofen was administered according to the degree of pain.

Assessment of surgical space conditions

To objectively assess the patient's surgical space conditions, we measured the CO_2 usage while the abdominal space was maintained [6], and measured the distance between the outer edge of the umbilicus port and the peritoneum vertically when the pneumoperitoneal pressure was increased from 8 to 12 mmHg [7, 8]. After the ports were inserted with 10 mmHg of pneumoperitoneal pressure, each surgeon marked the length from the umbilicus port to the peritoneum at 6 mmHg of pneumoperitoneal pressure using a 12-Fr flexible catheter (Fig. 1). The distance from the umbilical port to the peritoneum was then measured vertically while the patient was supine during pneumoperitoneum. A laparoscope was inserted through the lateral port to see whether a 12-Fr flexible catheter could touch the peritoneum. The distance from the umbilical port to the peritoneum was measured using a 12-Fr flexible catheter for each 2 mmHg increase in pneumoperitoneal pressure from 6 to 12 mmHg. The CO_2 usage from 8 to 12 mmHg was also calculated by summing the CO_2 usage required to increase from 8 to 10 mmHg and the CO_2 usage required to increase from 10 to 12 mmHg.

We asked the surgeons to assess the quality of the surgical conditions in each case using the Surgical Rating Score (SRS) [2]: SRS 1 = extremely poor condition, 2 = poor condition, 3 = acceptable condition, 4 = good condition and 5 = optimal condition. The surgeon had no information about the TOF data or the use/non-use of PNB. Additional neuromuscular relaxant was given when the SRS was assessed as 1. The determination of the SRS was made by the same surgeon without the individual patient data on TOF and the use/non-use of PNB. The measurements were performed right after the patient was placed in the Trendelenburg position at 25° and every 1 h after pneumoperitoneum was achieved until the removal of the prostate (Fig. 2).

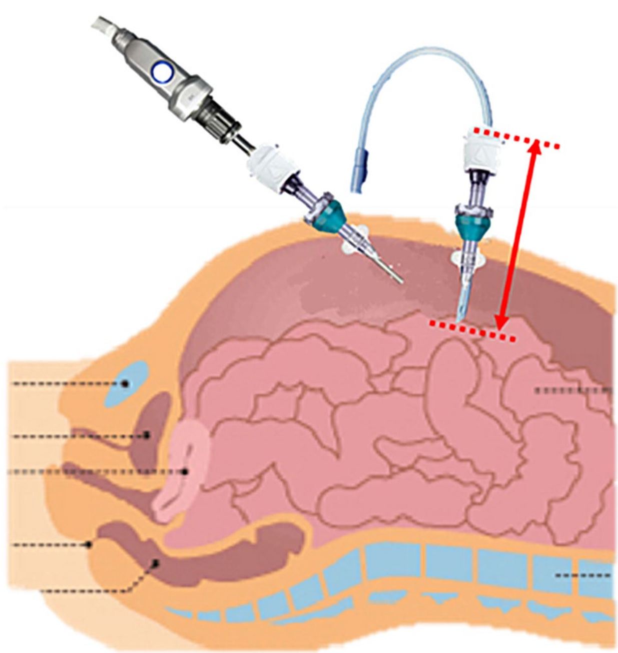


Fig. 1 Method used to measure the distance from the umbilicus port to peritoneum. The distance indicated by the red arrow was measured using a 12Fr flexible catheter

Data collection and definitions

The following data were collected from each patient's medical record: age, body weight, height, body mass index (BMI), comorbidity, ASA physical status, preoperative prostate-specific antigen value, the D'Amico risk classification, neoadjuvant chemotherapy, the total amount of each anesthetic drug (propofol, remifentanil, ketamine, morphine, rocuronium), pneumoperitoneum time, operation time, anesthesia time, and PACU management. Fentanyl 200 μg was converted into morphine 10 mg [9] in patients who had been administered fentanyl as a postoperative analgesic.

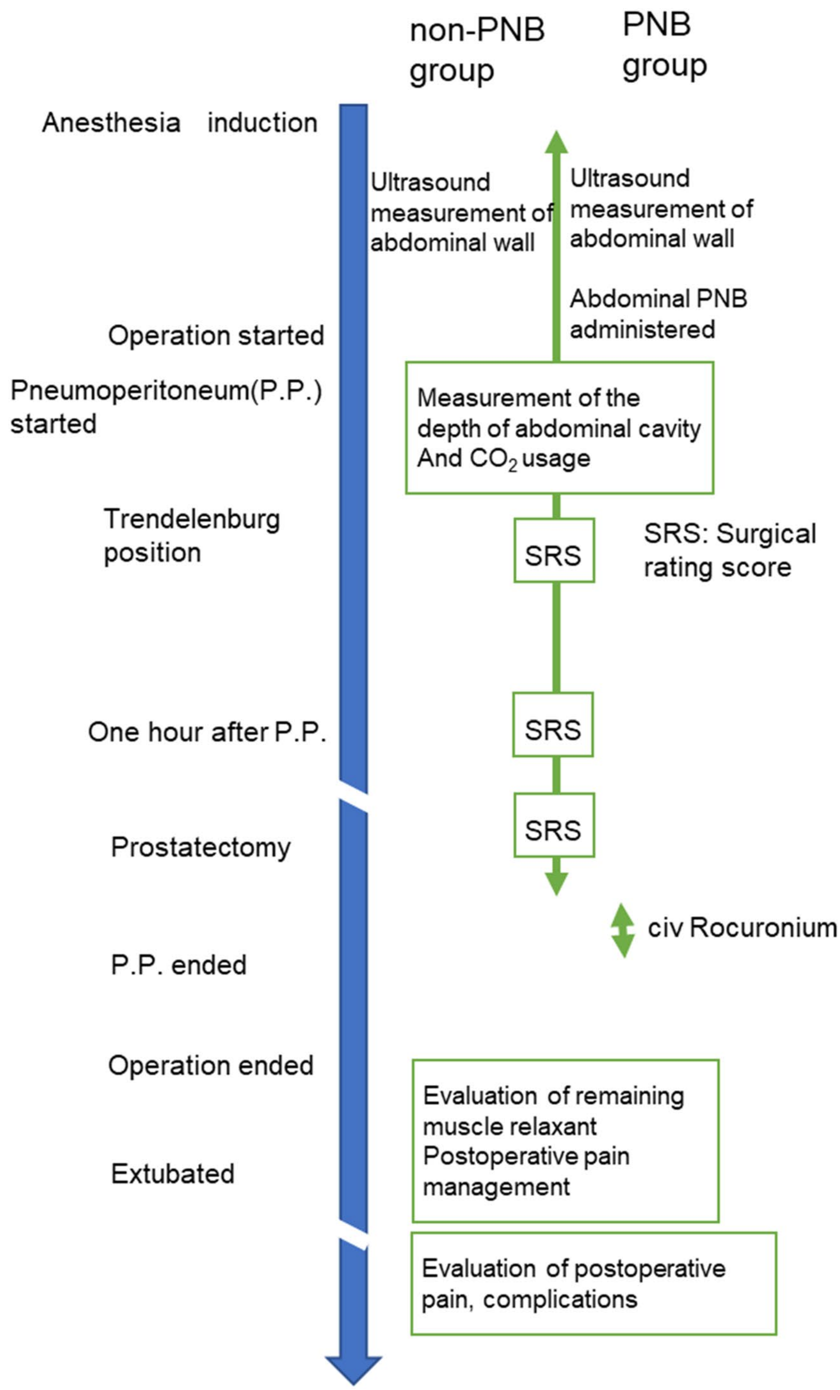
Outcomes and statistical analyses

The primary outcome of this study was the change in the depth of the abdominal cavity measured as the *Δdistance* from the umbilicus port to the peritoneum when the pneumoperitoneum pressure increased from 8 to 12 mmHg (compared between the non-PNB and the PNB groups). The secondary outcomes of this study were 1) the CO_2 usage when the pneumoperitoneum pressure was increased from 8 to 12 mmHg (compared between the non-PNB and the PNB groups) and the differences in the surgeon-rated SRS between the two groups. In addition, we compared the *Δdistance* values for the pressure increments of 6–8, 10, and 12 mmHg, respectively, in the PNB and non-PNB groups. To compare outcomes, we performed unpaired t tests. To compare the *Δdistance* from the umbilicus port to the peritoneum, we performed two-way ANOVA tests, Tukey's multiple comparison tests for intra-group difference, and Bonferroni's multiple comparison tests for between-group differences.

Normality of all variables was evaluated using the D'Agostino-Pearson normality test. To compare the other factors, we performed t tests, Mann–Whitney U tests, and χ^2 tests, with probability (p)-values < 0.05 accepted as significant. The data analyses were performed with GraphPad Prism 6 software (GraphPad Software, San Diego, CA) and EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria). Data are presented as means ± SDs, medians [25% quartile–75% quartile] or n values (%).

In a similar study in which the abdominal cavity depth was measured during pneumoperitoneum in 12 patients, a 5-mm (SD 5 mm) change of distance from the umbilicus port to the peritoneum was observed as the pressure changed

Fig. 2 Timeline of the study



from 8 to 12 mmHg [10]. In our pilot study, the mean value of the change of distance as measured by catheter during the pressure change from 8 to 12 mmHg was 12.0 ± 2.8 mm in the group with deep muscle relaxation and no PNB and 10.6 ± 1.8 mm in the group with moderate muscle relaxation and abdominal PNB ($p = 0.357$). To determine the appropriate size of groups for the present study, we calculated the sample size required for identification of a 2-mm difference in the abdominal cavity depth (an assuming SD of 2 mm) with a significance level of 0.05 and power of 0.85, resulting in a size of 18 patients per group.

Results

A total of 45 patients were eligible; 6 declined to participate and 1 was excluded due to a missing measurement (see Fig. 3). All 38 of the remaining patients completed the study.

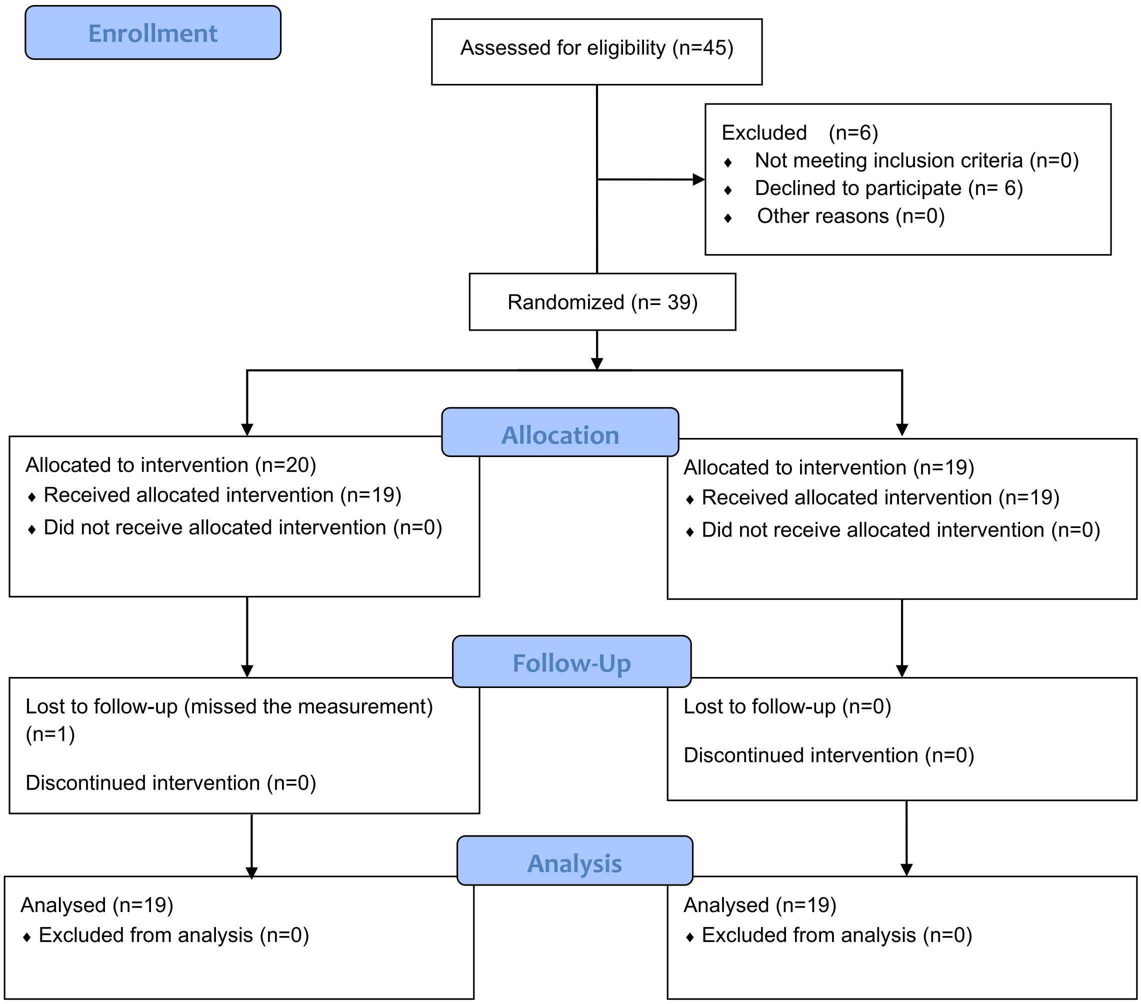


Fig. 3 Consort flow diagram of the patients

Table 1 Patient demographics

Variable	non-PNB (n = 19)	PNB (n = 19)	p value
Age, yrs	67.5 ± 6.5	68.7 ± 4.9	0.561
Height, cm	164.6 ± 6.1	164.9 ± 4.4	0.856
Weight, kg	67.3 ± 10.3	66.2 ± 7.5	0.699
BMI, kg/m^2	24.7 ± 2.9	24.3 ± 2.6	0.618
Hypertension, n (%)	7 (36.8)	9 (47.4)	0.511
Diabetes, n (%)	3 (15.8)	2 (10.5)	0.631
Dyslipidemia, n (%)	4 (21.1)	4 (21.1)	1.000
Smoker, n (%)	16 (84.2)	14 (73.7)	0.426
%VC, %	102.7 ± 14.3	101.4 ± 15.8	0.787
FEV1.0, %	75.8 ± 8.4	78.7 ± 9.3	0.335
ASA-PS II, n (%)	18 (94.7)	19 (100)	0.311
Preop PSA, ng/mL	5.87 [4.70–8.86]	5.58 [4.99–6.59]	0.660
D'Amico classification L/I/H, n (%)	2/6/11 (10.5/31.6/57.9)	1/6/12 (5.3/31.6/63.1)	0.828

Data are means ± SDs or medians [25% quartile–75% quartile]. BMI, body mass index; Preop, preoperative

Their characteristics are summarized in Table 1. No patient in either group had a history of abdominal surgery. There were no significant differences in demographics between the PNB and non-PNB groups.

Total amount of anesthetics

The total amounts of anesthesia-related agents used are listed in Table 2. Significantly higher doses of remifentanil and rocuronium were used in the non-PNB group compared to the PNB group. The non-PNB group showed also a significantly higher rate of sugammadex requirement compared to the PNB group. There was no significant between-group difference in the total dose of vasopressor. The rate of patients needing additional opioids in the PACU was significantly higher in the non-PNB group than in the PNB group. The total dose of morphine until leaving the PACU was thus significantly higher in the non-PNB group compared to the PNB group: 14.8 ± 4.2 vs. 11.2 ± 1.9 mg, p = 0.0015. There were no adverse events such as local anesthetic systemic toxicity, allergy, or hematoma formation associated with abdominal PNB.

Surgical space conditions

An increase in the distance from the umbilicus port to the peritoneum when the pneumoperitoneum pressure was increased from 6 to 12 mmHg was observed in every patient. There was no significant difference in the absolute value of the distance from the umbilicus port to the peritoneum between the PNB and non-PNB groups (6 mmHg: 10.98 ± 1.73 cm vs. 10.47 ± 1.59 cm, p = 0.374

Table 2 Perioperative data

Variable	non-PNB (n = 19)	PNB (n = 19)	Difference between means or in cumulative incidence (95% CI)	p value
Total doses of general anesthesia-related agents used				
Propofol, g	1.33 ± 0.38	1.19 ± 0.36	− 0.138 (− 0.380, 0.104)	0.256
Remifentanil, mg	3.00 ± 0.92	2.38 ± 0.55	− 0.620 (− 1.121, − 0.118)	0.017
Ketamine, mg	43.7 ± 12.1	41.0 ± 9.9	− 2.632 (− 9.923, 4.660)	0.514
Rocuronium, mg	145.6 ± 38.6	88.3 ± 23.8	− 57.33 (− 78.42, − 36.23)	< 0.001
Morphine, mg	13.4 ± 3.7	11.2 ± 1.9	− 2.237 (− 4.198, − 0.276)	0.050
Acetaminophen, n (%)	17 (89.5)	18 (94.7)	− 0.053 (− 0.223, 0.118)	0.624
Ephedrine, mg	8.8 ± 8.4	9.9 ± 9.8	1.053 (− 4.960, 7.066)	0.724
Phenylephrine, mg	0.10 ± 0.16	0.10 ± 0.19	0.002 (− 0.113, 0.118)	0.913
Sugammadex, n (%)	15 (78.9)	3 (15.8)	0.632 (0.386, 0.878)	< 0.001
Surgical data				
Requiring increased PP, n (%)	1 (5.3)	5 (26.3)	− 0.211 (− 0.433, 0.011)	0.075
Console time, min	136 ± 42	122 ± 38	− 14.16 (− 40.80, 12.49)	0.288
Pneumoperitoneum time, min	168 ± 42	159 ± 40	− 9.158 (− 36.06, 17.75)	0.494
Duration of surgery, min	196 ± 44	184 ± 43	− 12.05 (− 40.96, 16.86)	0.403
Duration of anesthesia, min	261 ± 51	254 ± 42	− 6.947 (− 37.37, 23.47)	0.646
Fluid administration, L	1.35 ± 0.37	1.30 ± 0.38	− 0.048 (− 0.296, 0.199)	0.811
Blood loss, g	66.1 ± 67.7	43.1 ± 34.8	− 23.05 (− 58.46, 12.36)	0.260
Urine out, mL	186 ± 176	120 ± 105	− 66.42 (− 162.0, 29.11)	0.328
Abdominal subcutaneous fat thickness, mm	14.1 ± 0.50	13.5 ± 0.45	− 0.621 (− 3.73, 2.49)	0.688
Abdominal muscle thickness, mm	12.5 ± 0.69	11.6 ± 0.55	− 0.842 (− 4.95, 3.27)	0.680
SRS				
After trendelenburg position	4.95 ± 0.23	4.84 ± 0.37	− 0.105 (− 0.310, 0.099)	0.303
One after pneumoperitoneum	4.95 ± 0.23	4.95 ± 0.23	0 (− 0.151 – 0.151)	1.000
After prostatectomy	4.95 ± 0.23	4.95 ± 0.23	0 (− 0.151 – 0.151)	1.000
Postoperative characteristics				
Postop opioid requirement in PACU, n (%)	6 (31.6)	0 (0)	0.316 (0.107, 0.525)	0.008
Shivering in PACU, n (%)	1 (5.3)	0	0.053 (− 0.048, 0.153)	0.311
Agitation in PACU, n (%)	0 (0)	2 (10.5)	− 0.105 (− 0.243, 0.039)	0.146

Data are means ± SDs

PACU postanesthesia care unit, *SRS* Surgical Rating Score

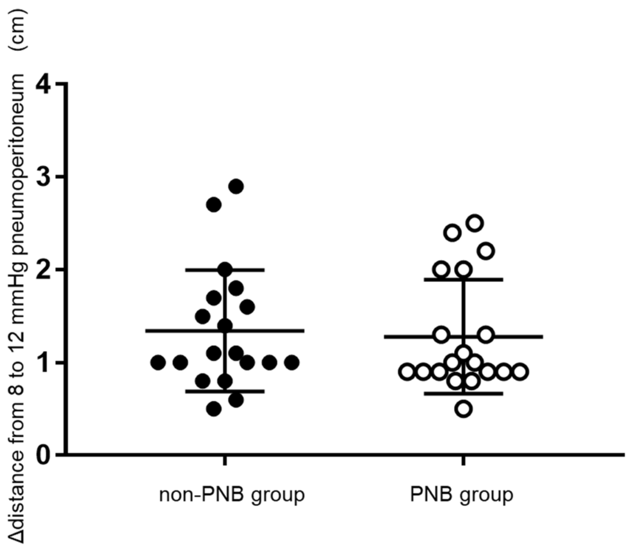


Fig. 4 Comparison of changes in the distance from the umbilicus port to the peritoneum. Comparison of changes in the distance from the umbilicus port to the peritoneum when the pneumoperitoneum pressure was increased from 8 to 12 mmHg between the non-PNB and PNB groups by unpaired t test. No significant difference in the change in distance from 8 to 12 mmHg was observed (non-PNB group vs. PNB group: 1.34 ± 0.65 vs. 1.28 ± 0.61 cm, p = 0.763)

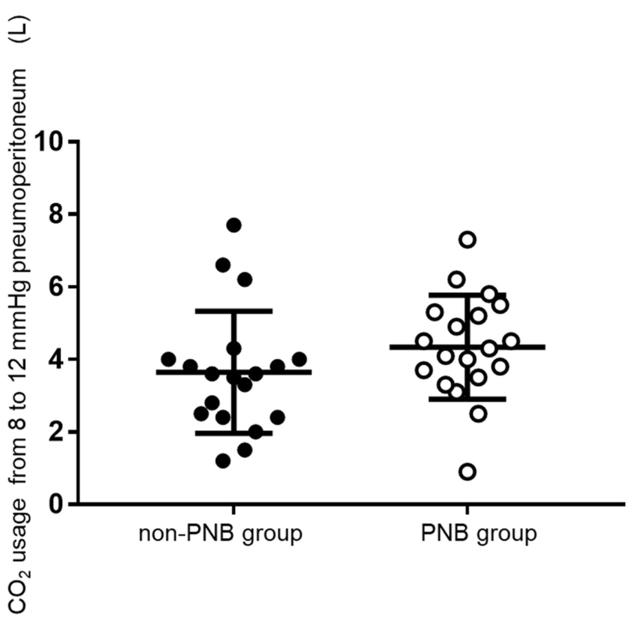


Fig. 5 Comparison of the CO_2 usage. Comparison of the CO_2 usage when the pneumoperitoneum pressure was increased from 8 to 12 mmHg between the non-PNB and PNB groups by unpaired t-test. No significant difference in CO_2 usage was observed for insufflation from 8 to 12 mmHg at pneumoperitoneum: non-PNB group vs. PNB group, 3.64 ± 1.68 vs. 4.34 ± 1.44 L, p = 0.180

and 12 mmHg: 13.21 ± 1.80 cm vs. 13.08 ± 2.26, p = 0.843, respectively) No significant difference in the *Δdistance* or in the CO_2 usage from 8 to 12 mmHg pneumoperitoneum was observed between the two groups (Figs. 4, 5). There was also no significant between-group difference in the SRS at any time point, and there was no need for additional rocuronium in either group for SRS assessment or at the request of the surgeon.

Comparisons of the *Δdistance* from the umbilicus port to the peritoneum between the PNB and non-PNB groups were also performed for increases of pneumoperitoneum pressure from 6 to 8 mmHg, from 6 to 10 mmHg and from 6 to 12 mmHg. Although there were significant intra-group differences in *Δdistance* for the different pressure increments ($p < 0.001$), there were no significant differences between groups on two-way ANOVA: non-PNB group [6–8 mmHg: 1.26 ± 0.81; 6–10 mmHg: 1.95 ± 1.20; 6–12 mmHg: 2.60 ± 1.36 cm], PNB group [6–8 mmHg: 0.96 ± 0.39; 6–10 mmHg: 1.51 ± 0.36; 6–12 mmHg: 2.24 ± 0.70 cm] (Fig. 6).

Discussion

In the present patient series, there was no significant between-group difference in the change in umbilicus-to-peritoneum distance (*Δdistance*) or in the CO_2 usage between 8 and 12 mmHg of pneumoperitoneal pressure in patients who underwent a RARP. There was also no significant difference in the SRS between the two groups. Although a significant increase in the distance from the umbilicus port to the peritoneum was observed in every patient when the pneumoperitoneum pressure increased from 6 to 12 mmHg, there was no significant difference in the *Δdistance* between the two groups.

The present study is the first to assess the effect of the use of an abdominal PNB on the surgical field. Although retrospective studies showed that epidural anesthesia and abdominal PNB reduced the dose of muscle relaxant used during abdominal open and robotic surgery [5, 11], no study has described the direct effect of abdominal PNB on the surgical field. A recent systematic review and meta-analysis [12] revealed that during laparoscopic surgery, a deep neuromuscular blockade was associated with an excellent or better SRS score than a moderate neuromuscular blockade; however, further investigations are required to address the heterogeneity and power shortages described in that review's trial sequential analysis. In our present study, both the objective and subjective assessments of the surgical field were comparable between the two patient groups. These results suggested that moderate muscle relaxation with abdominal PNB provides acceptable surgical conditions for surgeons during RARPs.

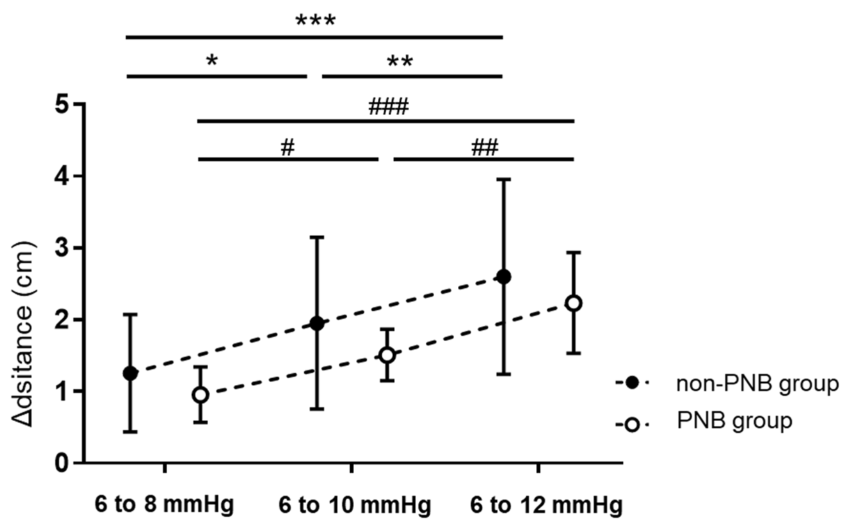


Fig. 6 Comparison of the delta distance from the umbilicus port to the peritoneum. Comparison of the Δ distance from the umbilicus port to the peritoneum when the pneumoperitoneum pressure was increased from 6 to 8 mmHg, from 6 to 10 mmHg and from 6 to 12 mmHg between the non-PNB and PNB groups. Although there were significant intra-group differences for each pressure change, there were no significant differences in results between groups: non-PNB group: 6–8 mmHg, 1.26 ± 0.81; 6–10 mmHg, 1.95 ± 1.20; 6–12 mmHg, 2.60 ± 1.36 cm; PNB group: 6–8 mmHg, 0.96 ± 0.39; 6–10 mmHg, 1.51 ± 0.36; 6–12 mmHg, 2.24 ± 0.70 cm. $^{*}p < 0.001$ vs. 6–8 mmHg, $^{**}p < 0.001$ vs. 6–10 mmHg and $^{***}p < 0.001$ vs. 6–8 mmHg in the non-PNB group. $^{\#}p < 0.001$ vs. 6–8 mmHg, $^{\#\#}p < 0.001$ vs. 6–10 mmHg and $^{\#\#\#}p < 0.001$ vs. 6–8 mmHg in the PNB group

As shown in Fig. 5, the *Δdistance* from the umbilicus port to the peritoneum increased significantly with increasing pneumoperitoneal pressure in both groups. A previous study reported that compared with moderate muscular relaxant, deep muscular relaxant allowed a larger intraabdominal volume of CO_2 insufflation and greater skin–sacral promontory distance at the establishment of pneumoperitoneum [10]. However, the increase in the abdominal cavity size showed a large interindividual variability and was not observed in all patients in that study. In the present study, all patients showed an increased distance from the umbilical port to peritoneum from 6 to 12 mmHg. However, the non-PNB group tended to have greater standard deviation, suggesting greater variability. This result may indicate that the abdominal cavity size is affected not only by the degree of muscle relaxation but also by pneumoperitoneum-related somatic pain. Intraoperative remifentanil doses were significantly smaller in the PNB group, indicating that abdominal PNB provided abdominal wall pain relief; if PNB was not performed, surgical stimulation by port insertion and somatic pain stimulation by pneumoperitoneum could have occurred. Differences in remifentanil dosage among patients in the non-PNB group were a possibility, but the detailed mechanisms underlying such differences were not clarified in this study. In any case, such differences would have had little impact on the clinical surgical field; this conclusion was also supported by our findings of no significant between-group differences in the duration of surgery or estimated blood loss.

We found that the non-PNB group with intraoperative deep neuromuscular blockade (higher dose of rocuronium) required reversal with sugammadex more frequently than the group with moderate neuromuscular blockade. This study also revealed that abdominal PNB significantly reduced intraoperative remifentanil use and additional opioid administration in the PACU. Other investigations have also reported that the amount of anesthetic agent was significantly lower in patients with PNB compared to those without PNB [5, 13]. The additional administration of an opioid in the PACU might prolong a patient's PACU stay. The combination of a moderate neuromuscular blockade with abdominal PNB may reduce this stay and thus the cost of the surgery.

Our study has several limitations. It was conducted at a single center with a single-blind design. Due to the single-blind design, it is possible that the attending anesthesiologists knew whether PNB had been performed, which could have affected their management of anesthesia. However, the measurement of the abdominal cavity and the assessment of the SRS were conducted by surgeons who were blinded to group assignment, and thus the assessment of the surgical field was reliable and without bias. Another potential study limitation was the use of a new measure—i.e., the distance from the umbilicus port to the peritoneum—for the size of the abdominal cavity. In addition, while it is difficult to determine whether an abdominal PNB has been successfully performed, the doses of remifentanil and morphine in the PNB group were significantly smaller than those in the non-PNB group, suggesting that PNB was effective in this study. Nonetheless, we have no direct evidence that the abdominal PNB with lower concentration of levobupivacaine facilitates muscular relaxation. Finally, there were differences between the groups not only in the presence or absence of abdominal PNB, but also in the depth of muscle relaxation. Therefore, it is difficult to conclude that the present results were due to abdominal PNB. Since the reliability of this new method has not been evaluated, further studies with more subjects are needed to assess the muscle-relaxing effects of PNB.

In conclusion, the present data suggest that moderate neuromuscular block with abdominal PNB maintained an adequate surgical space for RARP that was not significantly from the surgical space achieved by deep neuromuscular block.

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Declarations

Conflict of interest The authors declare no conflicts of interest.

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