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Comparison of the effects of deep and moderate neuromuscular block on respiratory system compliance and surgical space conditions during robot-assisted laparoscopic radical prostatectomy: a randomized clinical study*

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Abstract: Objective: Robot-assisted radical prostatectomy (RARP) requires pneumoperitoneum (Pnp) and a steep head-down position that may disturb respiratory system compliance (C_{rs}) during surgery. Our aim was to compare the effects of different degrees of neuromuscular block (NMB) on C_{rs} with the same Pnp pressure during RARP. Methods: One hundred patients who underwent RARP were enrolled and randomly allocated to a deep or moderate NMB group with 50 patients in each group. Rocuronium was administered to both groups: in the moderate NMB group to maintain 1–2 responses to train-of-four (TOF) stimulation; and in the deep NMB group to maintain no response to TOF stimulation and 1–2 responses in the post-tetanic count. Pnp pressure in both groups was 10 mmHg (1 mmHg=133.3 Pa). Peak inspiratory pressure (P_{peak}), mean pressure (P_{mean}), C_{rs}, and airway resistance (R_{aw}) were recorded after anesthesia induction and at 0, 30, 60, and 90 min of Pnp and post-Pnp. Surgical space conditions were evaluated after the procedure on a 4-point scale. Results: Immediately after the Pnp, P_{peak}, P_{mean}, and R_{aw} significantly increased, while C_{rs} decreased and persisted during Pnp in both groups. The results did not significantly differ between the two groups at any of the time points. There was no difference in surgical space conditions between groups. Body movements occurred in 14 cases in the moderate NMB group and in one case in the deep NMB group, and all occurred during obturator lymphadenectomy. A significant difference between the two groups was observed. Conclusions: Under the same Pnp pressure in RARP, deep and moderate NMBs resulted in similar changes in C_{rs}, and in other respiratory mechanics and surgical space conditions. However, deep NMB significantly reduced body movements during surgery.

Key words: Robot-assisted radical prostatectomy (RARP); Deep neuromuscular block; Respiratory mechanics; Surgical space condition
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1 Introduction

Robot-assisted radical prostatectomy (RARP) has advantages over open retropubic radical prostatectomy and laparoscopic radical prostatectomy, such as a clearer surgical field, less bleeding, thorough radical cure, and conserved urine control and sexual function. This has made it an important method for radical prostatectomy (Basiri et al., 2018). Because this modern surgical technique requires the patient to be in a steep head-down position and because pneumoperitoneum (Pnp) is used, it has a significant impact on cardiopulmonary function during surgery (Rauh et al., 2001; Atkinson et al., 2017). Inflation of

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the abdominal cavity with CO_2 can cause sharp hemodynamic changes owing to increased abdominal pressure. Airway pressure increases and respiratory system compliance (C_{rs}) decreases due to lifting of the diaphragm. The head-down position and, in particular, Pnp have a significant effect on C_{rs} (Park et al., 2012). CO_2 can be absorbed through the peritoneum or subcutaneously, and hypercapnia often occurs. Hypoxemia may also occur owing to reduced functional residual volume and atelectasis caused by elevation of the diaphragm (Chun et al., 2019). Increased airway pressure may cause lung injury and thus increase the incidence of postoperative lung complications (Güldner et al., 2015).

In patients undergoing laparoscopic surgery, it is important to reduce abdominal pressure in order to reduce lung injury. Some studies have reported on the use of a deep neuromuscular block (NMB) that may facilitate the use of low Pnp pressure during laparoscopic surgery, thereby reducing disturbance in the cardiopulmonary functions (Madsen et al., 2015; Bruintjes et al., 2017; Koo et al., 2018). Deep NMB is defined as: no responses to train-of-four (TOF) stimulation and 1–2 responses to post-tetanic count (PTC) during neuromuscular monitoring, compared to moderate NMB, which has 1–2 responses to TOF. However, at the same Pnp pressure, it is uncertain whether deep NMB can improve respiratory mechanics such as airway pressure, airway resistance (R_{aw}), and C_{rs} in RARP and other laparoscopic surgeries.

In this study, we compared the effects of different degrees of NMB on C_{rs} and other respiratory mechanics under the same Pnp pressure (10 mmHg; 1 mmHg=133.3 Pa) during RARP.

2 Subjects and methods

2.1 Study design

A total of 100 patients who underwent elective RARP were enrolled in this study between Sept. 15, 2018 and May 20, 2019. The inclusion criteria were: American Society of Anesthesiologists Physical Status Class I or II and no history of severe systemic disease. The exclusion criteria were: age >80 years; history of severe heart, lung, liver, or kidney disease; history of neuromuscular disease; body mass index (BMI) >30 kg/m^2 or <18.5 kg/m^2; and a history of severe drug allergy. The patients were randomly allocated to one of two groups, moderate NMB or deep NMB (50 patients in each group), using SPSS Statistics Version 20 (IBM, Armonk, NY, USA). The study flowchart is shown in Fig. 1.

2.2 Anesthesia

Upon admission of the patients to the operating room, the peripheral vein was cannulated for infusion and medication, and the left radial artery was cannulated to monitor the arterial pressure and blood gas analysis. The patients were anesthetized intravenously with 1–2 mg/kg propofol, 5 μg/kg fentanyl, and 0.6 mg/kg rocuronium. They were subsequently tracheally intubated and maintained with propofol (6–10 mg/(kg·h)) and remifentanil (10−20 μg/(kg·h)) by pump infusion to maintain a bispectral index (BIS) value of 40–60 (40–50 frequency) during surgery.

After induction of anesthesia and tracheal intubation, rocuronium was infused intravenously with an initial dose of 0.6 mg/(kg·h), and with subsequent dose adjustments to maintain 1–2 responses to TOF in the moderate NMB group, or no response to TOF and 1–2 responses to PTC in the deep NMB group. An additional bolus dose of rocuronium (5 mg) was administered as required during surgery or in the case of a sudden change in responses. Infusion of rocuronium was discontinued at the end of the Pnp, after which the surgery usually lasted for 30 min.

The patients were ventilated using the Dräger Fabius GS anesthesia workstation (Dräger Medical, Lübeck, Germany). The fraction of inspired oxygen (FiO_2) was 60% (mixed with 1 L oxygen and 1 L air), and a volume-controlled ventilation with an inspiratory pause of 10% was set with an inspiratory-to-expiratory ratio of 1:2, tidal volume of 8 mL/kg, respiratory rate of 12 times/min, and positive end expiratory pressure (PEEP) of 5 cmH_2O (1 cmH_2O= 98.06 Pa). The respiratory rate was adjusted before the Pnp to maintain an end-tidal pressure of CO_2 ($PETCO_2$) of 30–35 mmHg. Respiratory parameters were not adjusted if $PETCO_2$ was ≤60 mmHg in the Pnp, but if $PETCO_2$ was >60 mmHg, the respiratory rate was increased first. If $PETCO_2$ continued to rise, the tidal volume was increased appropriately. No lung recruitment was performed during the measurement.

Fentanyl (2 μg/kg) was administered before concluding the surgery. For reversal of NMB, neostigmine

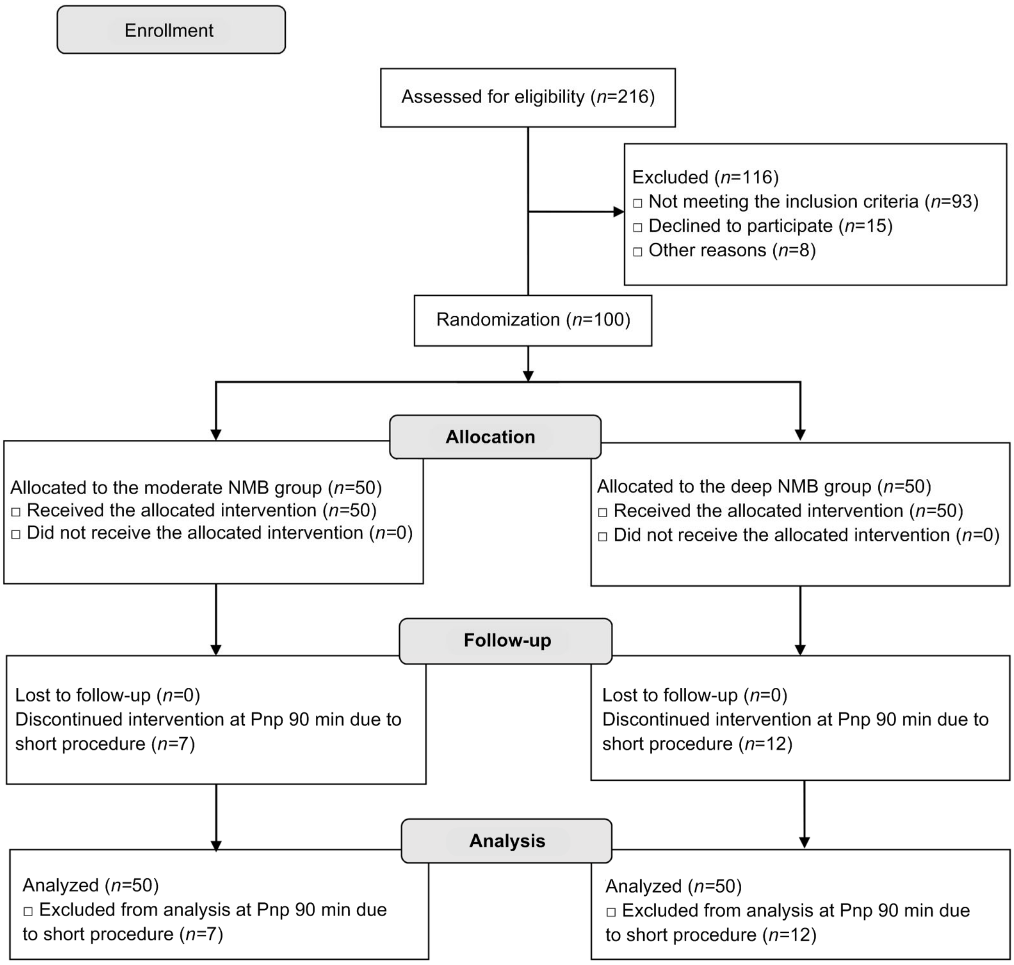

Fig. 1 Consolidated standards of reporting trials (CONSORT) flow diagram
NMB: neuromuscular block; Pnp: pneumoperitoneum

50 μg/kg and atropine 10 μg/kg in the moderate NMB group or sugammadex 2 mg/kg in the deep NMB group were intravenously administered under the guidance of the NMB monitor. When the TOF ratio (T4/T1) reached 0.9, the tracheal tube was removed and the patients were transferred to the post-anesthesia care unit.

2.3 Monitoring and data acquisition

Patients were monitored for electrocardiography, pulse oximetry, body temperature, BIS, invasive arterial pressure, $PETCO_2$, and ventilation pressure-volume loop using CARESCAPE Monitor B650 (GE Healthcare, Helsinki, Finland). Blood gas was analyzed using the ABL-90 FLEX analyzer (Radiometer Medical ApS, Brønshøj, Denmark) and NMB was monitored by acceleromyography of the adductor pollicis muscle with the TOF Watch SX (Organon, Dublin, Ireland). Two electrodes were placed over the left ulnar nerve; TOF was measured every 15 s during the surgery after calibration with supramaximal stimulation. In addition, PTC, the single twitch stimulation response count after a 50-Hz current tetanic stimulation, was measured every 5 min when there was no response to TOF (Fig. 2).

Pnp pressure in both groups was 10 mmHg. All surgeries were performed by two teams of surgeons. The surgeons were asked to evaluate the surgical space conditions after the procedure using a 4-point scale: 1, optimal, optimal/excellent surgical space conditions; 2, good, non-optimal conditions, but an intervention was unnecessary; 3, acceptable, an intervention was necessary to improve conditions; and 4, poor, unacceptable conditions that required

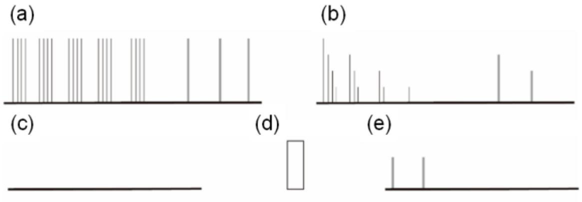

Fig. 2 Graphical illustration of neuromuscular monitoring results

(a) Responses to train-of-four (TOF) stimulation and single twitch stimulation (bold line) before muscle relaxant administration. (b) Responses to TOF and single twitch stimulation after muscle relaxant administration. With the increase of the depth of neuromuscular block (NMB), TOF responses decreased from the fourth response (T4) and disappeared in sequence. Responses to single twitch stimulation also gradually weakened and disappeared. One to two responses to TOF stimulation are labeled as a moderate NMB. (c) Deep NMB, no response to either TOF or single twitch stimulation. (d) A 50-Hz tetanic stimulation. (e) Count of the number of responses to single twitch stimulation. Two responses are given as an example

intervention to ensure acceptable surgical space (Staehr-Rye et al., 2014; Williams et al., 2020). Body movements during the surgery were also recorded.

Peak inspiratory pressure (P_{peak}), mean pressure (P_{mean}), C_{rs}, and R_{aw} were recorded after induction of anesthesia and at 0, 30, 60, and 90 min of Pnp and post-Pnp. Blood gas analysis was performed after induction and at 60 min of Pnp, and the arterial partial pressure of oxygen (PaO_2) and arterial partial pressure of CO_2 ($PaCO_2$) were recorded.

An attending anesthesiologist and a resident anesthesiologist performed anesthesia. The patients, surgeons, and the resident anesthesiologist who recorded the data were blinded to the level of NMB.

2.4 Statistical analysis

The normality of distribution of all variables was tested using the Kolmogorov-Smirnov test. The values of P_{peak}, P_{mean}, C_{rs}, R_{aw}, PaO_2, and $PaCO_2$ at different time points are presented as the median and interquartile ranges, as the data were not normally distributed. The patient characteristics, Pnp duration, and surgery duration are also presented as medians and interquartile ranges. Differences between multiple time points were analyzed using the Kruskal-Wallis test followed by the Kruskal-Wallis one-way analysis of variance (ANOVA) post-hoc tests. Differences between the two time points or between groups were analyzed using the Mann-Whitney *U* test, and the surgical rating score was compared between groups using the same test. The number of patients who showed body movements during surgery and the number of patients who had $PaCO_2$ >60 mmHg and oxygenation index (PaO_2/FiO_2) <300 mmHg were compared with the Chi-squared (χ^2) test between groups.

In order to determine the sample size, we analyzed the C_{rs} data in a pilot study of 10 patients during RARP. During the Pnp, the mean C_{rs} was 30 mL/cmH$_2$O with a standard deviation of 5. These data were also similar to the data reported by Rauh et al. (2001) and Brandão et al. (2019). The calculated results showed that in order to distinguish a 10% difference in C_{rs} between the moderate NMB and deep NMB groups with a significance level of 0.05 and a power of 90%, 49 patients were needed in each group.

A *P*-value of <0.05 was considered statistically significant. Analyses were performed using SPSS Statistics Version 20.

3 Results

Patient characteristics including age, height, body weight, BMI, Pnp time, and surgery time are shown in Table 1. There were no significant differences in any of these parameters between the two groups.

Immediately after Pnp, P_{peak}, P_{mean}, and R_{aw} significantly increased and C_{rs} decreased, these changes persisted during Pnp in both groups. After the end of Pnp, these metrics indicated improvements but did not return to the levels seen after induction. At any of the time points, these parameters were not

Table 1 Characteristics of the enrolled patients

Group	Age (year)	Height (cm)	Body weight (kg)	Body mass index (kg/m^2)	Duration of Pnp (min)	Duration of surgery (min)
Moderate NMB	68 (65–73)	169 (164–173)	67 (63–71)	23 (22–25)	122 (105–140)	146 (131–169)
Deep NMB	68 (63–73)	169 (165–170)	69 (65–75)	24 (22–26)	120 (90–136)	147 (117–171)

Data are presented as the median (interquartile range). NMB: neuromuscular block; Pnp: pneumoperitoneum significantly different between the groups (Tables 2–4). In the blood gas analysis within the same group, at 60 min after Pnp, $PaCO_2$ significantly increased while PaO_2 significantly decreased compared to levels immediately after induction (Table 5); $PaCO_2$ of >60 mmHg was observed in three cases in the moderate NMB group. The highest observed $PaCO_2$ was 65.9 mmHg, and there were no cases of $PaCO_2$ of >60 mmHg in the deep NMB group. An oxygenation index of <300 mmHg was found in two cases in the moderate NMB group and in two cases in the deep NMB group after induction. The lowest oxygenation index (213 mmHg) was detected in the deep NMB group. At 60 min of Pnp, there were seven cases of oxygenation index of <300 mmHg in the moderate NMB group and three in the deep NMB group, while the lowest index (223 mmHg) was found in the moderate NMB group. At 60 min of Pnp, there were no differences in the number of cases that had $PaCO_2$ of >60 mmHg and an oxygenation index of <300 mmHg between the groups (χ^2=1.375, P=0.241 and χ^2=1.778, P=0.182, respectively). There were no differences in either PaO_2 or $PaCO_2$ after induction or at 60 min of Pnp (Table 5).

There was no need to switch to open surgery for any patient in either group. The surgical space conditions according to the 1/2/3/4 scale were observed in 21/16/8/5 patients in the moderate NMB group and 28/15/6/1 patients in the deep NMB group, respectively, and there were no differences between the two groups (Z=−1.072, P=0.284; Fig. 3). There were 14 cases of body movement in the moderate NMB group

Table 2 Respiratory mechanics at different time points during surgery

Time point	P_{peak} (cmH_2O)		P_{mean} (cmH_2O)		C_{rs} (mL/cmH_2O)		R_{aw} ($cmH_2O/(L\cdot s)$)	
	Moderate NMB	Deep NMB	Moderate NMB	Deep NMB	Moderate NMB	Deep NMB	Moderate NMB	Deep NMB
After induction	16 (15–18)	16 (14–18)	6 (5–7)	6 (5–6)	56 (48–62)	54 (49–61)	11 (10–12)	11 (10–11)
Pnp 0 min	22 (19–25)	22 (20–27)	7 (6–8)	7 (7–8)	34 (30–43)	34 (28–39)	13 (12–14)	13 (11–14)
Pnp 30 min	26 (23–28)	26 (22–29)	8 (7–9)	8 (7–9)	28 (25–31)	30 (25–34)	13 (12–15)	13 (12–15)
Pnp 60 min	26 (23–29)	26 (24–29)	8 (7–9)	8 (7–9)	28 (24–32)	28 (24–32)	13 (12–15)	13 (12–14)
Pnp 90 min	27 (24–30)	28 (25–31)	8 (8–9)	8 (7–9)	28 (25–32)	27 (24–30)	13 (12–15)	13 (11–15)
Post-Pnp	19 (17–23)	18 (17–22)	7 (6–8)	6 (6–7)	44 (39–51)	45 (41–52)	12 (11–12)	11 (10–12)

Data are presented as the median (interquartile range). NMB: neuromuscular block; Pnp: pneumoperitoneum; P_{peak}: peak inspiratory pressure; P_{mean}: mean pressure; C_{rs}: respiratory system compliance; R_{aw}: airway resistance

Table 3 Pairwise comparisons of different time points for respiratory mechanics in the moderate NMB group

Time point	P-value			
	P_{peak}	P_{mean}	C_{rs}	R_{aw}
1–2	0	0.029	0	0
1–3	0	0	0	0
1–4	0	0	0	0
1–5	0	0	0	0
1–6	0.023	0.352	0.078	1.000
2–3	0.011	0.115	0.002	1.000
2–4	0.003	0.035	0	1.000
2–5	0	0.001	0.009	1.000
2–6	0.505	1.000	0.086	0.063
3–4	1.000	1.000	1.000	1.000
3–5	1.000	1.000	1.000	1.000
3–6	0	0.007	0	0
4–5	1.000	1.000	1.000	1.000
4–6	0	0.002	0	0
5–6	0	0	0	0.001

Data are presented as P-values for each parameter. P-values are adjusted for multiple comparisons using a Bonferroni correction. Time point: 1, after induction; 2, pneumoperitoneum (Pnp) 0 min; 3, Pnp 30 min; 4, Pnp 60 min; 5, Pnp 90 min; 6, post-Pnp. NMB: neuromuscular block; P_{peak}: peak inspiratory pressure; P_{mean}: mean pressure; C_{rs}: respiratory system compliance; R_{aw}: airway resistance

Table 4 Pairwise comparisons of different time points for respiratory mechanics in the deep NMB group

Time point	*P*-value			
	P_{peak}	P_{mean}	C_{rs}	R_{aw}
1–2	0	0	0	0
1–3	0	0	0	0
1–4	0	0	0	0
1–5	0	0	0	0
1–6	0.193	0.270	0.632	1.000
2–3	0.159	0.138	0.536	1.000
2–4	0.037	0.145	0.054	1.000
2–5	0.007	0.059	0.013	1.000
2–6	0.004	0.016	0	0.002
3–4	1.000	1.000	1.000	1.000
3–5	1.000	1.000	1.000	1.000
3–6	0	0	0	0
4–5	1.000	1.000	1.000	1.000
4–6	0	0	0	0
5–6	0	0	0	0.001

Data are presented as *P*-values for each parameter. *P*-values are adjusted for multiple comparisons using a Bonferroni correction. Time point: 1, after induction; 2, pneumoperitoneum (Pnp) 0 min; 3, Pnp 30 min; 4, Pnp 60 min; 5, Pnp 90 min; 6, post-Pnp. NMB: neuromuscular block; P_{peak}: peak inspiratory pressure; P_{mean}: mean pressure; C_{rs}: respiratory system compliance; R_{aw}: airway resistance

Table 5 Results of arterial blood gas analysis after induction of anesthesia and 60 min of Pnp

Time point	$PaCO_2$ (mmHg)		PaO_2 (mmHg)		$PaCO_2$ >60 mmHg		Oxygenation index <300 mmHg	
	Moderate NMB	Deep NMB	Moderate NMB	Deep NMB	Moderate NMB	Deep NMB	Moderate NMB	Deep NMB
After anesthesia induction	38 (36–40)	39 (36–41)	277 (230–313)	284 (235–321)	0	0	2	2
After 60 min of Pnp	45 (41–49)[1]	44 (40–49)[2]	254 (198–277)[3]	234 (206–290)[4]	3	0	7	3

Data are presented as the median (interquartile range) or number of patients. PaO_2: arterial partial pressure of oxygen; $PaCO_2$: arterial partial pressure of carbon dioxide; oxygenation index: PaO_2/fraction of inspired oxygen; NMB: neuromuscular block; Pnp: pneumoperitoneum. The Mann-Whitney *U* test was used to compare variables within groups. [1] $P<0.001$; [2] $P<0.001$; [3] $P=0.025$; [4] $P=0.002$

and one in the deep NMB group, and all movements occurred only during obturator lymphadenectomy as leg twitching. The between-group difference was significant ($\chi^2=11.294$, $P=0.001$).

4 Discussion

After Pnp, C_{rs} and other respiratory mechanics underwent obvious and expected changes; however, there was no difference between the deep NMB and moderate NMB groups at the same time points. Moreover, blood gas analysis at 60 min of Pnp indicated that $PaCO_2$ and the oxygenation index remained within the safe range in both groups.

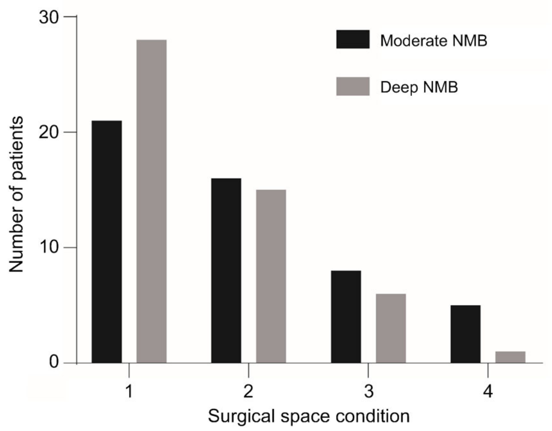

Fig. 3 Surgical space conditions of the two groups
Data are presented as numbers of patients. Surgical space conditions: 1, optimal; 2, good; 3, acceptable; 4, poor. NMB: neuromuscular block

The present findings reveal that under a relatively low Pnp pressure of 10 mmHg, deep NMB did not improve the surgical space conditions in RARP. The main disadvantage of moderate intraoperative NMB was body movement during obturator lymphadenectomy. In this study, we used a relatively low Pnp pressure to achieve good surgical space conditions under moderate NMB. With a clear field of vision, obturator lymphadenectomy during RARP may be closer to the obturator nerve than open retropubic radical prostatectomy and laparoscopic radical prostatectomy, while avoiding injury to the nerve. If electrical equipment is used, twitching of the ipsilateral leg is sometimes observed similar to tonic stimulation that is not attributable to pain. This reaction can only be eliminated by deepening NMB. If additional muscle relaxation is provided before obturator lymphadenectomy, more satisfactory surgical conditions in RARP can be achieved. Therefore, it appears that deep NMB is unnecessary for RARP. A longer duration of NMB and residual NMB caused by deep NMB may increase postoperative complications (Geldner et al., 2012). Although NMB induced by rocuronium can be rapidly and reliably reversed by sugammadex, the high cost of rocuronium has prevented its routine use to date (Aouad et al., 2017).

Although many studies have indicated that deep NMB may facilitate lower Pnp pressure in laparoscopic surgery, contrasting results have been reported (Baete et al., 2017; Barrio et al., 2017; Cho et al., 2018). In a study of laparoscopic cholecystectomy, the surgical space conditions at the standard Pnp pressure (12 mmHg) were superior to those at a low Pnp pressure (8 mmHg), and deep NMB did not improve these conditions (Barrio et al., 2017). Another study found that surgical space conditions were poor in low Pnp pressure, and deep NMB could improve the surgical space conditions under standard Pnp pressure but could not improve them under low Pnp pressure (Cho et al., 2018).

Deep NMB could not improve the surgical space conditions in RARP surgery in this study. We consider that in RARP, apart from pelvic dissection, prostatectomy and urethral anastomosis do not require a large surgical space; and a tense diaphragm has a relatively small effect on pelvic surgery. The enhanced magnification and articulation of the robotic technique were also considered in this case (Williams et al., 2020).

In order to improve ventilation effectiveness and avoid lung injury, lung-protective ventilation is currently applied in general anesthesia with a small tidal volume (6–8 mL/kg), PEEP, intermittent lung recruitment (Güldner et al., 2015; Park et al., 2016; Spadaro et al., 2016; Pereira et al., 2018; Kudoh et al., 2019), and "permissive hypercapnia" during laparoscopic surgery (Cho et al., 2018). PEEP and intermittent lung recruitment can improve C_{rs} disturbed by Pnp pressure and the head-down position in RARP (Pereira et al., 2018). Our results reveal that under the same Pnp pressure, deep NMB did not improve respiratory mechanics. Other studies have suggested that even low Pnp pressure application using deep NMB is not beneficial for cardiopulmonary function (Cho et al., 2018). In a study of robot-assisted surgery with patients in a head-down position, change of ventilatory driving pressure was distributed less to the lungs than to the chest wall, which is in contrast to surgery with patients in a supine position. In the same study, it was also found that deep NMB did not change respiratory mechanics (Brandão et al., 2019). Moreover, pressure-controlled ventilation during laparoscopic surgery can reduce airway pressure and improve C_{rs} compared with volume control ventilation (Assad et al., 2016; Kim et al., 2018). This points to future directions for the study and implementation of lung-protective ventilation in robot-assisted surgery.

This study has several limitations. First, it did not compare respiratory mechanics at different Pnp pressures or attempt to lower the Pnp pressure (such as to 8 mmHg). Second, because 0.6 mg/kg of rocuronium was used for tracheal intubation in patients in both groups, they were in a state of deep NMB for a certain period (Schultz et al., 2001), likely affecting the data after induction and early Pnp.

5 Conclusions

Under the same Pnp pressure in RARP, deep NMB and moderate NMB show similar results in respiratory mechanics and surgical space conditions. However, deep NMB can significantly reduce body movements during obturator lymphadenectomy. Therefore, as long as an additional muscle relaxant is added before obturator lymphadenectomy to avoid leg twitching, deep NMB is not necessary in RARP.

Contributors

Shao-jun ZHU, Xiao-lin ZHANG, and Qing XIE collected and analyzed the data. Shao-jun ZHU and Kui-rong WANG wrote the manuscript. Yan-feng ZHOU and Kui-rong WANG designed the study and edited the manuscript. All authors have read and approved the final manuscript and, therefore, have full access to all the data in the study and take responsibility for the integrity and security of the data.

Compliance with ethics guidelines

Shao-jun ZHU, Xiao-lin ZHANG, Qing XIE, Yan-feng ZHOU, and Kui-rong WANG declare that they have no conflict of interest.

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5). This study was approved by the Research Ethics Committee of the First Affiliated Hospital, Zhejiang University School of Medicine (Hangzhou, China), and written informed consent was obtained from all enrolled patients. The trial was registered prior to patient enrolment with the Chinese Clinical Trial Registry (No. ChiCTR1800017660; date of registration: Aug. 1, 2018).

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中文概要

题　目：深度神经肌肉阻滞对机器人辅助腹腔镜前列腺癌根治术呼吸顺应性和手术条件的影响：随机临床研究

目　的： 机器人辅助前列腺癌根治术中需要头低位和气腹，这将严重干扰呼吸顺应性（C_{rs}）。本研究比较机器人辅助腹腔镜前列腺癌根治术在相同气腹压力下不同程度的神经肌肉阻滞对 C_{rs} 的影响。

创新点： 不同深度神经肌肉阻滞对机器人辅助前列腺癌根治术 C_{rs} 的观察。

方　法： 将 100 例接受机器人辅助腹腔镜前列腺癌根治术的患者随机分配到中度神经肌肉阻滞组和深度神经肌肉阻滞组，每组 50 例。应用罗库溴铵维持神经肌肉阻滞。保持对 4 个成串刺激 1~2 个反应为中度神经肌肉阻滞组；对 4 个成串刺激无反应，而对强直后刺激 1~2 个反应为深度神经肌肉阻滞组。两组气腹压力均为 10 mmHg。记录麻醉诱导后及气腹 0、30、60 和 90 min 的吸气峰值压力、平均压力、C_{rs} 和气道阻力。手术结束时对手术条件进行评估。

结　论： 在机器人辅助腹腔镜前列腺癌根治术中，相同的气腹压力下，深度神经肌肉阻滞不能改善 C_{rs} 和手术条件，但能显著降低术中体动。

关键词： 机器人辅助前列腺癌根治术；深度神经肌肉阻滞；呼吸力学；手术条件