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Low intra-abdominal pressure and deep neuromuscular blockade laparoscopic surgery and surgical space conditions

A meta-analysis

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Abstract

Background: Low intra-abdominal pressure (IAP) and deep neuromuscular blockade (NMB) are frequently used in laparoscopic abdominal surgery to improve surgical space conditions and decrease postoperative pain. The evidence supporting operations using low IAP and deep NMB is open to debate.

Methods: The feasibility of the routine use of low IAP +deep NMB during laparoscopic surgery was examined. A meta-analysis is conducted with randomized controlled trials (RCTs) to compare the influence of low IAP + deep NMB vs. low IAP + moderate NMB, standard IAP +deep NMB, and standard IAP + moderate NMB during laparoscopic procedures on surgical space conditions, the duration of surgery and postoperative pain. RCTs were identified using the Cochrane, Embase, PubMed, and Web of Science databases from initiation to June 2019. Our search identified 9 eligible studies on the use of low IAP + deep NMB and surgical space conditions.

Results: Low IAP + deep NMB during laparoscopic surgery did not improve the surgical space conditions when compared with the use of moderate NMB, with a mean difference (MD) of −0.09 (95% confidence interval (CI): −0.55–0.37). Subgroup analyses showed improved surgical space conditions with the use of low IAP + deep NMB compared with low IAP + moderate NMB, (MD = 0.63 [95% CI:0.06–1.19]), and slightly worse conditions compared with the use of standard IAP + deep NMB and standard IAP + moderate NMB, with MDs of −1.13(95% CI:−1.47 to 0.79) and −0.87(95% CI:−1.30 to 0.43), respectively. The duration of surgery did not improve with low IAP + deep NMB, (MD = 1.72 [95% CI: −1.69 to 5.14]), and no significant reduction in early postoperative pain was found in the deep-NMB group (MD = −0.14 [95% CI: −0.51 to 0.23]).

Conclusion: Low IAP +deep NMB is not significantly more effective than other IAP +NMB combinations for optimizing surgical space conditions, duration of surgery, or postoperative pain in this meta-analysis. Whether the use of low IAP + deep NMB results in fewer intraoperative complications, enhanced quality of recovery or both after laparoscopic surgery should be studied in the future.

Abbreviations: IAP = low intra-abdominal pressure, NMB = deep neuromuscular blockade, PACU = postanesthesia care unit, PTC = post-tetanic count, TOF = train of four stimulation.

Keywords: deep neuromuscular blockade, laparoscopic surgery, low intraabdominal pressure, meta-analysis

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YW and JL contributed equally to this work.

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1. Introduction

The laparoscopic approach to surgery has become more popular than the open approach in recent years because of its associations with less postoperative pain, shorter hospitalization stays, and better patient satisfaction.[1] The traditional dose of intra-abdominal pressure (IAP) for laparoscopic surgery is approximately 15 mm Hg.[2] Elevated IAP is associated with peritoneal damage, impaired splanchnic, hepatic, and abdominal wall perfusion, and it may also decrease gastric mucosal oxygen saturation and cause postoperative pain.[3–6] Moreover, pneumoperitoneum has been implicated as a factor in postoperative shoulder pain.[7] Therefore, lower IAP might be a better choice for reducing postoperative pain and the risks of laparoscopy-related complications.[8] However, low IAP pneumoperitoneum is associated with an unacceptable surgical field, which increases the risk of intraoperative complications or the conversion to open surgery.[9,10]

Surgical workspace is determined by nonmodifiable factors (e.g., patients obesity, previous pregnancies and previous abdominal surgery) and modifiable factors (e.g., anesthesia-related factors, IAP, and body position).[11–13] Several clinical trials have reported that deep neuromuscular blockade (NMB) improves surgical conditions in different types of laparoscopic procedures.[14–16]

NMB may improve intubation conditions for anesthesiologists; however, NMB (and especially deep NMB) may also lead to postoperative residual curarization, which exposes the patient to additional risks, that is, longer NMB reversal times or incomplete recovery from the NMB, thereby compromising respiratory and upper airway function.[17,18] The use of sugammadex has made it possible to reverse deep NMB and minimize the adverse effects of residual NMB.[19] Currently, deep NMB +lower IAP are often used in abdominal surgery to improve surgical space conditions through relaxation of the abdominal wall and the prevention of sudden muscle contractions. [16,20] However, Cho et al [21] observed fewer cardiopulmonary benefits and poorer surgical space conditions with low intra-abdominal pressure during laparoscopy, and Ozdemir-van Brunschot et al [22] reported that low-pressure pneumoperitoneum facilitated by deep NMB during a laparoscopic donor nephrectomy failed to reduce postoperative pain and improve the quality of recovery during the early postoperative phase.

Nevertheless, the benefits of deep NMB with lower IAP for laparoscopic surgery is still open to debate. The objective of this meta-analysis was to explore the benefits and merits of using lower IAP and deep NMB during laparoscopic surgery.

2. Methods

This meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and was registered on PROSPERO (CRD42019126486). Ethical approval and participants informed consent were not required because all the data were based on previously published studies.

2.1. Amendments to the review protocol

We changed the 0–100 surgical rating scale to a 1–5 scale to improve the efficiency of the meta-analysis of the surgical space conditions. Furthermore, we addressed the item "other risks of bias" from the Cochrane risk-of-bias tool. We defined deep NMB as a having a posttetanic count (PTC) ≤ 5 create a unified standard for NMB.

2.2. Literature search strategy

The PubMed, EMBASE, Web of Science and Cochrane Library databases were searched from the first record to March 15, 2019 for eligible randomized controlled trials (RCTs). Keywords and Mesh terms were used in combination as follows:

1. ("Laparoscopy"[Mesh] OR laparoscope*[tiab] OR coelioscop*[tiab] OR celioscop*[tiab] OR peritoneoscop*[tiab]),
2. ("neuromuscular blockade"[MeSH] OR neuromusc*[tiab]),
3. (Deep[tiab] OR profound[tiab] OR intense[tiab] OR extreme [tiab] OR depth[tiab]) and
4. "low-pressure"[tiab]. No restrictions on language or publication date were applied and the reference lists of the retrieved articles were manually searched for additional studies.

2.3. Inclusion and exclusion criteria

The inclusion criteria were:

1. Design: RCTs elective laparoscopic surgery;
2. Population: adult patients (18–65 years-old), with the American Society of Anesthesiologists (ASA) physical status classification I-II;
3. Intervention: low IAP combined with deep NBM;
4. Control: low IAP + moderate NMB, standard IAP +deep NMB, and standard IAP +moderate NMB.

The criteria for exclusion were: people with chronic use of analgesics or psychotropic drugs and those with a known or suspected allergy to rocuronium or sugammadex.

2.4. Study selection

Two of the studys authors (Yiyong Wei and Jia Li) individually reviewed the studies for eligibility. Potentially relevant articles with full-texts were retrieved after screening their titles and abstracts. Disagreements were resolved through discussion with the other author.

2.5. Types of outcome measures

The primary outcome measure was the quality of the surgical space conditions. Studies gauging the length between the skin and sacral promontory were eliminated from the meta-analysis. The secondary outcome measures were postoperative pain and the duration of surgery.

2.6. Study characteristics and data extraction

The following data were extracted: author, journal and year of publication, sex, age, weight, body mass index, ASA physical status classification, body position during surgery, type of procedure, level of NMB, pressure of pneumoperitoneum in the experimental and control groups and the scale used to record the surgical space conditions, pain scores, and duration of surgery. Two authors (Yiyong Wei and Jia Li) extracted the data individually; differences were analyzed and clarified through discussion. Data were extracted if the mean, standard deviation (SD), and number of patients (n) were reported, or could be determined for the experimental and control groups. When the data were incomplete, we contacted the studys author(s) through e-mail with are quest for the missing data.

2.7. Study quality and risk-of-bias assessment

Two authors (Yiyong Wei and Jia Li) independently assessed the quality of the included RCTs using the Cochrane Collaboration's tool, which consists of 6 items:

1. random sequence generation (selection bias);
2. allocation concealment (selection bias);
3. blinding of participants and personnel (performance bias);
4. blinding of outcome assessment (detection bias);
5. incomplete outcome data (attrition bias); and
6. selective reporting (reporting bias).

The estimated risk of bias for each item was rated as "low,""unclear" or "high." Disagreements were resolved through discussion with another author. Judgments of the quality of the included studies were made independently by 2 authors (Yiyong Wei and Jia Li) using the Cochrane Collaborations tool for weighing the risk of bias.[23] Differences between the authors regarding the risk of bias for particular studies were resolved through discussion.

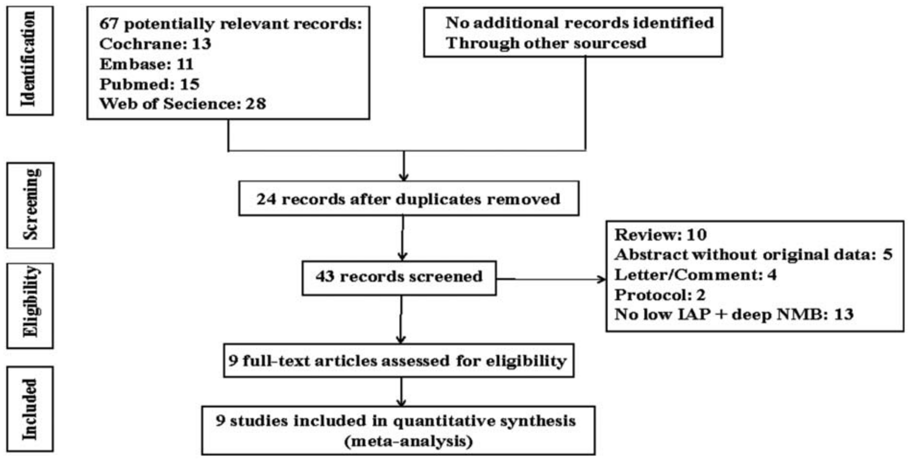

Figure 1. Flow diagram of select studies.

2.8. Data synthesis and meta-analysis

All reported scales were converted to the Leiden Surgical Rating Scale (L-SRS), as reported by Yoo et al.[20] The L-SRS ranges from 1 (extremely poor conditions) to 5 (optimal conditions) and the other scales were inversely scored, as needed. The duration of surgery was measured in minutes and postoperative pain was rated using an 11-point numerical rating scale. The data were analyzed using RevMan 5.3 software (The Nordic Cochrane Centre, The Cochrane Collaboration, 2014.) and were combined when an outcome was reported in at least 2 studies. Continuous data were summarized as a weighted mean difference (MD) with a 95% confidence interval (CI). Data were analyzed using a random-effects model to evaluate observed clinical heterogeneity between the studies (e.g., types of surgery and uses of IAP and NMB). Statistical heterogeneity was assessed using the I-2 test. Heterogeneity was considered to be present when the I-2 statistic was >50%. $P<.05$ was considered statistically significant.

2.9. Subgroup analyses

We performed predefined subgroup analyses, if the necessary data were available to explore possible causes of heterogeneity, and to identify which variables influenced the effect of NMB on surgical space conditions. The subgroups of variables were as follows: IAP (standard or low) and NMB (deep or moderate). We tested the effects of different levels of NMB and IAP.

3. Results

3.1. Study selection and characteristics

Our electronic search yielded 67 eligible records in total, 24 of which were duplicates. Of the 43 remaining records, 34 were excluded from the full text review after their titles and abstracts were screened. Finally, 9 RCTs were included in the meta-analysis. The flow diagram for the selection of studies is shown in Figure 1. The characteristics of the included studies are presented in Table 1.

All of the reports were written in English. The procedures that were performed most frequently were laparoscopic cholecystectomies (45%), nephrectomies (22%) and hysterectomies (11%); other procedures included laparoscopic prostatectomy (11%), and colorectal surgeries (11%). The tested levels of pneumoperitoneum varied between 1.1 kPa (8 mm Hg) and 2.0 kPa

Table 1

Primary study characteristics.

Study	Laparoscopic procedure	Experimental group	Control group	Number of patients	Surgical rating scale	Other outcome measures
Barrio 2017[24]	Chol	Low + deep	Low + moderate	60	1–4	Dur
Brunschot 2017[25]	Nephr	Low + deep	Low + moderate	34	1–5	Dur, Pain, Comp
Koo 2016[26]	Chol	Low + deep	Low + moderate	64	1–4	Dur, Pain
Rosenberg 2017[27]	Chol	Low + deep	Standard + moderate Low + moderate Deep + standard	120	0-10	Pain
Staehr-Rye 2014[28]	Chol	Low + deep	Low + moderate	48	1–4	Dur
Brunschot 2017[22]	Neph	Low + deep	Standard + deep	63	1–5	Dur, Pain, LOS, Comp
Madsen 2016[29]	Hyst	Low + deep	Standard + moderate	99	NA	Pain, Dur, LOS,
Yoo 2015[20]	Prost	Low + deep	Low + moderate	66	1–5	Dur, Pain
Cho 2018[21]	Colorectal	Low + deep	Standard + deep Standard + moderate	131	1–5	Dur, Pain, LOS, Comp

Chol = laparoscopic cholecystectomy, Comp = complications, deep = deep neuromuscular blockade, Dur = duration, Hyst = laparoscopic hysterectomy, LOS = length of hospital stay, Low = low intra-abdominal pressure, moderate = moderate neuromuscular blockade, NA = not applicable, Nephr = laparoscopic nephrectomy, Prost = laparoscopic prostatectomy, standard = standard intra-abdominal pressure.

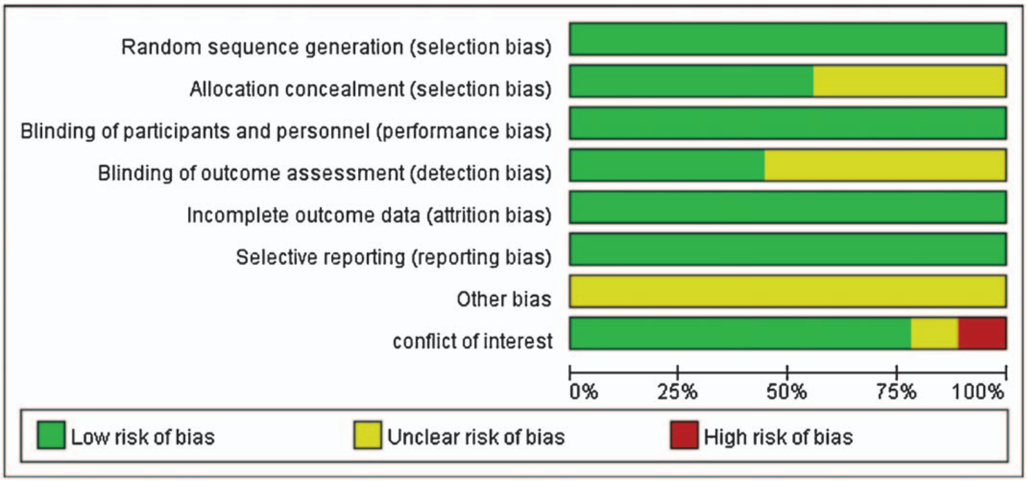

Figure 2. Assessment of risk of bias.

(15 mm Hg). All of the studies used rocuronium for deep NMB. The intubation dose varied between 0 and 1 mg/kg. In six studies (67%), low IAP +deep NMB was compared with low IAP +moderate NMB; in 3 studies, low IAP +deep NMB was compared with standard IAP +deep NMB; and in 3 studies, low IAP +deep NMB was compared with standard IAP +moderate NMB. These studies were not consistent in their definitions of deep NMB; 4 of the studies [20,21,24,25] used the maximum PTC of 2, 3 studies [22,26,27] defined deep NMB as PTC <5, and the other 2 studies [28,29] defined deep NMB as PTC = 1. Eight of the 9 studies included reports of the surgical space conditions, which is the primary outcome measure of this study.

The scales used to measure the quality of the surgical conditions consisted of 1–5 (44%), 1–4 (33%), and 0–10 (11%) ratings. We included the overall conditions at the end of the procedure in the meta-analysis. The other reported outcome measures were postoperative pain (56%) and duration of surgery (89%).

3.2. Study quality and risk of bias

The results of the quality assessment of the 9 included studies are presented in Figure 2 (averaged per item). All of the 9 studies were randomized. Allocation concealment was unclear in 50% of all studies. Blinding of the participants and personnel and blinding of the outcome measures were reported in 100% and 50% of the studies, respectively. None of the studies were found to have incomplete outcome data or selective outcome reporting. All of the studies had other risks of bias that were unclear. Finally, there was a low risk for conflict of interest in 75% of the studies; in one study, the authors received honoraria or funding from companies promoting deep NMB (and its reversal by sugammadex).[25]

3.3. Meta-analysis of the surgical space conditions

Eight studies were pooled in the meta-analysis of the surgical space conditions. No significant difference in improvement was found with the use of low IAP + deep NMB compared with the use of low IAP + moderate NMB, standard IAP +deep NMB or standard IAP +moderate NMB (Fig. 3) (MD = −0.09; 95% CI: −0.55 to 0.37; I^2 = 91%; P = .70).

3.4. Subgroup meta-analysis of the surgical space conditions

Surgical space conditions were improved by the use of low IAP + deep NMB compared with low IAP + moderate NMB, but not

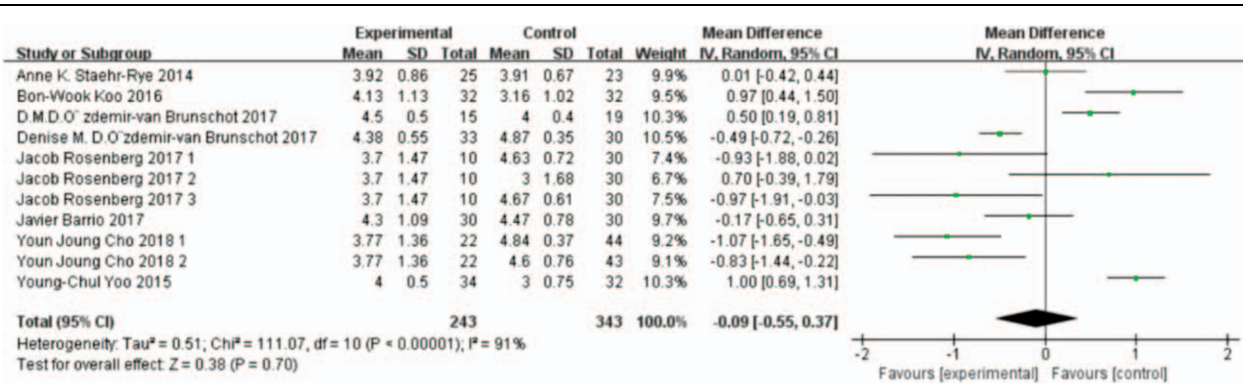

Figure 3. Surgical space conditions were not improved by the use of low IAP + deep NMB. Forest plots of the studies comparing surgical space conditions during laparoscopic procedures using low IAP + deep NMB vs low IAP + moderate NMB, standard IAP + deep NMB, or standard IAP + moderate NMB. The effect size was calculated as the mean difference in the surgical rating scale (range = 1–5) and corresponding 95% confidence intervals (95% CI).

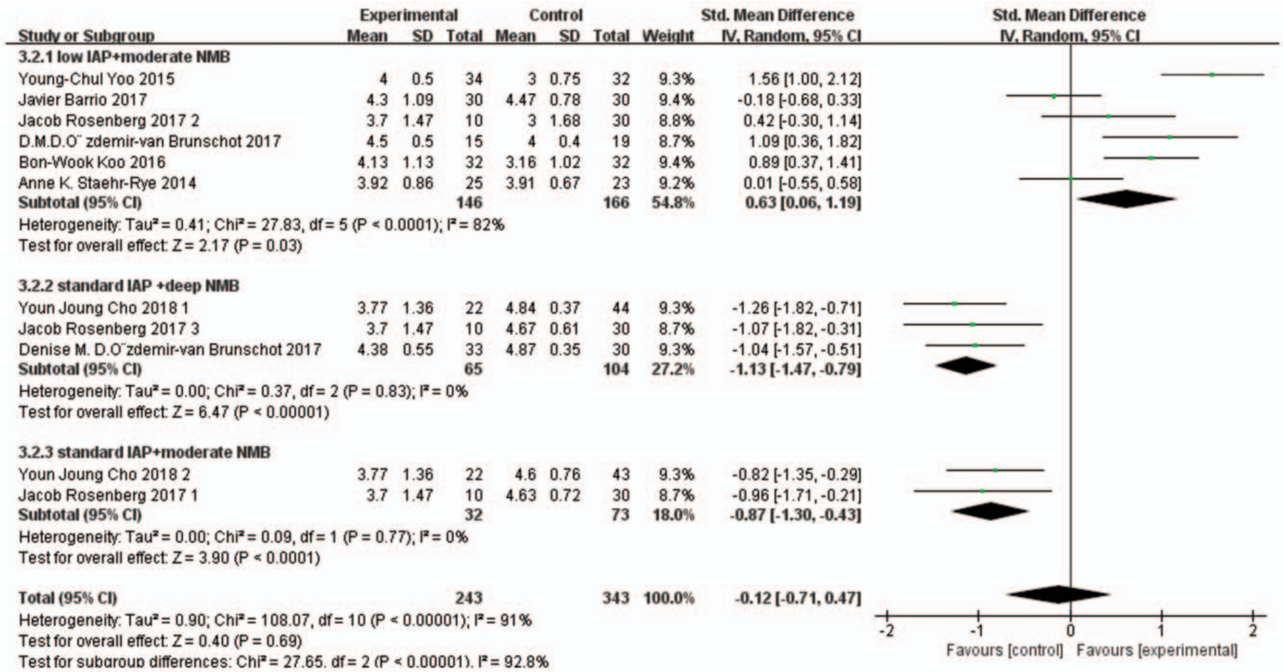

Figure 4. Subgroup meta-analysis of the surgical space conditions.

improved by the use of standard IAP + deep NMB, or standard IAP+ moderate NMB (Fig. 4). The effect size was calculated as the mean difference in the surgical rating scales (range=1–5) and corresponding 95% confidence intervals (95% CI).

3.5. Meta-analysis of the duration of surgery

Eight studies were included in the meta-analysis of the duration of surgery. Overall, the duration of surgery did not improve with the use of low IAP + deep NMB (MD=1.72[95% CI: −1.69 to 5.14]), see Figure 5. The between-study heterogeneity was 17%.

3.6. Meta-analysis of postoperative pain in the postanesthesia care unit

Five studies were pooled in the meta-analysis of postoperative pain in the postanesthesia care unit (PACU) during the first hour after surgery. Overall, there was no significant reduction in early postoperative pain in the group that received the low IAP + deep NMB (MD=−0.14[95% CI: −0.51 to 0.23]), as measured on an 11-point scale (Fig. 6). The between-study heterogeneity was 0%. We were not able to conduct any meta-analyses of postoperative pain after 24 hours, because few studies reported this outcome.

4. Discussion

This meta-analysis found that there are no difference in surgical space conditions during laparoscopic surgery when low IAP + deep NMB was compared with low IAP + moderate NMB, standard IAP + deep NMB or standard IAP + moderate NMB. The MD was −0.09 (95% CI: −0.55 to 0.37). However, the subgroup analysis showed that surgical space conditions improved with the use of low IAP + deep NMB, compared with low IAP + moderate NMB(MD=0.63[95% CI:0.06–1.19]), but worsened compared with standard IAP + deep NMB and

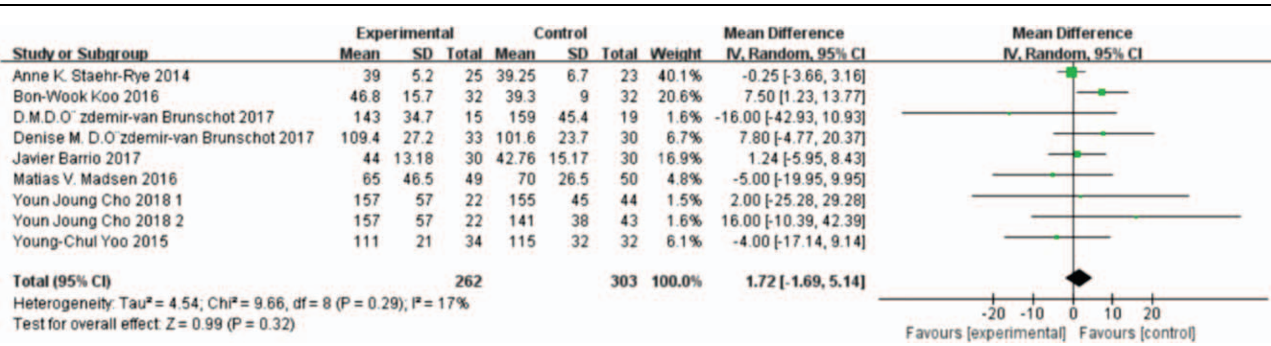

Figure 5. The duration of surgery is not significantly decreased by the use of low IAP + deep NMB. Forest plot of studies comparing the duration of surgery during laparoscopic procedures with low IAP + deep NMB vs low IAP + moderate NMB, standard IAP +deep NMB, or standard IAP +moderate NMB. The effect size is calculated as the mean difference in duration of surgery in minutes and corresponding 95% confidence intervals (95% CI).

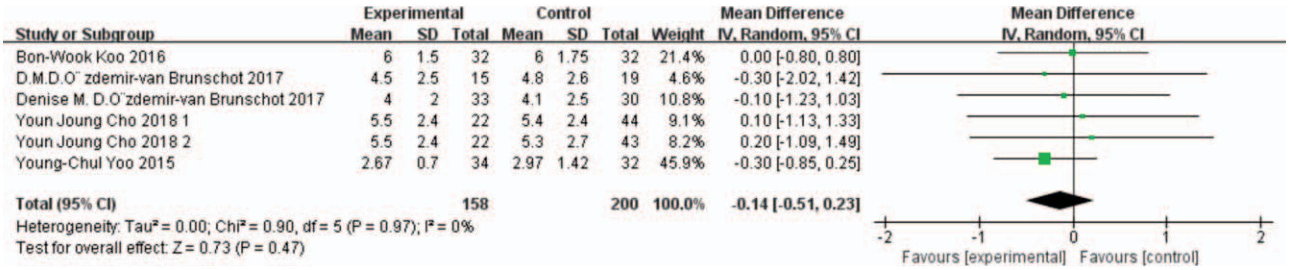

Figure 6. Postoperative pain in the post-anesthesia care unit was not reduced by the use of low IAP + deep NMB. A forest plot of the studies comparing postoperative pain 1 h after the laparoscopic procedures using low IAP + deep NMB vs low IAP + moderate NMB, standard IAP + deep NMB or standard IAP + moderate NMB. The effect size was calculated as the mean difference on the numerical rating scale (range = 0–10) and the corresponding 95% confidence intervals (95% CI).

standard IAP + moderate NMB, with MDs of-1.13(95% CI: −1.47 to 0.79) and −0.87(95% CI: −1.30 to 0.43), respectively.

The included studies used different scales to measure the surgical space conditions. Most of them used scales ranging from 1 (poor conditions) to 4 (optimal conditions) or from 1 (extremely poor conditions) to 5 (optimal conditions), and the scales were inversely scored, as needed. All of the studies used a 4-point scale to differentiate optimal/excellent, good, acceptable and poor conditions. Therefore, we converted these ratings to 5 (optimal/excellent conditions), 4(good conditions), 3 (acceptable conditions), 2(poor conditions), and 1(extremely poor conditions) almost never occurred, it seems that the conversion of the 4-point scale did not influence our results. The meta-analysis of the surgical space conditions between the use of low IAP+ moderate NMB and low IAP + deep NMB revealed a mean difference of 0.63, which in our view, was a clinically relevant improvement. As we know, pneumoperitoneum leads to detrimental physiological effects[30] that may be worse at higher insufflation pressures. Therefore, it may be favorable to control minimal intra-abdominal pressure during laparoscopic operation. Deep NMB may facilitate the performance of laparoscopic surgery at lower CO_2 insufflation pressures. In a previous study, the surgeon regulated the IAP with the deep or moderate NMB as the primary outcome. As expected, the adjusted average IAP was lower in deep NMB compared with moderate NMB. Deep NMB can relax muscle in a greater degree and limit the movement of patients, then improve visibility for the surgeon.[15] In another study, use of low IAP + deep NMB resulted in an improvement in surgical conditions compared with low IAP + moderate NMB.[31] Another recent systematic review [32] demonstrated that the use of deep NMB improved the surgical space conditions compared with moderate NMB during laparoscopic operation. These data indicate that low IAP + deep NMB was related to better surgical condition commonly than low IAP + moderate NMB.

However, compared with standard IAP + deep NMB and standard IAP + moderate NMB, the surgical space conditions worsened slightly when low IAP + deep NMB was used. Although abdominal muscle tones can be reduced by deeper NMB, and then the laparoscopic surgical spaces is expanded under the same IAP,[33–36] it remains dubious whether the deep NMB facilitates laparoscopic operation to be performed even in the low IAP.[14,37,38] In one study, the deep NMB contributed to better surgical conditions in the standard IAP, but the deep NMB was unsatisfactory for surgical conditions in the low IAP. Moreover, in 12 patients with a pressure of 8 mm Hg, the surgeon demanded higher IAP due to unacceptable laparoscopic visions.[39] Meanwhile, in previous studies, a low IAP of 6–8 mm Hg was linked with enhancive surgeon discomfort in the light of surgical field vision, but not a standard IAP of 12 mmHg,[40,41] and 24% patients needed conversion into a standard IAP for the fulfillment of surgery.[40] At the same time, in obese patients or patients with severe adhesions, the surgeon underwent difficulties associated with poor exposure.[42] In addition, 1 international guideline recommended to "use the lowest IAP allowing adequate exposure of the surgical space, rather than using a conventional pressure".[1] Further, a recent systematic review demonstrated that "the recommendation to use low IAP during laparoscopy is weak".[34] One aforementioned work also showed that, for the sake of establishing adequate surgical fields, the IAP had to be increased in half of the patients in despite of the level of NMB.[14] Strikingly, higher IAP brings increased height of the anterior abdominal wall and therefore more surgical dissection space and an expanded visual view. Consequently, IAP may be more likely to affect surgical spaces compared with the level of NMB. A recent report has also showed that in the standard IAP groups, no patient needed rescue intervention, whereas 12 patients experienced rescue intervention via increasing IAP and/or level of NMB in the low IAP groups (5 in the deep NMB group and 7 in the moderate NMB group) as a result of poor surgical conditions.[31] Accordingly, the study indicates that standard IAP+ deep NMB may be more likely to improve surgical space conditions.

However, 1 previous study had showed that increased IAP has been thought to have adverse effects on the intraabdominal organs and cardiovascular and pulmonary systems.[30] The European Association for Endoscopic Surgery guidelines[1] mentioned that an increased IAP automatically compresses the capillary beds, decreases splanchnic microcirculation, and consequently destroys oxygen supply to the intra-abdominal organs. Consistently, blood stream in the superior mesenteric artery and the hepatic portal vein decreased 24% during pneumoperitoneum was reported.[43] Currently, there is no robust evidence to suggest that the drawbacks of the standard IAP+ deep NMB and standard IAP + moderate NMB significantly outweigh the advantages. Perhaps standard IAP + deep NMB and standard IAP + moderate NMB might be preferable to low IAP+ deep NMB for laparoscopic surgery. Unfortunately, these results were poorly conveyed, and this important issue cannot be addressed in this meta-analysis. Therefore, further meta-analyses with larger numbers of studies should be conducted to explore this issue.

The meta-analysis of postoperative pain in the PACU showed no differences in early postoperative pain among the groups with low IAP + deep NMB. For surgical pain after laparoscopic surgery, it is less serious and has a shorter duration compared with open surgery,[44] however, it still leads to considerable discomfort and an elevated stress response.[45] The etiology of postoperative pain after laparoscopic surgery can be divided into at least 3 categories: visceral pain, incision pain, and referred shoulder tip pain. [46–48] Since postoperative pain has a multifactorial etiology and is also dependent on the perioperative analgesia regimen, it is difficult to establish a causal relationship between depth of neuromuscular blockade and postoperative pain. Commonly, the reasons of visceral pain and shoulder tip pain after surgery caused by pneumoperitoneum are surgical operation and stretching of the peritoneum, abdominal muscles, and diaphragm induced by IAP.[41,49] A previous study had showed that deep NMB can more efficiently soften the abdominal muscles compared with moderate NMB.[22] Accordingly, the use of deep NMB may relieve pressure-related postoperative pain. However, our results are in accordance with a previous meta-analysis[13] indicating that deep and moderate NMB leaded to similar degrees of postoperative pain after laparoscopic surgeries. In a laparoscopic cholecystectomy, it was still unclear whether a low IAP relieves postoperative abdominal pain or not,[16,41,42] although a recent review revealed that the most efficient intervention to decrease the incidence of shoulder pain was lower IAP,[49] perhaps higher IAP compresses the vessels or nerves in the abdominal cavity, and aggravates postoperative pain and extends the recovery of bowel movement, however, previous findings were inconsistent.[1,2,6,14,34,50] A Cochrane report demonstrated inadequate evidence for lower pain degree using low IAP.[6] No difference of the postoperative pain was observed in the present study. Currently, data on this aspect of postoperative pain are limited and more studies should be conducted to clarify its mechanism.

A limitation of the present study is the heterogeneity of the studies that compared the different types of laparoscopic surgery with different postoperative pain management protocols. For example, some studies[21,22,25] used patient-controlled analgesia, while one [24] used on-demand intravenous fentanyl. Some studies used low IAP + moderate NMB[20,24,26–28] and standard IAP + deep NMB[21,22,25]as the control treatment, while others used standard IAP + moderate NMB[21,25,29]. In these studies, the standards for IAP and NMB varied. For NMB, the more recent studies[11,15,20,24,51] maintained a TOF count of 1–2 in the moderate NMB group, and other studies maintained TOF counts of 0–1,[26] 2–3,[25] or 1–3[27] in the moderate NMB group. Most of the studies maintained a PTC of 1–2 [20,21,24,25] in the deep NMB group, but some maintained a PTC of 1–5[26,27] or 0–1[22,28,29] in the deep NMB group. Most of the studies maintained a low IAP of 8 mm Hg and a standard IAP of 12 mm Hg while 1 study maintained a low pressure of 6 mm Hg. [26]

In conclusion, this study provides evidence that low IAP + deep NMB does improve surgical space conditions compared with low IAP+ moderate NMB, standard IAP + deep NMB, and standard IAP + moderate NMB improve surgical space conditions compared with low IAP + deep NMB. However, there are no differences in postoperative pain and duration of surgery during laparoscopic surgery when low IAP + deep NMB was compared with low IAP + moderate NMB, standard IAP + deep NMB, and standard IAP + moderate NMB. Therefore, standard IAP + deep NMB and standard IAP + moderate NMB may be preferable in clinical practice. However, there are only 2 and 3 trials in standard pressure + deep NMB and standard pressure + moderate NMB, respectively. Therefore, we can not have a solid conclusion which protocol is more preferable. Further randomized controlled studies are warranted to address the heterogeneity and power shortage demonstrated by the meta-analysis.

Author contributions

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Methodology: Fude Sun.
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Writing – original draft: Jia Li.
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