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Pulmonary recruitment maneuver to reduce pain after laparoscopy: a meta-analysis of randomized controlled trials

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Abstract
Background We investigated the impact of pulmonary recruitment maneuver in reducing shoulder pain after laparoscopic procedure.
Methods We conducted a systematic review of the literature using Medline (1966–2014), Scopus (2004–2014), Popline (1974–2014), www.ClinicalTrials.gov (2008–2014), and Google Scholar (2004–2014) along with reference lists of electronically retrieved studies. Statistical meta-analysis was performed using the RevMan 5.1 software.
Results Six studies were included in the present systematic review, involving 571 patients. Among them, 291 (51 %) were offered a pulmonary recruitment maneuver, and 280 patients (49 %) were treated with conventional evacuation of pneumoperitoneum that included either passive evacuation or gentle pressing of the abdominal walls with the trocar ports open. The introduction of a pulmonary recruitment maneuver significantly decreased postoperative shoulder pain 12 h (435 patients, REM, MD −1.55, 95 % CI −2.01, −1.10), 24 h (435 patients, REM, MD −1.59, 95 % CI −2.00, −1.18), and 48 h post-operatively (335 patients, REM, MD −0.93, 95 % CI −1.37, −0.50). We also identified evidence of a potential beneficial effect in the reduction of postoperative upper abdominal pain. However, discrepancies in the interpretation of abdominal pain among the included studies precluded meta-analysis of this index.
Conclusions According to the results of our meta-analysis, pulmonary recruitment maneuver seems to be an easily performed, potentially preventive measure of post-laparoscopic shoulder pain. Further research is mandated, however, in the field, because firm results are precluded by the small number of included studies.

Keywords Pulmonary recruitment · Laparoscopy · Pain · Carbon dioxide · Pneumoperitoneum

Abbreviations

ASA	American society of anesthesiologists
RCT	Randomized controlled trial
MD	Mean difference
CI	Confidence interval
REM	Random-effects model

During the last decades, laparoscopic surgery gained significant ground in the operative field. As a minimally invasive technique it offers patients the advantages of fast-track surgery, as it seems to decrease the interval until return to daily activity [1]. This is mainly accomplished through reduction of postoperative pain. Nevertheless, it seems that still a significant proportion of patients require postoperative analgesia, because these patients seem to suffer from shoulder and back pain [2]. The intensity of this type of pain may range from subtle to severe and rarely persists for a period longer than 72 h [3, 4]. Various

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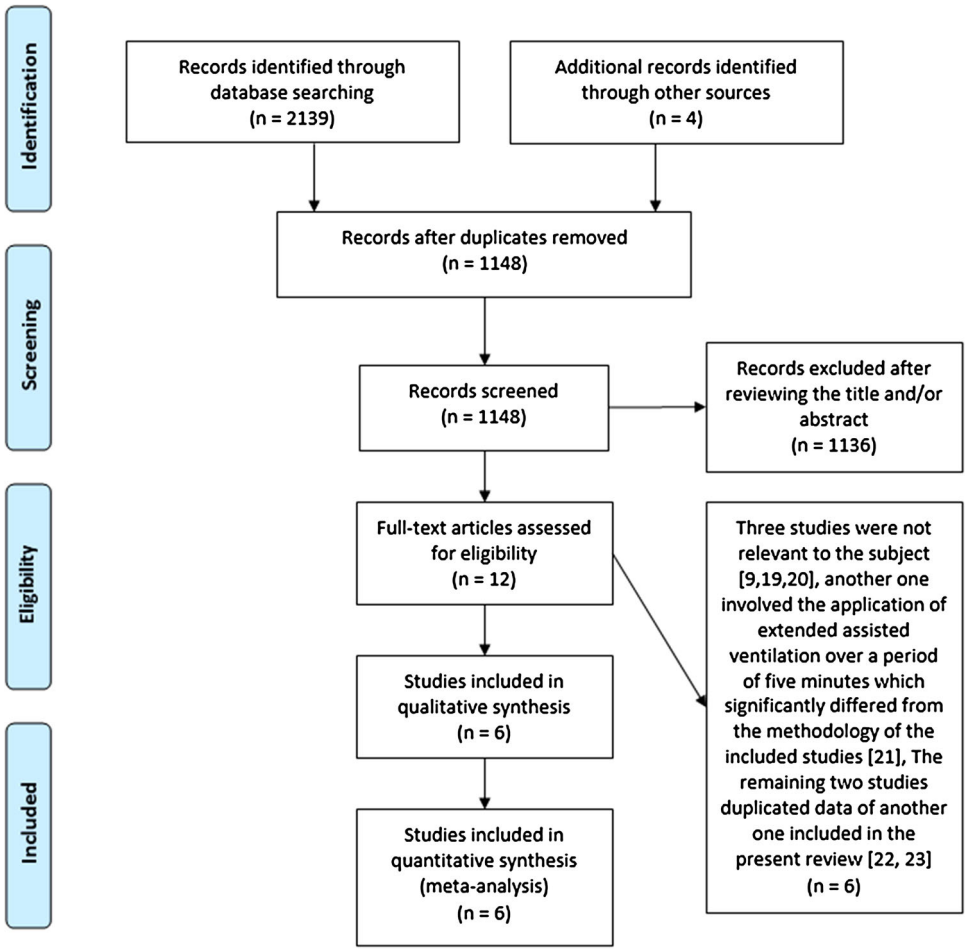

Fig. 1 Search strategy plot

pathophysiologic pathways have been proposed, with carbon dioxide residual and phrenic nerve damage during diaphragmatic stretching being the most accepted theories [5, 6]. While several number of studies have investigated in the past various techniques that could potentially alleviate this type of pain, these do not seem to have been accepted by the international community, mainly for reasons of feasibility and/or effectiveness [7–9].

During the last decade, several studies have proposed that a simple anesthesiologic maneuver involving pulmonary recruitment after the completion of the laparoscopic procedure might improve the postoperative pain scores of those patients. The pulmonary recruitment maneuver, which is described in our review, involves a series of positive pressure ventilations after the completion of the laparoscopic procedure. It increases the intra-abdominal pressure, and consequently reduces the residual gas in the abdominal cavity. Although the studies in the international literature seem to differ methodologically, these maneuvers seem to be generally restricted to a maximum of five inflations and to positive ventilation pressures that do not exceed 60 mmHg.

In this context, we performed a systematic review of the literature in order to reach firm conclusions regarding its effectiveness in reducing postoperative shoulder and abdominal pain.

Methods

Study design

The present study was designed according to the PRISMA guidelines [10]. Eligibility criteria were predetermined by the authors. No language or date restrictions were applied during the literature search. Only randomized controlled trials (RCT's) were held eligible for inclusion.

Literature search and data collection

Medline (1966–2014), Scopus (2004–2014), Popline (1974–2014), www.ClinicalTrials.gov (2008–2014), Cochrane Central Register of Controlled Trials CENTRAL (1999–2014), and Google Scholar (2004–2014) search

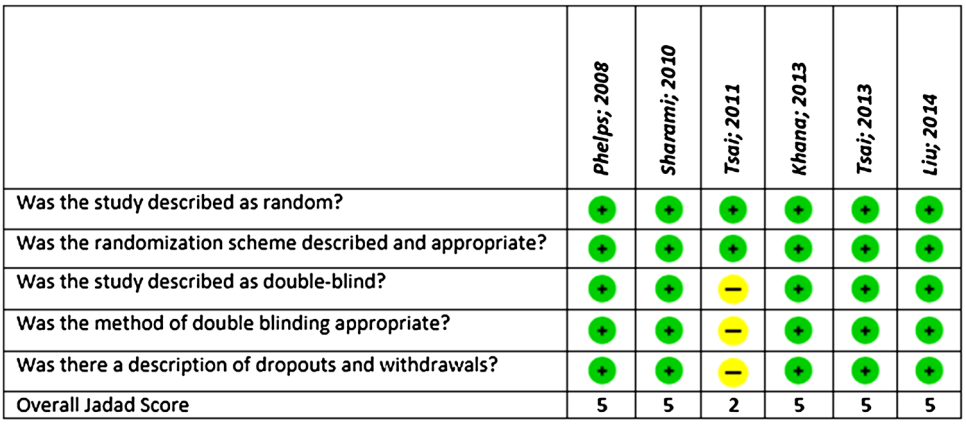

Fig. 2 Jadad scale score evaluation of included RCTs

engines were used in our primary search, together with reference lists from included studies. Our search was restricted to a minimum number of keywords in order to assess an eligible number that could be hand-searched, minimizing the loss of articles. All the articles that met or were presumed to meet the inclusion criteria were retrieved in full text. Search strategies and results are shown in Fig. 1.

We searched Medline using the MeSH terms ("lung" [MeSH Terms] OR "lung" [All Fields] OR "pulmonary" [All Fields]) AND ("laparoscopy" [MeSH Terms] OR "laparoscopy" [All Fields]) AND ("pain" [MeSH Terms] OR "pain" [All Fields]). Scopus was searched using the terms "pulmonary recruitment pain". An additional search strategy using the MeSH terms ("ventilation" [MeSH Terms] OR "ventilation" [All Fields] OR "respiration" [MeSH Terms] OR "respiration" [All Fields]) AND ("laparoscopy" [MeSH Terms] OR "laparoscopy" [All Fields]) AND ("pain" [MeSH Terms] OR "pain" [All Fields]).

www.ClinicalTrials.org and Popline were searched using the terms "pulmonary recruitment" and using the terms "ventilation laparoscopy pain". For Google Scholar, we used an extended keyword strategy in order to retrieve an eligible number of articles that could be hand-searched. This strategy included the terms "pulmonary recruitment maneuver pain laparoscopy laparoscopic".

In overall, 2,139 articles were retrieved following this search strategy, and 1,136 were excluded after reviewing the title and/or abstract. Twelve articles were retrieved in full text.

Quality assessment

Included studies were assessed for their methodological quality according to the modified Jadad scale using the following criteria: description of the studies as randomized along with details of randomization, description of the studies as double blind, details of double-blinding procedure, information on withdrawals, and allocation concealment (Fig. 2) [11].

Definitions

The study group in the present meta-analysis included patients offered a series of manual inflations (ranging from 2 to 5) to a maximum pressure that ranged from 40 to 60 mmHg among the included studies. The control group included patients offered either passive exsufflation of gas through the port site, or active exsufflation through gentle pressure of the abdominal wall.

Statistical analysis

Statistical meta-analysis was performed using the RevMan 5.1 software (Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2011). Confidence intervals were set at 95 %. Pooled mean differences (MD) and 95 % confidence interval (CI) for all primary and secondary outcomes were calculated, using the DerSimonian–Laird random-effect model due to the significant heterogeneity in the methodology of included studies (Tables 1, 2) [12]. Zero-to-hundred pain scale scores were converted to zero-to-ten scale scores in order to facilitate statistical analysis.

Results

Included and excluded studies

Six studies were included in the present systematic review, involving 571 patients [13–18]. Among these, 291 patients (51 %) were offered a pulmonary recruitment maneuver, and 280 patients (49 %) were treated with conventional evacuation of pneumoperitoneum that included either passive evacuation or gentle pressing of the abdominal walls with the trocar ports open.

Table 1 Methodological characteristics of included studies and potential bias (I)

Author; date	Type of study	Patient no	Type of operation	Treatment
Phelps et al. [13]; 2008	DB-RCT	54 versus 46	Minor laparoscopic procedures	Five manual inflations to a maximum pressure of 60 cm H_2O with the patient in Trendelenburg position (30°) versus gentle pressing of the abdominal wall and evacuation of CO_2
Sharami et al. [14]; 2010	DB-RCT	67 versus 64	Laparoscopic procedures for benign gynecologic lesions	Five manual inflations to a maximum pressure of 40 cm H_2O with the patient in Trendelenburg position (30°) versus passive evacuation of CO_2
Tsai et al. [15]; 2011	RCT	53 versus 51	Laparoscopic procedures for benign gynecologic lesions	Five manual inflations to a maximum pressure of 60 cm H_2O with the patient in Trendelenburg position (30°) versus gentle pressing of the abdominal wall and evacuation of CO_2
Khanna et al. [16]; 2013	DB-RCT	37 versus 39	Cholecystectomy or inguinal hernia	Two manual inflations to a maximum pressure of 60 cm H_2O with the patient in Trendelenburg position (30°) versus passive evacuation of CO_2
Tsai et al. [17]; 2013	DB-RCT	50 versus 50	Elective laparoscopic procedures for benign lesions	Instillation of isotonic normal saline (15–20 ml/kg) in the abdominal cavity accompanied by five manual inflations to a maximum pressure of 60 cm H_2O with the patient in Trendelenburg position (30°) versus gentle pressing of the abdominal wall and evacuation of CO_2
Liu et al. [18]; 2014	DB-RCT	30 versus 30	Combined diagnostic laparoscopy and hysteroscopy	Five manual inflations to a maximum pressure of 40 cm H_2O with the patient in Trendelenburg position (30°) versus gentle pressing of the abdominal wall and evacuation of CO_2

Six studies were excluded from the present review [9, 19–23]. Three of them were not relevant to the subject [9, 19, 20]. Another one was excluded as it did not involve the application of extended assisted ventilation over a period of 5 min which significantly differed from the methodology of the included studies [21]. The remaining two studies duplicated data of another one included in the present review [22, 23].

Meta-analysis was possible only in the case of shoulder pain, because studies assessing abdominal pain had significant discrepancies (Table 3).The methodological characteristics and the potential biases among the included RCTs are presented in Tables 1 and 2.

Shoulder pain

The introduction of a pulmonary recruitment maneuver significantly decreased postoperative shoulder pain 12 h (435 patients, REM, MD −1.55, 95 % CI −2.01, −1.10, Fig. 3), 24 h (435 patients, REM, MD −1.59, 95 % CI −2.00, −1.18, Fig. 4), and 48 h post-operatively (335 patients, REM, MD −0.93, 95 % CI −1.37, −0.50, Fig. 5). As expected, its potential to alleviate pain scores became more subtle as the postoperative interval increased, although always significant. This could be possibly explained by the observed decrement of mean pain scores during this time period (Table 2).

Abdominal pain

Tsai et al. reported that postoperative upper abdominal pain scores were lower among patients offered a pulmonary recruitment maneuver [15, 17]. However, this effect was not observed in the case of lower abdominal pain [15]. This effect might be explained by the accumulation of CO^2 in the upper abdomen due to the natural stance of the human body. Liu et al. reported that both static and dynamic (during coughing or standing) abdominal pain scores were significantly decreased among treated patients [18]. They did not, however, take into account the site of pain (upper or lower abdomen).

Table 2 Methodological characteristics of included studies and potential bias (II)

Author; date	Age	ASA status	Exclusion criteria	Intraoperative abdominal pressure (mmHg)	Intraoperative gas flow (L/min)
Phelps et al. [13]; 2008	33.8 ± 0.9 versus 35.0 ± 1.17	I or II	Hospitalization requirement, conversion to laparotomy, inability to follow-up patients for 48 h	15	2
Sharami et al. [14]; 2010	29 ± 6.1 versus 27.37 ± 6.0	I or II	Prior laparotomy, patients with intraoperative intra-abdominal pressure of >15 mmHg, conversion to laparotomy and inability to follow up	15	2
Tsai et al. [15]; 2011	42.1 ± 8.1 versus 41.0 ± 8.1	I or II	N/A	15	2
Khanna et al. [16]; 2013	43.5 (33–65) versus 53 (38–64)	I or II	Under-aged patients, refusal to participate, inability to understand and fill the questionnaire and pregnancy	14	1
Tsai et al. [17]; 2013	39.7 ± 9.04 versus 38.9 ± 8.46	I or II	Malignant disease	15	2
Liu et al. [18]; 2014	30.2 ± 3.7 versus 32.3 ± 5.0	I or II	Allergy to amide anesthetics and contraindications to tramadol, women with pre-existing pain disorders or using opioids or tranquilizers for more than one week and known substance abusers.	12	2

Table 3 Postoperative pain scores

Author; date	12 h	24 h	36 h	48 h
Shoulder pain				
Phelps et al. [13]; 2008	1.56 ± 0.3 versus 3.03 ± 0.45	1.08 ± 0.24 versus 2.57 ± 0.47	0.91 ± 0.25 versus 2.17 ± 0.43	N/A
Sharami et al. [14]; 2010	1.19 ± 1.7 versus 3.4 ± 2.9	0.89 ± 1.3 versus 2.6 ± 2.4	N/A	0.46 ± 0.72 versus 1.5 ± 1.6
Tsai et al. [15]; 2011	2.94 ± 3.33 versus 3.57 ± 3.59	2.87 ± 3.00 versus 4.22 ± 3.32	N/A	1.94 ± 2.73 versus 2.20 ± 2.42
Tsai et al. [17]; 2013	2.90 ± 2.93 versus 4.50 ± 3.41	2.76 ± 2.91 versus 4.52 ± 2.99	N/A	1.76 ± 2.50 versus 3.10 ± 2.88
Liu et al. [18]; 2014	N/S	N/S	N/A	N/S
Abdominal pain				
Tsai et al. [15]; 2011 (U)	3.94 ± 3.20 versus 6.12 ± 3.38	3.85 ± 3.15 versus 5.61 ± 2.82	N/A	2.81 ± 3.06 versus 3.24 ± 2.78
Tsai et al. [15]; 2011 (L)	5.85 ± 3.29 versus 6.55 ± 3.53	4.65 ± 2.54 versus 5.30 ± 2.89	N/A	3.42 ± 2.83 versus 3.33 ± 2.65
Tsai et al. [17]; 2013 (L)	5.30 ± 3.15 versus 6.90 ± 2.66	4.64 ± 2.95 versus 5.90 ± 1.80	N/A	2.78 ± 2.34 versus 3.66 ± 2.44
Liu et al. [18]; 2014	N/A	2.1 ± 1.8 versus 3.5 ± 2.1	N/A	N/A
Overall pain				
Khanna et al. [16]; 2013	3 (1–5) versus 5 (3–6)	3 (1.5–4.5) versus 4.5 (3–6)	N/A	N/A

N/A not available, *N/S* differences were not statistically significant

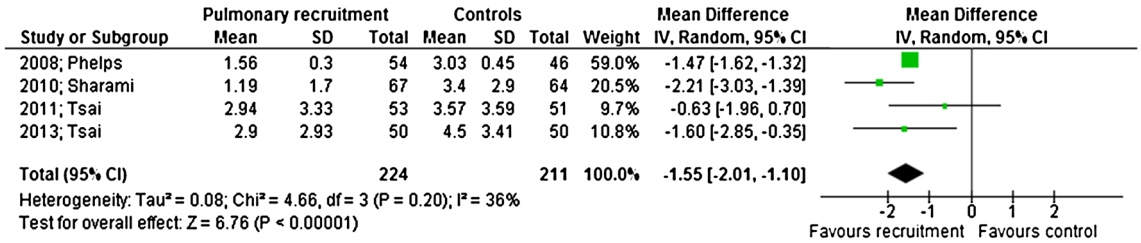

Fig. 3 Pain scores 12 h after the operation. The overall effect was statistically significant ($p < 0.001$). (*Vertical line* "no difference" point between the two regimens. *Squares* mean differences; *Diamonds* pooled mean differences for all studies. *Horizontal lines* 95 % CI)

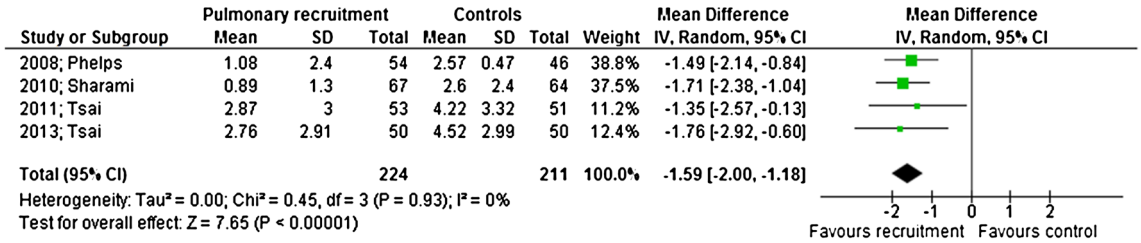

Fig. 4 Pain scores 24 h after the operation. The overall effect was statistically significant ($p < 0.001$). (*Vertical line* "no difference" point between the two regimens. *Squares* mean differences; *Diamonds* pooled mean differences for all studies. *Horizontal lines* 95 % CI)

Overall pain

With great interest, we observed that only one study analyzed the overall pain scores of patients [16]. These researchers concluded that pulmonary recruitment maneuver significantly decreased postoperative pain scores 24-h and 48-h after the operation ($p < 0.01$ in both cases).

Discussion

The introduction of minimally invasive surgery in current clinical practice has opened the routes of fast-track surgery. In this context, the improvement of postoperative pain scores of such patients becomes necessary.

Findings of our study and relation to previous studies

Our systematic review and meta-analysis is the first in the international literature that addresses the effect of pulmonary recruitment maneuver on postoperative analgesia of laparoscopic-treated patients. In their recent systematic review, Donatsky et al. reported that low dose pneumoperitoneum seems to be the best documented intraoperative preventive measure that minimizes postoperative shoulder pain [9]. However, this is not always feasible as certain categories of patients, such as obese patients, cannot be operated under the reported mean pressures of 10–12 mmHg. The same researchers (2013) counterintuitively proposed in another systematic review that intraperitoneal saline instillation could effectively reduce the postoperative pain of patients offered laparoscopic cholecystectomy [8]. Although, as a technique it is feasible, we could speculate that it might be accompanied by a sense of abdominal fullness which is not described in the aforementioned review and which could affect the patient's quality of life during the immediate postoperative period. Loizides et al. also performed a systematic review on wound infiltration with local anesthetic agents for laparoscopic cholecystectomy [24]. They concluded that as a technique, although it seems feasible and easy, the quality of evidence is very low to reach firm conclusions.

Implications for current clinical practice and future research in the field

Pulmonary recruitment maneuver seems to be a promising preventive measure of shoulder pain following laparoscopy which should, however, be applied only among uncomplicated patients. It is unclear, whether patients with ASA scores ≥III can tolerate this maneuver, as the increment of positive ventilation flows can reduce the right ventricular outflow and hence the return to the left ventricle. Certain remarks remain also unanswered. Single-port laparoscopic surgery gains ground during the last years; therefore it is essential to study the effects of this maneuver among patients offered this type of surgery. Future studies should

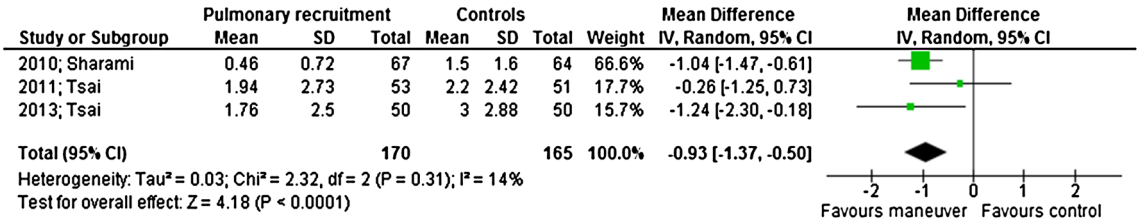

Fig. 5 Pain scores 48 h after the operation. The overall effect was statistically significant ($p < 0.001$). (*Vertical line* "no difference" point between the two regimens. *Squares* mean differences; *Diamonds* pooled mean differences for all studies. *Horizontal lines* 95 % CI)

also study the effect of this maneuver on upper abdominal and overall pain scores as well as the need for additional analgesia during the postoperative period. Together, they should also address the immediate postoperative quality of life scores. One may also contemplate that linear regression analysis could be performed in order to reduce the bias of confounders, such as mean and maximum intraoperative intra-abdominal pressures, duration of the surgical operation and the patient health status. It would be also interesting to investigate which is the minimum required number of ventilations and maximum pressures that efficiently improves the overall postoperative pain scores and quality of life of the patients.

Strengths and weaknesses of our study

The main strength of our study is the inclusion of high quality randomized trials, which by definition are Level of evidence I scientific reports [25]. Our conclusions are, however, limited mainly due to the low number of included studies. Another weakness of our meta-analysis relies on the heterogeneous methodology of included RCT's which is thoroughly explained in Tables 1 and 2. We, however, managed to confront this heterogeneity by applying only the DerSimonian random-effects model in all our analyses [12].

Conclusion

Our meta-analysis suggests that the pulmonary recruitment maneuver is an easily performed, possibly efficacious preventive measure of post-laparoscopic shoulder pain. Its use seems, however, to be restricted among otherwise uncomplicated cases offered a laparoscopic procedure. Therefore, its implementation should be restricted among patients of ASA status I or II. Further research is mandated, however, in the field because firm results are precluded by the small number of included studies.

Disclosures Vasilios Pergialiotis, Dimitrios-Efthymios G. Vlachos, Kostantinos Kontzoglou, Despina Perrea, and Georgios D. Vlachos have no conflicts of interest or financial ties to disclose.

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