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REVIEW ARTICLE

# Regional anesthesia for laparoscopic surgery: a narrative review

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**Abstract** Laparoscopic surgery has advanced remarkably in recent years, resulting in reduced morbidity and shorter hospital stay compared with open surgery. Despite challenges from the expanding array of laparoscopic procedures performed with the use of pneumoperitoneum on increasingly sick patients, anesthesia has remained largely unchanged. At present, most laparoscopic operations are usually performed under general anesthesia, except for patients deemed "too sick" for general anesthesia. Recently, however, several large, retrospective studies questioned the widely held belief that general anesthesia is the best anesthetic method for laparoscopic surgery and suggested that regional anesthesia could also be a reasonable choice in certain settings. This narrative review is an attempt to critically summarize current evidence on regional anesthesia for laparoscopic surgery. Because most available data come from large, retrospective studies, large, rigorous, prospective clinical trials comparing regional vs. general anesthesia are needed to evaluate the true value of regional anesthesia in laparoscopic surgery.

The search strategy used to find relevant references in PubMed is given as Appendix.

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**Keywords** Laparoscopic surgery · Regional · Spinal · Epidural · Neuraxial · Local · Anesthesia

**Abbreviations**

| | |
|---|---|
| ASA-PS | American Society of Anesthesiologists Physical Status |
| CSEA | Combined spinal–epidural anesthesia |
| EA | Epidural anesthesia |
| GA | General anesthesia |
| LIA | Local infiltration anesthesia |
| LC | Laparoscopic cholecystectomy |
| PONV | Postoperative nausea and vomiting |
| RA | Regional anesthesia |
| RCT | Randomized controlled trial |
| SA | Spinal anesthesia |
| TEA | Thoracic epidural anesthesia |

## Introduction

Laparoscopic surgery has reduced postoperative morbidity, pain, and pulmonary complications, shortened hospital stay, moved many procedures into the outpatient arena, and perhaps reduced overall costs [1–3]. However, laparoscopic surgery has also introduced new challenges for anesthesiologists due to the effects of pneumoperitoneum on circulation and respiratory function, the risk of venous gas embolism, and the pathophysiologic changes caused by extraperitoneal gas insufflation and extremes of patient positioning [4, 5]. As awake patients generally do not tolerate pneumoperitoneum well [6, 7], laparoscopic procedures are usually performed under general anesthesia (GA) [8, 9] with endotracheal intubation and mechanical ventilation in an attempt to ensure patient comfort, prevent aspiration, and maintain adequate oxygenation and ventilation in the presence of pneumoperitoneum [10]. Consequently, the use of regional anesthesia (RA) in laparoscopic surgery has been limited to patients at high risk for GA due to severe coexisting pulmonary, cardiac, or other disease [5, 11–13]. Published data on the use of RA for laparoscopic surgery are limited, and most published reports are neither randomized nor controlled. However, the successful use of RA in patients with severe comorbidities undergoing laparoscopic surgery raises interesting questions: As the risk of laparoscopic surgery under RA should be lower in healthier than in sick patients, what is the evidence regarding safety and effectiveness of RA in healthier individuals undergoing laparoscopic surgery? If RA is reasonable for laparoscopic surgery in high risk patients, is it also justified in low-risk patients? This narrative review was conducted to assess the evidence regarding the use of RA for laparoscopic surgery and evaluate the hypothesis that RA could be a reasonable option not only for patients at high risk for GA, but for healthier patients as well.

## Methods

This is a narrative review on the role of RA in laparoscopic surgery. We searched the literature for pertinent articles and case reports using the MEDLINE database (January 1975 to December 2009), the Cochrane Central Register of Controlled Trials (fourth quarter, 2009), Embase (January 1975 to December 2009), and the reference lists of all retrieved publications by combining the terms "laparoscopy" or "laparoscopic surgery" with "spinal" or "intrathecal" or "subarachnoid" or "epidural" or "regional" or "neuraxial" or "local" with the terms "anesthesia" or "anaesthesia". The search was limited to adult humans. Publications in languages other than English, on microendoscopic laparoscopic procedures routinely done in doctors' offices under local anesthesia, and publications addressing surgical issues without providing information about anesthetic technique were excluded. Two authors (GV, MK) reviewed the abstracts of all identified articles and the full text of all case reports, letters, and articles that seemed relevant to this review. Finally, 140 articles, case series, case reports, and letters were included in this review. When duplicate publications or publications of overlapping data were identified, we only used data from the newer or more detailed publication.

### Study quality

Most studies have important limitations with regard to quality and design. We mainly assessed quality using the following criteria:

1. Was the trial randomized?
2. Was the trial controlled?
3. Was the patient number acceptable?
4. Was the trial prospective?
5. Was the role and effectiveness of RA the main outcome?
6. Does the study strictly outline inclusion/exclusion criteria?
7. Does the study define cutoff points for pain/severe pain/need for analgesia consumption?
8. Was the sample described for important characteristics?
9. Does the study define cutoff point for agitation and need for sedation?
10. Does the study define cutoff points for conversion to GA?

Two independent reviewers (GV and MK) assessed quality by using the above criteria; any disagreements were resolved by discussion. If a consensus could not be reached, the opinion of the other two authors was sought. This quality assessment did not include case reports, case series, and letters. However, we also retrieved information from such publications if they presented information on a new or unexplored topic. We used only 8 of the 10 criteria (we excluded the last two) for quality assessment in studies exploring postoperative analgesia after laparoscopic surgery, because criteria number 9 and 10 were irrelevant in trials exploring postoperative analgesia after laparoscopic surgery. Finally, 62 articles comparing GA vs. RA in laparoscopic surgery were assessed for quality, and 20 (32.2 %) of them were randomized controlled trials (RCTs). Eleven of these 62 studies (17.7 %) met more than 7 of 10 quality criteria, 25 of 62 (40.3 %) met 5–7 criteria, and the remaining 26 (42.0 %) met 0–4 of 10 criteria. Twenty-four studies explored the effectiveness of RA on postoperative analgesia. Of those, 21 (87.5 %) were RCTs, 14 (58.0 %) met 7–8 of 8 quality criteria, eight (33.0 %) met 6 of 8 criteria, and two (8.3 %) met four or fewer criteria.

## Results

The search strategy yielded 2,859 abstracts for initial consideration. All records were entered into a Reference Manager v. 12 database, and 162 articles were found to be relevant. The full text of these 162 articles, case series, case reports, and letters were retrieved and examined. Finally, 140 articles assessing >20,809 patients in total were included. Studies were heterogeneous in terms of sample size, type of surgery, variables examined, instruments used for measuring outcomes, and primary outcome of interest. In fact, the role of RA in laparoscopic surgery was not the main outcome in many studies. Our findings are presented separately for three different types of operations, and the role of postoperative regional analgesia in laparoscopic surgery is discussed.

## Regional anesthesia for laparoscopic cholecystectomy

### *Summary*

We found only one RCT that compared RA vs. GA in 100 low risk (ASA physical status I or II) patients, with promising results [14]. All other publications were feasibility studies [11, 15–19], but two of them were well designed and showed promising results, with high patient satisfaction scores and no conversions to GA [14, 18]. In a single-center report, 3,492 patients had laparoscopic cholecystectomy (LC) with RA, and conversion to GA was only 0.5 % [16]. However, in another, smaller, study 3/26 patients (11.5 %) required conversion to GA, and 50 % of those patients experienced shoulder pain [19].

Thirteen articles were selected for retrieval. Only one was an RCT [14]; all others were feasibility studies [11, 15–19] or case reports [12, 13, 20–23]. The most important studies are presented in Table 1. Gramatica et al. [11] reported in 2002 a series of 29 patients with severe chronic obstructive pulmonary disease who had LC under epidural anesthesia (EA), with satisfactory results. Hamad and Ibrahim El-Khattary [15] reported for the first time in 2003 the use of spinal anesthesia (SA) for LC using nitrous oxide ($N_2O$) pneumoperitoneum in a small series of healthier patients; Tzovaras et al. [17] explored the feasibility of SA for LC with standard carbon dioxide ($CO_2$) and low-pressure pneumoperitoneum in healthier patients in 2006. As results of the pilot study by Tzovaras [14] were encouraging, an RCT was conducted in the same institution to compare SA vs. GA in 100 healthier patients undergoing elective LC with low-pressure (maximum 10 mmHg) pneumoperitoneum. There was no conversion from SA to GA, perioperative times (operation, postanesthesia care unit stay), and patient satisfaction scores were comparable between groups, but patients in the SA group had lower postoperative pain scores and significantly lower use of supplemental opioids.

**Table 1** Published data on laparoscopic cholecystectomy under neuraxial (spinal or epidural) anesthesia

| Reference, country | Patient population and ASA-PS | Study design and indication for RA | Results | Comments |
|---|---|---|---|---|
| Gramatica et al. [11], Italy | 29 | Severe COPD, EA | EA: satisfactory, no need for GA | 3 had urinary retention |
| Pursnani et al. [12], UK | 6; ASA 3–4 | Severe asthma or COPD, EA | 2/6 needed alfentanil for shoulder pain; overall, 6/6 satisfied with TEA | EA at T10–11, bupivacaine 0.5 % low-pressure pneumoperitoneum |
| Tzovaras et al. [14], Greece | 100; ASA 1–2 | RCT, SA vs. GA | No conversion to GA; less postoperative pain in SA group | Low-pressure pneumoperitoneum |
| Hamad et al. [15], Egypt | 10 | Feasibility study, SA, hyperbaric bupivacaine 10–12 mg + fentanyl 10 µg | One needed GA for shoulder pain; one omitted; 9/10 satisfied | T6–T8 block, $N_2O$ low-pressure pneumoperitoneum |
| Sinha et al. [16], India | 3,492 in SA vs. 538 in GA | Single-center report | In 18 (0.5 %), SA converted to GA; hypotension in 20.0 %; shoulder pain in 12.3 %; headache in 5.9 % | Surgical technique identical with GA; intra-abdominal pressure 8–10 mmHg; SA group, less PONV |
| Van Zundert et al. [18], Netherlands | 20 ; ASA 1–2 | Feasibility study, segmental thoracic SA | T10 SA with bupivacaine 5 mg + sufentanil 2.5 µg | Paresthesia in 1, all patients satisfied, no conversions to GA |
| Yuksek et al. [19], Turkey | 29; ASA 1–2 | Feasibility study, SA | SA converted to GA due to shoulder pain in 3 of 29 patients | 13 required IV fentanyl for shoulder pain, diaphragm washing with 2.0 % lidocaine effective |
| Tzovaras et al. [46], Greece | 15; ASA 1–2 | Feasibility study, SA | 14 of 15 patients satisfied | Low-pressure pneumoperitoneum |

*ASA-PS* American Society of Anesthesiologists–Physical Status, *EA* epidural anesthesia, *LC* laparoscopic cholecystectomy, *COPD* chronic obstructive pulmonary disease, *SA* spinal anesthesia, *GA* general anesthesia, *TEA* thoracic epidural anesthesia, *RCT* randomized controlled trial, *PONV* postoperative nausea and vomiting, *PFTs* pulmonary function tests, *IV* intravenous, $N_2O$ nitrous oxide

In another prospective study from Turkey, 29 ASA-PS 1 and 2 patients were recruited for LC under SA [19]. The operation was completed laparoscopically on 26 of 29. However, because of severe right shoulder pain, three of these 29 patients (11.5 %) needed conversion to GA and 13 required IV fentanyl; five of those 13 patients also required washing of the right diaphragm with 2.0 % lidocaine. Furthermore, a 2008 publication from India presented a single-center experience on 2,992 patients who had LC under SA over an 11-year period [24], and a 2009 publication by the same authors extended the observation period to 12 years and included 3,492 patients [16]. Hypotension requiring pharmacologic support (20.0 %), neck and/or shoulder pain (12.3 %), and postural headache (5.9 %) were the most common complications; only 0.5 % required conversion to GA. When comparing this group (3,492 patients) to 538 historical controls who had LC under GA, the authors found less postoperative pain and vomiting among SA patients and concluded that SA could perhaps be considered the anesthetic method of choice for elective LC.

In 2007, Van Zundert et al. [18] reported a series of 20 healthier patients who underwent LC under segmental thoracic (10th thoracic interspace) SA. Pain and anxiety were treated with modest doses of fentanyl or midazolam, respectively, and all patients had high satisfaction scores. Many other case reports or small case series report satisfactory outcome when RA is used for LC [12, 13, 20–23].

## Regional anesthesia for laparoscopic hernia repair

### *Summary*

One RCT on 40 patients reported that many patients became agitated and experienced chest pain [25], whereas many feasibility studies and case series [26–46] showed conflicting or disappointing results and suggested that T4-level blockade reduces conversions to GA [27]. Several studies reported excellent results, with no conversions to GA and high patient satisfaction [26, 37, 38, 40, 44, 46], thereby suggesting that RA can be the main anesthetic technique for laparoscopic hernia repair. In addition, a large, retrospective study by Sinha et al. [24] on 4,645 patients reported good outcomes, with only 0.01 % conversions to GA.

The first studies on RA for laparoscopic hernia repair were published in the 1990s and included 111 patients [27, 31, 38, 44, 47]. To date, all published studies (17 studies, Table 2) were retrospective, except for one RCT, with conflicting results [25]. SA was the main anesthetic technique in nine studies [24, 26, 33, 37, 38, 40, 43, 44, 46], whereas local infiltration anesthesia (LIA) was used in four studies [31, 32, 34, 41], EA in two [27, 35], combined spinal epidural anesthesia (CSEA) in one [25], and either SA or EA in one [47]. Of note, all 17 reports on RA for laparoscopic hernia repair or LC originated from departments of surgery and were published in surgical journals. Consequently, although evaluation of anesthetic technique was one of the main aims in these studies, important anesthesiology issues (including cutoff points between pain and severe pain, criteria for use of analgesia or sedation, and criteria for conversion to GA) were not sufficiently explored.

There are two distinct laparoscopic hernia repair techniques: In transabdominal preperitoneal repair, use of pneumoperitoneum is essential. In contrast, extraperitoneal hernia repair does not require pneumoperitoneum, yet peritoneal tears and pneumoperitoneum can occur in up to 64.0 % of patients [42, 44, 48]. Endoscopic, totally extraperitoneal inguinal hernioplasty confers superior early outcomes compared with open repair, but the presumed need for GA has been an argument against laparoscopic repairs [35]. Until the late 1990s, GA with controlled ventilation was the standard technique [8]; a study from The Netherlands reported that GA was used in 98.5 % of laparoscopic repairs but in only 40.2 % of open repairs [36].

Successful use of RA for laparoscopic hernia repairs was initially reported in selected patients deemed unfit for GA [29, 31, 32]. In a report from the USA, ten patients underwent primary laparoscopic inguinal hernia repair (three bilateral) under LIA [31], without any complications or conversions to GA. One year later, a prospective, nonrandomized study from the same institution on men at high risk for GA due to severe pulmonary disease compared LIA (ten patients) with GA (82 patients) and concluded that there were no significant differences between the two methods [32]. In another report, 35 patients had laparoscopic hernia repair under SA, with $N_2O$ as extraperitoneal gas. Despite the high frequency of peritoneal tears (64.0 %), $N_2O$ pneumoperitoneum was well tolerated [44]. Similarly, preperitoneal herniorrhaphy was successfully performed under EA in 36 patients [27]. In a French study of 15 laparoscopic hernia repairs under LIA supplemented by hypnosis, there was only one conversion to GA (6.7 %) [41]. In another prospective study from the USA, 30 patients underwent successful extraperitoneal laparoscopic hernia repair under SA without conversions to GA [37].

Reports of laparoscopic intraperitoneal hernia repair under RA in healthier individuals are scarce. In a study from Spain, 19 of 23 patients underwent laparoscopic ventral hernia repair under SA, whereas four patients (17.4 %) required conversion to open surgery or GA [28]. In a feasibility study from Greece, 25 ASA-PS 1 or 2 patients underwent laparoscopic ventral hernia repair under SA [46]. The hernia was umbilical or paraumbilical in nine cases, epigastric in five, and incisional in 11. There were no conversions to GA; most patients went home within 24 h

**Table 2** Published data on laparoscopic inguinal hernia repair under neuraxial (spinal or epidural) regional or local infiltration anesthesia

| Reference, country | Patient population and ASA PS | Study design; indication for RA | Results | Comments |
|---|---|---|---|---|
| Sinha et al. [24], India | 4,645 | Single institution experience, 11 years, SA | | Conversion to GA: 0.01 % |
| Hirschberg et al. [25], Germany | 40 | Evaluation of respiratory response to gas insufflations, CSEA vs. GA | Many agitated and chest pain | Anesthesia technique not related to stress response |
| Ali et al. [26], Saudi Arabia | 18; ASA 3 | Feasibility study, SA bupivacaine 22–25 mg + sedation | Excellent patient and surgeon satisfaction | Sedation with ketamine + propofol |
| Azurin et al. [27], France | 36 | Feasibility study, EA | All outpatients; 1 conversion to GA | Epidural anesthesia to T4 level block |
| Ferzli et al. [31], USA | 10 | Feasibility study, patients very sick for GA, LIA | 4 of 10 required sedation | No complications |
| Frezza et al. [32], USA | 92 | Pulmonary disease, LIA vs. GA | 10 LIA vs. 82 GA | No significant difference between LIA and GA |
| Ismail et al. [33], India | 675; 1,289 hernia repairs | Feasibility retrospective study, SA | No anesthetic complications | Recurrence rates similar in all groups |
| Kumar et al. [34], UK | 32 men, 1 woman | Prospective feasibility study | Laparoscopically guided ilioinguinal nerve block | Low pain scores, no transient femoral nerve block |
| Lal et al. [35], India | 22 male | Feasibility study, EA | 7 (32.0 %) converted to GA | 2.0 % lidocaine, T6 level block, 70.0 % conversion to GA if block less than T6 level |
| Molinelli et al. [37], USA | 30 | Retrospective study, SA | 44 hernias in 30 | No conversions to GA |
| Ohta et al. [38], Japan | 15 | SA + abdominal wall lifting vs. GA + pneumoperitoneum | Very good visibility with abdominal wall lifting | No complications, no conversions to GA |
| Schmidt et al. [40], Germany | 15; ASA 3–4 | All patients COPD, SA with hyperbaric lidocaine | All satisfied with SA | Mean hospital stay 1.5 days, low-pressure pneumoperitoneum |
| Sefiani et al. [41], France | 35 LC; 15 hernias | Retrospective feasibility study, LA + IV sedation | 13 of 35 LCs, 1 of 15 converted to GA for shoulder pain | Abdominal wall lifting technique |
| Sinha et al. [43], India | 480 | Single institution experience, SA | | 3/480 converted to GA |
| Spivak et al. [44], USA | 35 | Feasibility study, SA | Incidental peritoneal tears in 22 (64.0 %) | No conversion to GA, $N_2O$ pneumoperitoneum |
| Tzovaras et al. [46], Greece | 25; ASA 1–2 | Feasibility study, SA | All satisfied with SA | No conversions from SA to GA |
| Fierro et al. [47], Italy | 15 | 7 of 15 patients with very serious medical problems for GA, SA or EA | 5 EA vs. 10 SA; more satisfied with SA than EA | All had shoulder pain, one conversion to open repair |

*ASA-PS* American Society of Anesthesiologists–Physical Status, *EA* epidural anesthesia, *LC* laparoscopic cholecystectomy, *SA* spinal anesthesia, *GA* general anesthesia, *CSEA* combined spinal epidural anesthesia, *LIAm* local infiltration anesthesia, *COPD* chronic obstructive pulmonary disease, *IV* intravenous, $N_2O$ nitrous oxide

after surgery and were satisfied with the anesthetic method. The low-pressure $CO_2$ pneumoperitoneum used in that study could be the main reasons for the absence of conversions from SA to GA.

A few large, retrospective or observational studies have also been published. One from India in 2008 reported the use of SA as first choice in 480 patients undergoing (mostly unilateral) extraperitoneal inguinal hernia repair over an 8-year period [43]. This study excluded patients with strangulated or obstructed hernias but included patients with irreducible hernias. Conversion to GA was needed in only three patients (0.6 %), because either SA failed or shoulder pain persisted despite sedation. Postural headache occurred in 25 patients, and average time to discharge was 2.3 days. Shortly afterward, the same group published updated data, extending the observation period to 11 years and including 4,645 patients for various laparoscopic procedures, many of them hernia repairs [24], with similar results: 0.01 % of patients required conversion to GA, 18.2 % required pharmacologic support for hypotension, and 12.3 % experienced neck and/or shoulder pain. Lastly, a retrospective study from India described 675 patients (1,289 hernias) who had laparoscopic total extraperitoneal hernia repair [33]; 659 of 675 patients had SA and 16 had GA (2.4 %), thereby demonstrating the feasibility of having this procedure under SA without significant anesthetic complications. Another study from India evaluated EA for laparoscopic total extraperitoneal inguinal hernia repair in 22 men [35]. Although lumbar EA (2.0 % lidocaine with epinephrine) achieved a T6-level sensory block, seven of 22 patients (31.9 %) required conversion to GA. According to the authors, prevention and management of pneumoperitoneum and shoulder pain was the key in order to prevent conversion to GA, whereas conversion rate was >70.0 % when sensory block was below the T6 level. In a study from Saudi Arabia, 18 ASA-PS 3 patients had laparoscopic abdominal procedures under SA with T4-level sensory block, supplemented with midazolam for premedication and propofol/ketamine infusion for intraoperative sedation, with excellent patient and surgeon satisfaction [26]. Likewise, in a letter in 2008, Bhat [49] supported the use of thoracic EA for laparoscopic total extraperitoneal inguinal hernia repair, stating that a T6- to L5-level sensory block is needed, whereas a study published in 1996 reported successful laparoscopic hernia repair on 36 patients under EA with a T6-level sensory block [27]. Many other case reports and studies with small patient numbers support the use of RA for laparoscopic hernia repair [38–40, 45, 47].

Despite these reports encouraging the use of RA techniques for laparoscopic hernia repair, other investigators question their safety and efficacy. An RCT on 40 patients undergoing total extraperitoneal laparoscopic hernia repair under CSEA or GA showed no association between type of anesthesia and stress response. As most CSEA patients showed severe agitation often accompanied by chest pain, the authors concluded that CSEA is not recommended for this procedure [25]. However, use of nerve blocks as a sole or adjuvant analgesic method may be very useful [30, 34, 50]. Of note, severe bradycardia and cardiac arrest have been reported during laparoscopic hernia repair under CSEA [42].

## Neuraxial (spinal or epidural) anesthesia and LIA for other laparoscopic procedures

### *Summary*

Several studies suggest that neuraxial (spinal or epidural) anesthesia and LIA are safe and effective and are frequently used for other minor laparoscopic procedures. However, because most studies were not RCTs, data quality is limited, and these findings should be interpreted with caution. Laparoscopic tubal sterilization has been performed in the USA under LIA since 1971 [51], and many laparoscopic gynecologic procedures, including laparoscopic tubal ligation [52–54], clip sterilization [55, 56], in vitro fertilization [57, 58], and laparoscopy for infertility [59], are now frequently conducted under neuraxial, regional, or LIA. Data on the use of neuraxial anesthesia for a variety of laparoscopic surgical procedures are presented in Table 3. Overall, we reviewed 21 studies and case reports [28, 46, 48, 53, 58–74]. Of those, only 13 were RCTs [53, 59–61, 63, 64, 66, 67, 69–73], and only four compared neuraxial anesthesia vs. GA [59, 67, 69, 72]; the other eight RCTs compared different anesthetic doses, surgical, and/or anesthetic techniques, with patients undergoing neuraxial anesthesia in most cases. Four of these five RCTs concluded that neuraxial anesthesia was superior to GA with regards to pain, respiratory function, recovery time, and cost [59, 69, 72, 75], but one study reported high failure rate with EA [61]. In a study of 63 patients who underwent lift (gasless) laparoscopic surgery under neuraxial anesthesia, there were no conversions to GA [65]. Of note, neuraxial anesthesia could be ideal in certain special circumstances, such as pregnancy. In one case series, seven pregnant women had ovarian cyst resection with abdominal-wall lift under CSEA [74].

Data on LIA and other (excluding neuraxial) anesthetic techniques are presented in Table 4. Overall, we reviewed 21 studies, four of which were case series [51, 55, 76–94]. Of those, only six were RCTs [76–78, 82, 89, 90]: five compared LIA vs. GA and one compared $CO_2$ vs. $N_2O$ insufflation; all patients had LIA anesthesia [82]. A prospective study published in 1991 compared LIA vs. GA in 50 healthier patients and showed that respiratory mechanics were not affected [92]. Many other retrospective observational studies [79], case series [81, 93–97], or case reports [98] showed very good results when LIA, with or without sedation, is used for laparoscopic surgery. In a recent study, 175 end-stage renal disease patients underwent laparoscopic peritoneal dialysis catheter implantation with $N_2O$ insufflation under LIA, with very good results [80]. Key benefits of LIA in those studies include less emesis, less postoperative pain, shorter postoperative hospital stay, improved patient satisfaction, and improved overall safety. Some older studies with large patient numbers showed that LIA anesthesia with or without mild sedation is well tolerated for laparoscopic sterilization, gamete intrafallopian transfer, and staging of abdominal cancer [55, 83–87, 91]. Use of LIA anesthesia for laparoscopic sterilization is highly satisfactory and may result in significant cost savings compared with GA [83]. In two

**Table 3** Reports of various general and gynecologic surgery procedures performed under neuraxial (spinal or epidural) anesthesia

| Reference, country | Patient population and ASA-PS | Procedure | Study design | Results | Comments |
|---|---|---|---|---|---|
| Bejarano et al. [28], Spain | 19 | Ventral hernia repair | Feasibility study, SA | 4 SA converted to GA or open surgery | T2-level block, low pressure (12 mmHg) pneumoperitoneum |
| Tzovaras et al. [46], Greece | 25, ASA 1–2 | Laparoscopic ventral hernia repair | Feasibility study, SA | No conversions to GA, low postoperative pain scores, all satisfied | Low-pressure $CO_2$ pneumoperitoneum |
| Zacharoulis et al. [48], Greece | 45, ASA 1–2 | Laparoscopic transabdominal preperitoneal inguinal hernia repair | Feasibility study | 1 converted to GA, 2 converted to open surgery, 10 had shoulder pain, 16 needed urinary catheter | Low-pressure $CO_2$ pneumoperitoneum |
| De Santiago et al. [53], Spain | 52 women, ASA 1 | Tubal sterilization | RCT, SA lidocaine vs. levobupivacaine | Both regimens satisfactory | No significant differences between groups |
| Lehtinen et al. [58], Finland | 24 women | Laparoscopy for IVF | Prospective, GA vs. EA | EA did not prevent stress response to laparoscopy | |
| Kuramochi et al. [59], Japan | 20 women | Laparoscopic surgery for infertility | RCT, EA vs. GA | Very low intraoperative pain scores with EA | EA: less postoperative pain, better respiratory function and activity |
| Chilvers et al. [60], Canada | 64 women | Outpatient laparoscopy | RCT, lidocaine + 0 vs. 10 vs. 25 μg fentanyl, SA | SA: hypobaric lidocaine. 20 mg sufficient; optimal fentanyl dose is 25 μg | |
| Chiu et al. [61], Taiwan | 22 | Ligation internal spermatic varices | RCT, lumbar EA | 3 of 11 could not tolerate; required GA | High failure rate with EA |
| Ciofolo et al. [62], France | 7 women, ASA 1 | Gamete intrafallopian transfer | Prospective study, lumbar EA | Constant $CO_2$ insufflation | No evidence of respiratory depression |
| Henderson et al. [63], Canada | 9 | Outpatient gynecologic laparoscopy | RCT, SA sufentanil vs. lidocaine + sufentanil | Early termination | Sufentanil only: inadequate |
| Hong et al. [64], Korea | 72 | Robot-assisted laparoscopic radical prostatectomy | RCT: GA vs. TEA +GA | TEA + GA: better intraoperative ventilation, oxygenation; no significant postoperative differences | T4-level block, high-pressure pneumoperitoneum + extreme head-down position |
| Kruschinski et al. [65], Germany | 63 | Gynecologic (10 diagnostic, 17 ovarian tumor, 22 hysterectomy) | Feasibility study | All had neuraxial anesthesia, no conversions to GA | Gasless technique |
| Lee et al. [66], Korea | 60 | Laparoscopic subtotal gastrectomy | RCT comparing open vs. laparoscopic operation | All patients TEA + GA, satisfied | Urinary catheter may not be needed |
| Nishio et al. [68], Japan | 45 women | Gynecologic laparoscopy | Evaluation of $CO_2$ changes with $CO_2$ and $N_2O$ insufflations in GA vs. TEA | TEA patients maintained normal $PaCO_2$ by increasing spontaneous ventilation | Hypercarbia in mechanically ventilated patients |
| Stewart et al. [69], Canada | 40 women | Outpatient laparoscopy | RCT, SA vs. propofol GA | Faster recovery in SA group | |
| Vaghadia et al. [70], Canada | 30 women, ASA 1–2 | Laparoscopy | RCT, SA lidocaine: hypobaric 25 mg vs. hyperbaric 75 mg | In hyperbaric SA group 50.0 % had hypotension | 90.0 % would request SA again |

**Table 3** continued

| Reference, country | Patient population and ASA-PS | Procedure | Study design | Results | Comments |
|---|---|---|---|---|---|
| Vaghadia et al. [71], Canada | 30 | Laparoscopy | RCT, SA with hypobaric lidocaine, 3 different doses | Lidocaine 10 mg sufficient, more rapid recovery | |
| Vofsi et al. [72], Israel | 24 women, ASA 1 | Gynecologic laparoscopy <90 min | RCT, GA + $CO_2$ vs. GA-gasless vs. EA-gasless | All satisfied; less postoperative pain in EA group | |
| Wang et al. [73], China | 60 women, ASA 1–2 | Laparoscopy for ectopic pregnancy | RCT, SA; bupivacaine 15 mg + 4 different sufentanil dose | Sufentanil 5 μg is the optimal dose | All patients received propofol |
| Yamada et al. [74], Japan | 7 pregnant women | Laparoscopic ovarian cystectomy during pregnancy | Case series, CSEA to avoid GA during early pregnancy | No sedatives given, all tolerated procedure well | Gasless laparoscopy, with abdominal wall lift |
| Lennox et al. [75], Canada | 10 | Outpatient gynecologic laparoscopy | RCT, SA vs. GA | Lower pain scores and lower cost with SA | |

*ASA-PS* American Society of Anesthesiologists–Physical Status, *GA* general anesthesia, *EA* epidural anesthesia, *SA* spinal anesthesia, *RCT* randomized controlled trial, *TEA* thoracic epidural anesthesia, *IVF* in vitro fertilization, *CSEA* combined spinal epidural anesthesia, $CO_2$ carbon dioxide, $N_{O2}$ nitrous oxide, $PaCO_2$ partial pressure of arterial carbon dioxide

other retrospective studies with large patient numbers (2,650 and 2,825, respectively), LIA was used with satisfactory outcome (excellent hemodynamic stability, short hospital stay) in all cases [51, 88].

## Neuraxial, regional, or local blockade for analgesia after laparoscopic surgery

### *Summary*

Thirteen of 21 RCTs evaluating the role of neuraxial, regional, or local blockade for analgesia after laparoscopic surgery showed very encouraging results. In addition, many retrospective/feasibility studies evaluating RA in laparoscopic surgery demonstrated reduced postoperative pain compared with procedures carried out under GA. Pain is usually not a major problem after laparoscopic surgery. Data from studies evaluating the role of LIA, regional, or neuraxial anesthesia on pain control after laparoscopic surgery are presented in Table 5. We reviewed 24 studies, and 21 were RCTs. In 13 of these RCTs, results were very encouraging for the role of LIA, regional, or neuraxial anesthesia on pain control after laparoscopic surgery [99–111], but results were disappointing in four [112–115] and questionable in four [116–119]. In one prospective trial, LIA reduced postoperative pain [120]. Similarly, one cohort study with historical controls showed that use of thoracic epidural anesthesia (TEA) reduced hospital length of stay significantly [121]. Finally, in a recent retrospective study, TEA using continuous bupivacaine infusion significantly reduced opioid use [122].

Overall, many studies evaluating RA in laparoscopic surgery demonstrate reduced postoperative pain compared with procedures carried out under GA [14, 46, 59, 72, 75, 76]. Many of these studies are RCTs [14, 59, 67, 72, 76], but most include small patient numbers [59, 72, 75]; several others are feasibility studies [14, 46] without blinding or a control group. Of note, because postoperative pain is not the primary endpoint in most studies, the presumed advantage of RA over GA with regard to postoperative analgesia has not been well established. The large patient series originating from India compared a routinely performed anesthetic technique (SA) vs. a technique used under limited circumstances (GA) [24] but did not provide adequate information about GA. Nevertheless, one properly blinded/controlled study defined postoperative pain control as the primary end point but did not have a large patient population [14]. Plausible mechanisms explaining why SA could result in less postoperative pain include avoidance of discomfort related to endotracheal intubation, presence of residual analgesia for several hours after surgery, and reduced stress response associated with neuraxial anesthesia [99]. As percutaneous ilioinguinal nerve block is used for pain control after open groin-hernia repair, two studies suggest that laparoscopically guided ilioinguinal nerve blocks improve postoperative comfort after laparoscopic total extraperitoneal groin-hernia repair [30, 34]. A small RCT demonstrated that local anesthetic infiltration of

**Table 4** Other general and gynecologic surgery procedures performed under local infiltration anesthesia (LIA)

| Reference, country | Patient population and ASA-PS | Procedure | Study design | Results | Comments |
|---|---|---|---|---|---|
| Poindexter et al. [51], USA | 2,827 | Laparoscopic sterilization | Retrospective study, LIA in all patients | LIA: Shorter hospital stay | LIA: lower cost |
| MacKenzie et al. [55], UK | 200 women | Laparoscopic sterilization | Retrospective study, LIA in all patients | LIA: effective and safe | |
| Bordhal et al. [76], Norway | 125 women | Laparoscopic sterilization | RCT, LIA + sedation vs. GA | LIA: highly acceptable, faster recovery, less pain | LIA: shorter procedure, lower cost |
| Duh et al. [77] USA | 48 | Gastrostomy and jejunostomy | RCT, LIA + sedation vs. GA | 1 of 24 converted to GA | No difference between methods |
| Hatasaka et al. [78], USA | 14 women | Laparoscopic tubal ligation | RCT LIA + sedation vs. GA | LIA: shorter recovery, lower cost | Satisfaction the same |
| Iwasaki et al. [79], Japan | 68 | Preoperative laparoscopy in advanced gastric cancer | Evaluation of preoperative laparoscopy, LIA | LIA: effective and safe | |
| Keshvari et al. [80], Iran | 175 ESRD | Laparoscopic peritoneal dialysis catheter implantation | Poor candidates for GA | Procedures well tolerated, excellent long-term outcome | LIA + $N_2O$ insufflation |
| Kjer et al. [81], Sweden | 10 | Laparoscopic sterilization | Feasibility study | LIA + paracervical block, all satisfied | Discomfort in one case who also had pregnancy termination |
| Lipscomb et al. [82], USA | 49 women | Laparoscopic sterilization | RCT, local + $CO_2$ vs. LIA + $N_2O$ insufflation | $CO_2$ vs. $N_2O$; no difference | |
| Lipscomb et al. [83], USA | 65 women | Laparoscopic sterilization | Retrospective study, LIA vs. GA | LIA satisfactory, shorter recovery times, lower cost | |
| Merger et al. [84], New Caledonia | 732 women | Postpartum laparoscopic sterilization | Retrospective data collection, LIA | LIA: well tolerated | |
| Milki et al. [85], USA | 119 women, 175 procedures | Gamete intrafallopian transfer | Prospective cohort study, LIA + sedation | LIA + mild sedation: well tolerated | Surgeon and patients satisfied |
| Miller et al. [86], USA | 1,190 office procedures | Laparoscopic sterilization | Retrospective study, LIA + sedation | LIA + mild sedation: no anesthesia complications | |
| Munk et al. [87], Denmark | 52 women | Laparoscopic sterilization | Retrospective study, LIA | 3 LIA converted to GA for adhesions or inadequate relaxation | |
| Orlando et al. [88], Italy | 2,650 | Diagnostic laparoscopy | Retrospective study, LIA | LIA for all cases | Surgical complications: major 0.4 %, minor 1.5 % |
| Peterson et al. [89], USA | 100 women | Laparoscopic sterilization | RCT, LIA vs. GA | LIA: improved hemodynamic stability | Satisfaction similar in both groups |
| Raeder et al. [90], Norway | 125 | Laparoscopic sterilization | RCT, LIA + sedation vs. GA | LIA + sedation: shorter recovery, lower cost | Most would choose LIA again |

**Table 4** continued

| Reference, country | Patient population and ASA-PS | Procedure | Study design | Results | Comments |
|---|---|---|---|---|---|
| Sand et al. [91], Finland | 215 | Staging laparoscopy | Retrospective study, LIA | Lidocaine LIA: procedures well tolerated | |
| Subba et al. [92], India | 50 women<br>ASA 1 or 2 | Laparoscopic sterilization | Prospective study, LIA vs. GA | Awake patients increased respiratory rate by 17.0 % in response to $CO_2$ insufflation | |
| Tiras et al. [93], Turkey | 20 women | Laparoscopic sterilization | Prospective, micro-laparoscopy vs. standard laparoscopy, LIA + sedation | LIA + sedation: no difference between groups | Postoperative pain lower with microlaparoscopy |
| Waterstone et al. [94], UK | 21 women, 29 procedures | Laparoscopic zygote intrafallopian transfer | LIA + IV analgesia | Procedure well tolerated | |

*ASA-PS* American Society of Anesthesiologists Physical Status, *RCT* randomized controlled trial, *GA* general anesthesia, *ESRD* end stage renal disease, *IV* intravenous, $CO_2$ carbon dioxide, $N_{O2}$ nitrous oxide

suture fixation sites reduces early postoperative pain but does not reduce analgesic consumption after laparoscopic incisional or ventral hernia repairs [50].

LA has also been proposed as a means to reduce postoperative pain after laparoscopic surgery. However, a systematic review published in 2000 confirmed the effectiveness of intraperitoneal local anesthetics but questioned the effectiveness of port-site local anesthetic infiltration for postoperative analgesia [123].

## Discussion

Most studies on RA for LC in healthier patients appeared after 2003 but included small patient numbers and were not properly randomized [14]. Although several reports suggest that local or neuraxial anesthesia is a reasonable option, and literature reviews advocate using RA for laparoscopic surgery [124–126], RA has not gained popularity as a sole anesthetic technique for laparoscopic surgery, mainly because of concerns about $CO_2$ elimination and shoulder pain. These concerns need to be adequately addressed before RA can be considered the “preferred” method for laparoscopic surgery in healthier patients. As most laparoscopic procedures involve intra-abdominal $CO_2$ insufflation, $CO_2$ elimination is a concern. Data from healthier women undergoing laparoscopic surgery with $CO_2$ insufflation under RA or LIA suggest that $PaCO_2$ does not rise during surgery because awake women increase respiratory rate and minute ventilation [62, 68, 92, 127]. In order to avoid hypercarbia from $CO_2$ absorption, some reviews emphasize the need for GA, particularly for ASA-PS 3/4 patients, whereas several studies document the need to increase minute ventilation [128–130]. The rate of $CO_2$ absorption is related to the type of surgery [131]. For example, because simple gynecologic procedures are associated with low $CO_2$ absorption, they are routinely performed under RA [10, 59]. Published data indicate that LIA or RA is widely used in microlaparoscopy procedures requiring minimal gas insufflation (intra-abdominal pressure $\leq$12 mmHg) [5, 10, 60]. Insufflation pressure and time are the main factors affecting total $CO_2$ uptake. However, most studies measuring $CO_2$ absorption were conducted with insufflation pressures significantly >10 mmHg, and there are no data regarding absorption with pressures <10 mmHg.

Shoulder or neck pain is common during awake laparoscopic surgery and sometimes necessitates conversion to GA [47, 49]. Although shoulder or neck pain may be acceptable in patients with significant medical problems who could benefit from avoiding GA, the decision regarding RA for laparoscopic surgery could be different in healthier patients. If RA does not provide advantages, why should healthier patients prefer RA if they have to tolerate shoulder pain? Overall, reported rate of conversion from RA to GA due to intolerable shoulder pain has been 0–37.1 % for LC [11, 12, 15–19, 41] and 0–35.8 % for laparoscopic hernia repair [10, 24, 26, 27, 33, 35, 37, 38, 41, 43, 44, 46–48], but there is great variability between studies. However, whereas a 0 % conversion rate would be excellent, conversion rates approaching 30 % would not be acceptable for healthier patients in most medical centers in Europe or the USA. Yet, shoulder pain during laparoscopic surgery was absent or adequately relieved by sedatives and/

**Table 5** Role of neuraxial, regional, or local blockade for postoperative analgesia after laparoscopic surgery

| Reference, country | Patient population and ASA-PS | Operation | Study design | Results | Comments |
|---|---|---|---|---|---|
| Aono et al. [99], USA | 52, ASA 1 or 2 | LC | RCT, 3 groups (in two groups GA with different medication and in one group GA + TEA) | GA + TEA: catecholamines did not increase | Serum cortisol increased in all patients |
| Goldstein et al. [100], France | 180 | Gynecologic procedures | RCT, 3 groups Intraperitoneal instillation of bupivacaine vs. ropivacaine vs. saline | Opioid-sparing effect of ropivacaine was greater than bupivacaine. Ropivacaine prevents postoperative pain and decreases the need for morphine | Both local anesthetics reduce PONV |
| Ke et al. [101], USA | 75 women | Laparoscopy for pelvic pain, infertility, or sterilization | RCT, LIA before vs. LIA after vs. no LIA | LIA before incision: reduced pain 24 h postoperatively | |
| Khaira et al. [102], USA | 72 | Transperitoneal laparoscopic renal or adrenal surgery | RCT, port infiltration with bupivacaine vs. saline | Reduced opioid use in bupivacaine group | |
| Kim et al. [103], Korea | 83 | LAVH | RCT, LIA with bupivacaine vs. saline | Bupivacaine + IM ketorolac reduced pain after LAVH | |
| Liu et al. [104], Taiwan | 72 | LC | RCT, local ropivacaine vs. saline | Ropivacaine: less pain, earlier discharge | |
| Narchi et al. [105], France | 80 women | Diagnostic laparoscopy | RCT, intraperitoneal LIA vs. placebo | LIA injection intraperitoneal: less shoulder pain | |
| Pasqualucci et al. [106], Italy | 42 | LC | RCT, intra-abdominal bupivacaine-epinephrine vs. saline | Bupivacaine-epinephrine: reduced pain | LIA before + after surgery: reduced cortisol level |
| Pasqualucci et al. [107], Italy | 120 | LC | RCT, intraperitoneal bupivacaine + epinephrine vs. saline | Reduced pain in patients receiving LIA | LIA before surgery: lower cortisol level |
| Salman et al. [108], Turkey | 80 | Day-case laparoscopy | RCT, IV tenoxicam vs. IV fentanyl vs. bupivacaine infiltration vs. placebo | Lower pain scores with bupivacaine infiltration | Tenoxicam ineffective |
| Sarac et al. [109], Turkey | 70 | LC | RCT, LIA before vs. LIA after surgery vs. saline | Lowest pain scores: LIA infiltration at end of surgery | No LIA preemptive analgesic effect |
| Senagore et al. [110], USA | 38 | Laparoscopic colectomy | RCT, TEA vs. IV morphine PCA | TEA: improved postoperative analgesia | Length of stay: no difference |
| Luchetti et al. [111] Italy | 40 | LC | RCT, combined GA-EA vs. TIVA | GA-EA, less pain, lower opioid use shorter recovery time | GA-EA: shorter recovery time |
| Deans et al. [112], UK | 100 | Transabdominal preperitoneal laparoscopic hernia repair | RCT | Bupivacaine instillation in preperitoneal space did not reduce pain | |

**Table 5** continued

| Reference, country | Patient population and ASA-PS | Operation | Study design | Results | Comments |
|---|---|---|---|---|---|
| Hong et al. [113], Korea | 60 women, ASA 1 or 2 | Laparoscopy | RCT, control vs. piroxicam vs. suprascapular block | Piroxicam groups had lower pain scores | Suprascapular block not effective for shoulder pain |
| Newcomb et al. [114], USA | 55; 4 groups | LC | RCT for post-LC pain | Oral NSAIDs and LIA did not influence postoperative pain | |
| Nishikawa et al. [115], Japan | 30; >65 years | LC | RCT for postoperative pain, TEA vs. IV PCA | Postoperative analgesia similar in both groups | Higher satisfaction in IV PCA group |
| Johnson et al. [116], UK | 80 women | Laparoscopy | RCT | Bupivacaine vs. saline over peritoneal folds | Benefit only at 2 h postoperative |
| Ozer et al. [117], Turkey | | Gynecologic laparoscopy | RCT, subphrenic bupivacaine vs. saline | Bupivacaine: shoulder pain not different, but less pain with cough | |
| Palmes et al. [118], Germany | 133 | Laparoscopic fundoplication or hernia repair | RCT, intraperitoneal lidocaine in the beginning or the operation | Preemptive LIA: less postoperative pain after fundoplication | No effect in hernia repairs |
| Ure et al. [119], Germany | 50 | LC | RCT: preincision LIA with bupivacaine vs. saline | Minimal difference between groups | No significant differences |
| Inan et al. [120], Turkey | 142 | LC | Prospective study, LIA | LIA: lower postoperative pain and analgesic use | |
| Senagore et al. [121], USA | 22 vs. 22 controls | Laparoscopic right hemicolectomy or sigmoidectomy | Cohort study with historical controls, TEA vs. IV morphine | Median length of stay 1 day shorter with TEA | |
| Yoost et al. [122], USA | 38 | Laparoscopic nephrectomy or nephroureterectomy | Retrospective comparison: bupivacaine by continuous infusion vs. infiltration | Continuous bupivacaine: lower opioid use, shorter hospital stay | |

*ASA-PS* American Society of Anesthesiologists–Physical Status, *GA* general anesthesia, *LC* laparoscopic cholecystectomy, *TEA* thoracic epidural anesthesia, *RCT* randomized controlled trial, *PONV* postoperative nausea and vomiting, *LAVH* laparoscopic-assisted vaginal hysterectomy, *LIA* local infiltration anesthesia, *IV* intravenous, *IM* intramuscular, *PCA* patient-controlled analgesia, *NSAID* nonsteroid anti-inflammatory drugs, *TIVA* total intravenous anesthesia

or opioids, so that patients were very satisfied with RA [11, 12, 15–19, 24, 26, 27, 33, 37, 40, 41, 46, 47] in several studies, including a large RCT on 100 patients [14].

High-level sensory blockade seems to be the best approach, because high (thoracic spine) placement of the epidural or spinal anesthesia effectively reduces shoulder pain. The importance of high sensory blockade was clearly demonstrated in a study from India that showed the conversion rate to GA increased by 70 % when sensory block was below T6 [35]. Similarly, an older study showed that the conversion rate to GA was 2.7 % when a T4 sensory block was achieved [27]. Other measures aimed at reducing shoulder pain include positioning changes, abdominal massage, passive drainage and suprahepatic suction of residual gas, spraying bupivacaine on the peritoneum over the diaphragm, and "painting" the diaphragm with a gauze soaked in bupivacaine [49, 132, 133]. Shoulder pain is less severe with laparoscopic extraperitoneal hernias but is more troublesome with intraperitoneal hernias. In one study, 10.5 % of patients undergoing intraperitoneal hernia repair under high (T2) spinal blockade reported abdominal or shoulder discomfort that was successfully relieved with midazolam sedation [28], and a newer study on SA for laparoscopic intraperitoneal hernia repairs reported no conversions to GA [46]. In an attempt to lessen shoulder pain, $N_2O$ has been used for pneumoperitoneum because it is less irritating for the peritoneum [7, 15, 44]. Use of $N_2O$ and addition of opioids to intrathecal local anesthetic administration can reduce shoulder pain and the need for intraoperative analgesic supplementation [7, 60]. Likewise, intraperitoneal local anesthetic administration may reduce postoperative pain [134, 135]. Perioperative nonsteroid anti-inflammatory drugs may also attenuate shoulder pain and intraperitoneal local anesthetic administration [113]. Finally, use of low-pressure pneumoperitoneum (<10 mmHg) decreases shoulder pain incidence and severity [136] and may explain why there were no conversions from SA to GA for shoulder pain in the Tzovaras study [46]. Overall, some studies do not recommend RA [42, 50]; other studies indicate that shoulder pain occurs in 12.3 % of cases but is not a major problem [24]. In conclusion, because shoulder pain is a major, unacceptable problem in healthy patients, there is a need for anesthetic and surgical protocols aimed at reducing or eliminating patient discomfort before RA is accepted as standard technique for LC and laparoscopic hernia repair.

The observed advantage of RA with regard to postoperative nausea and vomiting (PONV) is similar. In most studies, comparison between groups is difficult because measures for preventing PONV are not described in detail. The higher incidence of PONV with GA is important, because PONV increases morbidity and can delay hospital discharge [5, 10, 137].

Finally, urinary retention and the need for urinary catheterization could be a serious disadvantage of RA in healthy patients [137]. The significantly higher incidence of urinary retention in intraperitoneal hernia repair compared with LC raises the question of whether retention is associated with the anesthetic technique or with the surgical procedure itself (dissection of the suprapubic area). The high incidence of prostate hypertrophy in elderly men could be another explanation [48].

The need for GA and controlled ventilation became debatable after newer publications reported uncomplicated outcomes in patients with severely compromised pulmonary function who had laparoscopic surgery under RA [11, 12, 29, 31, 32]. Although LC under GA results in less-severe early postoperative atelectasis and respiratory dysfunction compared with conventional cholecystectomy, early postoperative pulmonary function tests are significantly impaired compared with preoperative values and return to normal many hours or even days after LC performed under GA [138–140]. We do not know whether RA has any favorable effects compared with GA with regard to postoperative respiratory function and time to full recovery. The impact of pneumoperitoneum on the respiratory system of awake patients needs to be studied also, especially in healthier patients (ASA-PS 1/2) operated under RA. Although we assume that $PaCO_2$ will rise, we actually do not know whether the rise is clinically important, how long it takes for $PaCO_2$ levels to return to normal, and to what extent patients can compensate by increasing minute ventilation in response to hypercarbia. In addition, patient positioning should also be considered. In LC, patients are in the head-up position, whereas in laparoscopic hernia repair, they are in the head-down position. It is plausible that positioning can affect the ability of the respiratory system to cope with the $CO_2$ load, but this issue has not been explored.

As most studies in this review are observational, feasibility, or retrospective, with different patient characteristics and surgical techniques–rather than well-designed, rigorous RCTs–available data are not sufficient to confirm the safety and effectiveness of RA vs. GA for laparoscopic surgery. Therefore, we do not know whether RA confers advantages or disadvantages compared with GA with regard to respiratory-system mechanics, pain, PONV, hospital stay, or cost. Furthermore, several other clinically relevant questions remain unanswered: Which RA technique is more advantageous for each procedure—SA, EA, CSEA, or LIA? Which technique is more comfortable for the patient? Which technique is preferred by the surgeon? How high should the sensory and motor block be? Which local anesthetic, if any, should be preferred and why? In addition, the role of regional techniques vs. GA has not been adequately evaluated in the presence of intra-abdominal pressures >12 mmHg and in prolonged procedures. Clearly, the absence of data from RCTs and data regarding prolonged procedures and procedures with abdominal pressures >12 mmHg are major limitations of this review.

Overall, many clinically important questions on the role of RA in laparoscopic surgery cannot be answered based on available data and deserve further study. Is RA advantageous, efficient, and safe compared with GA for laparoscopic surgery? Data from prospective, well-designed RCTs with large patient numbers, well-defined patient populations (healthier, sick, or very sick patients), and similar surgical techniques are needed to answer this important question, but data do not yet exist. Future studies need to evaluate safety (aspiration risk, respiratory compromise, hypotension, postural headache) before attempting to evaluate RA efficacy. Obviously, the subject of RA for laparoscopic surgery remains largely unexplored and deserves further research.

## Conclusion

Although laparoscopic surgery has made remarkable progress in recent years, anesthetic care for laparoscopic surgery has remained largely unchanged. This review was conducted to evaluate available evidence on the safety and effectiveness of RA as an anesthetic technique for laparoscopic surgery. Based on currently available evidence, shoulder discomfort can be a major problem for patients undergoing laparoscopic surgery under RA; therefore, routine, widespread use of RA for laparoscopic surgery in healthier patients remains controversial. Because pain and anxiety can usually be addressed with supplemental analgesics, sedation, or application of local anesthesia on the diaphragm, locoregional anesthesia may be a reasonable choice in laparoscopic surgery, and the widely held belief that GA should be the method of choice for laparoscopic surgery may not be true. However, because currently available data have major limitations, including small number of prospectively studied patients and paucity of RCTs, many clinically important questions remain unanswered. The lack of high-quality data makes definitive comparison of RA vs. GA techniques problematic. Rigorous prospective RCTs on large numbers of patients and different, well-defined patient populations are needed to determine the true value of RA in laparoscopic surgery. Based on currently available evidence, we believe that protocols to maintain patient comfort during surgery should be established before RA can be considered acceptable as the standard technique for routine laparoscopic surgery.

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## Appendix: Search strategy for PubMed

1. Analgesia Epidural [MeSH]
2. Anesthesia Epidural [MeSH]
3. Anesthesia Local [MeSH]
4. Anesthesia Spinal [MeSH]
5. Cholecystectomy [MeSH]
6. Laparoscopic [MeSH]
7. Laparoscopy [MeSH]
8. Surgery [MeSH]
9. #1 and #7 or #1 and #6 and #8 or #1 and 5
10. #2 and #7 or #2 and #6 and #8 or #2 and 5
11. #3 and #7 or #3 and #6 and #8 or #3 and 5
12. #4 and #7 or #4 and #6 and #8 or #4 and 5
13. PubMed advance search: ((((((((((epidural) OR spinal) OR intrathecal) OR subarachnoid) OR local) OR regional) AND anesthesia) OR anaesthesia)) AND laparoscopic) AND surgery
14. PubMed advance search: (((((((((regional) OR epidural) OR spinal) OR local) OR neuraxial) AND anesthesia) OR anaesthesia)) AND laparoscopy
15. PubMed advance search: (((((((((((local) OR regional) OR epidural) OR spinal) AND anesthesia) OR anaesthesia)) AND postoperative) AND pain) AND laparoscopic) AND surgery
16. PubMed advance search: ((((((((((((local) OR regional) OR epidural) OR spinal) AND anesthesia) OR anaesthesia)) AND postoperative) AND pain)) AND laparoscopy. The search strategies for MEDLINE, Embase, and Cochrane were similar.

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