Review Article

Impact of spinal anaesthesia vs. general anaesthesia on peri-operative outcome in lumbar spine surgery: a systematic review and meta-analysis of randomised, controlled trials

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Summary

Lumbar spinal surgery is most commonly performed under general anaesthesia. However, spinal anaesthesia has also been used. We aimed to systematically review the comparative evidence. We only included randomised, controlled trials in this meta-analysis and calculated the risk ratio or standardised mean difference for haemodynamics, blood loss, surgical time, analgesic requirement, nausea and/or vomiting, and length of hospital stay. Eight studies with a total of 625 patients were included. These were considered to be at high risk of bias. Compared with general anaesthesia, the risk ratio (95% CI) with spinal anaesthesia for intra-operative hypertension was 0.31 (0.15–0.64), $I^2 = 0\%$ ($p = 0.002$); for intra-operative tachycardia 0.51 (0.30–0.84), $I^2 = 0\%$ ($p = 0.009$); for analgesic requirement in the postanaesthesia care unit 0.32 (0.24–0.43), $I^2 = 0\%$ ($p < 0.0001$); and for nausea/vomiting within 24 h postoperatively 0.29 (0.18–0.46), $I^2 = 12\%$ ($p < 0.00001$). The standardised mean difference (95% CI) for hospital stay was −1.15 (−1.98 to −0.31), $I^2 = 89\%$ ($p = 0.007$). There was no evidence of a difference in intra-operative hypotension and bradycardia, blood loss, surgical time, analgesic requirement within 24 h postoperatively, and nausea/vomiting in the postanaesthesia care unit. We conclude that spinal anaesthesia appears to offer advantages over general anaesthesia for lumbar spine surgery.

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Introduction

Spinal anaesthesia and general anaesthesia can be used interchangeably in selected and less extensive lumbar spine operations [1–12]. Each has advantages and disadvantages and may exert distinctive effects on peri-operative outcome [13]. Potential advantages of spinal anaesthesia include no airway instrumentation, profound analgesia, stable haemodynamics, less surgical blood loss and thus improved operating conditions; however, reported disadvantages include intra-operative anxiety, cough, hiccups and movement [1–4, 6–11]. In contrast, general anaesthesia renders the

patient motionless throughout the procedure and provides a secure airway, although it may lead to haemodynamic instability and greater intra-operative blood loss, analgesic requirements and postoperative nausea and vomiting [1–4, 7, 8, 10, 11]. Although the impact of spinal anaesthesia vs. general anaesthesia on peri-operative outcomes in lumbar spine surgery has been previously investigated, the results lack consistency [1–12]. We conducted this meta-analysis based on relevant randomised, controlled trials to specifically compare spinal anaesthesia with general anaesthesia on various peri-operative outcomes in lumbar spine surgery.

Methods

This meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [14]. An ethical review was exempted. A review protocol for this meta-analysis was not registered.

We planned to include randomised, controlled trials that incldued patients between 18 and 60 years old undergoing elective lumbar spine surgery where spinal anaesthesia was compared with general anaesthesia. Studies were included if they reported at least one of the following outcomes: haemodynamics; blood loss; analgesic requirement; nausea and/or vomiting; surgical time; and length of hospital stay. We excluded: observational studies, case reports, technical reports or reviews; studies comparing general anaesthesia with combined spinal/general anaesthesia; studies comparing general anaesthesia with epidural or caudal anaesthesia; duplicate reports of the same study.

We searched the following databases: PubMed (National Library of Medicine, National Center for Biotechnology Information); EMBASE; and the Cochrane Central Register of Controlled Trials. The following search terms were used: 'spinal anaesthesia'; 'general anaesthesia'; 'lumbar spine'; 'surgery'; and 'randomised controlled trial' (see Appendix 1). We also manually checked the reference lists of all relevant papers to identify additional studies that might have been missed by electronic searching. There was no language restriction. The last search was performed on July 1, 2016. Two investigators (TM and ZZ) independently performed the first screening based on title and abstract. The full text was then retrieved for each article of interest. The eligibility of each article was determined based on the inclusion and exclusion criteria. When consensus could not be reached, the senior investigator (LM) was consulted to resolve the disagreement.

The primary outcomes related to intra-operative haemodynamics. Secondary outcomes were blood loss, surgical time, analgesic requirement, nausea/vomiting and length of hospital stay. Haemodynamics were appraised by the incidence of hypertension, hypotension, tachycardia and bradycardia during surgery. Blood loss was calculated as the difference between the volume of suction from the surgical field (plus the weight of wet surgical swabs) and the volume of irrigation used by the surgeon (plus the weight of dry surgical swabs). Surgical time was defined as the duration from skin incision to the application of the surgical dressing. Analgesic requirement was assessed based on whether the patient received analgesics for pain relief after surgery. Nausea and/or vomiting were evaluated based on whether the patient had received anti-emetics after surgery. The length of hospital stay was the number of actual days the patient remained in hospital.

The risk of bias of each individual study was assessed using the Cochrane Collaboration's tool for assessing the risk of bias in randomised trials [15]. This tool addresses the following domains: (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 data outcome (attrition bias); (6) selective reporting (reporting bias); and (7) other bias. Each domain was graded as 'green', 'red' or 'yellow' reflecting a low, high or unclear risk of bias, respectively [15, 16]. A study was rated as having a high risk of bias overall if one or more of the first six domains were classified as having a high risk of bias. We planned to assess publication bias by visual inspection of the funnel plot, with a symmetrical plot indicating the absence of bias and an asymmetrical plot indicating the presence of bias.

The relevant data were extracted from the selected articles and entered into the Cochrane Review Manager (RevMan) programme (RevMan 5.3; Nordic Cochrane Centre, Copenhagen, Denmark). The

meta-analysis was performed using the statistical software within this programme. Risk ratios (RR) with 95% confidence intervals were calculated for dichotomous outcomes. Standardised mean differences (SMD) with 95% confidence intervals were calculated for continuous outcomes. The chi-squared test and I^2 statistic were used to estimate the statistical heterogeneity across the studies. When I^2 was $< 50\%$, low heterogeneity was assumed, and the effect was thought to be due to chance. Conversely, when $I^2 > 50\%$, high heterogeneity was thought to exist. A fixed-effect model was used for pooling, but a random-effects model was adopted if high heterogeneity was evident [17]. A p value < 0.05 was considered to be statistically significant.

Results

The initial search identified 111 publications. After the removal of 23 duplicates, 88 publications remained. After title and abstract screening, 79 publications were excluded according to the selection criteria, with the senior investigator consulted once for one disagreement in the process. One publication was excluded due to unavailability of the full-text article. A total of eight studies were deemed to qualify and were included in the final analysis [8–12, 18–20] (Fig. 1).

All eight included studies were randomised, controlled trials directly comparing the impact of spinal anaesthesia vs. general anaesthesia on peri-operative outcome in patients undergoing lumbar spine surgery. The total number of participants was 625 (313 in the spinal anaesthesia group, 312 in the general anaesthesia group). The sample size of these studies ranged from 56 to 122. Some studies did not specify the distribution of age, sex, weight, height and ASA physical status between the two groups, but simply reported these variables for all patients in the study overall. However, these demographic variables were similar between the spinal and general anaesthesia groups based on the studies that had the distribution reported (Table 1). The types of lumbar spine surgery were single- or double-level discectomy, microdiscectomy or laminectomy with the surgical time typically under 2 h (Table 1).

Randomisation was described adequately in seven studies [8, 10–12, 18–20] and inadequately in one study [9]. Six studies did not report allocation concealment. No study blinded participants and personnel. The blinding of outcome assessment was adequate in one study [12], but unclear in the other studies. Indeed, it was not possible to blind the participants and personnel in these studies as a result of using anaesthetic techniques for grouping. As a result, the included studies in this meta-analysis were at high risk of bias (Fig. 2). We did not evaluate publication bias because a minimum of 10 studies is recommended for the symmetry test using a funnel plot [20].

The spinal anaesthesia group had significantly lower incidences of intra-operative hypertension (4 studies, 328 patients, risk ratio (95% CI) 0.31 (0.15–0.64), $I^2 = 0\%$, $p = 0.002$) (Fig. 3) and tachycardia (5 studies, 428 patients, risk ratio (95% CI) 0.51 (0.30–0.84), $I^2 = 0\%$, $p = 0.009$) (Fig. 4) than the general anaesthesia group. There were no significant differences in the incidences of intra-operative hypotension (5 studies, 428 patients, risk ratio (95% CI) 1.48 (0.75–2.93), $I^2 = 73\%$, $p = 0.26$) (Fig. 5) and bradycardia (5 studies, 428 patients, risk ratio (95% CI) 0.87 (0.57–1.31), $I^2 = 19\%$, $p = 0.50$) (Fig. 6) between the two groups.

There was no significant difference in blood loss between the two groups (5 studies, 434 patients, SMD (95% CI) −1.56 (−3.12 to 0.00), $I^2 = 98\%$, $p = 0.05$). There was also no significant difference in surgical time between the groups (6 studies, 503 patients, SMD (95% CI) = −0.41 (−1.73 to 0.91), $I^2 = 98\%$, $p = 0.54$). However, the length of hospital stay in the spinal anaesthesia group was significantly shorter than in the general anaesthesia group (3 studies, 258 patients, SMD (95% CI) −1.15 (−1.98 to −0.31), $I^2 = 89\%$, $p = 0.007$).

Analgesic requirements in the postanaesthesia care unit were significantly less in the spinal anaesthesia group than in the general anaesthesia group (4 studies, 362 patients, risk ratio (95% CI) 0.32 (0.24–0.43), $I^2 = 0\%$, $p < 0.0001$) (Figure 7). However, there was no significant difference in analgesic requirements within 24 h postoperatively between these two groups (4 studies, 354 patients, risk ratio (95% CI) 0.98 (0.86–1.10), $I^2 = 44\%$, $p = 0.70$).

The spinal anaesthesia group had a significantly lower incidence of nausea and vomiting within 24 h

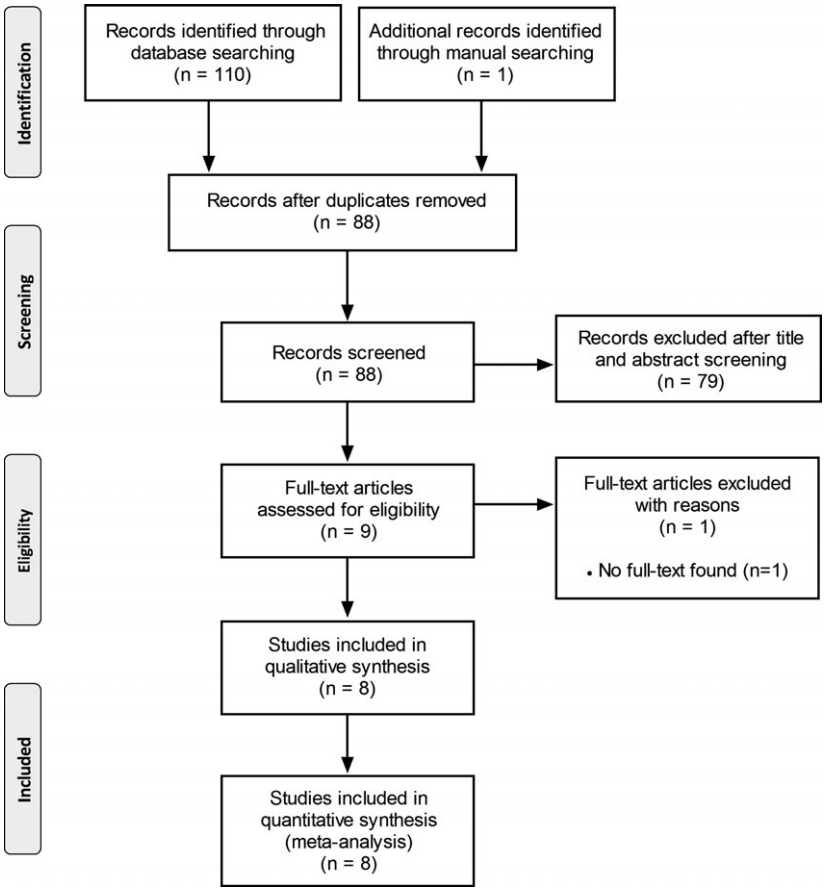

Figure 1 Flow chart showing the study selection process.

postoperatively than the general anaesthesia group (7 studies, 545 patients, risk ratio (95% CI) 0.29 (0.18–0.46), $I^2 = 12\%$, $p < 0.00001$) (Fig. 8). However, the incidence of nausea and vomiting in the postanaesthesia care unit did not significantly differ between the two groups (4 studies, 362 patients, risk ratio (95% CI) 0.94 (0.32-2.76), $I^2 = 67\%$, $p = 0.91$).

Discussion

This meta-analysis showed that the use of spinal anaesthesia for lumbar spine surgery is associated with a lower incidence of intra-operative hypertension and tachycardia, reduced analgesic requirement in the postanaesthesia care unit, less nausea and vomiting within 24 h postoperatively, and a shorter hospital stay compared with general anaesthesia. However, there are no differences between spinal anaesthesia and general anaesthesia with respect to intra-operative hypotension and bradycardia, blood loss, surgical time, analgesic requirement within 24 h postoperatively and nausea/vomiting in the postanaesthesia care unit. The results must be interpreted with caution, however, as all the studies were judged to be at high risk of bias.

General anaesthesia is the most commonly employed technique for spine surgery in the prone position in our practice. The use of regional anaesthesia is not widely accepted because: it might interfere with neurological assessment in the postoperative period; it might conceal a surgical haematoma; the anaesthetist might be blamed for a surgery-related nerve injury; and it cannot be used in lengthy and extensive procedures. However, growing evidence has emerged supporting the use of regional anaesthesia over general anaesthesia in patients undergoing simple, relatively short lumbar spine operations [1–12, 18, 19]. Although this topic has been recently discussed in two narrative reviews [21, 22], there has not yet been a meta-analysis specifically comparing the impact of spinal anaesthesia

Table 1 Characteristics of the randomised, controlled studies included in the meta-analysis.

References	Groups; n	Demographics (SA vs. GA)	Surgery (level)	Spinal anaesthesia	General anaesthesia	Outcomes
Attari et al. [10]	SA (35) GA (37)	Age; years (42 vs. 45) Male (22 vs. 20) Weight; kg (75 vs. 72) Height; cm (161 vs. 158) ASA 1 and 2 (ASA 2, 24 vs. 22)	Discectomy, laminectomy (level unspecified)	Bupivacaine 0.5% (3.0–3.2 ml) and fentanyl 25 μg intrathecally, sedation (propofol low rate infusion)	Induction (propofol + lidocaine + fentanyl), atracurium (for intubation only), maintenance (isoflurane + N_2O 50%)	Total surgical and PACU times, changes in heart rate and blood pressure, EBL, pain and analgesia, PONV, patient and surgeon satisfaction
Dagher et al. [20]	SA (36) GA (33)	Age; years (44 vs. 46) Male (25 vs. 13) Weight; kg (77 vs.76) Height; cm (172 vs. 169) ASA 1–3 (unspecified)	Microdiscectomy (L1)	Bupivacaine 0.5% (3–3.5 ml) intrathecally	Induction (propofol + fentanyl), vecuronium (for intubation only), maintenance (isoflurane + N_2O 70%)	Surgical time, pain and analgesia, urinary retention, PONV, patient and surgeon satisfaction
Jellish et al. [11]	SA (61) GA (61)	Age; years (43 vs. 46) Male (35 vs. 31) Weight; kg (84 vs. 85) Height; cm (173 vs. 170) ASA 1–3 (unspecified)	Laminectomy or disc surgery (L1-2)	Bupivacaine 0.75% (11 mg) intrathecally	Induction (thiopental + fentanyl), vecuronium (for intubation only), maintenance (isoflurane + N_2O 70%)	Total anaesthetic, surgical and PACU times, bradycardia and hypotension (< 80% of baseline values), tachycardia and hypertension (> 120% of baseline values), EBL, pain and analgesia,PONV, urinary retention, LOS
Kahveci et al. [8]	SA (40) GA (40)	Age; years (48 vs. 48) Male (28 vs. 22) Weight; kg (76 vs. 76) Height; cm (unspecified) ASA 1–3 (ASA 2, 21 vs. 18)	Lumbar spinal surgery (L1)	Bupivacaine 0.5% (3 ml) intrathecally, sedation (propofol low rate infusion)	Induction (propofol + fentanyl), atracurium (for intubation and maintenance), maintenance (sevoflurane)	Total anaesthetic, surgical and PACU times, bradycardia (< 50 bpm), tachycardia (> 100 bpm), hypotension (< 75% of baseline value), hypertension (> 125% of baseline value), EBL, surgeon satisfaction, pain and analgesia, PONV, LOS, cost of anaesthesia

(continued)

Table 1 (*continued*)

References	Groups; n	Demographics (SA vs. GA)	Surgery (level)	Spinal anaesthesia	General anaesthesia	Outcomes
Kara et al. [18]	SA (30) GA (30)	Age; years (51 vs. 49) Male (55% vs. 58%) Weight and height unspecified ASA 1-2 (ASA 2, 14 vs. 11)	Discectomy for lumbar disc herniation (L1-2)	Levobupivacaine 0.5% (10 mg) intrathecally	Induction (propofol + fentanyl), rocuronium (for intubation only), maintenance (desflurane + N_2O 60%)	Total anaesthetic, surgical and PACU times, bradycardia and hypotension (< 80% of baseline values), tachycardia and hypertension (> 120% of baseline values), EBL, surgeon satisfaction, pain and analgesia, PONV, ambulation, LOS, urinary retention, headache
Sadrolsadat et al. [12]	SA (50) GA (50)	Age; years (46 vs. 45) Sex unspecified Weight; kg (78 vs. 75) Height unspecified ASA 1-3, not specified within groups)	Laminectomy for lumbar disc herniation (L1-2)	Bupivacaine 0.5% (4 ml) intrathecally, sedation (propofol low rate infusion)	Induction (propofol + fentanyl), atracurium (for intubation and maintenance), maintenance (propofol and alfentanil infusion)	Total anaesthetic, surgical and PACU times, bradycardia and hypotension (< 80% of baseline values), tachycardia and hypertension (> 120% of baseline values), EBL, surgeon satisfaction, pain and analgesia, PONV
Vural et al. [9]	SA (33) GA (33)	Age unspecified Sex unspecified Weight and height unspecified ASA 1 and 2 (unspecified)	Spine surgery for lumbar disc herniation (L1)	Bupivacaine 0.5% (15 mg) intrathecally	Induction (thiopental + fentanyl), rocuronium (for intubation only), maintenance (desflurane + N_2O 50%)	No specification of tachycardia, hypotension, and hypertension, EBL, patient satisfaction, pain and analgesia, PONV, urinary retention, headache, costs
Yildirim Guclu et al. [19]	SA (28) GA (28)	Age, sex, weight and height unspecified ASA 1-2 (unspecified)	Microdiscectomy (L1)	Bupivacaine 0.5% (15 mg) intrathecally	Induction (thiopental + fentanyl), vecuronium (for intubation only), maintenance (desflurane + N_2O 50%)	Hormones, surgical time, heart rate and blood pressure (comparison of absolute values), pain and analgesia, PONV, urinary retention, headache, ambulation, LOS, patient satisfaction

SA, spinal anaesthesia; GA, general anaesthesia; PACU, postanaesthesia care unit; EBL, estimated blood loss; PONV, postoperative nausea and vomiting; LOS, length of hospital stay; bpm, beats per minute. Values for age, weight and height are standard deviation.

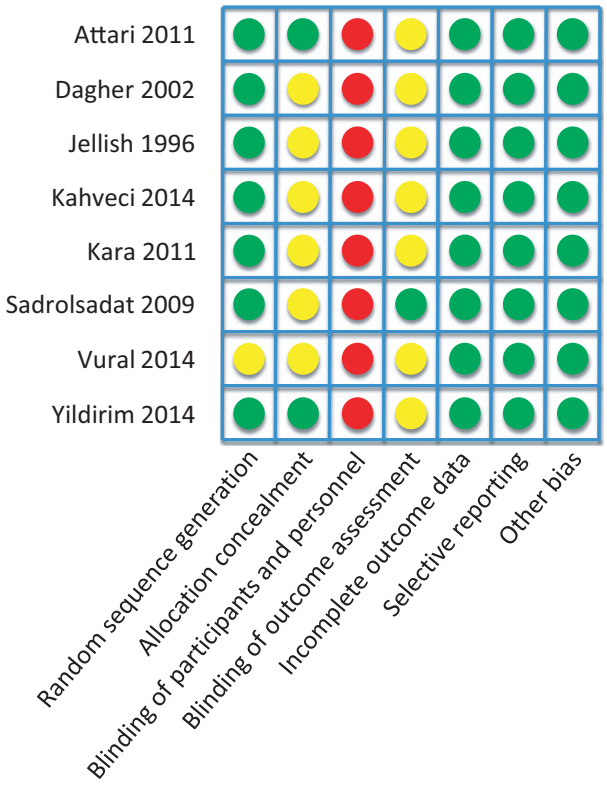

Figure 2 Assessment of the risk of bias of the included studies. The green, red and yellow dots reflect low, high and 'unclear' risk of bias, respectively.

and general anaesthesia on peri-operative outcomes. In addition, these two reviews included only three [21] and five [22] randomised, controlled trials that had specifically compared spinal anaesthesia with general anaesthesia in spine surgery, respectively, and their discussion was not specific to spinal anaesthesia due to the inclusion of epidural anaesthesia [21, 22] and local/regional anaesthesia [22]. Therefore, there was a need to comprehensively and specifically examine the effect of spinal anaesthesia on patient outcome in comparison with general anaesthesia based on a systematic review and meta-analysis.

The finding of a lower incidence of intra-operative hypertension and tachycardia with spinal anaesthesia concurs with previous non-randomised studies [1, 3, 7]. This may be attributable variously to pharmacological sympatholysis [23], profound surgical analgesia [24], reduced stress response [11] and the avoidance of endotracheal instrumentation [6]. In terms of hypotension and bradycardia, a previous retrospective analysis of 803 patients concluded that spinal anaesthesia is associated with milder hypotension and bradycardia than general anaesthesia in elective lumbar spine operations [1]; however, our meta-analysis does not corroborate this finding. The discrepancy may be due to timely intravascular volume repletion and vasopressor administration in the randomised, controlled trials included in this meta-analysis [8, 9, 11, 12, 18], and also the more robust, randomised study design.

This meta-analysis confirmed that spinal anaesthesia is associated with a reduced analgesic requirement in the postanaesthesia care unit. This can be attributed to the effective blockade of nociceptive transmission by spinal anaesthesia and the longer duration required for the sensory block to recede as compared with the motor block [8, 9, 11]. However, this early analgesic benefit does not extend to 24 h in this meta-analysis. The reduced incidence of nausea and vomiting following spinal anaesthesia when compared with general anaesthesia during the period of 24 h postoperatively,

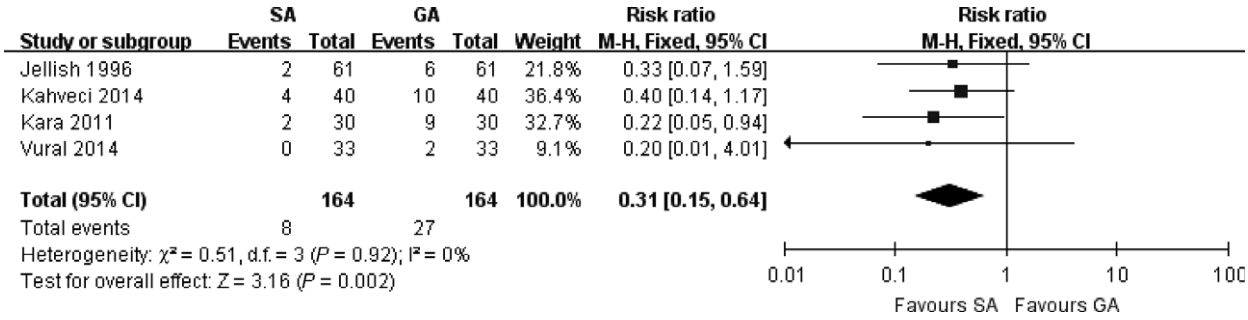

Figure 3 Forest plot showing the risk ratio of intra-operative hypertension. M-H, Mantel–Haenszel; df, degrees of freedom; SA, spinal anaesthesia; GA, general anaesthesia.

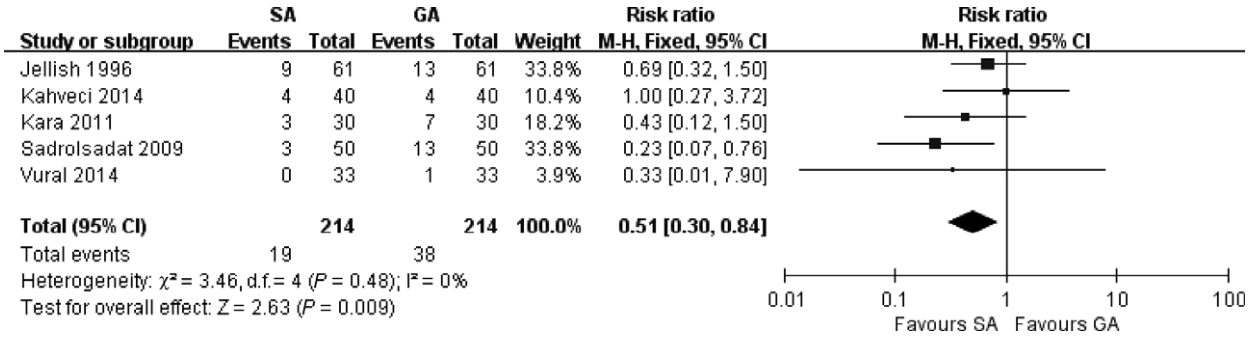

Figure 4 Forest plot showing the risk ratio of intra-operative tachycardia. M-H, Mantel–Haenszel; df, degrees of freedom; SA, spinal anaesthesia; GA, general anaesthesia.

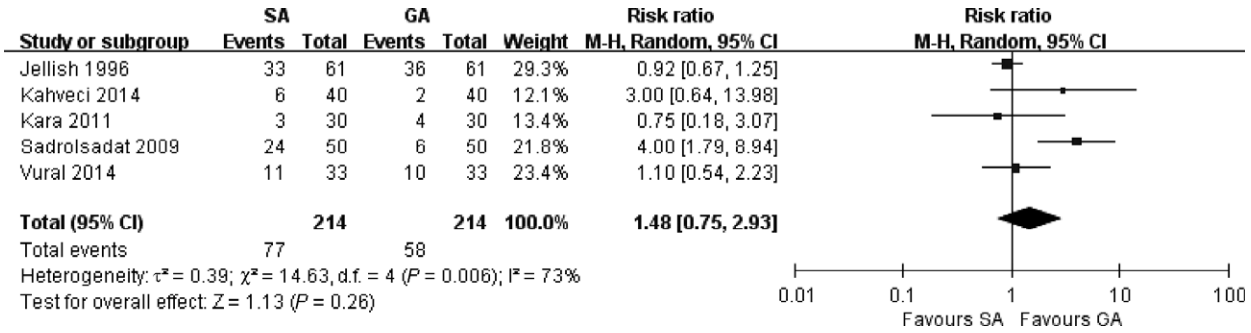

Figure 5 Forest plot showing the risk ratio of intra-operative hypotension. M-H, Mantel–Haenszel; df, degrees of freedom; SA, spinal anaesthesia; GA, general anaesthesia.

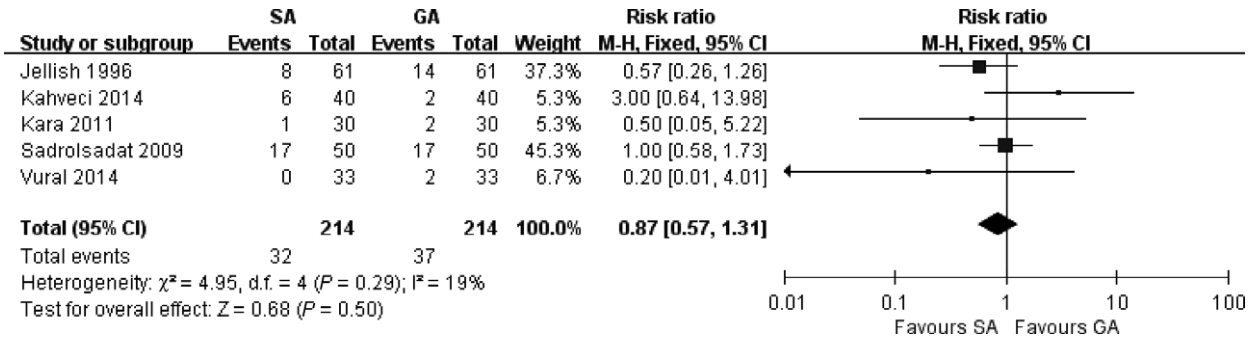

Figure 6 Forest plot showing the risk ratio of intra-operative bradycardia. M-H, Mantel–Haenszel; df, degrees of freedom; SA, spinal anaesthesia; GA, general anaesthesia.

but not in the postanaesthesia care unit, is intriguing. The aetiology of postoperative nausea and vomiting is complex [25]. Variation in anaesthetic maintenance (e.g. volatile vs. intravenous agents) and analgesic protocols (e.g. whether or not opioids are included in the intrathecal injection) among the included studies may have confounded the early incidence of nausea/vomiting, which typically is limited to the period of time in the postanaesthesia care unit. The shorter stay in hospital with spinal anaesthesia may have been influenced by an improved recovery profile, including a lower analgesic requirement and less nausea and vomiting. Finally, the lack of evidence of a difference in blood loss between the spinal and general anaesthesia groups contradicts the belief that spinal anaesthesia is associated with less blood loss. This has been attributed to

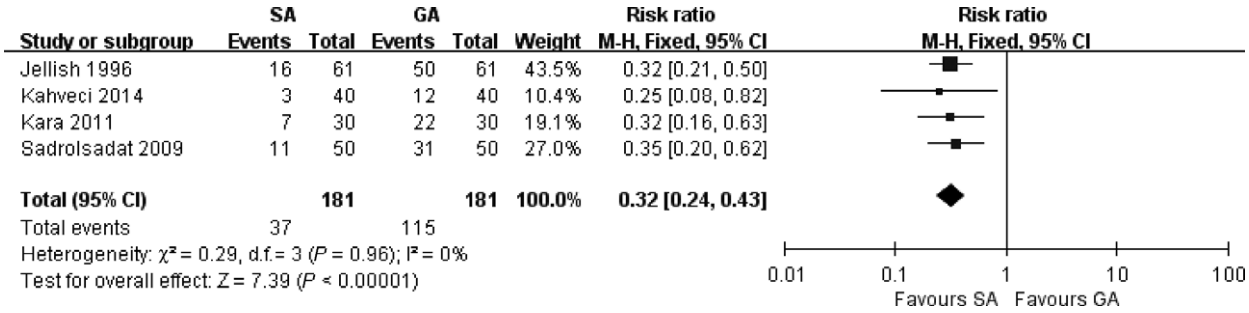

Figure 7 Forest plot showing the risk ratio of the analgesic requirement in the postanaesthesia care unit. M-H, Mantel–Haenszel; df, degrees of freedom; SA, spinal anaesthesia; GA, general anaesthesia.

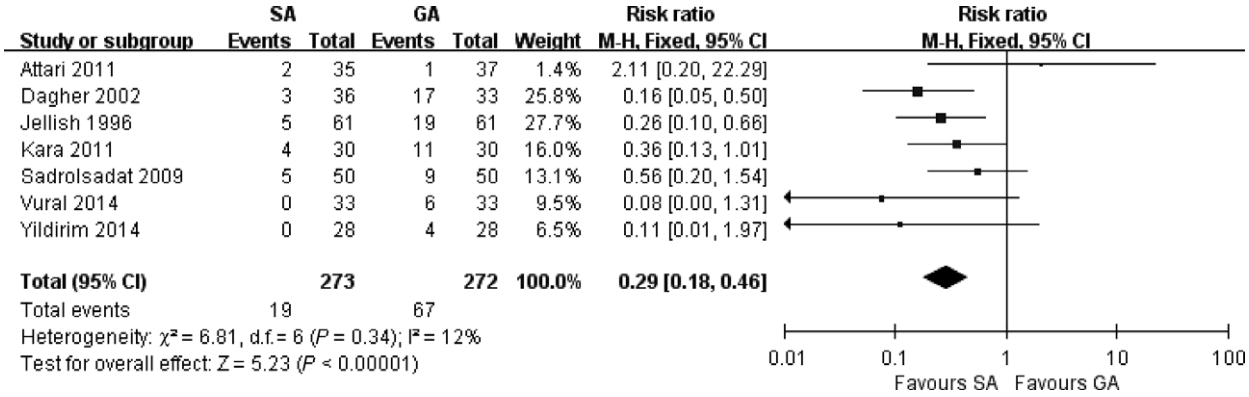

Figure 8 Forest plot showing the risk ratio of nausea and vomiting within 24 h postoperatively. M-H, Mantel–Haenszel; df, degrees of freedom; SA, spinal anaesthesia; GA, general anaesthesia.

fewer episodes of intra-operative hypertension, less venous congestion, facilitated venous drainage secondary to lower intrathoracic pressure in a patient who is spontaneously breathing [10, 11], and the favourable coagulation profile associated with spinal, but not general, anaesthesia [26].

This meta-analysis has several limitations. First of all, the heterogeneity of surgery, anaesthetic protocols and outcome measurements confounds the comparison between different studies, and introducing bias in this meta-analysis. Second, most of the studies did not report how the patients, care providers and outcome assessors were blinded. Nonetheless, we acknowledge that blinding is not always feasible given the fact that both the surgery and anaesthesia in these studies cannot be masked. Third, we excluded one potentially relevant study as we could not obtain the full text [27]; also the number of included studies was too small to allow a meaningful assessment of publication bias. Lastly, the randomised, controlled trials included in this meta-analysis did not assess the outcomes that matter most to patients, including peri-operative complications and the effectiveness of the surgical intervention. Indeed, the small sample size of these studies makes the assessment of these low-chance events improbable.

We conclude that, although the included trials are at high risk of bias, there seems to be evidence that spinal anaesthesia may offer benefits over general anaesthesia in selected lumbar spine operations. Large-scale, well-designed, randomised, controlled trials are warranted to overcome the limitations of these previous studies. In addition, the outcomes that matter the most to patients such as the effectiveness of the surgical intervention should also be taken into account. More detailed reporting of methodology is needed in future studies.

Competing interests

No external funding or competing interests declared.

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Appendix: Search terms used in electronic databases

PubMed

1 "Anesthesia, Spinal"[Mesh]
2 spinal anesthesia[Text Word]
3 #1 OR #2
4 "Anesthesia, General"[Mesh]
5 general anesthesia[Text Word]
6 #4 OR #5
7 "Lumbar Vertebrae"[Mesh]
8 lumbar spine[Text Word]
9 lumbar*[Text Word]
10 #7 OR #8 OR #9
11 "Surgical Procedures, Operative"[Mesh] AND "surgery" [Subheading]
12 surgery[Text Word]
13 #11 OR #12
14 "Randomized Controlled Trials as Topic"[Mesh] AND "Randomized Controlled Trial" [Publication Type]
15 random*[Text Word]
16 #14 OR #15
17 #3 AND #6 AND #10 AND #13 AND #16

Embase

1 exp " spinal anesthesia"/
2 "spinal anesthesia": ab,ti
3 #1 OR #2
4 exp "general anesthesia"/
5 "general anesthesia": ab, ti
6 #4 OR #5
7 exp "lumbar spine"/
8 "lumbar spine":ab, ti
9 "lumbar*": ab, ti
10 10.#7 OR #8 OR #9
11 exp "surgery"/
12 "surgery": ab, ti
13 #11 OR #12
14 exp "randomized controlled trial"/
15 "random*": ab,ti
16 #14 OR #15
17 #3 AND #6 AND #10 AND #13 AND #16

Cochrane Library

1 MeSH descriptor:[Anesthesia, Spinal] explode all trees
2 spinal anesthesia: ti,ab,kw(Word variations have been searched)
3 3.#1 OR #2
4 MeSH descriptor: [Anesthesia, General] explode all trees
5 general anesthesia: ti,ab,kw(Word variations have been searched)
6 6.#4 OR #5
7 7. MeSH descriptor:[Lumbar Vertebrae]explode all trees
8 8. lumbar spine: ti,ab,kw(Word variations have been searched)
9 9. lumbar*: ti,ab,kw
10 10. #7 OR #8 OR #9
11 11. MeSH descriptor: " Surgical Procedures, Operative " explode all trees
12 12. surgery: ti,ab,kw(Word variations have been searched)
13 13. #11 OR #12
14 14. MeSH descriptor: " randomized controlled trial " explode all trees
15 15. random*: ti,ab,kw(Word variations have been searched)
16 16. #14 OR #15
17 17. #3 AND #6 AND #10 AND #13 AND #17

