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Original research article

Perioperative outcome and cost-effectiveness of spinal versus general anesthesia for lumbar spine surgery

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ABSTRACT

Background and aim: General anesthesia (GA) is the most commonly used anesthetic technique for spinal surgery. This study aimed to compare spinal anesthesia (SA) and GA in patients undergoing spinal surgery, in terms of perioperative outcome and cost effectiveness.

Materials and methods: The study included 80 patients with ASA (American Society of Anesthesiologists) physical status I–II. The patients were randomized to receive SA ($n = 40$) or GA ($n = 40$). Heart rate (HR), mean arterial blood pressure (MABP), blood loss, duration of surgery, duration of anesthesia, surgeon satisfaction, and duration in the post-anesthesia care unit (PACU) were recorded. Postoperative analgesic requirement, nausea and vomiting (PONV), perioperative hemodynamic variables, and anesthetic costs were determined.

Results: HR and MABP were significantly higher in the GA group than in the SA group at the end of surgery and at PACU admission. Duration of anesthesia, surgeon satisfaction, postoperative analgesic requirement, and anesthetic costs were significantly higher in the GA group. Mean blood loss was lower in the SA group than in the GA group, but the difference was not significant. Duration of surgery, duration in the PACU, perioperative hemodynamic variables, and complications were similar in both groups.

Conclusions: SA could be considered a reliable alternative to GA in patients undergoing lumber spine surgery, as it is clinically as effective as GA, but more cost effective.

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1. Introduction

Lumbar spine surgery can be performed using spinal anesthesia (SA) or general anesthesia (GA). Although regional anesthesia has some advantages, GA is the most commonly used [1,2]. GA is preferred by anesthesiologists and neurosurgeons because it is widely accepted by patients and facilitates surgery of long duration with patients in the prone position and with a secured airway [3]. In contrast, some surgeons prefer SA for many surgical procedures because it has rapid onset, avoids nerve injury, prevents pressure necrosis, reduces intraoperative blood loss, and decreases the incidence of pulmonary complications [4–6]. Some additional advantages of SA include early discharge from the post-anesthesia care unit (PACU), little pain, and less nausea and vomiting (PONV) [1,2,7].

SA is widely used for the surgical treatment of lower extremity injuries, total joint arthroplasty, and inguinal herniorrhaphy [8–10], but the literature includes only a few reports on the use of SA for lumbar spine surgery [1,2,7,11]. Nonetheless, several studies reported that SA is a more cost-effective alternative to GA [12–14]. As such, the present study aimed to compare SA and GA in patients undergoing spinal surgery, in terms of perioperative outcome and cost effectiveness.

2. Materials and methods

The study protocol was approved by the Ankara Numune Training and Research Hospital Ethics Committee and all the participants provided written informed consent. The study included 80 patients aged ≥18 years with ASA physical status I–II that were scheduled to undergo single-level spinal surgery. The patients were randomized into two groups via computer-generated randomization: SA group ($n = 40$) and GA group ($n = 40$). Exclusion criteria included diabetes mellitus, severe cardiac, hepatic, or renal disease, coagulopathy, localized infection, and a body mass index (BMI) >25 kg m^{-2}. All patients were preoperatively premedicated with midazolam 0.02 mg kg^{-1} IV. Heart rate (HR), noninvasive blood pressure, and peripheral O_2 saturation were monitored. All procedures were performed by the same surgeon and anesthesiologist.

In the GA group anesthesia was induced using fentanyl 2–4 μg kg^{-1} IV and propofol 3–5 mg kg^{-1} IV. All patients underwent endotracheal intubation, which was facilitated via administration of atracurium 0.5 mg kg^{-1} IV. Positive pressure ventilation was initiated and maintained for the duration of surgery with a tidal volume of 8–10 mL kg^{-1} and a ventilatory rate adjusted to maintain an end-tidal PCO_2 of 30–40 mmHg. Anesthesia was maintained with a minimal alveolar concentration of sevoflurane 1.5–2 vol% in 2.0 L of fresh gas flow (FiO_2, 0.4). Atracurium 10 mg IV was administered every 20 min. Hemodynamic functions were maintained within 20% of baseline by adjusting the inspired inhalational agent, supplemental fentanyl injection, and vasoactive drugs, as needed. At the start of skin suturing sevoflurane was discontinued and the fresh gas flow was changed to 6 L min^{-1} of oxygen. Neuromuscular blockade was reversed by administering neostigmine 0.04 mg kg^{-1} IV and atropine 0.02 mg kg^{-1} IV. Patients were extubated when they met the criteria for tracheal extubation (respiratory rate >8, spontaneous breathing with a minimum of 8 mL kg^{-1} of body weight, ability to sustain a 5-s head lift, sustained hand grip, and sustained arm lift).

In the SA group, patients were placed in a seated position, and SA was administered via a single-injection technique using a midline method at the L2–3 or L3–4 interspace and a 26G needle. Following free flow of cerebrospinal fluid, 3 mL of bupivacaine 0.5% (Marcaine® Spinal heavy 0.5%) was injected and the patient was then placed in the prone position. Surgery was initiated after checking the level of block via the pin-prick test every 2 min. Oxygen was administered via nasal cannula at 2 L min^{-1}. During surgery patients in the SA group were sedated with an intravenous propofol infusion titrated at 25–50 μg kg^{-1} min^{-1}. Sedation was maintained at a moderate level, according to ASA classification [15]. Patients under moderate sedation can respond purposefully to verbal commands and can maintain adequate spontaneous ventilation. During surgery the accuracy of the sedation level was evaluated by an observer every 5 min using the Modified Observer's Assessment of Awareness/Sedation (MOAA/S) scale, as follows: MOAA/S score 0: does not respond to deep painful stimulus; 1: does not respond to mild prodding or shaking; 2: responds only after mild prodding or shaking; 3: responds only after loudly and/or repeatedly calling by name; 4: lethargic response to calling by name in a normal tone; 5: responds readily to calling by name in a normal tone (alert); 6: agitated. An MOAA/S score of 3 was maintained via propofol titration.

All patients were discharged from the operating room to the PACU. All procedures were performed by the same neurosurgeon and consequently the effects of confounding variables were avoided. PACU discharge criteria were defined as an Aldrete recovery score >8 and the ability to move the blocked extremity, with pain and nausea under control.

2.1. *Data collection*

Age, gender, BMI, and ASA physical status score were recorded preoperatively. HR and mean arterial blood pressure (MABP) were recorded after initiation of anesthesia, after initiation of surgery, after surgery was completed, and after anesthesia was completed. These parameters were also recorded upon admission to the PACU and before transfer to the hospital ward. Intraoperative blood loss was calculated based on the volume of blood in suction bottles and the weight of bloody gauze. All fluids added to the surgical field were quantified and deducted from the measured volume of blood in suction bottles.

Surgeon satisfaction was considered as the subjective opinion of the surgeon about the anesthesia, in consideration of bleeding, patient movement, muscular relaxation, and view of the surgical area, and was scored using a 100-point visual analog scale (VAS). Duration of anesthesia (time from the patient's entry into the operating room until transfer to the PACU), duration of surgery (time from incision to placement of surgical dressing), and duration in the PACU (total time in the

PACU) were recorded for each patient. Hemodynamic changes, including tachycardia, bradycardia, hypertension, and hypotension, were recorded during surgery and PACU stay. A decrease of 25% or increase of 25% from baseline in MABP was defined as hypotension and hypertension, respectively. HR values >100 bpm and <50 bpm were defined as tachycardia and bradycardia, respectively. The incidence of PONV and postoperative analgesic requirement were recorded in the PACU. The severity of pain and nausea in the PACU were evaluated using a 100-point VAS. Meperidine 25 mg IV and metoclopramide 10 mg IV were given to patients with VAS pain or nausea scores >50 mm. Meperidine was administered every 30 min when necessary.

The cost of anesthesia for each patient, including supplies (spinal needle, local anesthetic, ventilation tubes and bag, filter, syringes, fluids, and oxygen masks), drugs, and gases were recorded from the start of anesthesia to discharge from the PACU. Costs were calculated in Turkish Lira (₺) based on the data obtained from the hospital information management system database (Cozum HBYS v.4.0, Sisoft Company, Ankara, Turkey). The costs associated with monitors and anesthetic machines were not included in the calculated anesthesia costs, nor were physician labor costs, as they are paid a fixed monthly income.

2.2. *Statistical analysis*

The power value was evaluated using the G-power v.3.1 package program. An a priori power analysis based on a previously published study [16] suggested that a minimum of 28 patients in each group was required to detect a ≥30% reduction in anesthesia costs between the SA and GA groups with a power of 95% at the 5% level of significance. Statistical analysis was performed using SPSS v.15.0 for Windows (SPSS, Inc., Chicago, IL, USA). The Kolmogorov–Smirnov test was used to determine the distribution of variables. After testing for normal distribution, data were compared using the unpaired Student's *t*-test and the chi-square test. Nonparametric statistical methods were used to analyze heterogeneous variables. The Mann–Whitney *U* test was used to analyze nonparametric variables. The level of statistical significance was set at $P < 0.05$.

Table 1 – Patient characteristics.

	Group SA (*n* = 40)	Group GA (*n* = 40)	P value
Age (years)	48.10 ± 12.17	47.95 ± 11.6	0.832
Gender (*n*) (M/F)	28/12	22/18	0.248
Weight (kg)	75.75 ± 9.44	76.35 ± 7.72	1.000
ASA (I/II) (*n*)	19/21	22/18	1.000

Values are expressed as number ratio or mean ± SD.
GA: general anesthesia, SA: spinal anesthesia.

3. Results

There were no significant differences in demographic characteristics, baseline HR, or baseline MABP between the two groups (Table 1). Perioperative findings are shown in Table 2; duration of surgery and bleed loss did not differ significantly between the two groups ($P = 0.790$ and $P = 0.652$, respectively). Duration of anesthesia was significantly shorter in the SA group than in the GA group (84.45 ± 22.80 min vs. 102.05 ± 25.59 min, $P < 0.05$). Surgeon satisfaction with surgical conditions was significantly lower in the SA group than in GA group (VAS satisfaction score: 68.5 ± 6.5 vs. 77.0 ± 7.0, $P < 0.001$). Intraoperative bleeding requiring blood transfusion did not occur in either group. The incidence of hemodynamic changes, including hypotension, hypertension, bradycardia, and tachycardia, were similar in both groups during the perioperative period (Tables 2 and 3).

HR values were significantly higher in the GA group than in the SA group at the first minute of surgery ($P = 0.015$), at the end of surgery ($P < 0.001$), at PACU admission ($P < 0.001$), and at discharge from PACU ($P < 0.001$) (Fig. 1). MABP values were significantly higher in the GA group than in the SA group at the end of surgery ($P = 0.04$) and at PACU admission ($P = 0.049$) (Fig. 2). Postsurgical findings are shown in Table 3. Duration in the PACU (19.6 ± 4.6 min in the SA vs. 20.9 ± 5.3 min in the GA, $P = 0.641$) and duration of hospitalization (2.5 ± 0.9 d in the SA vs. 3.1 ± 1.3 d in the GA, $P = 0.155$) were similar in both groups. The percentage of patients with POVN was similar in both groups (15% of the SA vs. 10% of the GA; $P = 1.0$). In all, 12 patients in the GA group requested

Table 2 – Surgery/anesthesia-related intraoperative parameters.

	Group SA (*n* = 40)	Group GA (*n* = 40)	P value
Anesthetic time (min)	84.45 ± 22.51	102.05 ± 25.26	0.006*
Surgical time (min)	70.70 ± 22.2	72.75 ± 25.34	0.588
Amount of bleeding (mL)	126.5 ± 40.0	133.50 ± 37.25	0.521
Intraoperative tachycardia (*n*)	4 (10%)	4 (10%)	1.000
Intraoperative bradycardia (*n*)	6 (15%)	2 (5%)	0.737
Intraoperative hypertension (*n*)	4 (10%)	10 (25%)	0.139
Intraoperative hypotension (*n*)	6 (15%)	2 (5%)	0.737
Satisfaction of the surgeon with anesthesia (100-point VAS)	68.5 ± 6.5	77.0 ± 7.0	<0.001*

Values are expressed as mean ± SD, numbers (*n*), and percentages (%).
GA: general anesthesia, SA: spinal anesthesia, VAS: visual analog scale.
* $P < 0.05$.

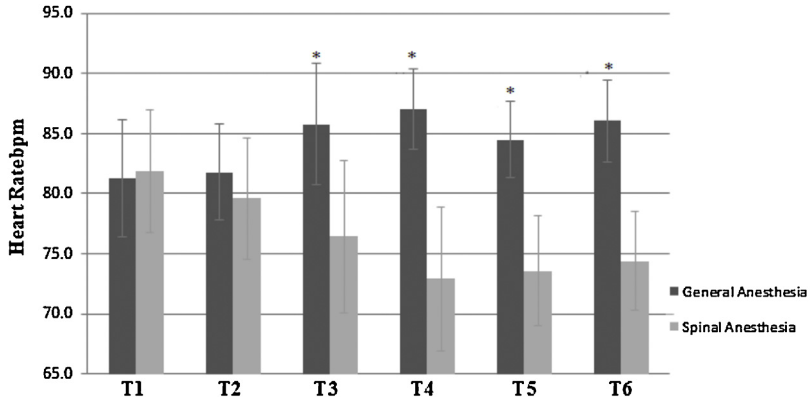

Fig. 1 – Heart rate (HR) levels. Values are presented as mean ± SD. *P < 0.05. Before induction (T1), 1 min after induction (T2), 1 min surgery (T3), end of surgery (T4) admission to the PACU (T5), discharge from the PACU (T6).

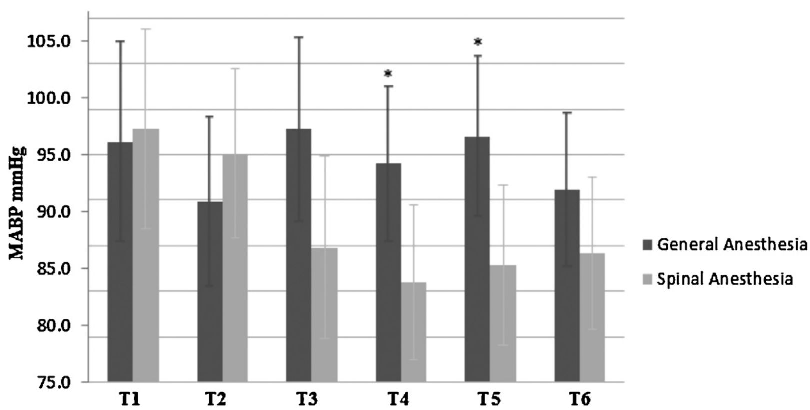

Fig. 2 – Mean arterial blood pressure (MABP) levels. Values are presented as mean ± SD. *P < 0.05. Before induction (T1), 1 min after induction (T2), 1 min surgery (T3), end of surgery (T4) admission to the PACU (T5), discharge from the PACU (T6).

analgesic postoperatively, versus 3 in the SA group ($P < 0.001$). Total meperidine consumption in the PACU was lower in the SA (75 mg) than in the GA (300 mg), the difference was significant ($P < 0.001$). Anesthetic costs were significantly lower in the SA group than in the GA group (22.27 ± 3.74 ₺ vs. 74.35 ± 9.02 ₺, $P < 0.001$).

4. Discussion

The present findings show that SA was associated with shorter duration of anesthesia, a lower incidence of analgesic requirement, and lower anesthesia costs, as compared to

Table 3 – Postoperative parameters.

	Group SA (*n* = 40)	Group GA (*n* = 40)	P value
PACU time (min)	19.55 ± 4.58	20.85 ± 5.20	0.507
Tachycardia (*n*)	2 (5%)	6 (15%)	0.263
Bradycardia (*n*)	2 (5%)	2 (5%)	1.000
Hypertension (*n*)	2 (5%)	8 (20%)	0.087
Hypotension (*n*)	4 (10%)	2 (5%)	0.675
Nausea/vomiting (*n*)	6 (15%)	4 (10%)	0.737
Analgesic requirement in the PACU (*n*)	3 (7.5%)	12 (30%)	<0.001*
Hospital stay (days)	2.50 ± 0.93	3.10 ± 1.24	0.043*
Cost of anesthesia (₺)	22.27 ± 3.74	74.35 ± 9.02	<0.001*

Values are mean ± SD, numbers (*n*), and percentages (%).
GA: general anesthesia, PACU: post anesthesia care unit, SA: spinal anesthesia.
₺ – the Turkish Lira sign.
* $P < 0.05$.

GA. SA or GA can be used for lumber spine surgery; however, only a limited number of randomized, controlled prospective studies have been performed to determine which anesthetic technique is associated with fewer perioperative complications and lower anesthesia costs, and the findings are inconsistent. McLain et al. [7] reported a case controlled analysis of 400 patients that underwent lumbar spine surgery with SA or GA, and showed that SA was effective and safe as GA. They also reported that SA was associated with shorter duration of anesthesia, a lower incidence of nausea and analgesic need, and fewer adverse effects. Conversely, Sadrolsadat et al. [11] reported that GA has advantages over SA, and that GA could decrease the incidence of adverse effects associated with anesthesia. They concluded that additional clinical trials were necessary to confirm their findings.

In the present study the duration of anesthesia was significantly shorter in the SA group than in the GA group. McLain et al. [7] observed that duration of anesthesia was shorter in their SA group than in their GA group. The shorter duration of anesthesia associated with SA is due to a reduction in time required at the end of the surgery for assessing patient responsiveness and respiratory function prior to extubation and transfer to the PACU. Furthermore, less assistance is required for positioning the patients for SA [3,12,13]. We think another advantage of SA and its associated shorter duration of anesthesia is that it facilitates more efficient use of the operating room.

It was reported that SA is associated with less blood loss during lower limb orthopedic and vascular procedures than GA [14]. Jellish et al. [17] confirmed these findings in a prospective randomized trial of SA and GA that included 122 patients undergoing lumbar disc procedures. They associated less intraoperative blood loss in the SA group to lower blood pressure and HR. Conversely, Sadrolsadat et al. [11] did not observe a difference in the volume of intraoperative bleed loss between SA and GA, which is in agreement with the present findings; in the present study there was no significant difference in intraoperative blood loss or duration of surgery between the SA and GA groups. It was suggested that the lower volume of blood loss associated with SA is due to the shorter duration of surgery in patients administered SA. Patients undergoing lumbar spine procedures under SA were hemodynamically more stable than those that received GA [17,18]. At the end of surgery and at PACU admission in the present study HR and MABP were significantly higher in the GA group, and HR values were higher in the group GA at the first min of surgery, at the end of surgery, at PACU admission, and at discharge from PACU. Additionally, there were no differences in hemodynamic changes, such as hypotension, hypertension, bradycardia, and tachycardia, intraoperatively, postoperatively, or during PACU stay between the SA and GA groups, and SA was hemodynamically well tolerated. The present finding that maximum intraoperative MABP and HR changes from basal values were significantly less in the SA group is not unexpected, because SA prevents surgically induced stress to a greater degree than GA [14].

The few studies in the literature that evaluated surgeon satisfaction with anesthesia reported inconsistent findings. Dagher et al. [19] reported that patient and surgeon satisfaction was significantly better in their SA group; however, Sadrolsadat et al.'s [11] findings related to surgeon satisfaction were similar to those observed in the present study. In the present study surgeon satisfaction was lower in the SA group, although there was an adequate level of anesthesia and there was not a significant difference is duration of surgery between the two groups. Surgeon familiarity with GA and patient wakefulness adversely affected surgeon satisfaction in the SA group, which may have also been further affected negatively by the prolonged duration of surgery. Jellish et al. [17] reported that patients in their SA group required longer PACU stays than those in their GA group. In contrast, Sadrolsadat et al. [11] did not observe a difference in the duration PACU stay between patients that received SA and GA. The present study findings confirm Sadrolsadat et al.'s findings. Discharge from PACU in the present study may have been longer in the SA group because patients remained in the PACU until full motor/sensory recovery was observed.

In the present study 12 patients in the GA group requested analgesic post-surgery, versus 3 in the SA group. Sadrolsadat et al. [11] also reported that the incidence of analgesic requirement was higher in patients given GA. Jellish et al. [17] reported that 4-fold more patients given GA for spinal surgery requested postoperative analgesia, as compared to those given SA. Less pain and analgesic requirement in the PACU following SA might be associated with two different mechanisms. There may be a pre-emptive effect in which SA reduces the pain response by inhibiting nociceptive pathways [20,21]. In the present study, both HR and MABP were also more physiologically stable in SA patients during PACU admission. These findings can reflect a lower level of stress and pain in SA patients.

The incidence of POVN was similar in the present study's SA and GA groups. More patients in the GA group requested analgesic than in the SA group and total meperidine consumption in the PACU was higher in the GA than in the SA. In fact, it is expected that the incidence of POVN in the GA group would be higher than in the SA group. Because, nausea is a known side effect of meperidine. In contrast to the present findings, Salman et al. [22] reported that postoperative nausea was more prevalent in the intravenous meperidine group than in the epidural bupivacaine group.

Currently, provision of effective health services at the lowest possible cost is necessary due to widespread budgetary constraints. Several studies have indicated that SA is more cost-effective than GA [16,23,24]. The present findings also show that SA is more cost-effective than GA, which is in agreement with Chakladar et al. [25] who suggested that SA offers savings of £80 per case of hip fracture surgery, as compared to GA. They determined the anesthesia costs by calculating the cost of equipment, drugs, and gas, together with personnel expenses; however, in the present study anesthesia costs were calculated according to the equipment, drugs, and gas costs, with the exclusion of personnel expenses. Nursing and physician labor costs were not included in the present study's analysis because they receive a fixed monthly income. The present study determined that SA was ₺52.1 less expensive per case than GA in patients undergoing spinal surgery. Macario et al. [26] reported that anesthesia costs only account for approximately 6% of total hospital costs. The present study has 1 limitation—the exclusion of nursing and physician labor costs.

5. Conclusion

The present findings show that SA was as effective as GA in patients undergoing spinal surgery. SA reduced both anesthesia costs and analgesic requirement. Based on the present findings, we think SA is a cost-effective alternative to GA for lumber spine surgery.

Conflict of interest

None declared.

Acknowledgement and financial support

None declared.

Ethics

The work described in this article has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans; Uniform Requirements for manuscripts submitted to Biomedical journals.

Authors' contributions

KK, DO, and DG designed the study. CD, SA, and RO collected the data. KK, CD, and RO performed the statistical analysis statistics and interpreted the data. KK, DO, DG, and SA generated the draft of the paper.

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