Spinal Versus General Anesthesia for Orthopedic Surgery: Anesthesia Drug and Supply Costs

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Total hip or knee replacement surgeries are common orthopedic interventions that can be performed with spinal anesthesia (SA) or general anesthesia (GA). No study has investigated the economic aspects associated with the two anesthetic techniques for this common surgery. We randomized 40 patients to receive either SA or GA and analyzed the drug and supply costs for anesthesia und recovery. Anesthesia-related times, hemodynamic variables, and pain scores were also recorded. Total costs per case without personnel costs were almost half in the SA group compared with the GA group; this was a result of less cost for anesthesia ($P < 0.01$) and for recovery ($P < 0.05$). This finding was supported by a sensitivity analysis. There were no relevant differences regarding anesthesia-related times. Patients in the GA group were admitted to the postanesthesia care unit with a higher pain score and needed more analgesics than patients in the SA group (both $P < 0.01$). We conclude that SA is a more cost-effective alternative to GA in patients undergoing hip or knee replacement, as it is associated with lower fixed and variable costs. Moreover, SA seems to be more effective, as patients in the SA group showed lower postoperative pain scores during their stay in the postanesthesia care unit.

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Many surgeries can be performed with spinal anesthesia (SA) or general anesthesia (GA). However, there are only limited and confounding data available regarding costs and anesthesia-related times (1–6).

Hip or knee replacement are common orthopedic surgeries that can be performed using SA or GA without differences regarding mortality or morbidity (7,8). We tested the hypothesis that SA is less expensive and more efficient than GA for total hip or knee replacement. Effectiveness was evaluated by comparing anesthesia-related times and the need for postoperative antiemetics and analgesics. Costs were assessed by recording all supplies, drugs, and gases used in each case excluding personnel costs.

Methods

After obtaining ethical committee approval and written, informed patient consent, patients (ASA physical status I–III) undergoing elective total hip or knee replacement were enrolled in this study. Hip replacement was performed using the transtrochanteric approach; tourniquet in knee replacement was discontinued just before closing of the surgical area. Patients were randomized using the sealed envelope technique to receive either SA or GA. Exclusion criteria were ASA physical status >III, history of allergy to anesthetic drugs, renal or liver disease, history of abuse of alcohol or narcotic substances, diseases of the central nervous system, and severe obstructive or restrictive pulmonary disease. Criteria for early withdrawal from the study were any surgical or anesthetic complication that prevented the assessment of study variables, clinically relevant residual neuromuscular relaxant effect, or any other complication that necessitated prolonged tracheal intubation after surgery.

Patients were premedicated with midazolam and received an infusion of 500 mL Ringer's lactate solution preoperatively. Standard monitoring (electrocardiography, noninvasive arterial blood pressure, and pulse oximetry [OXI]) was established before anesthesia. Arterial blood pressure monitoring was applied if necessary on the discretion of the treating anesthesiologist. Bradycardia (<50 bpm) was treated with glycopyrrolate, and hypotension (systolic arterial blood pressure [SYS], <90 mm Hg or a decrease of more

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than 50 mm Hg from the baseline) was treated with infusion and/or bolus application of etilefrine. Intraoperative and postoperative fluid regimes were at the anesthesiologist's discretion.

GA was induced by fentanyl (2–4 μg/kg IV) and propofol (3–5 mg/kg IV). Orotracheal intubation was facilitated by rocuronium (0.6 mg/kg IV). Positive pressure ventilation was initiated and maintained for the duration of surgery with a tidal volume of 8 to 10 mL/kg and a ventilatory rate adjusted to maintain an end-tidal P_{CO_2} of 30 to 40 mm Hg. Anesthesia was maintained with one minimal alveolar concentration of sevoflurane (age-adjusted, approximately 1.7 Vol%) in 2.0 L fresh gas flow (F_{IO_2}, 0.4). Supplemental doses of fentanyl 1–2 μg/kg IV were given to treat hemodynamic increases of more than 15% above preinduction baseline values. Sevoflurane was discontinued with the beginning of the skin sutures and the fresh gas flow was changed to 6 L/min of oxygen. After performing the control radiograph of the implant the tracheal tube was removed when the patient met the criteria for tracheal extubation (spontaneous breathing with a minimum of 8 mL/kg body weight, respiratory rate >8, ability to sustain a 5-s head lift, sustained hand grip, and sustained arm lift).

SA was performed after skin infiltration with lidocaine 2% (2–3 mL) by a single-injection technique using a midline approach at the L2–3 or L3–4 interspace with a 26-gauge needle with the patient in the sitting position. After free flow of cerebrospinal fluid, 3 mL of bupivacaine 0.5% was injected, and the patient was turned supine. No adjustment in injectate volume was made for patients' height.

Urinary catheterization was performed in each patient immediately after induction of anesthesia. Intraoperatively, each patient received an upper body blanket for warmed air (Bair Hugger; Augustine Inc., Eden Prairie, MN) to maintain normothermia. A cell saver was used intraoperatively in patients undergoing hip replacement surgery.

All patients were discharged from the operating room to the postanesthesia care unit (PACU) for recovery. Postoperative pain was evaluated with a visual analog scale (VAS) from 0 = no pain to 10 = the worst pain imaginable. Postoperative analgesia was standardized with paracetamol 1 g IV and additional boluses of piritramid 3 mg IV to achieve analgesia VAS scores of ≤3. The quality of recovery was assessed using the objective criteria of modified Aldrete scoring recommendations in each patient (9). Each variable, consciousness, activity, respiration, circulation, and oxygen saturation, was scored with numbers of 0, 1, 2, with a maximum achievable score of 10. PACU discharge criteria were defined as reaching modified Aldrete score >8, ability to move the blocked extremity, with pain and nausea under control (VAS <3).

Demographic data (age, sex, height, weight, ASA physical status, number of comorbidities) and the hemodynamic values (heart rate, systolic, diastolic, and mean blood pressures, and OXI) were recorded before the start of anesthesia, at 5, 10, 15, 30, 60, 120 min after start of anesthesia and 5 min before end of anesthesia. In the PACU these values were recorded immediately at the admission and immediately before transfer to the hospital ward. Incidences of postoperative nausea and vomiting (PONV) and postoperative pain significant enough to require pharmacological treatment described above were also recorded in the PACU.

The following four time intervals were recorded: start of anesthesia to skin incision; skin incision to end of surgery; end of surgery to transfer to PACU; and PACU arrival to transfer to normal ward. Total time was defined as the duration from start of anesthesia until transfer to normal ward.

The costs of anesthesia supplies, drugs, and gases used in each case were recorded during the entire procedure from the start of anesthesia to discharge from PACU. Costs, calculated in 2004 Euro values, were constant throughout the 2-mo period of the study. All calculated values refer to the direct expense incurred to the hospital rather than to what a patient would be charged (10). "Supplies" consisted of all used items, including cannulae, tubes, tubing, syringes, needles, spinal needles, fluids, and oxygen masks. "Drugs" consisted of all opened ampoules on condition that one needle and one syringe of the appropriate size were used for each drug and that broken but not completely used drugs were discarded. "Gas" consisted of the costs for sevoflurane which was calculated using the formula published by Enlund et al. (11). Duration and flow rates of oxygen therapy in the PACU were not recorded and calculated as they were similar in both groups; therefore only the costs of the oxygen mask and tubing were included. Costs for urinary catheterization and for warmed air heating were not included as it was performed in each patient. Costs for cell saver supplies and transfusion of packed red blood cells were not analyzed. Costs for swabs, unsterile gloves, disinfection fluid, and soda lime were not included. Capital equipment depreciation was not included as all monitors and anesthetic machines were available to both groups. The costs for nursing, physician reimbursement, maintenance of the center, and additional patient supplies (e.g., linen and catering) were also excluded. "Costs/min Anesthesia" was defined as total drug and supply costs (i.e., costs for anesthesia and recovery) divided through the time of intraoperative anesthesia service in minutes excluding personnel costs. Furthermore, we calculated the fixed and variable costs (10). "Fixed costs" were defined as costs that arise by induction of SA or GA anesthesia (spinal needle, local anesthetic, ventilation tubes and

Table 1. Demographic Characteristics

	GA group (n = 20)	SA group (n = 20)
Weight (kg)	80 ± 15	81 ± 17
Height (cm)	171 ± 7	167 ± 7
Age (yr)	61 ± 10	64 ± 9
ASA I/II/III	2/13/5	3/11/6
Comorbidities	1.5 (1–2)	2.0 (1–2)
Duration of surgery (min)	111.3 ± 36.6	109.0 ± 26.3

Values are mean ± SD or median (range). GA = general anesthesia; SA = spinal anesthesia. There were no significant differences between groups.

Table 2. Cost of Anesthesia Excluding Personnel Costs

	GA group	SA group	P value
Anesthesia			
Supplies	34.5 ± 5.2	27.0 ± 7.5	<0.01
Drugs/Gas	51.5 ± 10.5	16.8 ± 5.9	<0.01
Subtotal	*86.0 ± 10.1*	*43.8 ± 11.0*	*<0.01*
Recovery			
Drugs/Supplies	3.6 ± 0.9	2.6 ± 1.5	<0.05

Values are mean ± SD in Euros. GA = general anesthesia; SA = spinal anesthesia.

bag, filter, tube), whereas "variable costs" were defined as costs that are associated with maintenance of anesthesia or continuous infusion therapy (consumed narcotic gas, infusions, analgesics).

All patients were evaluated in the PACU by anesthetic staff without reference to the present study. Blinding as to patient group was not possible. During the study period, anesthetic, surgical, and nursing staffs did not change. Discharge criteria and nursing standards also remained the same. Costs were calculated by an unblinded anesthesiologist who was not involved in the care of any study patient.

Sample size estimates were based on total anesthesia costs in Euros for providing SA or GA in patients undergoing hip or knee replacement. It was estimated that a sample size of 12 per group would provide 80% power to detect a clinically meaningful difference of 30 Euros (within-group SD, 25 Euros) at $\alpha = 0.05$. The sample size was increased to 20 per group, resulting in a power of 96% and an α of 0.05. After testing for normal distribution, data were compared using the unpaired Student's t-test and the χ^2 test. A P value of <0.05 was considered significant.

Results

Forty patients were enrolled into the study (20 in each group), and both groups were well matched for demographic data (Table 1).

Total costs per case, excluding personnel costs, were 89.6 Euros in the GA group and 46.3 Euros in the SA group ($P < 0.01$). Thereby, costs for anesthesia ($P < 0.01$) and for recovery ($P < 0.05$) were less with SA than with GA. Higher costs for GA were caused by both higher variable and higher fixed costs compared with SA. Accordingly, costs per minute anesthesia were also more expensive with GA ($P < 0.01$). GA resulted in higher variable costs than fixed costs, whereas SA resulted in lower variable costs than fixed costs (Tables 2 and 3).

There were no clinically relevant differences regarding anesthesia-related times between groups. The induction time was shorter in the GA group, this was offset by the increased "end of surgery to transfer time" in the GA group. Time for recovery and total time were similar in both groups (Table 4).

Patients in the GA group were admitted to PACU with a higher pain score and needed more analgesics than patients in the SA group (Table 4). Five patients in each group received antiemetic therapy with ondansetron (Table 4).

We found no difference in the hemodynamic profile between the groups. No anesthesia-related complications, except PONV and hypotension, occurred. No spinal block failed, so data of all patients were analyzed. Residual motor block from SA had no impact, as physical therapy started on the first postoperative day.

We performed one univariate (A) and three multivariate sensitivity analyses (B, C, D) to determine how robust our cost-effectiveness analysis is to changing drug regimes and prices (Table 5). Scenario A was calculated without the use of rocuronium. For scenario B the fresh gas flow was reduced from 2 L/min to 1 L/min. Sevoflurane was exchanged by isoflurane in a 2 L/min fresh gas flow in scenario C. For scenario D the fresh gas flow was again reduced to 1 L/min again using isoflurane. All scenarios were calculated without the use of rocuronium. SA was less expensive than GA in patients undergoing hip or knee replacement in our scenarios (Table 5).

The total costs, age, number of comorbidities, and anesthesia-relevant times in patients undergoing knee replacement were comparable with those of patients undergoing hip replacement (Table 6). Drug and disposable costs are listed in Table 7.

Discussion

GA and SA have proven to be effective anesthetic methods for patients undergoing elective hip or knee replacement. No study has investigated the costs associated with both anesthetic techniques for these common surgeries. We found that elective hip or knee replacement with SA is associated with significantly lower drug and supply costs for intraoperative and postoperative anesthesia service than with GA. Both anesthetic techniques showed comparable times for anesthesia, surgery, and recovery.

Table 3. Management Ratios Excluding Personnel Costs

	GA group	SA group	*P* value
Costs/case	89.6 ± 13.0	46.3 ± 11.0	<0.01
Costs/min anesthesia	0.6 ± 0.1	0.3 ± 0.1	<0.01
Costs variable	46.5 ± 10.8	17.1 ± 6.1	<0.01
Costs variable/min anesthesia	0.3 ± 0.0	0.1 ± 0.0	<0.01
Costs fixed	42.7 ± 4.5	29.4 ± 7.2	<0.01
Costs fixed/min anesthesia	0.3 ± 0.1	0.2 ± 0.1	<0.01

Values are mean ± SD in Euros. GA = general anesthesia; SA = spinal anesthesia.

Table 4. Effectiveness of General and Spinal Anesthesia

	GA group	SA group	*P* value
Anesthesia induction time (min)	10.6 ± 4.9	16.4 ± 5.8	<0.01
End of surgery to transfer (min)	5.2 ± 4.1	0 ± 0	<0.01
Anesthesia time (min)	150.7 ± 41.3	146.3 ± 26.9	NS
PACU time (min)	146.5 ± 37.6	163.8 ± 55.4	NS
Total time (min)	314.0 ± 50.9	330.1 ± 56.5	NS
Pain at admission to PACU (VAS)	4.7 ± 4.0	0.4 ± 1.2	<0.01
Piritramid (mg) in PACU	10.4 ± 5.5	5.5 ± 4.7	<0.01
PONV (%) in PACU	15	10	NS

Nonpercentage values are mean ± SD. PACU = postanesthesia care unit; PONV = postoperative nausea and vomiting; GA = general anesthesia; SA = spinal anesthesia; VAS = visual analog scale.

Table 5. Results of the Sensitivity Analysis for Four Different Scenarios (A–D)

	GA group		SA group		
	Costs/case	Costs/min	Costs/case	Costs/min	*P* value
Observation	89.6 ± 13.0	0.62 ± 0.12	46.3 ± 11.0	0.32 ± 0.07	<0.001/<0.001
Scenario A	84.3 ± 13.0	0.59 ± 0.11	46.3 ± 11.0	0.32 ± 0.07	<0.001/<0.001
Scenario B	68.0 ± 9.8	0.48 ± 0.11	46.3 ± 11.0	0.32 ± 0.07	<0.001/<0.001
Scenario C	59.9 ± 9.1	0.43 ± 0.13	46.3 ± 11.0	0.32 ± 0.07	0.0002/0.006
Scenario D	55.7 ± 8.6	0.40 ± 0.12	46.3 ± 11.0	0.32 ± 0.07	0.006/0.03

Values are mean ± SD in Euros (always exclusively personnel costs). GA = general anesthesia; SA = spinal anesthesia. Costs/case = Costs per case; Costs/min = Costs per minute anesthesia time; Scenario A = without rocuronium in the GA group; Scenario B = 1.0 L/min fresh gas flow without rocuronium; Scenario C = isoflurane instead of sevoflurane without rocuronium; Scenario D = isoflurane in a 1.0 L/min fresh gas flow without rocuronium. *P* values calculated for Costs/case GA versus Costs/case SA, respectively; Costs/min GA versus Costs/min SA.

Table 6. Subgroup Analysis

	GA group		SA group	
	Hip (n = 12)	Knee (n = 8)	Hip (n = 10)	Knee (n = 10)
Age (yr)	61 ± 9	60 ± 11	64 ± 10	64 ± 7
Comorbidities	1.5 (1–2)	1.5 (1–2)	2 (1–2)	2 (1–2)
Total time (min)	304 ± 50	329 ± 49	320 ± 65	341 ± 43
Total costs (Euros)	87 ± 13	93 ± 12	47 ± 11*	45 ± 11*

Values are mean ± SD or median (range).
Total costs in Euros exclude personnel costs.
GA = general anesthesia; SA = spinal anesthesia; Hip = hip replacement therapy (SA: n = 12; GA: n = 10); Knee = knee replacement therapy (SA: n = 8; GA: n = 10).
* P < 0.001 hip SA versus hip GA and knee SA versus knee GA.

Although the actual costs for drugs and supplies may vary considerably among hospitals, the price structure is comparable worldwide (Table 7). Nevertheless, we performed a sensitivity analysis including one univariate and three multivariate analyses to test the stability of our results to major changes in drug costs or drug regimes. Even major changes, such as change from sevoflurane to isoflurane, induction without muscle relaxants, or reduction of fresh gas flow from 2.0 to 1.0 L/min, did not change our main

Table 7. Drug and Disposable Costs

Drugs	EUR	Disposables	EUR
Bupivacaine 0.5% 5 mL	0.94	Gloves sterile	0.18
Fentanyl 0.5 mg/10 mL	0.51	Laryngeal mask *	5.70
Isoflurane 100 mL*	14.53	Oxygen mask	0.47
Midazolam 5 mg/5 mL	0.20	Spinal needle 26-gauge with introducer	5.22
Piritramide 15 mg	0.63	Suction tube	0.11
Propofol 200 mg/20 mL	1.31	Tube	4.40
Rocuronium 50 mg/5 mL	5.25	Ventilation tubes and bag	10.15
Sevoflurane 250 mL	140.99		
Xylocaine 2% 5 mL	0.42		

Costs for drugs and disposables in Euros including dilution if necessary; * for the calculation of the Sensitivity analyses only

result that SA is less expensive than GA in patients undergoing hip or knee replacement.

Our finding that SA is more cost-effective than GA supports the findings of Lennox et al. (4) in outpatient gynecological laparoscopy and is in contrast to other studies that reported less or comparable cost for GA compared with SA for knee and laparoscopic surgery in outpatients (2,3). The main difference between these reports and ours is the longer anesthesia time in our study. Schuster et al. (6) underlined that cost comparisons of anesthesia techniques largely depend on the surgical duration of the cases studied. In a retrospective chart analysis in patients undergoing various surgical procedures and anesthetic drug regimes they found that SA offers a cost advantage over GA. We found lower variable and fixed costs in the SA group than in the GA group; thus the economic advantage of SA increases with increasing case duration. As a further consequence, there is no intraoperative breakeven point where SA becomes more cost intensive than GA.

Intraoperative anesthesia costs only account for approximately 6% of total hospital costs (12). However, presuming that 1000 patients receive SA instead of GA, this would result in a saving of 43,300 Euros, which is approximately the annual salary of an anesthesia resident in Austria.

Although personnel costs are a major factor in health economic studies, we have knowingly neglected this important cost category for two reasons (13).

First, our investigation could not detect any differences regarding the anesthesia relevant times. Times for anesthesia, surgery, and recovery were comparable between both groups. The induction time was shorter in the GA group compared with the SA group (10.6 minutes versus 16.4 minutes; $P < 0.01$); however, this advantage was offset by the faster "end of surgery to transfer" times in the SA group.

Second, staffing of our PACU is not dependent on the number of patients and is therefore fixed. Thus, a reduction in length of stay in PACU is not associated with decreased personnel costs. In our study PACU times were comparable between groups. In other studies comparing SA and GA, PACU times vary considerably, depending on the length of surgery and discharge criteria used (3–5,14,15). We used the modified Aldrete score with further modifications such as the ability to move the blocked extremity, nausea under control, and a VAS score of ≤3. In our institution, it is standard that patients are not transferred to normal ward from PACU until they can move blocked extremities. However, eligibility for PACU bypass is under discussion, and the recovery from nerve blockade may not be a criterion for discharge from PACU in the future (15). Each patient had a urinary catheter for hygienic reasons in the early postoperative period; therefore, ability to void could not be assessed. It remains unclear whether different transfer regimes concerning these two facts (residual nerve blockade, ability to void) would have influenced PACU times in the SA group.

In addition to the decreased costs in the SA group, VAS scores at admission to PACU were less with SA than with GA, and the need for analgesics for postoperative pain therapy in the PACU was also less.

Economic considerations should not influence a physician unless both methods offer a comparable medical outcome. Both methods, SA and GA, have proven to show comparable morbidity and mortality risks (7,8). Cost analyses must always be read with caution, as cost structure might differ among hospitals. We attempted to reduce the impact of this problem by performing a sensitivity analysis, which proves the robustness of our finding. Nevertheless, an analysis of the individual cost structure is necessary to apply the results of the current study. Another limitation of our study is that patient preferences were neglected.

We conclude that SA is associated with less fixed and variable costs and lower postoperative pain scores during the stay in the PACU. Therefore, SA is a more cost-effective alternative to GA in the immediate postoperative period for patients undergoing hip or knee replacement. This finding is in contrast to a number of studies performed in outpatients. Further studies are necessary to determine cost-effectiveness of SA for different indications, durations of surgery, and patient collectives. The literature concerning this important issue is conflicting.

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