

SYSTEMATIC REVIEW

Perioperative costs of local or regional anesthesia *versus* general anesthesia in the outpatient setting: a systematic review of recent literature



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Abstract

Background and objectives: In this systematic review, we carried out an assessment of perioperative costs of local or regional anesthesia *versus* general anesthesia in the ambulatory setting.

Methods: A systematic literature search was conducted to find relevant data on costs and cost-effectiveness analyses of anesthesia regimens in outpatients, regardless of the medical procedure they underwent. The hypothesis was that local or regional anesthesia has a lower economic impact on hospital costs in the outpatient setting. The primary outcome was the average total cost of anesthesia calculated on perioperative costs (drugs, staff, resources used). **Results:** One-thousand-six-hundred-ninety-eight records were retrieved, and 28 articles including 27,581 patients were selected after reviewing the articles. Data on the average total costs of anesthesia and other secondary outcomes (anesthesia time, recovery time, time to home readiness, hospital stay time, complications) were retrieved. Taken together, these findings indicated that local or regional anesthesia is associated with lower average total hospital costs than general anesthesia when performed in the ambulatory setting. Reductions in operating room time and postanesthesia recovery time and a lower hospital stay time may account for this result.

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Conclusions: Despite the limitations of this systematic review, mainly the heterogeneity of the studies and the lack of cost-effectiveness analysis, the economic impact of the anesthesia regimes on healthcare costs appears to be relevant and should be further evaluated.

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Introduction

In recent decades, industrialized countries have witnessed a significant increase in medical care costs.¹ In the current times of resource constraints, the financial sustainability of healthcare systems has become of paramount importance. This increased the relevance of economic criteria in decision-making processes, thus fostering the diffusion of economic evaluations in healthcare.

With regard to surgery, the majority of overall costs are represented by fixed costs and are highly dependent on hospitalization and the length of stay.² Incentives toward a leaner and cheaper perioperative process have led to a continuous increase in ambulatory surgery over recent years.³ However, the assumption that ambulatory surgery is always cheaper than inpatient surgery is not always true: the outpatient perioperative process should be well conceived and optimized to minimize its own fixed costs, as inefficiencies are multiplied by a high turnover.⁴

The main factors affecting ambulatory surgery process fixed costs are the operating room time, the occupancy of the postoperative care unit and the time to discharge. Indeed, the cost-effectiveness of the outpatient perioperative process depends on its ability to optimize these most labor-intensive and resource-consuming phases.⁵

Regional anesthesia has been increasingly employed in the outpatient setting, given its unique characteristics of selectivity and efficacy in the control of acute postoperative pain. Outpatient regional anesthesia economic externalities have been investigated by some studies, which have associated its systematic adoption with a decrease in anesthesia-controlled operating room time and thus in the operating room fixed costs, potentially translating into a significant increase in patient turnover and ultimately hospital revenues.^{5,6} Moreover, regional anesthesia is associated with a very high postoperative care unit bypass rate and with a lower incidence of postoperative anesthesia-related side effects, such as nausea and vomiting, excessive sedation and dizziness, which, in the ambulatory setting, may significantly prolong the day-hospital length of stay, jeopardize the meeting of discharge criteria or even cause unscheduled hospital readmissions.^{5,6}

On the other hand, the recent evolution of general anesthesia techniques has led some to challenge a supposed superiority of regional anesthesia techniques in the outpatient setting with regard to their safety and side-effect profile. The extensive use of laryngeal masks and anesthetic drugs with a more favorable pharmacokinetic profile has actually led to a reduction in the incidence of postoperative complications, an increase in the postanesthesia care unit (PACU) bypass rate and a potential reduction in

the average anesthesia-controlled operating room time.⁷ If, following these recent developments, a difference in cost-effectiveness between the two anesthesia regimens still persists, it is not clear.

Despite the importance of the topic for the future development of our profession, in a context where ambulatory surgery is continuously growing and has been estimated to account for the vast majority of all surgical procedures in the near future,¹ a systematic review of all the contrasting evidence on this theme is still lacking.

The aim of this work is to provide a systematic review of the recent literature to test the hypothesis that the use of local or regional anesthesia is associated with significantly lower average total hospital costs than general anesthesia when applied in the ambulatory setting.

Methods

Search strategy

A literature search of the electronic PubMed/MEDLINE, Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science, and Google Scholar databases was carried out to find relevant data on the costs or cost-effectiveness of general and local or regional anesthesia performed in an ambulatory setting. The primary outcome was the average total cost of anesthesia. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were applied in carrying out this systematic review.⁸

The search algorithm was based on the clinicoeconomic question coded into the PICO framework and constructed combining a set of terms referring to outpatient setting (Patient), regional anesthesia (Intervention), general anesthesia (Comparator), cost or cost-effectiveness analysis (Outcome). To formulate the best query for the literature search, many attempts were made to be sure to include all terms relevant for our clinico-economic question. The final search query was ((outpatient*) OR (out-patient*) OR (ambulatory) OR (day-surgery) OR (day surgery) OR (day-case) OR (day case)) AND ((anaesthesia) OR (anesthesia) OR (anaesthetic*) OR (anesthetic*)) AND (general) AND ((block*) OR (local) OR (regional) OR (loco-regional) OR (locoregional) OR (nerve) OR (spinal) OR (epidural)) AND ((cost-effective) OR (cost*) OR (cost-efficacy) OR (cost-effectiveness) OR (cost-utility) OR (economic*)).

The last literature search was performed on 10th May 2021 in all databases. No specific study design was defined. Search was without language restriction. Reference lists of the retrieved articles were also screened for additional data.

Eligibility criteria

Studies were included in the systematic review when they met each of the following inclusion criteria: a) original article published in peer-reviewed journal; b) the study includes adults only; c) the study compares regional and general anesthesia in outpatient setting; d) the study reports data on cost or cost-effectiveness analysis. Anesthesia was considered general anesthesia whenever loss of consciousness was achieved, and arousal was not achievable at verbal command. With regional anesthesia was meant any technique aimed at achieving a reversible loss of sensation of a limb or a body area through the administration of a local anesthetic in close proximity of a peripheral nerve, a plexus or the spinal nerve roots or the spinal cord. Local anesthesia was considered a reversible loss of sensation of a body wall area achieved through the infiltration of a local anesthetic directly into tissues. An outpatient setting was defined as a surgery or medical treatment for which the patient was discharged the same day (less than 24 hours) regardless of whether it required or not to occupy a hospital bed. The average total cost of anesthesia per case encompassed the perioperative costs of drugs, staff labor and resources used. Readmissions and complications were excluded from the cost calculation.

The exclusion criteria were a) articles not within the field of interest of this review (for example, medical procedures not in ambulatory setting); b) review articles, letters, or editorials; c) case reports or case series (less than 10 patients included); and d) articles published prior to 2000 to restrict the search to the recent literature to retrieve updated costs.

Study selection

Titles and abstracts of the retrieved records were independently reviewed by three researchers (MP, GT, FM) applying the inclusion and exclusion criteria mentioned above. Full texts of the selected articles were retrieved and read to determine their eligibility for inclusion. Any disagreement between authors was resolved by discussion.

Quality assessment

The quality of the studies included in the systematic review was critically assessed using the Consensus on Health Economic Criteria (CHEC) list.⁹ The assessment tool had 19 indicators, and each indicator was assessed for every study using yes or no depending on whether the required information was reported. The quality assessment was performed by two independent authors; any disagreement between the authors was resolved in a consensus meeting.

Data extraction and analysis

For each included study, two authors (MP, FM) extracted information concerning basic data (authors, year of publication, country of origin, type of study, medical procedure, number of patients, mean age, gender), methods (type of anesthesia, anesthetic drug), and outcomes (average total costs and main findings regarding the cost analysis).

Another author checked all extracted data independently (GT). During data extraction from the selected studies, the following secondary outcomes were judged interesting for the topic and were also included: anesthesia time, recovery time, time to home readiness, hospital stay time, and complications.

All currencies of the included studies were converted to United States dollars (USD) according to CCEMG – EPPI-Centre Cost Converter v.1.6 (last update: 29th March 2021, <http://eppi.ioe.ac.uk/costconversion/default.aspx>).

Results

Literature search

The literature search from the PubMed/MEDLINE, Cochrane CENTRAL, Web of Science, and Google Scholar databases yielded a total of 1,698 records. After reviewing titles and abstracts and excluding those published prior to 2000 and not related to the clinicoeconomic question, 91 articles were selected. The full text was retrieved for all. Following the eligibility assessment, 63 articles did not meet the inclusion criteria and were excluded from the systematic review. Of these, 23 were excluded because not in the outpatient setting, 17 were reviews, surveys, or abstracts, 16 did not include data on costs, 6 reported sparse data on different anesthesia types and medical procedures and 1 article was a case report. Manual searches of the reference lists of the selected articles did not yield any additional records. Finally, 28 studies including 27,581 patients were identified as potentially relevant and were selected for the systematic review.^{10–37} All of the included studies were published in English. These studies covered the period from January 2000 to May 2021. Search results and article selection are displayed in a PRISMA flow chart (Fig. 1).

Selected studies

The characteristics of the selected studies are reported in Table 1. They were conducted in various countries across the world (Europe, North America, Oceania, Africa). The sample size of the included studies ranged from 20 to 14,713 adults who underwent various medical procedures under general and local or regional anesthesia in an outpatient setting. General anesthesia was compared to local anesthesia in 15 studies,^{10,13,14,16–24,27,30,33} to spinal anesthesia in 7 studies,^{12,15,25,31,32,34,35} and to both in 5 studies.^{26,28,29,36,37} Medical procedures were different and included laryngoplasty, knee arthroscopy, biopsy, hernia repair, hysteroscopy, and others. Studies were included irrespective of the induction method of anesthesia (inhalation, infusion, topical). Regional anesthetic techniques encompassed axillary brachial plexus block,³³ ilioinguinal-hypogastric³⁷ or paracervical¹⁸ or peripheral²⁴ or sciatic-femoral^{23,28,30} nerve block, and epidural²⁶ or spinal^{15,25,28,29,31,32,34–37} or intravenous regional³³ anesthesia. Thirteen studies were randomized controlled trials,^{12,22,23,25,26,28–32,34,36,37} 2 of which were double-blinded,^{23,25} and 15 were observational with a prospective^{16,27,33} or a retrospective^{10,11,13–15,17–21,24,35} design. The overall quality of the included studies was assessed with the CHEC list (Appendix A). None of the stud-

Table 1 Included studies comparing costs of general and local or regional anesthesia regimen for different outpatient medical procedures in an outpatient setting.

Authors	Year	Country	Study design	Medical procedure	Number of patients evaluated	Mean age (years)	% Male
Li et al. ¹⁰	2020	USA	Retrospective, observational	Anterior shoulder stabilization surgery	7,103	NR	69.4
Bokshan et al. ¹¹	2019	USA	Retrospective analysis	Anterior Cruciate Ligament Reconstruction	14,713	<20 years: 30.4% 20–29 years: 27.6% 30–39 years: 19.1% >40 years: 22.9%	59.3
Gebhardt et al. ^[12]	2018	Germany	Prospective, RCT	Knee arthroscopy	50	48.5	64
Hamilton et al. ¹³	2018	Canada	Retrospective cohort study	Shoulder surgery	1,623	50.5	66.7
Chandran et al. ^{14, a}	2018	Australia	Retrospective, observational	Injection laryngoplasty	20	63.08	70
Camponovo et al. ¹⁵	2014	Switzerland	Retrospective, observational	Knee arthroscopy	56	50	55.3
Penketh et al. ^{16, b}	2014	Canada	Prospective, ^c comparative, observational	Hysteroscopy	118 ^d	56.7 ^d	–
Sivalingam et al. ¹⁷	2013	USA	Retrospective, observational	Ureteral stent placement for obstructing stones	119	53.11	44.54
Ahonkallio et al. ^{18, e}	2012	Finland	Retrospective, observational	Endometrial thermal ablation with Novasure	36	NR	–
Covarelli et al. ^{19, a}	2012	Italy	Retrospective, observational	Sentinel lymphnodes biopsy	153	50	52
Stoffels, et al. ²⁰	2011	Germany	Retrospective, observational	Sentinel lymphnodes excision	300	57.7	60.7
Mitchell et al. ^{21, a}	2011	UK	Retrospective, observational	Sacral nerve stimulation	111	56.68	3.33
Kushawaha et al. ²²	2008	United Kingdom	Prospective, RCT	Open hemorrhoidectomy	41	52.68	60.97
Mostafa et al. ²³	2008	Egypt	Prospective, Double, blind, RCT	Knee arthroscopy	60	48.33	41.67
Horn et al. ^{24, a}	2007	USA	Retrospective, observational	Upper extremity surgical procedures	213	41.59	55.39

Table 1 (Continued)

Authors	Year	Country	Study design	Medical procedure	Number of patients evaluated	Mean age (years)	% Male
Nishikawa et al. ²⁵	2007	Japan	Prospective,	Prostate biopsy	80	72	-
Nordin et al. ^{26, a}	2007	Sweden	Double, blind, RCT Prospective, multicenter	Inguinal hernia repair	616	56	98
Spanknebel et al. ²⁷	2006	USA	RCT Prospective, observational	Thyroidectomy	1,194	49.57	41.09
Casati et al. ²⁸	2004	Italy	Prospective, RCT	Knee arthroscopy	120	43.5	54.2
Forssblad et al. ²⁹	2004	Sweden	Prospective,	Knee arthroscopy	343	NR	NR
Casati et al. ³⁰	2002	Italy	RCT Prospective, RCT	Knee arthroscopy	40	48.5	60
Danelli et al. ³¹	2002	Italy	Prospective,	Hysteroscopic ablation of endometrial neoplasm	40	52.50	-
Lennox et al. ³²	2002	Canada	RCT Prospective,	Gynecological laparoscopy	20	34.5	-
Chan et al. ³³	2001	Canada	RCT Prospective, observational	Hand surgery	126	39.67	62.7
Martikainen et al. ³⁴	2001	Finland	Prospective,	Knee arthroscopy	60	40.3	55
Chilvers et al. ³⁵	2000	Canada	RCT Retrospective, comparative	Gynecological laparoscopic sterilisation	52	34.46	-
Li et al. ³⁶	2000	USA	Prospective, RCT	Anorectal surgery	93	41.33	72.04
Song et al. ³⁷	2000	USA	Prospective, RCT	Unilateral inguinal herniorrhaphy	81	39	86.42

NR, not reported; RCT, randomized controlled trial.

^a Day-case setting.

^b Day-case setting in the operating room for general and local anesthesia, outpatient setting for local anesthesia.

^c Cost analysis is retrospective.

^d Refers only to group of patients underwent local anesthesia in outpatient setting.

^e Day-case setting for general anesthesia and outpatient setting for paracervical block.

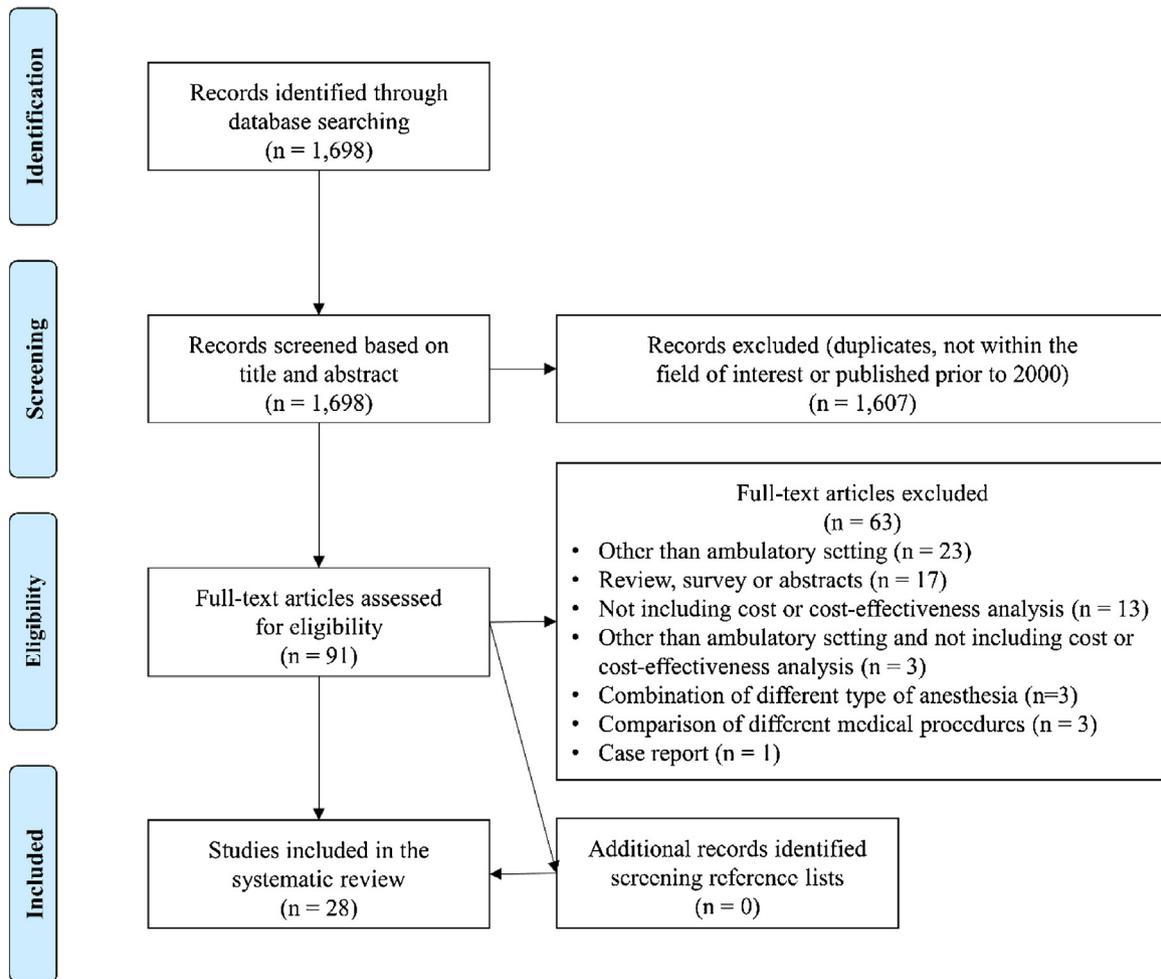


Figure 1 PRISMA flow chart of the retrieved, excluded and analyzed studies.

ies satisfied at least 80% of the CHEC list criteria, and 11 studies met less than 50% of the criteria. Thus, overall, the methodological quality was judged to be moderate.

Cost analysis

The main findings of the cost analysis are summarized in [Table 2](#). The average total cost of anesthesia per case encompassed the perioperative costs of drugs, staff labor and resources used, except four studies that also included the cost of room management.^{19,22} Readmissions and complications were excluded from the cost calculation. Ten studies^{10,11,14,16–18,21,24,26,27} not reporting the average total costs of anesthesia were also included, as they compared the average total costs of the entire medical procedure on the basis of the costs of the anesthetic regimen used. None of the selected studies reported data on cost-effectiveness analysis. Regardless of the medical procedure, the total costs were significantly higher for general anesthesia than local^{14,16,17,19–22,27} or regional^{11,12,15,18,24,25,28,32–34,37} anesthetic techniques in almost all included studies, other than five studies that reported no statistically significant difference between loco-regional and general anesthesia.^{13,23,30,31,35} Only one study

reported higher costs in patients who received the loco-regional anesthesia.¹⁰ Furthermore, three studies comparing all three types of anesthesia^{26,29,36} confirmed the lowest costs for medical procedures under local anesthesia and similar costs between general and spinal or epidural anesthesia,^{26,29} except one showing higher costs under general anesthesia.³⁶ Major cost savings for medical procedures under local anesthesia were reported for ureteral stent placement (74%),¹⁷ hysteroscopic resection (67% if performed in the office and 50% in the operating room),¹⁶ and anorectal surgery under local anesthesia with sedation (52%)³⁶; this last study also included a group undergoing anorectal surgery under spinal anesthesia, for which cost savings of only 18% were reported with respect to general anesthesia. Thus, anorectal surgery under local anesthesia was associated with the lowest costs, mainly due to the ability of patients to bypass phase 1 recovery units.³⁶ Cost savings of nearly 40% were reported for injection laryngoplasty under local anesthesia,¹⁴ knee arthroscopy under spinal anesthesia^{12,15} and endometrial thermal ablation under paracervical nerve block¹⁸ compared to general anesthesia. Significant cost savings in respect to general anesthesia were also reported in anterior cruciate ligament reconstruction¹¹ under loco-regional anesthesia and in sentinel lymphnodes biopsy/excision under

Table 2 Main findings of the selected studies about cost analysis and secondary outcomes.

Authors	General anesthesia			Local/Regional anesthesia			Outcomes			
	Anesthetic	No. of patients	Average total costs (USD)	Type	Anesthetic	No. of patients	Average total costs (USD)	Main findings about cost analysis (primary outcome))	Other study findings (secondary outcomes)	Resources included for the calculation of costs
Li et al. ¹⁰	NR	3,903	15,670	Loco-regional anesthesia	NR	1,576	19,929	Average total costs were significantly higher in patients undergoing regional anesthesia.	Several other contributors to higher costs are described.	Medical procedure costs
Bokshan et al. ¹¹	NR	3,737	19,249	Loco-regional anesthesia	NR	10,976	17,469	Average total costs were significantly lower in patients undergoing regional anesthesia.	General anesthesia, Hispanic ethnicity, Chronic medical condition, male gender, operative time and age are predictors of increased costs.	Medical procedure costs
Gebhardt et al. ¹²	Sulfentanil and Propofol	25	71.92	SA	Chloroprocaine 1%	25	41.02	Anesthesia costs are inferior in case of regional anesthesia.	Spinal had faster recovery with patients reaching discharge earlier (117 vs. 142 min)*. Pain occurred earlier in the general anesthesia group. Patients felt significantly more uncomfortable after general anesthesia.	Anesthesia costs

Table 2 (Continued)

Authors	General anesthesia			Local/Regional anesthesia				Outcomes		
	Anesthetic	No. of patients	Average total costs (USD)	Type	Anesthetic	No. of patients	Average total costs (USD)	Main findings about cost analysis (primary outcome)	Other study findings (secondary outcomes)	Resources included for the calculation of costs
Hamilton et al. ¹³	Volatile anesthetics or intravenous with propofol	241	60	Interscalene brachial plexus single shot block, or catheter	20–40 mL of 0.5% ropivacaine with 1:400,000 epinephrine	1,382	82	No statistically significant difference between groups.	Increased risk of an emergency department visit within 30 days for patients who received a regional anesthesia.	Costs incurred after surgery
Chandran et al. ^{14, a}	NR	6	2071	LA	NR	14	1251	Average total costs of injection laryngoplasty under LA are significantly lower than under GA with cost savings of 40%. Major contributors are direct and indirect operating theater costs.	Length of stay (h): 8.8 GA vs 6.4 LA*	Medical procedure costs

(Continued)

Authors	General anesthesia			Local/Regional anesthesia			Outcomes			
	Anesthetic	No. of patients	Average total costs (USD)	Type	Anesthetic	No. of patients	Average total costs (USD)	Main findings about cost analysis (primary outcome))	Other study findings (secondary outcomes)	Resources included for the calculation of costs
Camponovo et al. ¹⁵	Intravenous propofol and fentanyl	28	104	SA	Chloroprocaine 1%	28	63	SA for knee arthroscopy is associated with cost reductions per patient compared with GA. Cost reductions in the SA group are due to: the ability to systematically bypass the PACU, faster discharge time, the lower incidence of pain and postoperative nausea and vomiting. Operative hysteroscopic resection under LA is less expensive than under GA, especially if performed in the office compared to the OR. Reduced staff costs are the primary reason for saving.	Anesthesia time: 64 vs. 62 min. Discharge time: 326 (GA) vs 203 min (SA)*	Anesthesia supplies, drugs, staff
Penketh et al. ¹⁶	NR	NR	1,485	LA in operatory room LA in office	NR	NR	LA in operatory room: 716 LA in office: 482		NR	Medical procedure costs

(Continued)

Authors	General anesthesia			Local/Regional anesthesia			Outcomes			
	Anesthetic	No. of patients	Average total costs (USD)	Type	Anesthetic	No. of patients	Average total costs (USD)	Main findings about cost analysis (primary outcome)	Other study findings (secondary outcomes)	Resources included for the calculation of costs
Sivalingam et al. ¹⁷	NR	73	30,060	LA	Lidocaine 1% ^b	46	7,770	Average total cost is nearly 4 times greater for the GA group compared to LA. Ureteral stent placement can be safely and effectively performed under LA in the office.	No difference in complications between GA and LA.	Medical procedure costs
Ahonkallio et al. ^{18, c}	NR	20	2,333	Peripheral block	20 mL ropivacaine 2 mg mL ^{-1, d}	16	1,333	Endometrial thermal ablation under PB is cheaper than GA and results in significantly reduced health service costs. The difference is due to lower costs of the hospital ward and anesthesia, and partly to overhead costs.	NR	Medical procedure costs
Covarelli et al. ^{19, a}	NR	41	373	LA	10–25 mL 1% mepivacaine and 0.5% L-bupivacaine in equal parts	112	258	Average total costs for groin and axillary sentinel lymph node biopsy under GA are significantly higher than those under LA.	No differences in the number of complications.	Operating room management, personnel, drugs, instruments

(Continued)

Authors	General anesthesia			Local/Regional anesthesia			Outcomes			
	Anesthetic	No. of patients	Average total costs (USD)	Type	Anesthetic	No. of patients	Average total costs (USD)	Main findings about cost analysis (primary outcome)	Other study findings (secondary outcomes)	Resources included for the calculation of costs
Stoffels et al. ²⁰	NR	89	500	LA	450 mL physiological solution, 50 mL Lidocain 1%, 0.5 mg Epinephrin	211	47	The costs were significantly less in a procedures room performed under local anesthesia compared to general anesthesia in an operating room.	No differences in the number of postoperative complications nor in oncological outcomes.	Anesthesia costs
Mitchell et al. ^{21, a}	NR	64	1,244	LA	NR	47	1,026	Sacral nerve stimulation under LA is associated with reduced costs compared to GA.	LA is associated with shorter hospital stay ^e and quicker recovery. Similar symptom score and success rate for both anesthesia.	Medical procedure costs
Kushwaha et al. ²²	Propofol 1.5–2 mg kg ⁻¹ and fentanyl 10 µg kg ⁻¹ with sevoflurane ^f	22	714	LA	20 mL 1% lidocaine with 1:10,000 epinephrine	19	503	Excluding the cost of post-operative follow-up, LA was 1.5 times cheaper than GA. This difference is due to the saving in GA and recovery room costs.	LA is associated with similar tolerance and clinical outcome compared to GA.	Suture materials, drugs, day surgery bed, staff costs, recovery room, post-operative medication.

(Continued)

Authors	General anesthesia			Local/Regional anesthesia			Outcomes			
	Anesthetic	No. of patients	Average total costs (USD)	Type	Anesthetic	No. of patients	Average total costs (USD)	Main findings about cost analysis (primary outcome)	Other study findings (secondary outcomes)	Resources included for the calculation of costs
Mostafa et al. ²³	Intravenous remifentanyl $0.5 \mu\text{g kg}^{-1} \text{min}^{-1}$ or alfentanil $2 \mu\text{g kg}^{-1} \text{min}^{-1}$ and propofol $9 \text{ mg kg}^{-1} \text{h}^{-1}$	40	492 for remifentanyl 541 for alfentanil	Sciatic-femoral nerve block	25 mL ropivacaine	20	393	Costs of disposals, pre-operative and post-operative times are higher for the sciatic-femoral block group, however average total costs (including also drugs) are insignificant between GA and sciatic-femoral nerve block.	Length of stay in PACU: 28 min for remifentanyl GA vs 25 min for alfentanil GA vs 28 for sciatic-femoral nerve block	Disposal, drugs, staff
Horn et al. ^{24, a}	Propofol with sevoflurane or desflurane, fentanyl or sufentanyl	121	4,780	Peripheral nerve block	Mepivacaine 1.5% with 10% sodium bicarbonate	92	3,656	Perioperative costs in the peripheral nerve block group are significantly lower than in the GA group.	PACU time: 49 min (GA) vs 15 min (PNB)*	Medical procedure costs

(Continued)

Authors	General anesthesia			Local/Regional anesthesia			Outcomes			
	Anesthetic	No. of patients	Average total costs (USD)	Type	Anesthetic	No. of patients	Average total costs (USD)	Main findings about cost analysis (primary outcome)	Other study findings (secondary outcomes)	Resources included for the calculation of costs
Nishikawa et al. ²⁵	Intravenous fentanyl 1 $\mu\text{g kg}^{-1}$ and propofol 6 $\text{mg kg}^{-1} \text{h}^{-1}$	40	74	SA	Lidocaine 1% 1 mL	40	49	The use of peripheral nerve block in upper extremity surgery is feasible and associated to significant cost savings. Average total costs are significantly lower in the SA group. Costs of drugs and supplies used in the operatory room are reduced for the SA, whereas the labor costs are higher in both operatory room and recovery unit. SA may be a suitable cost-effective alternative to GA for elderly ambulatory prostate biopsy.	Postoperative complications: 11.7% (GA) vs 3.3% (PNB)* Time to home-readiness: 30 min (GA) vs 38 min (SA)* No pain in the recovery unit for 75% patients in GA vs 80% patients SA groups. * No adverse events at home.	Drugs, equipment, staff

(Continued)

Authors	General anesthesia			Local/Regional anesthesia				Outcomes		
	Anesthetic	No. of patients	Average total costs (USD)	Type	Anesthetic	No. of patients	Average total costs (USD)	Main findings about cost analysis (primary outcome)	Other study findings (secondary outcomes)	Resources included for the calculation of costs
Nordin et al. ^{26, a}	NR	199	2,964	SA/epidural anesthesia LA	SA/epidural anesthesia: NR LA: 50:50 mixture of 1% mepivacaine and 0.5% bupicavaine	SA/epidural anesthesia: 164/35 = 199 LA: 205	SA/epidural anesthesia: 3,010 LA: 2,508	Average total costs of LA are significantly lower than the other two groups. Intra-operative (anesthetic equipment, duration of surgery and anesthesia) and post-operative (time in recovery room, unplanned overnight admission) costs are reduced for LA compared to SA/epidural anesthesia and GA. No difference between SA/epidural anesthesia and GA.	NR	Medical procedure costs
Spanknebel et al. ²⁷	NR	85	3,153	LA	Lidocaine and bupicavaine	217	2,760	Average total costs are significantly higher for GA than LA. Extensive procedures and increased operating room times impact significantly on costs.	Thyroidectomy under LA results in similar outcome and morbidity rate to GA with reduced costs.	Medical procedure costs

(Continued)

Authors	General anesthesia			Local/Regional anesthesia			Outcomes			
	Anesthetic	No. of patients	Average total costs (USD)	Type	Anesthetic	No. of patients	Average total costs (USD)	Main findings about cost analysis (primary outcome)	Other study findings (secondary outcomes)	Resources included for the calculation of costs
Casati et al. ²⁸	Intravenous remifentanyl 0.1–0.3 $\mu\text{g kg}^{-1} \text{min}^{-1}$ and propofol 2–4 $\mu\text{g mL}^{-1}$	40	317	sciatic-femoral nerve block SA	sciatic-femoral nerve block: 25 mL 2% mepivacaine SA: 8 mg 0.5% bupivacaine	sciatic-femoral nerve block: 40 SA: 40	sciatic-femoral nerve block: 220 SA: 308	The use of sciatic-femoral nerve block results in the lowest total costs. Costs of drugs and disposable material required for anesthesia are lower in the SA group than the others.	Regional anesthesia techniques reduce the rate of admission and the duration of stay in the PACU as compared with GA. The time readiness for home discharge are shorter in the GA group than regional anesthesia.	Drugs, devices, staff
Forssblad et al. ²⁹	Propofol and alfentanil	88	236	LA	LA: 30 mL 0.5% prilocaine with 4 $\mu\text{g mL}^{-1}$ adrenaline	LA: 181	LA: 76	The knee arthroscopy in LA is associated with lower cost than knee arthroscopy in SA and GA, because of the shorter recovery time of LA that reduces the need for recovery beds and postoperative care.	Recovery time: 139.1 min (GA) vs 33.6 min (LA) vs 230.1 min (SA).	Drugs, devices, staff

(Continued)

Authors	General anesthesia			Local/Regional anesthesia			Outcomes			
	Anesthetic	No. of patients	Average total costs (USD)	Type	Anesthetic	No. of patients	Average total costs (USD)	Main findings about cost analysis (primary outcome))	Other study findings (secondary outcomes)	Resources included for the calculation of costs
Casati et al. ³⁰	Intravenous remifentanyl 0.1–0.3 $\mu\text{g kg}^{-1} \text{min}^{-1}$ and propofol 2–4 $\mu\text{g mL}^{-1}$	20	291	SA	SA: 60–90 mg 5% lidocaine with 5–10 mg ephedrine	SA: 74	SA: 219		Time in hospital: 280.4 min (GA) vs 130.4 min (LA) vs 350.3 min (SA)	
				Sciatic-femoral nerve block	25 mL 2% mepivacaine	20	288	Average total costs between GA group and sciatic-femoral block group in patients undergoing knee arthroscopy are not statistically significant. Costs related to the time spent in the PACU are statistically significant lower for the sciatic-femoral block group (USD 2.0) compared with the GA group (USD 55.7).	Time in the hospital: 170 min (GA) vs 277 min (Sciatic-femoral block)* Length of stay in PACU: 23 min (GA) vs 5 min* VAS pain: 7 (GA) vs 0*	Disposable materials, drugs, staff
Danelli et al. ³¹	Intravenous remifentanyl 0.25 $\mu\text{g kg}^{-1} \text{min}^{-1}$ and propofol 4 $\mu\text{g mL}^{-1}$	20	260	SA	10 mg 0.5% bupivacaine	20	282	No differences in average total costs between the two groups.	Hospital discharge time: 156 min (GA) vs 296 min (SA)*	Disposable materials, drugs, staff

(Continued)

Authors	General anesthesia			Local/Regional anesthesia			Outcomes			
	Anesthetic	No. of patients	Average total costs (USD)	Type	Anesthetic	No. of patients	Average total costs (USD)	Main findings about cost analysis (primary outcome))	Other study findings (secondary outcomes)	Resources included for the calculation of costs
Lennox et al. ³²	Fentanyl 2 µg kg ⁻¹ and propofol 2 mg kg ⁻¹ , 65% nitrous oxide	10	127	SA	3 mL 10 mg lidocaine and 10 µg sufentanil	10	94	Average total cost of anesthesia and recovery is significantly less for patients in the SA group than the GA group. Recovery costs are similar, whereas mean costs of anesthesia is significantly less in the SA group. Cost savings are due to lower cost of anesthetic supplies, sterilization, drugs.	Pain control is similar. Anesthesia time: 6.6 min (GA) vs 6.6 min (SA) PACU time: 112 min (GA) vs 101 min (SA) Postoperative pain: 50% (GA) vs 0% (SA)* Nausea/vomiting: 0% (GA) vs 30% (SA)	Supplies, drugs, staff

(Continued)

Authors	General anesthesia			Local/Regional anesthesia				Outcomes		
	Anesthetic	No. of patients	Average total costs (USD)	Type	Anesthetic	No. of patients	Average total costs (USD)	Main findings about cost analysis (primary outcome))	Other study findings (secondary outcomes)	Resources included for the calculation of costs
Chan et al. ³³	Propofol, fentanyl, with isoflurane (up to 1.5%), 60% nitrous oxide	39	718	Intravenous regional anesthesia	Intravenous regional anesthesia: 35–45 mL 0.5% lidocaine	Intravenous regional anesthesia: 45	Intravenous regional anesthesia: 513	The intra- and post-operative costs are the least in the intravenous regional anesthesia group than GA and axillary block, reflecting cost savings of approximately 30% in both cases. intravenous regional anesthesia is associated with short induction time, lower anesthetic drug and equipment costs in the operatory room, and with less demand on nursing time and lower drug and supply costs in the PACU.	Total hospital stay time: 240 min (GA) vs 180 min (intravenous regional anesthesia)* vs 244 min (axillary block) Anesthesia time: 83 min (GA) vs 72 min (intravenous regional anesthesia)* vs 106 min (axillary block) PACU recovery time: 70 min (GA) vs 45 min (intravenous regional anesthesia)* vs 63 min (axillary block)	Disposable materials, drugs, staff
				Axillary block	Axillary block: 40–50 mL 3% chloroprocaine and 2% or 1.5% lidocaine with 1:200,000 epinephrine	Axillary block: 42	Axillary block: 755			

(Continued)

Authors	General anesthesia			Local/Regional anesthesia			Outcomes			
	Anesthetic	No. of patients	Average total costs (USD)	Type	Anesthetic	No. of patients	Average total costs (USD)	Main findings about cost analysis (primary outcome))	Other study findings (secondary outcomes)	Resources included for the calculation of costs
Martikainen et al. ³⁴	Intravenous propofol 2 mg kg ⁻¹ and alfentanil 1 mg with sevoflurane (up to 8%)	30	333	SA	3 mL 2% lidocaine	30	293	Average total costs are significantly reduced for SA. However, GA is more cost-effective than SA in ambulatory knee surgery, if a short recovery unit time is required.	Recovery unit time: 218 min (GA) vs 224 min (SA) Time to home-readiness: 96.4 min (GA) vs 140.8 min (SA)* Post-operative pain low (VAS < 4 in 100% patients in SA vs in 86.7% in GA groups).	Disposable materials, drugs, staff
Chilvers et al. ³⁵	Propofol, fentanyl or sufentanil, and mivacurium or succinylcholine, with isoflurane nitrous oxide	28	99	SA	2–2.5 mL 1% lidocaine and 10–25 µg fentanyl	24	107	Average total costs for anesthesia and recovery are similar between the two groups. Use of SA in alternative to GA does not reduce costs or improve efficacy of anesthesia and recovery for outpatient laparoscopy.	Anesthesia time: 10 min (GA) vs 18 min (SA)* PACU recovery time: 94 min (GA) vs 123 min (SA)* Time to discharge: 124 min (GA) vs 150 min (SA)	Disposable materials, drugs, staff

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(Continued)

Authors	General anesthesia			Local/Regional anesthesia			Outcomes			
	Anesthetic	No. of patients	Average total costs (USD)	Type	Anesthetic	No. of patients	Average total costs (USD)	Main findings about cost analysis (primary outcome)	Other study findings (secondary outcomes)	Resources included for the calculation of costs
				Ilioinguinal-hypogastric nerve block	Ilioinguinal-hypogastric nerve block: 30 mL of 0.25% bupivacaine, 1% lidocaine and propofol 25–150 $\mu\text{g kg}^{-1} \text{min}^{-1}$	Ilioinguinal-hypogastric nerve block: 28	Ilioinguinal-hypogastric nerve block: 288	Ilioinguinal-hypogastric nerve block is the most cost-effective techniques for outpatients undergoing unilateral herniorrhaphy with respect to recovery, patient comfort, and associated incremental costs.	Phase 1 PACU: 5 min (ilioinguinal block) vs 40 (GA)* vs 35 (SA)* Phase 2 unit: 153 min (ilioinguinal block) vs 168 (GA) vs 276 (SA)* Time to home-readiness: 133 min (ilioinguinal block) vs 171 (GA)* vs 280 (SA)* Time to actual discharge: 158 min (ilioinguinal block) vs 208 (GA)* vs 309 (SA)* Maximum pain VAS: 15 (ilioinguinal block) vs 39 (GA)* vs (34) SA* Maximum nausea VAS: 1 (ilioinguinal block) vs 27 (GA)* vs 4 (SA)*	

NR, not reported; PACU, post-operative anesthesia care unit. Currency is expressed with United States dollars (USD). **Type of anesthesia:** GA, general anesthesia; LA, local anesthesia; SA, spinal anesthesia.

^a Day-case setting.

^b Four patients received also i.v. midazolam.

^c Day-case setting (8 h) for general anesthesia and outpatient setting (4 h) for paracervical block.

^d When necessary also Alfentanil 0.5 mg.

^e Overnight stay for 38% of patients of the GA group due to adverse effects of the anesthesia.

^f This group received also a perianal block as for the LA group.

^g Patients received also 1–2 mg midazolam i.v. for sedation.

* Statistically significant.

local anesthesia.^{19,20} Reduced staff costs^{16,33,36} and drugs or supplies,^{18,20,25,26,32,33,37} ability to bypass the postoperative PACU or phase 1 recovery unit,^{15,24,36} and shorter recovery time^{12,22,26,28,29,37} are the main anesthetic procedure factors associated with health care cost reductions.

Among studies comparing different types of regional anesthesia, two randomized trials found spinal anesthesia to be more expensive than both sciatic-femoral nerve blocks in patients undergoing knee arthroscopy,²⁸ even if the costs of drugs and disposables were lower, and ilioinguinal-hypogastric nerve block for unilateral inguinal herniorrhaphy³⁷ and reduced PACU costs were the primary reasons for this difference for both surgeries. Chan et al.³³ found that intravenous regional anesthesia decreased costs of 30% compared to axillary brachial plexus block due to shorter induction time and lower drug and supply requirements. Two studies which used treatment codes for patient selection did not specify the type of peripheral block performed.^{10,11}

Contrasting results were achieved by analyzing the costs of a subgroup of studies focusing on knee arthroscopy, which was investigated in 6 randomized clinical trials^{12,23,28–30,34} and in one retrospective observational study.¹⁵ Cost advantages were demonstrated for regional anesthesia^{12,15,28,34} in half of the studies, but similar costs were found in the other two trials.^{23,30} The remaining study²⁹ confirmed that there was no statistically significant difference between spinal and general anesthesia but found reduced costs only for knee arthroscopy under local anesthesia. Reduced drugs and/or disposable materials and recovery time were associated with cost savings, further supporting the overall results of this systematic review.

Secondary outcomes

Twelve trials^{12,14,15,21,28–31,33,35–37} reported data on the duration of hospital stay; all studies found a shorter length of stay for local^{14,21,29,36} or regional^{12,15,30,31,33,37} anesthesia, except one that did not reveal any difference.³⁵

Postanesthesia recovery time was investigated in 12 studies.^{12,21,23,24,28–30,32–35,37} Local or regional anesthesia techniques significantly decreased the PACU time.^{12,21,24,28–30,33,35,37} In particular, Song et al.³⁷ showed that patients undergoing ilioinguinal-hypogastric nerve block spent less time in the phase 1 PACU (5 minutes) compared to patients operated on under general anesthesia (40 minutes) but also than patients undergoing spinal (35 minutes) anesthesia; moreover, these latter techniques required more time to recover in the phase 2 unit than the other two techniques. Thus, ilioinguinal-hypogastric nerve block was associated with lower costs than the spinal technique as regional anesthesia for unilateral herniorrhaphy. No difference in the duration of recovery stay was found in three studies.^{23,32,34} Time readiness for home discharge was significantly shorter for general anesthesia in 3^{25,28,34} out of 5 studies reporting this datum.^{25,28,34,36,37}

Data on anesthesia time conflicted with three studies reporting lower times for local and regional techniques^{33,35,36} and three^{15,32,37} finding no statistically significant difference.

The overall rates of complications or side effects and clinical outcomes were similar^{12,13,17,19–22,25,36} or more favorable^{15,24,30,32,37} for medical procedures under local or regional anesthesia.

Discussion

The vast majority of the studies included in this systematic review were concordant in showing an association between local or regional anesthesia and lower perioperative costs, regardless of the surgical procedure.^{11,12,14–30,32–34,36,37} This is consistent with data identifying in the operating room time the major fixed cost incurred during the perioperative process.² The anesthesia-controlled operating room time was defined as the portion of this time required by the anesthesiologist to perform the anesthesia technique of choice. When this time is reduced, overall hospital costs decrease. We know that regional anesthesia is associated with a reduction in anesthesia-controlled operating room time, fastening both the induction and postoperative phases.⁵ Our main finding is that local anesthesia is associated with a greater reduction in total costs further confirms the hypothesis of a reduction in anesthesia-controlled operating room time as the main factor affecting the overall total cost reduction observed, as local infiltrative anesthesia requires, on average, less time to be performed.

Only two studies^{23,30} found the cost profile of peripheral nerve block-based anesthesia to be similar to that of general anesthesia regarding sciatic nerve block. A possible explanation can be that sciatic nerve block is a so-called “deep block”, i.e., an advanced block, requiring more skills and possibly more time to be performed than other peripheral nerve blocks usually applied in the outpatient setting. Marhofer et al.³⁸ describes well the relative difficulty in the localization of the nerve and the surrounding anatomical structures due to their depth. However, Ehlers et al.³⁹ and Marhofer⁴⁰ have also shown that this block may be associated with a faster onset and higher efficacy when ultrasound-guided compared to nerve stimulation guidance. It remains to be demonstrated that these advantages actually translate into increased cost-effectiveness when compared to general anesthesia or other techniques in the ambulatory setting.

The second factor with a known impact on the perioperative process total costs is the PACU bypass rate or the recovery time when the patient requires postoperative supervision. The PACU is a highly work-intensive environment whose fixed cost is relevant.² Total cost reduction may be achieved in case of a consistently high PACU bypass rate by a reduction in nurses equivalent staff required.^{23,30} Our results confirm regional and local anesthesia techniques to be associated with a higher PACU bypass rate and a lower recovery time in comparison to general anesthesia.

The third factor that affects average total costs is the time to readiness for discharge, directly affecting the day-hospital length of stay. As discussed above, the overall day-hospital length of stay represents a significant fixed cost in the ambulatory perioperative process.⁴ Regional anesthesia has been associated with a lower incidence of postoperative anesthesia-related complications and side effects, translating into a quicker functional recovery and a lower time to discharge.³

In general, we can conclude that local and regional anesthesia is associated with lower total hospital costs when performed in the ambulatory setting. It is likely due to three factors: a reduction in total anesthesia-controlled operating room time, a reduction in postanesthesia recovery time and an overall shorter length of stay. These results apply to contexts where regional anesthesia can be performed regularly and systematically and where dedicated pathways are in place to enhance patient turnover in the outpatient setting, which is often the case in ambulatory surgical centers. Indeed, as stated by Philip and colleagues, a higher PACU bypass rate will only generate cost savings if utilization actually increases or staffing actually decreases.^{23,30} Moreover, the reduction in anesthesia-controlled operating room time per procedure is a few minutes and thus becomes significant only if many ambulatory procedures are performed in a given program and if an induction room allows for performing the following block while the previous patient is still undergoing surgery.⁵ Cost-effectiveness comparisons of different anesthesia techniques are dependent on the surgical duration of the case.^{41,42} Schuster et al.,⁴¹ in 2005, performing a regression function, demonstrated that the advantage of spinal anesthesia over general anesthesia in terms of operating room total fix costs reduction can be estimated to be 13% for a 50 minutes case, 9% for a 100 minutes case, and 5% for a 200 minutes case.^{23,30} These data highlight the fact that regional anesthesia cost-effectiveness depends on patient turnover and is higher in contexts characterized by high turnover and high case load per operating room, such as ambulatory surgery.

Our systematic review has some limitations. Heterogeneity among studies may represent a potential source of bias in a systematic review. This heterogeneity is likely to arise through baseline differences among the patients in the included studies, diversity in methodological aspects between different studies, and different study quality. We detected significant heterogeneity and poor quality of design among several studies in our systematic review. However, we used the CHEC list to assess the methodological robustness of the studies, and some of the criteria were not properly applicable to all studies since most of them were cost-minimization analyses. The meta-analysis was substantially hampered by the presence of this heterogeneity, which would make it challenging to compare the studies. Heterogeneity was also present in estimates of savings, which vary widely and may be explained by several reasons, such as implementation differences, hospital setting, and patient mix. These analyses are often not comparable among published studies due to variations in the type of cost data and accounting practices used. Such limitations preclude the possibility to estimate an effect size.

Our literature search was carried out on four major medical databases that should provide robust and reliable search results. The inclusion of other sources might refine our search strategy, specifically the inclusion of specialized databases (i.e., NHS Economic Evaluation Database). Moreover, we selected studies published since 2000 to be sure to include only the most recent and updated data about costs. However, problems with the breadth of costs and outcomes considered exist in all the studies. Last, none of the included studies was a cost-effectiveness analysis; thus, comparing the relative costs and outcomes of the two different anes-

thesia regimens and estimating the possible healthcare gains were not feasible. This means that the robustness of the results and conclusions about the impact of the anesthesia regimen on the average total costs is uncertain. Hence, a cost-effective analysis is necessary to undertake an assessment of both costs and effectiveness and to determine which anesthesia regimen is the most cost-effective procedure for ensuring that resources are being used wisely.

Conclusions

Despite the limitations of this systematic review, mainly the heterogeneity of the studies and the lack of cost-effectiveness analysis, the economic impact of the anesthesia regimes on healthcare costs appears to be relevant and should be further evaluated.

Conflicts of interest

The authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at [doi:10.1016/j.bjane.2021.09.012](https://doi.org/10.1016/j.bjane.2021.09.012).

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