

Cost minimisation and cost effectiveness in anaesthesia for total hip replacement surgery, in Belgium ? A study comparing three general anaesthesia techniques

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Abstract : The aim of the prospective randomised study is to compare the cost effectiveness of three general anaesthesia techniques for total hip replacement surgery and the cost minimisation by use of anaesthetics. For induction propofol was used in the three techniques. For maintenance, we used desflurane, or sevoflurane, or propofol. There was no significant difference in consumption of drugs for pain treatment, treatment of nausea and vomiting or cost of hospital stay or total cost for pharmacy. In terms of cost-effectiveness we can consider that the three techniques are similar. The cost of an I.V. technique was always higher than inhaled anaesthetics. The major cost in anaesthesia is the fee for the anaesthesiologist. But all in, the cost of anaesthesia was only 15,1% of the total cost of the procedure. Cost of inhaled or I.V. anaesthetics was 0,55% to 1,0% of the total cost. There was a discrepancy between the measured consumption of inhaled anaesthetics and the consumption (and cost) on the invoice. Cost minimisation based on anaesthetic medication is ridiculously by small considering the total cost of the procedure.

Keywords : Cost ; propofol ; desflurane ; sevoflurane.

INTRODUCTION

Cost containment is, in many countries, one of the major objectives in health economy. In anaesthesia we can use different techniques for a total hip replacement procedure.

The aim of this prospective randomised study is to compare the cost-effectiveness in Belgium of three general anaesthesia techniques using propofol, desflurane or sevoflurane. By cost effectiveness we consider the success of the procedure (24, 20). We can compare the treatment cost of side effects such as pain or post-operative nausea and vomiting (PONV) and other costs such as the cost of the hospital stay (duration) and total cost for pharmacy (17). Away from cost effectiveness we can also use cost minimisation as the comparison of acquisition cost of various alternative drugs without regard to the outcome or associated side effects (24).

Different papers in the literature have proven that inhaled anaesthetics are cheaper than an I.V. technique with propofol (2-4). The low flow technique and the pharmacokinetic properties of desflurane or sevoflurane could make a difference in terms of consumption of anaesthetics and cost (10). This consumption is linked to the MAC-value and the solubility coefficients in the different tissues but essentially to the flow of fresh gases (10, 18). Firstly, we measured the real consumption of anaesthetics and compared these measured costs to the detailed invoice of each patient. We also calculated an invoicing coefficient, as the difference in percentage between the measured cost and the invoice. Secondly, we compared the different anaesthesia techniques by looking at to cost effectiveness in terms of pain and post-operative nausea and vomiting, hospital stay duration and total cost for pharmacy. Finally we considered cost minimisation for anaesthetics compared to the total invoice for the surgical procedure.

METHODS

After approval of our local ethical committee, we randomised the anaesthesia technique in three different groups of 20 patients. Group 1 used propofol (Disprivan®) and desflurane (Suprane®), group 2 propofol and sevoflurane (Sevorane®), group 3 only propofol. All patients received an oral premedication of 0.25 or 0.5 mg alprazolam. Induction of anaesthesia was done with propofol 1% 20 ml (1 to

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2 mg.kg⁻¹ weight) in group 1 and 2, and in group 3 with propofol 1% 50 ml (T.C.I. of 4 µg.ml⁻¹ plasma) (Diprifusor®-Alaris, Belgium). Analgesia was based on 3 µg.kg⁻¹ of sufentanil 10 ml, and muscle relaxation on 0.5 mg.kg⁻¹ of atracurium 50 mg.

Maintenance of anaesthesia was managed by using a Bis-monitor (Aspect-U.S.A.) to obtain a value around 40. The patient was ventilated with 50% oxygen and 50% nitrous oxide (Julian-Dräger-Lübeck-Germany). We started with a gas flow of 2 l.min⁻¹ until equilibrium was obtained between inspired and expired anaesthetics. Then we used a low flow of 0.8 l.min⁻¹. Muscle relaxation was maintained with a TOF-guard monitor (Organon – Swords – Dublin – Ireland) at a value of one or no response on the train of four. During anaesthesia, a bolus of 10 mg of atracurium and 10 µg of sufentanil was administered when necessary. The anaesthesiologist used the aforementioned basic anaesthesia technique but was free to adapt it to the evolution of the procedure. Systolic blood pressure was maintained above 80 mmHg and ephedrine was used on demand.

At the end of the procedure residual curarisation was evaluated by using train of four, DBS and tetanus 50 Hz. If necessary a dose of glycopyrrolate 0,5 mg-neostigmine 2,5 mg was administered.

After surgery the patient was admitted to the P.A.C.U. All medication as well as the pain score (visual analogue scale 0-10) and the P.O.N.V. events were noted.

All the procedures were done by the same anaesthesiologist, the same surgical team and the same nurse-team in the P.A.C.U.

The cost of anaesthesia was calculated using the specific records of the procedure. To evaluate the consumption of anaesthetic gases we weighed the vaporisers before and after each anaesthesia (Mettler Toledo PG-S, balance 0.1 g Greifensee Switzerland). Conversion from mg to ml was done by using the specific weights of the volatile anaes-

thetics (Desflurane, 1,465 g.ml⁻¹, Sevoflurane 1,52 g.ml⁻¹) such as in the study of BOLDT and col. (2).

The IV fluids were considered as an anaesthesia cost and were invoiced. Other costs including devices and disposables such as anaesthesia machines, monitoring, endotracheal tubes, catheters and face masks were noted but not used in this study, for the reason that they are not detailed in the individual invoice and are covered, in Belgium, by the cost of hospitalisation which is the same for each patient.

We only compare the measured consumption of drugs and IV fluids to the detailed invoice of each patient.

The average (mean) cost is calculated by dividing the total cost by the number of patients. The median cost is the value where in an ordinal classification of figures, going from the lowest to the highest value, half of the figures is on the left and half on the right side.

Data are expressed as mean values ± Stdev. Mann-Whitney, Kruskal-Wallis Test and unpaired t-test were used when appropriate. P-values < 0.05 are regarded as significant. All statistics were performed by an independent society for medical statistics.

The price in euros of the different anaesthetics is given per unit in table 1.

RESULTS

Due to methodological problems we retain only 18 patients in group 2 and 19 in group 3.

Table 2 shows that there is no statistical difference between the groups for age, weight, BMI, duration of surgery, time in the PACU, and the total duration of hospitalisation. There is a statistical difference for gender between the groups 1 and 2, and the third (P = 0.023).

Table 1
Price per unit

PRODUCT	Price per unit in €	Unit of delivery in ml	Unit of invoice in ml
Desflurane	0,21	240	10
Sevoflurane	0,58	250	10
Propofol	3,69 13,51	20 50	20 50
Sufentanil	0,62 2,50	2 10	2 10
Tracrium	4,10	5	5

Table 2
Sample description

	Group 1 : desflurane	Group 2 : sevoflurane	Group 3 : propofol	TOTAL	P-value
Proportion of males	24%	11%	50%	25%	0.023
Age (Years)	70.7 (± 8.7)	72.8 (± 6.9)	68.6 (± 10.9)	70.7 (± 9.0)	0.353
Weight (Kg)	68.3 (± 12.1)	69.8 (± 12.7)	77.5 (± 16.8)	71.7 (± 9.0)	0.104
BMI (kg.m ⁻²)	26.0 (± 4.4)	26.0 (± 4.4)	27.3 (± 5.6)	26.5 (± 4.7)	0.650
Surgery duration (min)	150 (± 36)	153 (± 40)	150 (± 3.1)	151 (± 35)	0.974
Time in the PACU (min)	57.6 (± 58.3)	44.3 (± 47.1)	53.8 (± 60.6)	52.2 (± 55.2)	0.820
Duration of hospitalisation (days)	10.3 (± 3.8)	10.0 (± 3.99)	12.3 (± 4.7)	10.9 (± 4.7)	0.265

Table 3
Anaesthesia consumption in ml. and costs in euros from measured values for induction and maintenance

	Desflurane	Sevoflurane	Propofol	TOTAL
Mean consumption (ml)	27.0	11.1	127.8	
Median consumption (ml)	25.9	10.5	125	
Max Consumption (ml)	54.6	15.1	200	
Induction mean cost	3.69	3.69		
Mean cost (€)	5.68	6.42		
Median cost (€)	5.45	6.11		
Max cost (€)	11.47	8.78		
Anaesthesia mean cost (€)	9.37	9.57	34.53	17.24
Anaesthesia median cost (€)	9.14	9.41	33.77	10.43
Anaesthesia Max cost (€)	15.16	12.47	54.04	54.04

Table 3 relates the results of the measured values of consumption and the cost of anaesthesia and maintenance in the three groups. Group 1 and 2 needed propofol for induction and inhaled anaesthetics for maintenance. This implies a cost of 3.69 euros for induction. So in the groups, we consider the cost for maintenance, induction and for both titled "anaesthesia". For group 3, the same drug was used for induction and maintenance. Costs in group 3 are significantly higher than in the 2 other groups. The mean difference between group 1 and 3 is 25,16 € (P-value < 0.0001, 95% CI -29,95 €, -20,36 €), between group 1 and 2, 0.20 € (P-value = 0.782, 95% CI -1,66 €, 1.26 €) and between group 2 and 3, 24,96 € (P-value < 0.0001, 95% CI 19,91 €, 30,00 €). There is a significant difference in cost between inhaled techniques of group 1 and 2 and an I.V.-technique (group 3). There is no significant difference in cost between desflurane and sevoflurane.

In table 4 we note the invoice such as defined by each individual detailed invoice. Compared two by two, there was no significant difference between the groups.

In table 5 we compare the measured and the invoiced cost expressed as mean values. To our surprise there was a real difference between the invoiced and the measured cost. We calculated an "invoicing coefficient", the invoiced versus measured cost expressed in percentage. We show that the invoice of anaesthetic gases was done in a standardised manner per 10 ml, where despite the prescription of the anaesthesiologist, most of the time, 60 ml of desflurane and 30 ml of sevoflurane were accounted by the pharmacist. There is a real difficulty in assessing the real consumption of anaesthetic gases, specifically when a low flow technique is used with a Julian® ventilator.

The mean use of crystalloids was 3 × 500 ml of Plasmalyte A® for a cost of 8,3 €, and a mean use of 1 × 500 ml colloids (Voluven®) for a cost of 3,9 €. There was no statistical difference between groups (Table 5).

To evaluate the cost effectiveness of the different techniques we consider nausea and vomiting as well as the pain scores and analgesics, the duration of hospital stay and the global cost for pharmacy. (Table 6). There was no other difference between

Table 4
Invoiced cost in €

	Desflurane	Sevoflurane	propofol	TOTAL	P-value
Total cost	5420.91 (± 1261.64)	5654.13 (± 1097.97)	5394.49 (± 2196.04)	5420.91 (± 1563.25)	0.716
Own cost for patient	1527.79 (± 1228.75)	1854.50 (± 1059.23)	2441.14 (± 1462.02)	1926.38 (± 1294.31)	0.089
Cost of hospitalisation	2377.15 (± 685.46)	2770.74 (± 1296.66)	2436.00 (± 984.73)	2524.15 (± 1006.31)	0.449
Cost for pharmacy	177.32 (± 52.51)	207.89 (± 62.78)	198.40 (± 58.00)	192.96 (± 58.00)	0.311
Cost for prosthesis	1823.12 (± 390.49)	1777.01 (± 389.39)	1670.59 (± 240.63)	1759.27 (± 348.71)	0.398

Table 5
Comparison between mean measured and mean invoiced cost in € and the invoicing coefficient

COST		desflurane	sevoflurane	Propofol	TOTAL	P-value
anaesthetics	Invoice	16.74	24.17	31.48	23.86	< 0.001
anaesthetics	Measured	9.19	9.57	34.53	17.18	< 0.001
anaesthetics	Invoicing coefficient	182.2%	252.6%	91.2%	136.9%	
anaesthetics, sufentanil, atracurium	Invoice	27.34	34.07	43.31	34.61	< 0.001
anaesthetics, sufentanil, atracurium	Measured	17.75	17.03	43.63	25.55	< 0.001
anaesthetics, sufentanil, atracurium	Invoicing coefficient	154.0%	200.1%	99.3%	135.5%	
perfusion - IV fluid	Invoice	28.87	31.05	31.16	30.29	0.515
perfusion - IV fluid	Measured	13.34	14.06	12.31	13.37	0.668
perfusion - IV fluid	Invoicing coefficient	216.4%	220.8%	253.1%	226.6%	
Cost of antiemetics	Invoice	0.59	1.88	1.84	1.41	0.444
Cost of antiemetics	Measured	1.26	1.82	3.05	2.00	0.553
Cost of antiemetics	Invoicing Coefficient	46.8%	103.3%	60.3%	70.5%	

Table 6
Mean invoiced cost for analgesics in €

	Desflurane	Sevoflurane	Propofol
Paracetamol	21,15	21,54	18,77
Analgesics	1,77	1,70	2,06
N.S.A.I.D.S.	2,96	3,30	3,69
TOTAL	25,88	26,54	24,52

the groups. For anti-emetic medication, there was no significant difference between group1 and the others. Despite the fact that in the literature anaesthetic gases are more “pro-emetic” than propofol, there is a lower cost in the desflurane group [8]. Premedication by alprazolam costs 0,18 €. Lidocaine was used before the administration of propofol and costs 1,16 €. For safety reasons we systematically prepared a syringe with atropine 1 mg (0,21 €) and ephedrine (0,27 €).

The fee for the anaesthesiologist, the surgeon, and the physiotherapist is respectively 405,60 €, 828,83 €, and 138,76 €.

The fixed value for antibiotics is 19,13 €. Anti-thrombotic medication is good for 33,25 €. The mean cost for gastric protection by ranitidine is 1,91 € and this medication was systematically used in patients with a history of gastritis, gastric ulcer, reflux or N.S.A.I.D. use. Antiseptic solutions (mean value) used during surgery and the post-operative time account for 39,53 €. In order to administer certain drugs, mini-infusion bags of NaCl or dextrose (150-250 ml) were used for a mean cost of 6,60 €.

Table 7 compares the cost of anaesthesia (including, anaesthetics, opiates, muscle relaxants, infusions, and the fee for the anaesthesiologist corrected for supplements) and the total cost of the hip-prosthesis surgery. We compared it by correlating the average cost for anaesthesia to the average cost of the procedure for each group and we defined it as

Table 7

Repartition of invoice total cost in term of anaesthesia

	Desflurane	Sevoflurane	Propofol	TOTAL
Average cost of intervention	5234.75	5654.13	5394.49	5420.91
Average cost of anaesthesia (fee corrected for supplements, anaesthetics, opiates, curare, perfusion)	643.52	825.19	896.59	781,20
Anaesthesia (including agents, opiates and curare) individual cost	0.55% (\pm 0.19)	0.61% (\pm 0.15%)	1.0% (\pm 0.58)	0.71% (\pm 0.40)
Anaesthesia (including agents, opiates and curare) in terms of average total cost	0.52%	0.60%	0.80%	0.64%
Anaesthesia (fee corrected for supplements, anaesthetics, opiates, curare, perfusion) individual cost	12.2% (\pm 3.4)	14.4% (\pm 3.9)	19.3% (\pm 10.8%)	15.1% (\pm 7.2)
anaesthesia (fee corrected for supplements, anaesthetics, opiates, curare, perfusion) in terms of average of total cost	12.3%	14.6%	15.7%	14.2%
Prosthesis in terms of individual cost	35.5% (\pm 6.7)	32.3% (\pm 7.6)	40.2% (\pm 28.9)	36.0% (\pm 17.4)
Prosthesis in terms of average total cost	34.8%	31.4%	31.0%	32.5%

the individual cost. We compared the same cost to the total cost for all the groups, in terms of average total cost. The mean value for anaesthesia is 15.1% (\pm 7%) of the individual invoice or 14,2% of the total cost. The prosthesis seems to be an important part of the invoiced cost, 36,0% (\pm 17.4%). Does it make sense that some orthopedic companies graciously send a surgical-nurse to help the surgeon ?

DISCUSSION

In every country, physicians, managers or politicians attempt to control the cost of health care (7, 9, 11, 13, 24). Many health care systems are inefficient or inequitable and costs are increasing (9, 11). Different approaches have been used. Cost minimisation compares the acquisition cost of various alternative drug regimens without regard to the outcome or associated side effects (14, 24). Our study compared three different anaesthetic regimens, using desflurane, sevoflurane and propofol. The I.V. technique is significantly more expensive than anaesthetic gases as described by Boldt, Dolk and others (2, 4). There are no differences in terms of cost between desflurane and sevoflurane. We used a low flow technique for a period of \pm 151min. For longer procedures there could be a difference related to the human tissue/gas partition coefficient of desflurane and sevoflurane in muscle and in fat, respectively for desflurane 0.78 (0.62-0.94) and for sevoflurane 1.7 (1.1-2.4) and in fat for desflurane 13 (12-15) and for sevoflurane 37 (34-41) (5). It means that accumulation in fat and muscles, in time, is proportionally lower with desflurane than

sevoflurane. On the other hand, with the differences in M.A.C.value (desflurane 5,17%-sevoflurane 1,77% for the age of 65 years) between both drugs we can expect a three times higher consumption ($5,17/1,77 = 2,92$) of desflurane (6). In low flow, the equilibrium is reached faster with desflurane than sevoflurane (10). The factor three (2, 6) between desflurane and sevoflurane is modified by using a low flow technique, as in our study where consumptions were respectively 27,0 ml for desflurane and 11,1ml for sevoflurane. The factor is 2,43 for a surgical procedure of 151 min (\pm 3.5). As low flow anaesthesia is by evidence required for cost containment, desflurane may be preferred for longer procedures.(18) By the way, the difference in cost between desflurane and sevoflurane will be effective if the price of desflurane is one third or less than the equivalent price of sevoflurane (Table 1).

Cost effectiveness analysis, expresses the costs of an intervention in units of success or effect (20, 24). In our study, a Bis-monitor was used to adjust the level of hypnosis (19, 21). There was no difference between groups, nor for the duration of stay in the PACU (52,2 min), the treated post-operative morbidity or the duration of hospitalisation (10,9 d.). Cost-effectiveness looks at the differences in outcome between groups. In these terms of cost we analyse the cost for pain killers, the cost for prevention and treatment of P.O.N.V., the total cost for pharmacy. There was no significant difference between groups. Interesting is the problem of PONV (8, 12). In our study, the cost for preventive or rescue medication was statistically equal between groups. So if we admit that anaesthetic gases are "pro-emetic", we probably have to

consider different other factors such as gender, previous history of PONV, opiates and smoking habits (1, 12). In our study, there is a statistical difference between groups for gender, in that we have a larger proportion of women in group 1 and 2, and a larger proportion of males in the group of propofol. This should give us more PONV in the risk-groups 1 and 2 (1). This was not measured. So we can assume that in our study, other factors than gender may be predominant, probably the use of opiates (1, 23).

Health economists look at cost and benefits by using the invoices. Our study compared the measured cost and the invoices. This has never been done before. Differences between measured and invoiced costs for anaesthetics can be explained by the difficulty to evaluate the real consumption of anaesthetic gases. There is no way to calculate it, because the gas flows and also the uptake of anaesthetics are variable during the procedure (10). We have to measure this consumption by weighing the vaporisers and by converting the measurements to millilitres of anaesthetics (2). Our anaesthetic machines don't measure the real consumption of inhalation agents. Computer programs can help to evaluate the consumption (15).

The invoicing coefficient of 136,9% cannot be fully explained in this way. We have to consider the invoice procedure, to correct it and to adjust it to reality. As in the case of supermarkets an optical identification of each ampoule can help to register the real consumption of drugs instead. Computer simulation or injection techniques of inhaled anaesthetics can help to evaluate the real consumption of gases.

In some countries, economists and politicians hope to reduce the health care costs by introducing a fixed amount for medication and procedure, defined by each APR-DRG (all patients refined, diagnosis related groups) (3). They hope to moderate pharmaceutical costs and to generate cost minimisation in the hospitals. To calculate it, in Belgium, they use the individual invoice of each patient. Does this make sense in anaesthesia? (2, 14, 20).

We first have to consider that the cost for anaesthetics forms a ridiculously small part of the invoiced cost for the procedure (mean 0.71% - average 0.64%). The invoiced cost for inhaled anaesthetics is higher in our study than the measured cost. Second, the cost for anaesthesia, including anaesthetics, opiates, muscle relaxants, perfusions, and the fee for the anaesthesiologist is only 15,1% of the invoiced cost of the procedure. That means that the highest variable cost in anaesthesia

is not the drug, but the fee for the anaesthesiologist (20, 24). On the other hand, surgical cost, hospitalisation cost (mean duration of 10.9 days) and cost for prosthesis make up 85% of the total invoiced cost. To save money in the procedure for total hip replacement we have to consider other variables than anaesthesia, such as the cost for surgical prosthesis or the cost for hospital stay. Fast track anaesthesia and surgery are more cost-saving than cost-minimisation for medications (16, 22).

In our study, we have not included the fixed cost, essentially because we did not have differences between groups in terms of investment costs (for materials) or human resources costs.

To conclude, we have proven that measured costs and invoiced costs for inhaled anaesthetics are different. In terms of cost-effectiveness there is no difference between groups. In terms of cost-minimisation, the cost of anaesthetics is ridiculous considering the total amount of the invoice. Inhaled anaesthetics are cheaper than I.V.-techniques, as described in other studies. Cost minimisation should be done by using inhaled anaesthetics, but the profit is particularly small and will only make sense by the mass effect of the number of procedures in a country. A particularity of this study was the calculation of the invoicing coefficient showing a difference between the real and the invoiced consumption of inhaled anaesthetics or medication.

Acknowledgements

All my thanks to Dr M. Coltura and Dr B. Verhaeghe for reviewing this paper.

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