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Original article

Costs optimization in anaesthesia

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Summary. *Objectives:* The aim of this study is to analyze the direct cost of different anaesthetic techniques used within the Author's hospital setting and compare with costs reported in the literature. *Methods:* Mean cost of drugs and devices used in our local Department of Anaesthesia was considered in the present study. All drugs were supplied by the in-house Pharmacy Service of Parma's General Hospital. All calculation have been made using an hypothetical ASA1 patient weighting 70 kg. The quality of consumption and cost of inhalation anaesthesia with sevoflurane or desflurane at different fresh gas flow were analyzed, and the cost of total venous anaesthesia (TIVA) using propofol and remifentanil with balanced anaesthesia were also analyzed. In addition, direct costs of general, spinal and sciatic-femoral nerve block anaesthesia used for common plastic surgery procedures were assessed. *Result:* The results of our study show that the cost of inhalational anaesthesia decreases using fresh gas flow below 1L, and the use of desflurane is more expensive. In our Hospital**,** the cost of TIVA is more or less equivalent to the costs of balanced anaesthesia with sevoflurane in surgical procedure lasting more than five hours. The direct cost was lower for the spinal anaesthesia compared with general anaesthesia and sciatic- femoral nerve block for some surgical procedures. (www.actabiomedica.it)

Key words: direct cost, inhalational anaesthesia, total venous anaesthesia, regional anaesthesia

Introduction

Cost containment has become a priority in all areas of health care. Pharmaco-economics is the discipline describing and analyzing drug's cost.

Operating room is one of the principal costs in the manage of an Hospital and a mindful management of its costs is necessary to reduce the costs without jeopardize patient's safety .

The budget for anaesthesia accounts only 3-5% of a single surgical procedure (1).

Although anaesthesia's cost are the slightest compared to the cost of a surgical procedure a reasonable saving for each treatment can lead to an impressive total saving due to the high number of procedures performed every year (1-3).

For the sake of simplicity anaesthesia's cost are divided into (4):

Direct: drugs, medical devices used for a specific treatment, possible wastes of not used drugs and devices.

Indirect: linked to the effects of anaesthesia (recovery time, sides effects, use of monitorized beds, additional drugs therapy in the post operative time, etc).

Fixed: costs that remain the same regardless the quantity and quality of procedures (rent, salaries, building equipment).

Variable costs: Costs that change with quantity and quality of services provided (agent used, drugs and devices).

Every day anaesthesiologists has to choose between several drugs and medical devices that he or she believe the most suitable for the type of procedure and his or her skills; very often although the specialist is unaware of the costs of the drugs and devices used. In their study, Jhonstone e Jozefzcyk, showed that an

informative program can lead to a rapid reduction of the anaesthesia's cost of 23% without affecting safety and quality of the procedure. In the same study, on the other hand, it's demonstrated that after two months from the informative program the costs rises again. The Authors suggested that the difficulty of anaesthesiologist to accept restrictions on dugs and equipment use and the effort of drug company to use high cost drugs may have been responsible for the result (3-4).

Inhalational anaesthesia

The cost of the new inhalational agents Sevoflurane and Desflurane, that the Azienda Ospedaliero Universitaria di Parma, had choose from long time over Isoflurane is a theme of debate. These two agents have low solubility in blood which leads to shorter wash- in and wash out processes with faster induction and emergence (Tab. 1) and facilitates rapid equilibrations between the alveolar and effect site (brain)concentrations making them ideally suited for low flow techniques. Sevoflurane is more potent (MAC=2.05%) than Desflurane (MAC 6%) and the potency of an inhaled anesthetic is indicated by its MAC (minimum alveolar concentration that prevents movement in 50% of patients in response to painful stimulation as the skin incision in surgery) (5-6).

A number of studies showed that high flow anaesthesia tended to be more expensive than low- flow once, reducing the fresh gas flow lower than 1 lt/min during maintenance of anaesthesia is associated with a remarkable saving of money (2-3).

Furthermore low-flow anaesthesia reduce environmental pollution and helps to maintain heat and humidity of exhaled air preserving muco-ciliar clearance (7). The potential risk linked to the administration of hypoxic mixture or the formation of toxic compound doesn't represent a contraindication for low flow anaesthesia , but only the necessity to pay more attention and to be more cautious.

With the introduction in the ventilators of the inhaled mixture monitor and with the modern carbon dioxide (CO2) absorber this risk has become negligible (14).

Table 1. Inhaled agents solubility (8)

Agent	Partition coefficent 37°C		MAC
	Blood-gas	Fat-Blood	
Sevoflurane	0,65	48	2,05%
Desflurane	0,45	27	6,00%
Isoflurane	1,4	45	1,15%

W.C. Levine. Procedure di anestesia clinica del Massachusetts General Hospital 8ªedizione. Delfino

Total intravenous anaesthesia (TIVA)

As confirmed by recent literature, another main theme of discussion is the comparison between Total intravenous anaesthesia (TIVA) and balanced anaesthesia.

Propofol and remifentanil and an association of these two, represent the drugs of choice in procedure needing a fast emergence (fast-track) and in ambulatory surgery.

Many studies underlines the different cost of Propofol and Remifentanil in different country around the world, in the USA remifentanil is very expensive (2, 3).

Moreover incidences of PONV (post operative nausea and vomiting) are similar after TIVA and inhalational anaesthesia in patients premedicated with antiemetics and the faster emergence after TIVA doesn't seem to have an incidence on the reduction of the turn over in the operating room. The needs of specific pumps and medical devices as, for example, the BIS (bispectral index monitoring) for monitoring the depth of anaesthesia (8) leed to an even higher cost of the TIVA.

For these and other reasons, the use of TIVA in reduced at particular and selected cases.

General anaesthesia vs locoregional anaesthesia

Literature puts attention on indirect costs of general and loco-regional anaesthesia; time to perform the block and recovery time, recovery room utilization time and nurses personnel used, the need of additional drugs in the post-op are all the variable analyzed. From the valuation of all these factors emerges a lesser cost of the loco-regional anaesthesia while the difference in the direct costs, as material and drugs implied in the two technique doesn't' seem significant (9, 10).

In our hospital is difficult to estimate costs linked to time of anaesthesia and so we decided to analyze only direct costs of general anaesthesia, loco regional one and sedo-analgesia for a specific surgical procedure with equal results and with equal skills of the anaesthesiologists.

Aim of the study

The aim of the study is to analyze the direct costs of different type of anaesthesia in our department and to compare the data with the ones found in literature.

To analyze the costs we used the hospital's mean price list 2014 (vat excluded) supplied by the Pharmacy Service of the Azienda Ospedaliero-Universitaria Parma (Tab. 2).

Method/Cost calculation

Cost minimization

For the analysis of the direct costs of the anaesthesia we used the common method of the cost minimization which permit to confront varies techniques that have the same result without considering the sides effects (4).

All the calculation has been applied to an hypothetical patient ASA 1, 40 years, 70 kg and 170 cm of heights.

Inhalational anaesthesia

In our Hospital a bottle of 250 ml of sevoflurane (Sevorane®) costs 84.8 euro (0.339 per millilitre), a

Table 2. Mean price at Azienda Ospedaliero Universitaria di Parma for medical devices and drugs used in the different techniques (price/unit)

Anaesthetic costs			
Opiods			
Morphine f 10 mg/ml	€ 0,239	Alfentanyl f 5 mg/10 ml	€ 2,88
Fentanyl f 0,1 mg/2ml	€ 0,193	Sufentanyl f 0,250 mg/5 ml	€ 3,278
Remifentanil fl 2 mg	€ 1,395	Tramadol f 100 mg/2 ml	€ 0,193
Intravenous NSAIDSs/ paracetamol			
Ketoprofen f 100 mg/5ml	€ 0,207	Paracetamol fl 1 g/100 ml	€ 0,616
Ketorolac f 30 mg/ml	€ 0,145		€ 0,000
Oral opiods			
Tramadol gtt 100 mg/ml fl 10ml	€ 0,244	Methadone 1 mg/ml fl 20 mg	€ 0,404
Paracetamol/Codeine 500 mg+30 mg	€ 0,063	Oxycodone crp 10 mg	€ 0,340
Oral NSAIDs/paracetamol			
Ketoprofen cp 50 mg	€ 0,018	Ketoprofen cp 200 mg rp	€ 0,081
Ketoprofen cp 100 mg	€ 0,054	Paracetamol cp 500 mg	€ 0,020
Hypnotics			
Thiopental fl 500 mg	€ 3,393	Ketamine 50 mg/ml f 2 ml	€ 2,979
Propofol 10 mg/ml fl 20 ml	€ 0,466	Midazolam 5 mg/ml	€ 0,163
Etomidate 2 mg/ml f 10 ml	€ 2,600	Midazolam 15 mg/3 ml	€ 0,297
Inhaltional agents			
Sevoflurane fl 250 ml	€ 84,80	Desflurane fl 240 ml	€ 50,349
Muscle relaxants			
Cis-atracurium 2 mg/ml fl 5 ml	€ 1,796	Atracurium 10 mg/ml f 5 ml	€ 2,880
Mivacurium 2 mg/ml f 10 ml	€ 4,272	Rocuronium 10 mg/ml f 5 ml	€ 1,780

bottle of 240 of desflurane (Suprane®) costs 50.349 euro (0.21 per millilitre).

We calculated the theoretical consume and costs of sevoflurane and desflurane at different fresh gas flow at constant MAC of 1 during the maintenance of anaesthesia.

The difficulty in the calculation of the use of the agents and therefore the cost of inhalational anaesthesia is due to the fact that ssevflurane and desflurane are liquids that operate as gas. The cost of inhalation agents was determined by using the formula quoted by Dion in the Canadian Journal of Anaesthesia and widely used in literature (10-11),

$$\text{Cost} = \frac{\text{Px Fx Tx Mx C}}{\text{2142x d}}$$

P: vaporise %, F fresh gas flow (l/min), T: duration (minute), M: molecular weight (g) C: cost, D density (g/ ml).

Molecular weight, density, and cost are specific for each agent (Tab. 3).

The inhalational protocols we used were based on published works (2).

Propofol /remifentanil anaesthesia vs Sevoflurane/ remifentanil anaesthesia

For intravenous anaesthesia we considered the use of not TCI pumps with standard dosage taken from literature.

The results of the comparison of the two techniques:

Induction (the same in the two techniques): 2 mg/kg of Propofol, 1 mcg/kg of Remifentanil and 0.15 mg/kg of Cis-atracurio.

Table 3. Chemical identity of the agents used

Agent	Molecular wheight (g)	Density (g/ml)	Price/ml (€)	Price/bottle (€/ml)
Sevoflurane	200,05	1,52	0,339	84,8/250
Desflurane	168,04	1,47	0,209	50,349/240

Maintenance: - Inhalational: Sevoflurane 1 MAC, 1 l/min FGF, 0,1-0,3 mcg/kg/min remifentanil;

- TIVA: continuous infusion of propofol (150 mcg/kg/min) and remifentanil (0,1-0,3 mcg/kg/min + 1 BIS electrod.

General vs regional anaesthesia

We analyzed direct costs of general and regional anaesthesia for a certain type of surgical procedure, with same result and same anaesthesiologist skills.

We valuated the prices for an hypothetic patient undergoing a surgical procedure of cutaneous graft of the lower limb, performed in Plastic Surgery department and of the duration of 90 minutes.

For this procedure the choice of anaesthesiologic techniques are:

- Periferal block of sciatic and femoral nerves performed with 25 ml of carbocaine 2% and the help of nerve- stimulator.

- Spinal anaesthesia performed with 8 mg of hyperbaric bupivacaine 0.5%

- General anaesthesia

Results

Inhalational anaesthesia

In Tab. 4 we reported the results of the costs of Sevoflurane and Desflurane at different fresh gas flow (0.8, 1, 2, 3, lt/min) at constant MAC for an hour of inhalational anaesthesia.

We found that at MAC 1 the sevoflurane and desflurane consumption, and cost, increase linearly with fresh gas flow

Table 4. Costs of Sevoflurane and Desflurane at different fresh gas flow (FGF) (0.8, 1, 2, 3, lt/min) at constant MAC for an hour of inhalational anaesthesia

FGF	Sevoflurane	Desflurane
0,8 l/min	€ 3,099	€ 4,411
1 l/min	€ 3,749	€ 5,379
2 l/min	€ 6,249	€ 9,414
3 l/min	€ 7,499	€ 12,104

Table 5. Cost comparison analysis for TIVA and inhalational anaesthesia for a standard patient of 70 kg for 90 minutes

	TIVA	Inhalational
Induction		
1 fl propofol	€ 5,455	€ 5,455
2 fl cis-atracurium		
Remifentanil 1 mcg/kg		
Maintenance		
Propofol: 150 mcg/kg/min	€ 2,330	
Sevoflurane: 0,8 l/min FGF, MAC 1 (3%)		€ 4,499
Remifentanil 0,1-0,3 mcg/kg/min*	€ 0,00*	€ 0,00*
BIS: 1 elctrod	€ 20,50	
Total	€ 28,29	€ 9,954

*for the Remifentanil we considered the price of one vial of 2 mg due to the fact that for the duration of the procedure (90 minutes) are necessary 1,960 mg

TIVA vs balanced anaesthesia

In Tabb. 5-6 we report the differences between the two techniques.

General vs regional anaesthesia

In the following tables (Tabb. 7-8) we show the direct cost and the modification of the price between different types of anaesthetics agents and devices needed for the different approaches.

We didn't consider the price for masks, tubes and disposable kit used in both technique.

Conclusion

The anesthesiologist can choose between different techniques but often lacks in knowledge of prices for drugs and medical devices used. The aim of the study is to compare theoretical cost of various anaesthesiologic techniques and provide information about the costs of the products widely used in the practical clinic. The authors develop the study with the collaboration of the Pharmacy Service of the Hospital which has a fundamental role in the clinical governance of the resources and in monitoring possible wastes. Nowadays, more than ever in the past, is critical to contain the costs and wastes, promoting the use of drugs and medical devices with a more advantageous cost/benefit ratio.

In a recently published review (3) the Authors suggests simple measures to be applied in the daily practical clinic as the usage of fresh gas flow at less than 1L/minute in inhalational anaesthesia to reduce the consumption of the expensive alogenate agents Sevoflurane and Desflurane.

Low flow anaesthesia thanks to the constant innovation and to the new exhaled gas monitor and modern ventilator is a safe procedure to perform rou-

Table 6. Cost comparison analysis for TIVA and inhalathional anaesthesia for a standard patient of 70 kg for 300 minutes

	TIVA	Inhalational			
Induction	€ 5,455	€ 5,455			
1 fl propofol					
2 fl cis-atracurium					
Remifentanil 1mcg/kg					
Maintenance					
Propofol: 150mcg/kg/min	€ 2,330				
Sevoflurane: MAC 1	€ 7,330				
(FGF)		€ 15,497 (0,8 l/m)	€ 18,746 (1 l/m)	€ 31,244 (2 l/m)	€ 37,493 (3 l/m)
BIS: 1 electrod	€ 20,50				
Remifentanil 0,1-0,3mcg/kg/min*	€ 4,185	€ 4,185			
Total	€ 37,470	€ 25,137	€ 28,386	€ 40,884	€ 47,133

* for the Remifentanil used in the induction we considered the price of one vial of 2 mg and for the maintenance three vial (for the duration and dosage 6,370 mg are necessary)

Table 7. Mean price at Azienda Ospedaliero Universitaria di Parma for medical devices and drugs used in the different techniques (price/unit)

Technique	Price/unit	Technique	Price/unit
Bi-Block		**Spinal An.**	
Locoplex needle	€ 7,700	Spinal needle 25G W	€ 4,240
Mediset Set	€ 1,800	Mediset Set	€ 1,800
General An.		**Sedation**	
Cis-atracurium 10 mg/5 ml	€ 1,796	Midazolam 5 mg/ml	€ 0,163
Mivacurium 20 mg/10 ml	€ 4,272	Fentanyl 0,1 mg/2 ml	€ 0,193
Sevoflurane fl 250 ml	€ 84,800	Remifentanil 2 mg	€ 1,395
Desflurane fl 240 ml	€ 50,349	Propofol 1% 20 ml	€ 0,466
Tubo OT	+/- 1 €		
		Local anaesthethic agents	
Lidocaina 2% 10 ml	€ 0,172	L-bupivacaine 0,25% F. 10 ml	€ 8,922
Hyperbaric bupivacaine 0,5% F. 4 ml	€ 0,863	L -bupivacaine 0,5% F. 10 ml	€ 9,631
Hyperbaric bupivacaine 1% F. 2 ml	€ 0,388	Ropivacaine 0,75% F. 10 ml	€ 1,850
Mepivacaine 2% F. 10 ml	€ 0,919	Ropivacaine 1% F. 10 ml	€ 2,577

Table 8.

Technique	Drugs and devices cost
General anaesthesia * inhal/ TIVA	9.95 - 7.78 (+ BIS 20.5)
Spinal anaesthesia	7 €
Bi-Block	12 €

* values taken from Tab 6 for a duration of 90 minutes

tinely every day (12), leading to a consistent economic saving and reduction of pollution (13).

In this study the results confirm that the consumption of alogenate increase linearly with the increase of fresh gas flow (FGF) supplied by ventilator and using flow under one litre the costs decrease considerably. Moreover the use of Desflurane is more expensive.

In the study the price of carbon dioxide (CO2) absorber, which is replaced more frequently with low flow, wasn't considered .

The study reject the assumption, reported in literature, of a higher cost of TIVA. If the literature confirm a cost 10 times higher for TIVA over inhalational anaesthesia (recommending the use of this technique only in selected cases), the analysis in our Hospital and the results obtained demonstrate that the cost of TIVA is more or less equivalent to the cost of inhalational anaesthesia, except for the economic value for the infusion pump, outflows and BIS electrode. In the long surgical procedure the cost of BIS electrode can be amortize by the low cost of IV drugs. This is true in surgical procedure lasting more than 5 hours or if compared to inhalational anaesthesia with FGF equal or higher than 2L/minute (13).

In the study we confronted also the cost of regional anaesthesia and general anaesthesia for an hypothetic Plastic Surgery procedure of debridment cutaneus and graft of the duration of 90 minutes.

In our hospital is difficult to estimate costs linked to time of anaesthesia (indirect cost) and so we decided to analyze only direct cost for a specific surgical procedure with equal results and with equal skills of the anaesthesiologists.

Our results confirmed the ones found in literature (9-14).Spinal anaesthesia is the less expensive technique .

In the regional anaesthesia the main difference in prices is due to the type of anaesthetic agent used. The choice depends on the onset and offset of the agent and its linked to the type of surgical procedure.

It's also necessary to keep in mind the consumption of general anaesthetic is time related meanwhile for the regional anaesthesia the initial cost might be elevated but after that the need of drug and materials is negligible.

The debate in favour of regional techniques over general anaesthesia might consider also other factors as indirect costs.

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