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Comparison of direct costs associated with the use of balanced general anesthesia and total intravenous anesthesia (TIVA) techniques

Comparación de los costos directos asociados al uso de técnicas de anestesia general balanceada y anestesia total intravenosa (TIVA)

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What do we know about this problem?

No published current data comparing the different pharmacological techniques for general anesthesia maintenance are available in Colombia.

What is new about this study?

This study provides updated information to allow informed decision-making based on cost differences among the various general anesthesia techniques in Colombia.

Abstract

Introduction: Healthcare costs are increasing against the backdrop of scarce resources. Surgical procedures are an important part of healthcare spending, and the cost of anesthetic techniques is relevant as part of the total cost of care and it is a potential target for expenditure optimization. Although important economic differences have been reported internationally for general anesthesia options, there are no publications in Colombia that compare current costs and allow for informed and financially responsible decision-making.

Objective: To quantify and compare direct costs associated with the various general anesthesia options most frequently used at the present time.

Methods: Cost minimization analysis based on a theoretical model of balanced general anesthesia using isoflurane, sevoflurane, desflurane in combination with remifentanil, and TIVA (propofol and remifentanil). Initial results were obtained using a deterministic simulation method and a sensitivity analysis was performed using a Monte Carlo simulation.

Results: The average total cost per case for the different anesthetic techniques was COP 126381 for sevoflurane, COP 97706 for isoflurane, COP 288605 for desflurane and COP 222 960 for TIVA.

Conclusions: Balanced general anesthesia with desflurane is the most costly alternative, 1.2 times more expensive than TIVA, and 2 and 3 times more costly than balanced anesthesia with sevoflurane and isoflurane, respectively. TIVA ranks second with a cost 1.8 times higher than balanced anesthesia with sevoflurane and 2.5 times higher than balanced anesthesia with isoflurane.

Keywords: Cost and cost analysis; Anesthesia, general; Anesthesia, intravenous; Balanced anesthesia; Drug cost; Economics.

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Resumen

Introducción: Los costos de la atención en salud son crecientes y se enfrentan a un escenario de recursos escasos. La realización de procedimientos quirúrgicos hace parte importante de la atención y del gasto en salud, el costo de las técnicas anestésicas utilizadas es relevante en el costo total de la atención y es un objetivo potencial para la optimización del gasto. Aunque a escala internacional se han reportado diferencias económicas importantes entre las alternativas para anestesia general, en Colombia no se cuenta con publicaciones que comparen los costos actuales y permitan una toma de decisiones informada y responsable económicamente.

Objetivo: Cuantificar y comparar los costos directos para Colombia de las diferentes alternativas para anestesia general usadas con más frecuencia en la actualidad.

Métodos: Análisis de minimización de costos basado en un modelo teórico de anestesia general balanceada con isoflurano, sevoflurano, desflurano en combinación con remifentanilo y TIVA (propofol y remifentanilo). Se obtuvieron resultados iniciales utilizando una simulación con un método determinista y se realizó un análisis de sensibilidad con una simulación de Montecarlo.

Resultados: El costo total promedio por caso para las diferentes técnicas anestésicas fue de COP 126.381 para sevoflurano, COP 97.706 para isoflurano, COP 288.605 para desflurano y COP 222.960 para TIVA.

Conclusiones: La anestesia general balanceada con desflurano es la alternativa de mayor costo, es 1,2 veces más costosa que la TIVA, y 2 y 3 veces más que la balanceada con sevoflurano e isoflurano, respectivamente. La TIVA ocupa el segundo lugar con un costo 1,8 veces superior a la balanceada con sevoflurano y 2,5 veces a la balanceada con isoflurano.

Palabras clave: Costos y análisis de costo; Anestesia general; Anestesia intravenosa; Anestesia balanceada; Costo de los medicamentos; Costo de oportunidad.

INTRODUCTION

Every year, 313 million major surgical procedures are performed worldwide (1). In 2012, 5.1 million surgeries were carried out in Colombia (2) and all of these procedures required one form of anesthetic technique or another. This is of particular relevance considering that health sector demand and spending are the fastest growing items in the world economy (3), with global spending amounting to USD 8.3 trillion (equal to 10% of the world gross domestic product [GDP]) and per capita spending amounting to USD 1,080, with a growth of 3.9% per year, even higher than the 3% world economic growth (4). In the specific case of Colombia, the cost of health care accounts for 7% of the GDP, ranking second as the highest public expenditure after debt service (5). For 2012, per capita health spending in Colombia was USD 530 (6).

In Colombia and in the world, fulfillment of health system missions is up against an economy of limited resources and disproportionate increases in demand (7). Healthcare is based on decision-making, and every decision is tied to resource allocation to a specific option, at the expense of various other possibilities. This choice in a shortage scenario creates opportunity cost, understood as loss of benefits when a particular resource is chosen (8). In healthcare, decision-making goes beyond clinical considerations, impacting also economic aspects that affect the entire system. For this reason, choice in health should always be based on the best cost-benefit ratio, namely, one in which the best possible return on resources is obtained while maintaining quality care (9).

This research is conducted within the framework of adult patients taken to surgery under general anesthesia, a scenario which requires selecting among different anesthetic techniques with the ultimate goal of ensuring optimal conditions for undertaking the surgical procedure and highest safety for the patient. The cost of the anesthetic practice accounts for 5% of the entire cost of patient care in surgery (10); when multiplied by the total number of procedures performed over time, this percentage results in a significant total cost (11).

A non-systematic review of the literature conducted in 2003 reported that, in England, the cost of TIVA (Total Intravenous Anesthesia) was 1.7 to 4 times higher than general anesthesia with isoflurane, 2.5 to 4 times higher than anesthesia with desflurane, and 1.3 to 3.8 times higher than anesthesia with sevoflurane (12). In 2005, a cost-effectiveness economic review of a randomized clinical trial in Colombia reported a cost per minute of USD 0.095 for isoflurane, USD 0.17 for sevoflurane and USD 0.2 for desflurane (13). In 2008, a cost minimization analysis of a randomized clinical trial carried out in Serbia reported a cost per case of EUR 17.4 for balanced anesthesia and EUR 22.1 for TIVA (14). In 2014, a systematic review with meta-analysis compared balanced general anesthesia and TIVA in outpatient surgery in a pediatric population, and described that TIVA was more costly than balanced anesthesia, with a mean difference per case of USD 11.29 (95% CI USD 8.62-USD 13.96), and high heterogeneity (I2 = 86%) (15). In 2015, a cost minimization analysis based on a retrospective study in China concluded that there was no significant cost difference between balanced anesthesia with sevoflurane/remifentanil and TIVA (16). In 2018, a cost-effectiveness study based on a randomized clinical trial conducted in Hungary reported a cost per hour of EUR 12.15 for balanced anesthesia and EUR 22.11 for TIVA in otolaryngological surgery (17).

The results of the reviewed studies varied due to drug prices depending on unique market characteristics and variations at different time points and places. The particular conditions of each market, and the resulting heterogeneity, make it difficult to extrapolate the results of one study to a different context (in time and place), as external validity is limited because direct extrapolation to other countries, contexts or historical moments is impaired. The objective of this economic review is to quantify and compare direct costs for Colombia of the different options most frequently used for general anesthesia at the present time in the country, such as balanced general anesthesia with isoflurane, sevoflurane and desflurane (in combination with remifentanil) and total intravenous anesthesia (TIVA).

METHODS

A cost minimization analysis was conducted (18-23) on the basis of a theoretical model of balanced general anesthesia with isoflurane, sevoflurane, desflurane combined with remifentanil, and TIVA (propofol and remifentanil). This economic assessment method was chosen because the results of the non-systematic literature review carried out by the authors showed no differences for the main clinical outcomes in terms of safety and effectiveness of the anesthetic techniques, except for postoperative nausea and vomiting (24-37). This condition of relatively similar outcomes associated with the various techniques reviewed made the direct cost comparison among the anesthetic techniques possible. The main variables impacting the final cost of the four anesthetic techniques were then defined based on the economic analyses published on this topic (11,12,14-17,38-42), allowing a cost minimization analysis using a micro-costing technique (43). Indirect costs or costs associated with workforce productivity were not included in the methodological design of this study.

The variables to be included were defined as differential or non-differential cost, according to their role in standard administration of general anesthesia, and differential-cost variables, i.e., those whose value changes according to patient condition, the length of the surgical intervention and the type of anesthesia, were included. Non-differential cost variables whose costs remain unchanged regardless of the type of patient, operation or anesthesia, were excluded (15,44).

Variables selected for differential cost calculation included length of the surgery, patient weight, consumption in milliliters of the halogenated anesthetic, the hourly dose of remifentanil and propofol, cost of hospital pharmacy services (administrative roles) and cost of the BIS electrode. Price ranges were determined for all medications and devices based on a search in the domestic market (45).

The use of formulas was selected over all other strategies used for estimating the consumption of the halogenated anesthetic such as measurement of the vaporizer volume or weight measurement before and after anesthesia. The main reason was the theoretical nature of this research (12). The literature search yielded three formulas, the first one proposed by Loke and Shearer in 1993 (46), the second by Nakada in 2010 (42) and the third by Biro in 2014 (47). The Biro formula was selected over the other two because it was designed to be used in pharmacoeconomic studies and because it is backed by the strongest arguments and has been used in the largest number of studies (26,48-50).

To determine anesthetic doses, a search was conducted in the literature of the mean site-effect concentrations for a range of various surgical stimuli (51-54). An effect site concentration of 6-7 ng/mL was used during intubation, with an initial bolus of 2-3 µg/kg, and 2-5 ng/mL for maintenance at an infusion rate of 0.1 to 0.2 µg/kg/min (55-57). For propofol, the effect site concentration was 4 µg/mL for induction and 3 µg/mL for maintenance, resulting in 2-3 mg/kg for induction and 6-8 mg/kg/h for maintenance (28,29,51).

Modeling of different scenarios was initially done in Microsoft Excel® (2013), simulating balanced general anesthesia administration (either with sevoflurane, desflurane or isoflurane) and TIVA with propofol and remifentanil. The cost of each vial used was taken into consideration when assessing the cost of each of the intravenous drugs such as propofol and remifentanil, regardless of whether it was used in full (58); in contrast, the cost of halogenated gases was calculated by milliliter. The sale price of the drugs made available to the public by the Health Ministry was used (59).

After completing this deterministic analysis, a Monte Carlo simulation was run using the @Risk software, simulating 100,000 simultaneous scenarios for each of the four options. Variables were combined and assigned a random value within a pre-determined range, using a triangular data distribution for all the variables. This distribution was used because of the paucity of data on the distribution of the variable values in actual scenarios in the Colombian setting (reflected in the absence of publications on this topic in the medical literature) and because of its versatility for modeling distributions characterized by two extreme points and one probable point, as is the case of the variables selected for this modeling (60). The gamma distribution was used in the time variable

Table 1. Parameters used for the Monte Carlo simulation.

Variable	Minimum	Most probable	Maximum	Distribution
Patient weight (kg)	45	70	120	Triangular
Pharmacy cost	10 %	15 %	20 %	Triangular
Infusion equipment	COP 15,000	COP 30,000	COP 35,000	Triangular
BIS electrode	COP 30,000	COP 40,000	COP 60,000	Triangular
Remifentanil price	COP 6,000	COP 10,000	COP 35,000	Triangular
Propofol price	COP 800	COP 8,000	COP 26,000	Triangular
Price of isoflurane bottle	COP 41,600	COP 99,030	COP 443,895	Triangular
Price of sevoflurane bottle	COP 250,000	COP 400,000	COP 600,000	Triangular
Price of desflurane bottle	COP 490,000	COP 560,000	COP 800,000	Triangular
MAC, first hour	1	1.2	1.3	Triangular
FGF, 1 hour	1.5	2	2.5	Triangular
MAC, maintenance	0.6	0.7	0.8	Triangular
FGF, maintenance	0.6	1	1.2	Triangular
Remifentanil 1h µg/kg/min	0.18	0.2	0.4	Triangular
Remifentanil, Maintenance µg/kg/min	0.135	0.18	0.2	Triangular
Propofol bolus mg/kg	0.5	1.2	3	Triangular
Propofol bolus 1 h mg/kg/h	4	6	8	Triangular
Propofol, Maintenance mg/kg/h	3	5	6	Triangular
Hour	1	3.7	12 (infinite)	Gamma

BIS: bi-spectral index; COP: Colombian Peso; FGF: fresh gas flow; Kg: kilogram; MAC: Minimum alveolar concentration; Mg: milligrams.
Source: Authors.

(Table 1) (61). Variance contribution was used when analyzing the results (62).

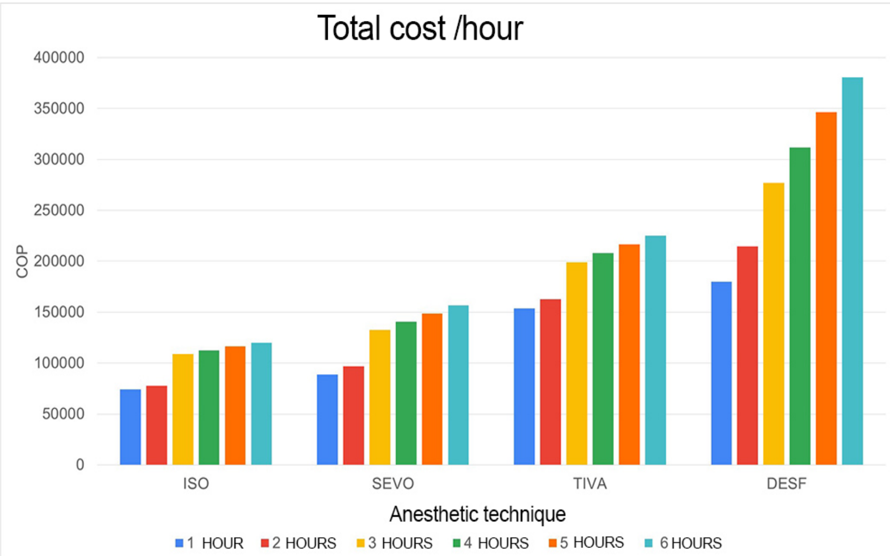
No patient data were used for this study at any time. For this reason, from the ethical standpoint and under the Colombian legislation, it was classified as a low risk study not requiring the approval of a research ethics committee. In order to ensure appropriate and complete reporting, this economic study adheres to the international guidelines of the Consolidated Health Economic Evaluation Reporting Standards (CHEERS).

RESULTS

The results derived from the deterministic model based on an average case of a 70 kg adult patient were as follows: cost for the first hour of COP 65,157 for balanced anesthesia with isoflurane, COP 80,047 for sevoflurane, COP 145,100 for TIVA and COP 171,300 COP for desflurane. At 6 hours, the cost was COP 111,115 for balance anesthesia with isoflurane, COP 147,721 for sevoflurane, COP 207,800 for TIVA and COP 370,050 for desflurane (Figure 1).

The results of the probabilistic method using the Monte Carlo simulation were as follows: total average cost for anesthesia with sevoflurante of COP 126,381, the minimum being COP 60,962 and the maximum COP 474,271; for anesthesia with isoflurane, the total cost was COP 97.706, ranging between a minimum of COP 52,693 and a maximum of COP 363,439; and for anesthesia with desflurane, the average cost was COP 288,605, with a minimum of COP 119.037 and a maximum of COP 1,208,667. For TIVA, the average cost was

FIGURE 1. Total cost/hour, deterministic method.



COP: Colombian Pesos; DESF: Desflurane; ISO: Isoflurane; SEVO: Sevoflurane.

SOURCE: Authors.

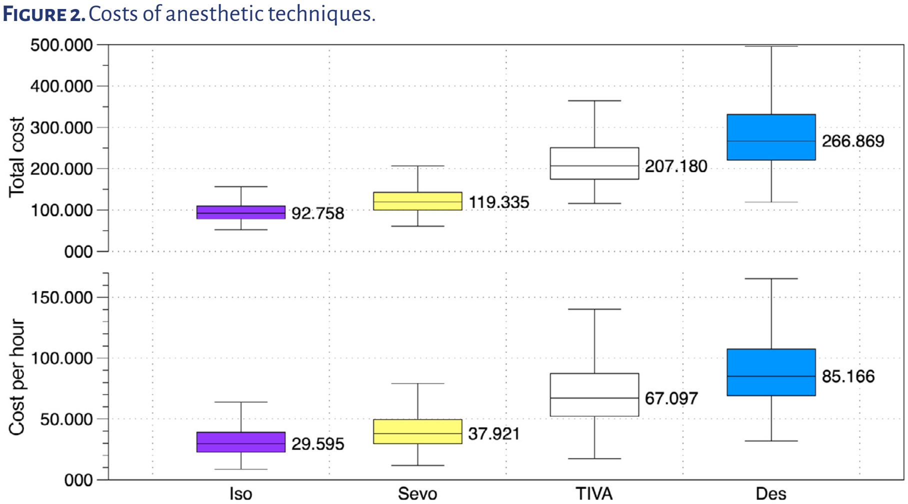
TABLE 2. Cost of anesthetic techniques.

Anesthetic technique	Average cost in thousand COP (90% CI)	Minimum cost in thousand COP	Maximum cost in thousand COP
Balanced with isoflurane	97 (67-147)	52	363
Balanced with sevoflurane	126 (83-196)	60	474
Balanced with desflurane	288 (180-473)	119	1,208
TIVA	222 (148-355)	115	1,174

COP: Colombian Pesos.

SOURCE: Authors.

FIGURE 2. Costs of anesthetic techniques.



COP: Colombian Pesos; DESF: Desflurane; ISO: Isoflurane; SEVO: Sevoflurane.

SOURCE: Authors.

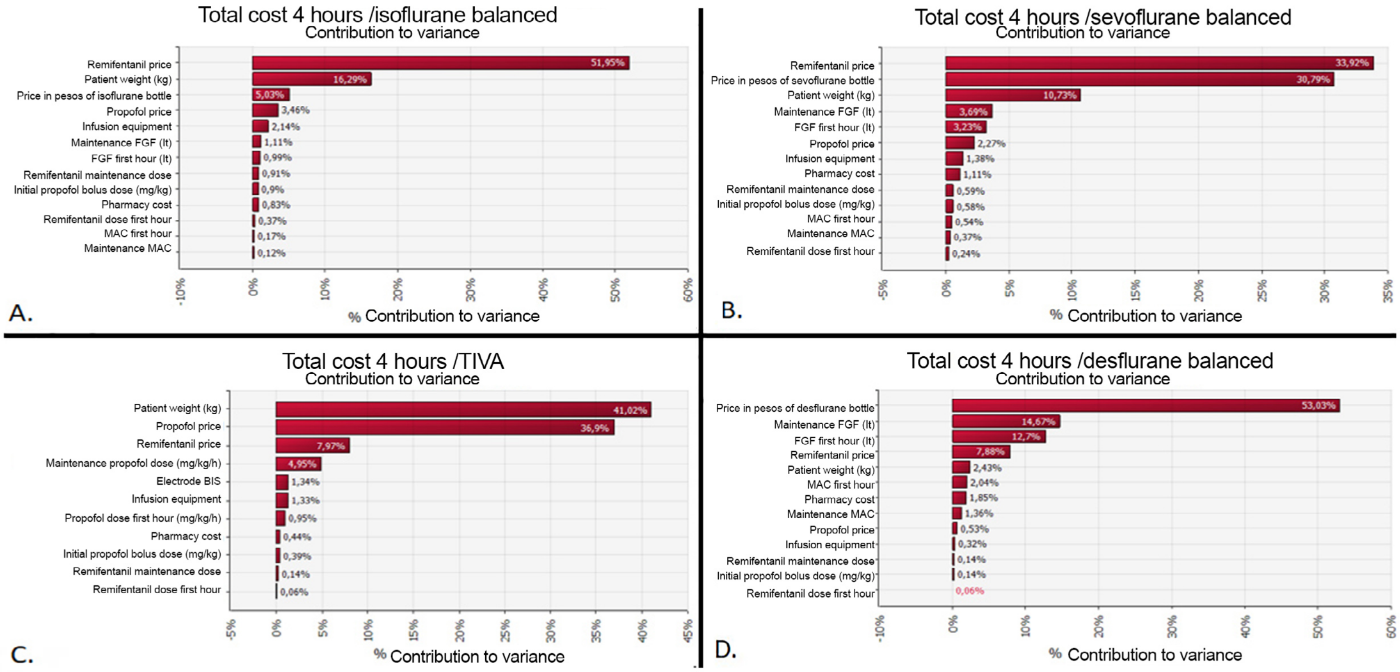
COP 222,960, ranging between a minimum of COP 115,806 and a maximum of COP 1,174,901 (Table 2, Figure 2).

In terms of the variables with the highest impact on cost according to the variance for sevoflurane in the first hour, the highest impact was found for the price of remifentanil, the price of propofol and the price of the sevoflurane bottle; and at six hours, the highest impact was found for the price of remifentanil, the price of the sevoflurane bottle and patient weight. For isoflurane, the variables with the highest impact were the price of remifentanil, the price of propofol and the price of the infusion equipment for the first hour and, for the sixth hour, the price of remifentanil, patient weight and the price of propofol. For desflurane in the first hour, the variables were the price of the desflurane bottle, fresh gas flow and the price of remifentanil and, for the sixth hour, the price of the desflurane bottle, the price of remifentanil, and fresh gas flow. For TIVA in the first hour, the variables were the price of propofol, patient weight and the price of the infusion equipment and, for the sixth hour, the price of propofol, patient weight and the price of remifentanil (Figure 3).

When the total average cost of TIVA was compared with balanced anesthesia with sevoflurane, the probability density showed that, in 99.9% of cases, TIVA was more costly, with a total average cost of 177% of the cost of anesthesia with sevoflurane. When comparing the total average cost of TIVA versus balanced anesthesia with desflurane, the probability density showed that, in 78.2% of cases, TIVA was less costly than balanced anesthesia with desflurane, with a mean of 79% of the cost of anesthesia with desflurane. When comparing the total average cost of TIVA versus balanced anesthesia with isoflurane, the probability density showed that, in 100% of cases, TIVA was more costly than balanced anesthesia with isoflurane, with a mean of 228% of the cost of isoflurane anesthesia.

When the total average cost of balanced anesthesia with desflurane was compared with sevoflurane, the probability

FIGURA 3. Costos de técnicas anestésicas.



FUENTE: Autores.

density showed that, in 100% of cases, the desflurane-based technique was more costly than the technique with sevoflurane, with a mean of 218% of the cost of sevoflurane for the desflurane technique. When comparing the total average cost of balanced anesthesia with desflurane versus TIVA, the probability density showed that, in 78.6% of cases, the desflurane-based technique was more costly than TIVA, with a mean of 122% of the cost of TIVA for the desflurane technique. When comparing the total average cost of balanced anesthesia with desflurane versus balanced anesthesia with isoflurane, the probability density showed that, in 100% of cases, the desflurane-based technique was more costly than the isoflurane technique, with a mean of 303% of the cost of the isoflurane-based technique for the desflurane technique.

DISCUSSION

The results of this economic model lead to the assertion that, by late 2020 in Colombia, the cost of balanced general anesthesia with desflurane was the highest, with an average cost (for 100,000 simulated scenarios) 1.2 times higher than TIVA, 2 times higher than balanced anesthesia with sevoflurane and 3 times higher than balanced anesthesia with isoflurane. TIVA was second only after balanced general anesthesia with desflurane, 1.8 times more costly than balanced anesthesia with sevoflurane, and 2.5 times more costly than balanced anesthesia with isoflurane.

The variables with the highest impact on the cost of each type of anesthesia vary. This knowledge is of the utmost importance when considering cost reduction strategies because it helps focus efforts on the variables with the highest contribution to cost. For anesthesia with desflurane, the price of desflurane, the price of remifentanil and maintenance fresh gas flow (FGF) have the highest impact; for TIVA, the variables with the highest impact are the price of propofol, patient weight and the price of remifentanil; for sevoflurane-based anesthesia, remifentanil and sevoflurane prices, and patient weight have the highest impact; and for isoflurane-based anesthesia, variables with the highest impact are the price of remifentanil, patient weight, and the price of propofol.

The comparison between the different anesthetic techniques shows significant cost differences. Although anesthesia costs appear to be negligible when compared with the total cost of patient care, multiplied by a large number of cases they are quite significant. As a variable to be taken into consideration when selecting an anesthetic technique, cost has an impact not only in the form of immediate cost savings or increases for a hospital or a health system, but also as money that could be used to cover other healthcare needs, such as serving a larger number of patients, improving workforce salaries, improving infrastructure, etc. This would enable the achievement of the "quadruple goal" (63) proposal for high quality and value care, namely, best health outcomes, greater patient satisfaction, lower costs, and enhanced provider and healthcare team experience.

Comparisons between this study and other studies published in the literature revealed methodological heterogeneity. However, there are other economic analyses based on retrospective studies, randomized clinical trials and simulations of varying sizes, although significantly smaller than this study. In terms of results, the main difference found was that total intravenous anesthesia is not the most costly option, while balanced general anesthesia with desflurane is. Like other studies comparing balanced general anesthesia with isoflurane against any other technique, this study found that this modality was the least costly in all the simulated scenarios.

The strengths of this study include the validity of its results for Colombia, because the data came from the domestic context and covered a wide range of prices and values for the variables. It is an innovative study, given that no other study covering the topic of price differences among the various types of general anesthesia available or using a methodology like the one used in this study was found in the literature. Another strength related to the methodology is the soundness and consistency of the results, which were maintained even after conducting the sensitivity analysis with the probabilistic method.

This study has limitations. Given that it is a model-based study, no patients or real scenarios were used, and its results are limited to the variables included and the range of values assigned to those variables. Although the values are based on the available data, they do not cover the total universe of scenarios that can occur in reality due to contingencies, including drug shortages or significant market price variations, as has been the case during the COVID-19 pandemic. This study did not include indirect costs or workforce productivity-related costs, topics which could be assessed in future studies.

CONCLUSION

Using the economic model built for this research in the scenario of adult patients undergoing non-cardiac surgery under general anesthesia in Colombia, significant differences in the total cost of the various anesthetic techniques were identified. The least costly technique was balanced anesthesia with isoflurane, followed by balanced anesthesia with sevoflurane, total intravenous anesthesia and, finally, balanced anesthesia with desflurane. It behoves the reader to interpret this information as a basis for informed decision-making in order to determine whether the cost of selecting one anesthetic technique over another is worth considering.

ETHICAL DISCLOSURES

Ethics committee approval

No patient data were used for this study at any time. For this reason, from the ethical standpoint and under the Colombian legislation, it was classified as a low risk study not requiring the approval of a research ethics committee.

Protection of human and animal subjects

The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data

No patient data were used for this study at any time.

Right to privacy and informed consent

No patient data were used for this study at any time.

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Authors' contributions

JCGF. Study planning, data collection, interpretation of the results, and drafting of the manuscript.

DARV. Study planning, data collection, interpretation of the results, data analysis and drafting of the manuscript.

CGA. Interpretation of the results, and drafting of the manuscript.

Assistance for the study

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Conflict of interest

We declare that none of the authors has a conflict of interest.

Submissions

None declared.

Appreciation

None declared.

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