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ECONOMIC ANALYSIS OF ANESTHETIC DRUG WASTAGE : A PROSPECTIVE OBSERVATIONAL STUDY IN A TERTIARY CARE CENTER

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ABSTRACT

Background : Anesthetic drug wastage has economic and environmental consequences, but data from lower-middle-income countries remain scarce. This study quantified intraoperative drug wastage, distinguishing avoidable from routine wastage, and estimated its annual cost in a Moroccan tertiary care center.

Material and Methods : This prospective observational study was conducted in the central operating theater of a military teaching hospital over one month (March 2023). The first two elective cases of each operating room per day were included (189 interventions, 982 syringes). For seven drugs (propofol, fentanyl, rocuronium, ephedrine, atropine, lidocaine and midazolam), prepared, administered and discarded volumes were recorded. Wastage was classified as avoidable (syringe prepared but never administered) or routine (residual drug in a partially used syringe). Costs were based on 2023 hospital acquisition prices and extrapolated to 6,000 procedures per year.

Results : Atropine was prepared in every case and never administered. Ephedrine was prepared in every case and administered in 52.9% (95% CI 45.8–59.9). Routine wastage predominated for propofol, fentanyl, rocuronium and lidocaine, reflecting a mismatch between vial size and dose. The estimated annual cost of wastage was 244,018 Moroccan dirhams (MAD) (≈24,402 USD); propofol (40.9%) and fentanyl (18.0%) accounted for 58.9% of this loss. Avoidable wastage of emergency drugs (ephedrine and atropine syringes prepared but never administered) cost 30,060 MAD per year.

Conclusions : Most anesthetic drug wastage in this setting was preventable. On-demand preparation of emergency drugs for stable elective patients and procurement of smaller presentations of propofol, lidocaine and fentanyl could reduce both costs and the environmental burden of anesthesia, although the safety of on-demand preparation should first be evaluated prospectively.

KEYWORDS

Anesthetics, intravenous; cost analysis; drug costs; medical waste; operating rooms; sustainability

MAIN ARTICLE

INTRODUCTION

Anesthesia departments are among the most intensive consumers of drugs in the hospital. Although anesthetic agents represent a modest fraction of total hospital expenditure, their use is systematic and repeated for every patient, so small inefficiencies add up to substantial costs.[1] Wastage of anesthetic drugs has been reported to account for a considerable part of intraoperative drug expenditure, with estimates ranging from 20% to 50% in some series.[2-4] Intravenous anesthetics are particularly prone to wastage because of their short stability once opened, the need to prepare some agents in advance for safety reasons, and commercial presentations that often do not match clinical doses. Beyond the financial burden, the disposal of unused drugs such as propofol contributes to environmental contamination, an issue that has become central to sustainable, or "green", anesthesia.[5-7]

Most available data come from high-income countries. Studies from India and Turkey have shown that the lack of appropriate vial sizes is a major driver of wastage in resource-constrained settings,[4,8,9] but, to our knowledge, no study has described wastage patterns in North Africa, where procurement constraints and drug prices differ. The aim of this study was to quantify anesthetic drug wastage in a Moroccan tertiary care center, to distinguish avoidable from routine wastage, to estimate the corresponding annual cost, and to identify practical targets for reducing both expenditure and the ecological footprint of anesthesia without compromising patient safety.

METHODS

Study design and setting

We conducted a prospective, descriptive, observational study in the central operating theater of a tertiary care military teaching hospital in Morocco, from March 1 to March 31, 2023. The study involved only observation of routine drug handling and no intervention or identifiable patient data. The study is reported according to the STROBE guidelines.[10]

Population and sampling

To obtain a feasible sample of daily activity while preserving data accuracy, we included the first two consecutive patients operated on in each operating room each day. We included patients aged 15 years or older undergoing elective surgery or procedures under general anesthesia (with or without mechanical ventilation), procedural sedation, spinal anesthesia or peripheral nerve block. Exclusion criteria were age below 15 years, emergency surgery, cardiac surgery, cesarean delivery and sedation performed outside the operating theater (radiology suites).

Data collection

Data were recorded by nurse anesthetists using a standardized case report form. For each procedure, the form documented the number of ampoules or vials opened and the volumes prepared, administered and discarded for each study drug. Additional variables included age, sex, American Society of Anesthesiologists (ASA) physical status,[11] surgical specialty, anesthetic technique, and the grade of the lead anesthesia provider (professor, specialist or supervised resident).

Study drugs and definitions

Seven drugs were selected because of their frequency of use and economic relevance in our institution: propofol (200 mg/20 mL), fentanyl (500 µg/10 mL), rocuronium (50 mg/5 mL), ephedrine (30 mg/1 mL), atropine (1 mg/1 mL), lidocaine (400 mg/20 mL) and midazolam (5 mg/5 mL). Bupivacaine and morphine were not included because they are supplied in a single presentation in our institution, leaving no room for an alternative procurement strategy.

The preparation rate was defined as the proportion of included cases in which the drug was drawn into a syringe, and the administration rate as the proportion of prepared syringes that were at least partly administered. Following Atcheson et al.,[12] wastage was classified as avoidable (syringe prepared in anticipation of use but never administered) or routine (volume remaining in a syringe that had been partly administered).

Cost analysis

Unit acquisition costs were obtained from the 2023 hospital pharmacy price list. The cost of wastage was calculated as the discarded volume multiplied by the acquisition cost per milliliter, and expressed as the mean cost per included patient (total cost of wasted drug divided by 189). Annual costs were extrapolated by multiplying the mean cost per patient by an annual caseload of 6,000 procedures, corresponding to the number of elective procedures performed in the central operating theater in 2022. Costs are reported in Moroccan dirhams (MAD) and

converted to US dollars at an approximate 2023 rate of 1 USD $\approx$ 10 MAD. Only the cost of the drug itself was considered; consumables (syringes, needles, tubing) and hazardous waste disposal were excluded. To account for uncertainty in the extrapolation, a sensitivity analysis was performed by varying the mean cost per patient and the annual caseload by $\pm 20\%$, separately and simultaneously.

Statistical analysis

Data were analyzed with Jamovi version 2.3.21.0. Categorical variables are presented as numbers and percentages, and key proportions with 95% confidence intervals (CI) calculated by the Wilson method. No formal sample size calculation was performed, as all cases meeting the sampling criteria during the study period were included.

RESULTS

Study population

A total of 189 interventions were observed, involving 982 prepared syringes. Patient and procedural characteristics are shown in Table 1. Most patients were male (56.1%) and classified as ASA I or II (98.4%). General anesthesia was the most frequent technique (58.2%), followed by spinal anesthesia, procedural sedation and peripheral nerve blocks. Anesthesia was led by a supervised resident in 61.4% of cases.

Drug preparation and administration

Preparation and administration rates are summarized in Table 2. Ephedrine and atropine were prepared systematically in all cases, and fentanyl in 94%, whereas propofol (71%), midazolam (63.0%) and rocuronium (57%) were prepared according to the anesthetic plan.

Avoidable wastage

Avoidable wastage was driven by the systematic preparation of emergency drugs. Atropine was prepared for all 189 patients and never administered (0%; 95% CI 0–2.0), so that every prepared syringe was discarded; extrapolated to the annual caseload, this corresponds to 6,000 ampoules. Ephedrine was administered in 100 of 189 cases (52.9%; 95% CI 45.8–59.9), so that 47.1% of ephedrine syringes were discarded unused. Although midazolam was prepared on demand, 23 of 119 prepared syringes (19.3%; 95% CI 13.2–27.3) were not administered.

Routine wastage

Routine wastage depended on the anesthetic technique and on the pharmaceutical presentation. Propofol generated the largest volume of residual waste. The highest waste per patient (about 260 mg) occurred during total intravenous anesthesia with target-controlled infusion for short gastroenterology procedures, in which two to three 20 mL vials were pooled to fill a 50 mL syringe, most of which remained unused at the end of the procedure. Mean routine fentanyl waste was 183 µg per patient under general anesthesia and 213 µg under spinal anesthesia, where a 500 µg ampoule was opened for an intrathecal dose of a few micrograms. Lidocaine was almost fully used when the 20 mL vial served for peripheral nerve blocks, whereas about 90% of the vial was discarded during general anesthesia, where only 20–40 mg was needed to attenuate propofol injection pain or the response to intubation.

Economic impact

The estimated annual cost of wastage for the seven drugs was 244,018 MAD (≈24,402 USD) (Table 3). In the sensitivity analysis, varying either the mean cost per patient or the annual caseload by ±20% yielded an annual cost of 195,214 to 292,822 MAD, and varying both simultaneously yielded 156,172 to 351,386 MAD. Routine wastage accounted for most of this loss: propofol (99,720 MAD; 40.9%) and fentanyl (44,040 MAD; 18.0%) together represented 58.9% of the total. Avoidable wastage of ephedrine and atropine (syringes prepared but never administered) cost 30,060 MAD per year (ephedrine 19,380 MAD; atropine 10,680 MAD). Including the residual volume of partly used ephedrine syringes (11,100 MAD), the total annual cost of emergency drug wastage was 41,160 MAD. For midazolam, the cost of wastage amounted to about 5 MAD per prepared syringe.

DISCUSSION

This study shows that intraoperative drug wastage represents a substantial and largely preventable loss in a North African teaching hospital, estimated at approximately 244,000 MAD per year for only seven drugs. Two distinct mechanisms were identified: avoidable wastage, linked to the systematic preparation of emergency drugs, and routine wastage, linked to a mismatch between commercial presentations and clinical doses. Routine wastage was financially dominant.

This figure should be regarded as a conservative estimate. Only acquisition costs were included, whereas for inexpensive drugs such as atropine the syringe and needle often cost

more than the drug itself. Including consumables, nursing preparation time and hazardous waste disposal would increase the true cost of each wasted dose, as reported in other analyses.[2,3,9]

The cost of readiness: emergency drugs

Ephedrine and atropine are routinely prepared "just in case" to allow an immediate response to hypotension or bradycardia. In our elective, largely ASA I–II population, atropine was never administered and nearly half of ephedrine syringes were discarded. Similar findings were reported by Atcheson et al., who observed negligible use of these drugs in routine cases,[12] and by Lejus et al., who identified atropine and ephedrine as a major source of waste in the operating theater.[13] Barbariol et al. showed that, despite low unit costs, the volume of such waste makes these drugs a significant financial burden.[14]

Atropine remains an essential medicine for safe surgery,[15] and its immediate availability must be preserved. The tension between safety and efficiency may be addressed by moving from systematic preparation to immediate availability. Prefilled syringes, with long shelf lives, reduce both waste and preparation errors.[16] In a lower-middle-income setting, however, their higher unit cost must be weighed against the cumulative cost of wasted ampoules, consumables and nursing time. Given the low price of generic atropine in Morocco, the break-even point may be difficult to reach on direct costs alone, and their adoption should rather be justified on safety grounds. For stable elective patients, a simpler alternative is to keep an unopened ampoule and a labeled syringe at the workstation, which could save thousands of ampoules each year.[12] However, this study did not assess preparation times, treatment delays or adverse events, so the safety of this strategy remains a hypothesis that should be evaluated prospectively before it is adopted.

Vial-size mismatch: routine wastage

Propofol accounted for 40.9% of the total cost of wastage, mainly during target-controlled infusion for short gastroenterology procedures, where filling a 50 mL syringe inevitably leads to large residual volumes. This is consistent with Chaudhary et al.[4] and Kaniyil et al.,[8] who identified large propofol presentations as major contributors to waste, and with Mankes, who showed that smaller presentations could substantially reduce propofol waste.[17] Preparing smaller initial volumes and refilling the syringe when needed is another simple option for short procedures.

Lidocaine illustrates the same problem. Stocking only 20 mL vials suits peripheral nerve blocks but results in about 90% wastage during general anesthesia. Hospital pharmacies often favor a

single presentation to obtain lower unit prices, but our data suggest that the hidden cost of discarding most of each vial may exceed the savings from bulk purchasing for some indications.[9] Similarly, using 100 µg fentanyl ampoules instead of 500 µg ampoules for spinal anesthesia would be a simple, high-impact measure. Procurement choices should therefore be clinically driven, with smaller presentations of propofol (10 or 20 mL), lidocaine (2 or 5 mL) and fentanyl available where they match actual use.

For midazolam, the cost of wastage was about 5 MAD per prepared syringe, partly because standard dilutions exceed the dose actually needed for premedication; drawing up only the predicted dose could reduce this loss. Rocuronium was wasted in small volumes, but its high unit cost made it the fourth largest contributor, as also reported by Peker et al.[9]

Clinical experience and training

The influence of provider grade on drug use was not formally analyzed in this study, and any observed differences would be confounded by patient characteristics, anesthetic technique and surgical complexity; this question deserves dedicated study. Simple educational interventions on drug costs have been shown to reduce expenditure by up to 23% without affecting quality of care.[1,18] In a teaching hospital where most cases are managed by residents, integrating pharmacoeconomics and sustainability into the residency curriculum could have a durable effect.

Environmental burden

The healthcare sector contributes substantially to global pollution, creating a paradox in which health systems worsen environmental threats to public health.[19,20] Anesthesiologists therefore have an ethical responsibility to reduce the environmental impact of their practice.[21,22] Although attention has focused mainly on volatile anesthetics, intravenous drug waste also matters: the production and incineration of unused drugs contribute to indirect emissions, and propofol discarded into sinks may reach wastewater and is toxic to aquatic organisms.[5] Using the smallest suitable presentation, disposing of unused propofol by incineration rather than into drains, and preparing drugs on demand are therefore both economic and environmental measures.[6,7]

Limitations

This study has several limitations. First, it was conducted in a single center over one month, which limits generalizability. Second, including only the first two elective cases of each operating room introduces a selection bias, as these cases may differ from later cases in surgical complexity, procedure duration, anesthetic technique and time of day; wastage in complex or

urgent cases was not captured. Third, annual costs were extrapolated from 189 procedures observed over one month to 6,000 procedures per year, assuming that the sample is representative of the yearly case mix, which we could not verify; the sensitivity analysis therefore provides a plausible range rather than a precise estimate. Fourth, data were collected by nurse anesthetists who were aware of the study, which may have modified their practice. Fifth, the study period partly overlapped with Ramadan, which may have influenced the case mix. Sixth, the influence of provider grade and of patient characteristics, anesthetic technique and surgical complexity on drug use was not analyzed. Finally, costs were based on institutional acquisition prices and excluded consumables and disposal.

CONCLUSION

Anesthetic drug wastage in our institution represents a significant and largely preventable economic and environmental burden, driven by the systematic preparation of emergency drugs and by vial sizes that do not match clinical doses. On-demand preparation of emergency drugs for stable elective patients, with prefilled syringes where cost-effective, and procurement of smaller presentations of propofol, lidocaine and fentanyl are potential measures to align economic efficiency with sustainable anesthetic care; their effect on patient safety should be evaluated in prospective studies.

TABLES :

Table 1 : Patient and procedural characteristics

Characteristic	n	%
Sex		
Male	106	56.1
Female	83	43.9
Age group (years)		
15–39	51	27.0
40–64	93	49.2
≥65	45	23.8
ASA physical status		
I	101	53.4
II	85	45.0
III	3	1.6
Anesthetic technique		
General anesthesia	110	58.2
Spinal anesthesia	46	24.3
Procedural sedation	23	12.2
Peripheral nerve block	10	5.3
Lead anesthesia provider		
Supervised resident	116	61.4
Specialist	38	20.1
Professor	35	18.5
Surgical specialty		
Visceral surgery	54	28.6
Orthopedics/trauma	50	26.5
Neurosurgery	21	11.1
Gastroenterology	21	11.1
Otorhinolaryngology	16	8.5
Gynecology	10	5.3
Thoracic surgery	9	4.8
Maxillofacial surgery	8	4.2

Data are presented as n (%). ASA: American Society of Anesthesiologists.

Table 2 : Preparation, administration and dominant type of wastage of the study drugs
(N=189 interventions)

Drug	Presentation	Preparation rate (%)	Administration rate (%)	Dominant wastage
Ephedrine	30 mg/1 mL	100	52.9	Avoidable
Atropine	1 mg/1 mL	100	0	Avoidable
Fentanyl	500 µg/10 mL	94	100	Routine
Lidocaine	400 mg/20 mL	75	100	Routine
Propofol	200 mg/20 mL	71	100	Routine
Midazolam	5 mg/5 mL	63.0	80.7	Mixed
Rocuronium	50 mg/5 mL	57	100	Routine

Preparation rate: proportion of cases in which the drug was drawn into a syringe.
Administration rate: proportion of prepared syringes that were at least partly administered.
Routine wastage: residual drug in partly administered syringes. Avoidable wastage: prepared syringes discarded unused.

Table 3 : Estimated annual cost of anesthetic drug wastage by drug and mechanism

Drug	Routine loss per patient (MAD)	Avoidable loss per patient (MAD)	Annual cost (MAD)	Annual cost (USD)	Share of total (%)
Propofol	16.62	—	99,720	9,972	40.9
Fentanyl	7.34	—	44,040	4,404	18.0
Ephedrine	1.85	3.23	30,480	3,048	12.5
Rocuronium	5.08	—	30,480	3,048	12.5
Midazolam	2.78	0.42	19,198	1,920	7.9
Atropine	—	1.78	10,680	1,068	4.4
Lidocaine	1.57	—	9,420	942	3.9
Total			244,018	≈24,402	100

Losses are expressed as the mean cost per included patient (total cost of wasted drug/189). Annual costs were extrapolated to 6,000 procedures per year using 2023 hospital acquisition prices. MAD: Moroccan dirham; USD: US dollar (1 USD ≈ 10 MAD). Percentages may not total 100 because of rounding.

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