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Evaluation of wastage of commonly used anaesthetic agents in the operating theatres of a South African teaching hospital

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Background. Anaesthetic drug wastage negatively impacts the already constrained economy in developing countries such as South Africa (SA). However, safe anaesthetic drug administration during both elective and emergency surgeries can be achieved without increasing wastage or costs. Drugs frequently wasted include those required in emergencies. Cost-reduction strategies, particularly in drug wastage, represent a potential area for short-term savings in hospital drug budgets. Increasing clinician awareness of drug wastage can help modify practices, leading to reduced waste while maintaining high-quality patient care.

Objective. To evaluate wastage of commonly administered anaesthetic drugs, and to evaluate preventable and routine drug wastage and its cost.

Methods. A prospective observational study was conducted in the operating theatre of Chris Hani Baragwanath Academic Hospital, a tertiary hospital in SA. Prospective data were collected for all patients who presented for elective and emergency surgical procedures at this institution over a 2-week period. Drug preparation and administration were determined by the treating anaesthesiologist. The amount of remaining drug in syringes and opened ampoules was considered as wasted. Routine drug wastage was defined as the remaining drug after the required dose was administered, while preventable drug wastage referred to drugs drawn but not administered to the patient.

Results. Data were collected from 373 participants, of whom 58% were undergoing elective surgery. The average drug wastage was 29.7%, comprising 21.3% routine wastage and 8.4% preventable wastage, with an effect size of 0.47 ($p<0.001$). Propofol accounted for the highest frequency of routine drug wastage, while preventable wastage was predominantly attributed to adrenaline, atropine and suxamethonium (emergency pharmacological agents). The average cost of routine wastage was ZAR3.85, significantly higher than the ZAR1.32 for preventable drug wastage ($p<0.001$). Multivariate regression analysis revealed a significant association between paediatric surgical cases and increased anaesthetic drug wastage ($p=0.004$).

Conclusion. The cost and wastage of anaesthetic drugs pose significant challenges in healthcare institutions, particularly in developing countries with limited resources. Implementing cost-effective strategies, such as using smaller ampoules and prefilled syringes, has been demonstrated to reduce drug wastage without compromising patient care.

Keywords: anaesthetic drugs, routine drug wastage, preventable drug wastage, drug cost, general anaesthesia, regional anaesthesia, sedation technique

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Increasing healthcare costs create ongoing stress globally for governments and healthcare systems.[1] This burden necessitates an awareness drive, and for clinicians and healthcare workers to practise cost-effective methods in patient health management. In 2017, 10% - 15% of the total healthcare cost in South Africa (SA) was attributed to the use of pharmaceutical agents.[2,3] Healthcare workers should be made aware of this matter, and should assist in the reduction of this financial burden by exploring cost-effective methods in the use of pharmacotherapy that would have minimal impact on the quality and safety of patient care.

Wastage of anaesthetic drugs has been reported in various publications.[4-7] Approximately USD13 - 30 (ZAR234.52 - 541.20) worth of anaesthetic drugs are wasted per case in nearly 25 million cases in the USA annually.[8] In a study by Kaniyil *et al.*,[9] investigating the financial impact of anaesthetic drug waste at a government medical college hospital in India, the total cost of wastage was found to be INR59 631.49 (ZAR 14 484.86), with an average daily loss of INR1 987.67 (ZAR486.36). A prospective observational study conducted across 12 regional hospitals in Italy estimated annual waste in operating theatres and intensive care units (ICUs) to be USD92 569 (ZAR1 669 944.76).[4]

Previous investigators have demonstrated adrenaline, atropine, succinylcholine, phenylephrine and propofol as the most commonly wasted intravenous anaesthetic agents, as they are often drawn up in anticipation of intraoperative emergencies.[5,7] A 2013 study from Nigeria reported a wastage of over 50% of intravenous anaesthetic agents, including propofol and 0.5% bupivacaine, over a 3-month period.[10]

Drug wastage also contributes to environmental contamination. An intravenous agent such as propofol, which is often used in theatre and ICU environments, can pose an environmental hazard when there is improper disposal of unused or half-used ampoules. Propofol is a lipid-soluble anaesthetic drug that is not biodegradable.[11] It is highly toxic to aquatic organisms should it end up in hydrospheres, and can contribute to global warming through its recommended disposal technique of incineration.[4,11-13] The choice of certain

anaesthetic agents such as volatile or inhalational agents can further contribute to the environmental carbon footprint through the emission of greenhouse gases.[11]

In resource-limited developing countries with ongoing drug shortages, minimising pharmaceutical waste is essential.[2,5] This can assist in optimising resource allocation and ensuring the efficacy of available medications. The absence of systematic audits in SA underscores the need for investigations aimed at identifying cost-reduction strategies through the optimisation of anaesthetic practices, while maintaining safe and effective patient management. The aim of the present study was to evaluate the wastage of commonly used anaesthetic drugs in the operating theatres at Chris Hani Baragwanath Academic Hospital (CHBAH). The focus was on intravenous and intrathecal drug administrations in theatre settings, aiming to educate and raise awareness among anaesthesia providers, while proposing future cost-saving measures that do not compromise patient safety.

Methods

A prospective, observational single-centre study was performed at CHBAH in Soweto, Johannesburg, a tertiary academic hospital affiliated to the University of the Witwatersrand. Data of participants presenting for elective and emergency surgery at the JD-Allen Theatre Complex and the Neonatal and Maternity Theatres were collected over a 2-week period between 11 and 22 July 2022. One researcher (PM) collected all data across the different theatres, following every theatre case in the time period. Approval to conduct the study was granted by the Human Research Ethics Committee (HREC – Medical), University of the Witwatersrand (ref. no. M220264 R14/49).

Data comprised all adult and paediatric participants who presented for surgery in the specified time period. The included participants received anaesthesia as either general, regional or sedation. Data on drug wastage were collected at the end of every case. Drug preparations and administration were decided by the anaesthesiologist conducting the case (not involved in the study).

Participant data were excluded when drug syringes were unlabelled, syringes were already discarded in the biohazardous sharps containers, or for participants who presented to remote site areas (gastroscope, magnetic resonance imaging, endovascular suites, etc.) for intervention procedures requiring anaesthesia care.

The amount of drug remaining in syringes and in opened ampoules was considered as wasted. In this study, routine drug wastage was considered as the amount of drug remaining after a required dose for the case was administered to the patient, while preventable drug wastage referred to drugs drawn up for anaesthesia purposes but not utilised during the surgical case and therefore discarded.

A data collection sheet was utilised to collect information that was captured electronically onto the Research Electronic Data Capture (REDCap) system. The cost of each drug was worked out according to CHBAH's pharmacy acquisition cost per millilitre or milligram (mL or mg) of that drug. Researchers requested the pharmacist to provide a list of the cost per ampoule and the volume (mL) or weight (mg) contained in each ampoule. Using this information, we calculated the cost per mL or mg and subsequently determined the cost of the volume or weight left unutilised at the end of the surgical case.

Data were presented as means and standard deviations (SDs) for continuous variables, and as frequencies for categorical variables. Statistical analysis was conducted using SPSS Statistics for Windows, version 28.0 (IBM Corp., USA), with the threshold for statistical significance at $p \leq 0.05$. Levene's test was used to assess the homogeneity of variances, and deviations of data points from their mean. Welch's *t*-test, a variation of the independent two-sample *t*-test, was employed to compare means when the assumption of equal variances was violated.

A statistical model was developed to analyse the relationship between pharmacological agents and various surgical categories based on the collected data points. Univariate and multivariate logistic regression analyses were conducted to assess the association between anaesthetic drugs, surgical categories (routine and preventable) and drug wastage. In the univariate analysis, each predictor was tested for its association with drug wastage outcomes. Variables with $p<0.1$ were included in the multivariate logistic regression model. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated to quantify the strength of these associations. This analysis was performed using R statistical programming version 4.40, with statistical significance set at $p<0.05$.

Results

Data points of 373 participants who presented for surgery were collected (Table 1). Most cases were elective at a frequency of 58% (n=216), while 42% of cases were emergencies. Obstetric and orthopaedic cases (97 and 61 cases, respectively) were the most commonly performed surgical procedures. Acute care surgical cases encompass surgical emergencies excluding trauma-related surgeries. These cases include emergency laparotomies for acute abdominal pathologies (e.g. appendicectomies, perforated hollow viscera), incision and drainage of abscesses, and other septic surgical conditions.

General anaesthesia was more frequently performed (n=190; 51%) than regional anaesthesia (n=165; 44%) and the sedation technique (n=18; 4.8%). Spinal anaesthesia (n=185) was the most frequently performed regional anaesthetic technique. Caesarean sections (obstetrics procedures: 26%) and lower-limb orthopaedic procedures are regularly performed under spinal anaesthesia in this institution.

A total of 1 864 drug preparations, which represent the total number of ampoules of anaesthetic drugs used during the study period, were prepared and administered to 373 participants. Some participants received up to 12 different drug preparations per

Table 1. Surgical procedure types and patient distribution (N=373)

Procedure	Patients, *n*	Total observations, %
ACS	21	5.6
Breast	10	2.7
Burns	5	1.3
Colorectal	14	3.8
ENT	25	6.7
Gynaecology	47	12.6
Hepatobiliary	5	1.3
Maxillofacial	11	2.9
Neonatal	3	0.8
Neurosurgery	1	0.3
Obstetrics	97	26.0
Orthopaedics	61	16.4
Paediatrics	34	9.1
Radiology	4	1.1
Trauma	4	1.1
Urology	22	5.9
Vascular surgery	9	2.4

ACS = acute care surgery; ENT = ear, nose and throat.

surgical procedure. Table 2 illustrates the quantity of anaesthetic drugs administered to the study participants. The first column of the table provides the amount of each pharmacological agent contained in a single ampoule. The most commonly administered anaesthetic drugs were fentanyl (*n*=320; 17.2%), 1% propofol (*n*=188; 10.1%) and intravenous paracetamol (*n*=130; 7%).

The percentage of routine drug wastage was more than 2.5 times that of preventable wastage. Although preventable drug wastage was significantly lower than routine drug wastage (8.4% v. 21.3%), emergency anaesthetic drugs, including adrenaline (94.4%), atropine (85.7%) and suxamethonium chloride (36.2%), exhibited considerably higher percentages of preventable wastage than routine (Table 3).

The 21.3% routine wastage is statistically significantly different from the 8.4% preventable wastage, with an effect size of 0.47. This large effect size highlights the magnitude of the problem. Equality of variance was evaluated using Levene's test, which yielded a significant $p<0.001$. Consequently, Welch's *t*-test was performed, also producing a significant result.

The average cost for routine drug wastage (ZAR3.83) was statistically significantly different from the average preventable wastage (ZAR1.32) (Table 4), although the calculated effect size of 0.03 suggests a small effect (<0.2). Equality of variance was again tested using Levene's test, which yielded a significant $p<0.001$. Consequently, Welch's *t*-test was performed, and the result was significant.

The four surgical categories with the highest routine drug wastage percentages were neurosurgery (55%), obstetrics (51.86%), gynaecology (44.86%) and paediatric surgery (42.46%) (Table 5), despite neurosurgical cases accounting for only 0.3% of the total observations (Table 1). Preventable drug wastage was highest in neonatal surgical cases, accounting for 33.33%.

Table 5S (Appendix 1: http://coding.samedical.org/file/2331) presents a detailed breakdown of the percentage wastage of routine and preventable anaesthetic drugs across surgical disciplines. In neurosurgical, paediatric and neonatal cases, 1% propofol consistently shows high routine wastage, with rates of 55%, 61.64% and 48.25%, respectively.

A univariate logistic regression model was employed to examine associations between anaesthetic drug agents, surgical categories and routine and preventable drug wastage. When a multivariable regression model was applied, 0.5% bupivacaine-hydrochloride with dextrose was the only drug that showed statistical significance ($p<0.001$) (Table 6). Additionally, paediatric surgical cases were found to be associated with increased wastage of anaesthetic drugs in this audit ($p=0.004$).

Discussion

Distinguishing between routine and preventable drug wastage is essential for accurately quantifying the potential waste of pharmacological agents in theatre settings.

In this audit, overall wastage was higher for routine drug wastage (21.3%) than preventable drug wastage (8.4%). This difference can be attributed to the fixed dosages per ampoule of various pharmacological agents, which are often supplied in volumes exceeding the required amount. As a result, excess drug amounts that are not administered to the patient contribute to routine drug wastage. This is particularly relevant in paediatric anaesthetic cases, where smaller drug volumes are required, which are often further diluted to administer a calculated dose, leading to potential wastage. Appendix 1, which provides a detailed breakdown of the percentage wastage of routine and preventable anaesthetic drugs per surgical discipline, highlights the relatively higher routine wastage in neonatal (32.17%) and paediatric

Table 2. Type and amount of anaesthetic drugs administered (*N*=1 864)

Pharmacological agent	Drug syringes, n	Drug syringes, %
Adrenaline (1 mg/mL)	71	3.8
Alfentanil (1 mg/mL)	11	0.6
Atropine (1 mg/mL)	21	1.1
0.5% bupivacaine-hydrochloride with dextrose (4 mL)	124	6.7
0.5 % bupivacaine-hydrochloride with adrenaline (20 mL)	30	1.6
Calcium chloride (10 mmol/10 mL)	2	0.1
Cisatracurium (10 mg/5 mL)	11	0.6
Dexamethasone (4 mg/mL)	115	6.2
50% dextrose (20 mL)	9	0.5
Ephedrine (50 mg/mL)	41	2.2
Etomidate (20 mg/10 mL)	9	0.5
Fentanyl (100 µg/2 mL)	320	17.2
Glycopyrrolate (0.4 mg/2 mL)	62	3.3
Ketamine (100 mg/10 mL)	64	3.4
Midazolam (5 mg/5 mL)	51	2.7
Morphine (15 mg/mL)	113	6.1
Neostigmine (2.5 mg/mL)	62	3.3
Ondansetron (8 mg/4 mL)	28	1.5
Oxytocin (5 IU/mL)	111	6.0
Paracetamol (1 g/50 mL)	130	7.0
Phenylephrine (10 mg/mL)	93	5.0
0.5% plain bupivacaine-hydrochloride (10 mL)	69	3.7
1% propofol (20 mL)	189	10.1
Remifentanil (2 mg/mL)	6	0.3
Rocuronium (50 mg/5 mL)	75	4.0
Suxamethonium chloride (100 mg/2 mL)	47	2.5

(42.6%) cases. The primary contributor to this increased wastage was 1% propofol, with wastage rates of 55% and 61.64%, respectively.

In this study, propofol was available in 20 mL and 50 mL ampoules with a 1% concentration, with 50 mL ampoules reserved for total intravenous anaesthesia. The majority of waste is routine, as patients typically do not require the full 20 mL ampoule.[3,14] This is particularly relevant in paediatric and neonatal surgical cases, where much smaller amounts of propofol are required for both the induction and maintenance of anaesthesia. This finding is consistent with other studies, such as one by Mankes,[12] where propofol was among the most commonly wasted drugs, with an average of 69.86 mg wasted per case, accounting for 45% of the total wastage. Some studies have suggested that smaller ampoules, such as 10 mL vials of 1% propofol, should be made available, particularly for paediatric cases and smaller adult patient populations.[5] The use of smaller vials in these patients could help to reduce the amount of routine drug wastage of propofol.[5] To date, no audits have compared drug wastage in healthcare institutions by evaluating smaller volume drug vials v. standard vials, owing to the unavailability of smaller vials.

In contrast to the present study, Atcheson *et al.*[7] demonstrated that preventable drug wastage occurred more frequently, with <20% attributed to routine drug wastage. Pre-emptive drug preparation in emergency theatres contributes to the increased preventable drug wastage by anaesthesiologists. In the present audit, the anaesthesiologists administering anaesthesia care to patients were not part of the research team. This decision was made by researchers to ensure that the anaesthesiologists' usual care practices were maintained, and to blind them to the study's objectives. However, the results of this study, where preventable drug wastage was lower than routine wastage, may have been influenced by the anaesthesiologists' inadvertent awareness of the study measures and goals, despite efforts to blind them to the study objectives. This suggests the possibility of a Hawthorne effect, where clinicians may have altered their practices, with many choosing not to routinely draw up emergency drugs such as adrenaline and ephedrine, which are commonly used to treat hypotension during anaesthesia.[7]

Adrenaline, suxamethonium chloride and atropine were among the individual drugs with the highest levels of preventable drug wastage. Suxamethonium chloride, a muscle relaxant, is crucial in emergency situations where the risk of aspiration is elevated, and during preparations for difficult airway management. It is also routinely drawn up as an emergency drug for the treatment of anticipated laryngospasms, particularly in paediatric cases.[7] Chaudhary *et al.*[3] observed that suxamethonium chloride wastage accounted for 92.63% of the total drug wastage in their study. It is possible to prevent the wastage of this muscle relaxant without compromising patient safety. It has been suggested that placing an unopened ampoule at the anaesthetic station, along with a prefilled syringe of saline, could potentially reduce suxamethonium wastage.

Adrenaline and atropine are emergency drugs routinely drawn up in emergency and paediatric theatres at this institution as part of the emergency protocol. However, these pharmacological agents are frequently discarded, as they typically remain unutilised. Other studies and institutional protocols advocate for the use of prefilled syringes, which could serve as a possible solution to wastage of emergency drugs in theatres. The use of prefilled syringes can help to reduce costs and minimise medical dilution errors, especially in paediatric theatres, where dilutions of pharmacological agents such as suxamethonium chloride are required.[15-17] Evidence-based

Table 3. Routine and preventable percentage of drug wastage

Pharmacological agent	Total routine wastage, %	Total preventable wastage, %
Adrenaline	5.3	94.4
Alfentanil	20.9	9.1
Atropine	7.6	85.7
0.5% bupivacaine-hydrochloride with dextrose	54.0	0.0
0.5% bupivacaine-hydrochloride with adrenaline	21.0	0.0
Calcium chloride	10.0	0.0
Cisatracurium	30.9	0.0
Dexamethasone	5.1	1.7
50% Dextrose	54.4	0.0
Ephedrine	37.3	7.3
Etomidate	11.7	0.0
Fentanyl	12.8	0.3
Glycopyrrolate	4.5	0.0
Ketamine	15.2	9.4
Midazolam	31.6	12.5
Morphine	31.8	5.3
Neostigmine	6.2	0.0
Ondansetron	5.6	0.0
Oxytocin	1.2	3.9
Paracetamol	8.3	0.8
Phenylephrine	57.2	16.1
0.5% plain bupivacaine-hydrochloride	32.4	0.5
Propofol	35.1	3.4
Remifentanil	57.7	0.0
Rocuronium	21.8	2.9
Suxamethonium chloride	1.1	36.2
Overall wastage	21.3	8.4

Table 4. Average cost of routine and preventable drug wastage

Pharmacological agent	Average cost RDW, ZAR	Average cost PDW, ZAR
Adrenaline	0.50	4.87
Alfentanil	10.39	4.76
Atropine	0.33	4.00
0.5% bupivacaine-hydrochloride with dextrose	2.65	0.00
0.5% bupivacaine-hydrochloride with adrenaline	7.50	0.00
Calcium chloride	1.57	0.00
Cisatracurium	11.73	0.00
Dexamethasone	0.51	0.16
50% dextrose	16.49	0.00
Ephedrine	17.05	3.46
Etomidate	4.29	0.00
Fentanyl	0.60	0.03
Glycopyrrolate	0.61	0.00
Ketamine	1.41	0.31
Midazolam	2.11	0.28
Morphine	1.29	0.14
Neostigmine	0.40	0.00
Ondansetron	0.18	0.00
Oxytocin	1.87	3.92
Paracetamol	0.92	0.09
Phenylephrine	20.66	9.91
0.5% plain bupivacaine-hydrochloride	5.10	0.00
1% propofol	5.05	0.32
Remifentanil	100.80	0.00
Rocuronium	8.32	1.36
Suxamethonium chloride	0.14	4.83
Overall average cost	3.85	1.32

RDW = routine drug wastage; PDW = preventable drug wastage.

Table 5. Percentage of drug wastage against average cost of drugs per surgical discipline

Surgical discipline	Total % RDW	Average cost RDW, ZAR	Total % PDW	Average cost PDW, ZAR
Acute care surgery	18.77	2.58	6.55	0.20
Breast unit	24.33	3.46	20.00	0.84
Burns	34.00	5.66	0.00	0.00
Colorectal unit	23.21	3.14	7.14	0.30
ENT	33.10	6.02	0.00	0.00
Gynaecology	44.86	3.81	2.13	0.09
Hepatobiliary	30.00	4.00	0.00	0.00
Maxillofacial	25.45	13.67	0.00	0.00
Neonates	32.17	4.28	33.33	4.45
Neurosurgery	55.00	7.33	0.00	0.00
Obstetrics	51.86	3.51	0.00	0.00
Orthopaedics	31.71	5.44	3.28	0.14
Paediatric surgery	42.46	4.49	14.41	0.91
Radiology	6.25	2.30	0.00	0.00
Trauma	22.50	2.18	0.00	0.00
Urology	31.44	4.72	2.27	0.61
Vascular surgery	40.72	4.17	22.22	1.96
Undocumented	17.05	3.69	9.46	1.58
Average	21.29	3.85	8.41	1.32

RDW = routine drug wastage; PDW = preventable drug wastage; ENT = ear, nose and throat.

Table 6. Logistic regression analysis of anaesthetic drugs and surgical categories

	Univariate			Multivariable		
Pharmacological agent	**OR**	**95% CI**	***p*-value**	**OR**	**95% CI**	***p*-value**
Adrenaline	-	-	-	-	-	-
Alfentanil	9.57	1.91 - 49.7	0.005	3.62	0.08 - 216	0.5
Atropine	1.76	0.23 - 9.77	0.5	-	-	-
0.5% bupivacaine-hydrochloride with dextrose	399	117 - 1 797	<0.001	210	20.3 - 5 502	<0.001
0.5% bupivacaine-hydrochloride with adrenaline	8.38	2.51 - 33.3	<0.001	15.2	0.29 - 1 247	0.2
Dexamethasone	1.25	0.38 - 4.84	0.7	-	-	-
50% dextrose	33.5	6.58 - 218	<0.001	-	-	-
Ephedrine	21.4	7.19 - 80.4	<0.001	-	-	-
Etomidate	2.09	0.10 - 16.5	0.5	-	-	-
Fentanyl	3.25	1.27 - 11.0	0.028	1.65	0.21 - 34.9	0.7
Glycopyrrolate	1.16	0.26 - 5.08	0.8	-	-	-
Ketamine	6.55	2.27 - 23.8	0.001	6.97	0.29 - 375	0.3
Morphine	14.3	5.44 - 49.2	<0.001	36.7	0.59 - 3 333	0.084
Neostigmine	1.47	0.37 - 6.18	0.6	-	-	-
Ondansetron	1.29	0.17 - 7.02	0.8	-	-	-
Oxytocin	0.31	0.04 - 1.62	0.2	-	-	-
Paracetamol	2.35	0.82 - 8.47	0.14	2.91	0.21 - 81.1	0.5
Phenylephrine	40.9	15.1 - 145	<0.001	-	-	-
0.5 % plain bupivacaine hydrochloride	10.8	3.88 - 38.4	<0.001	4.05	0.54 - 85.9	0.2
Propofol	17.3	6.81 - 58.5	<0.001	8.55	1.29 - 171	0.058
Surgical category						
ACS	-	-		-	-	-
Breast unit	2.13	0.41 - 11.1	0.4	-	-	-
Burns	4.8	0.63 - 45.5	0.13	-	-	-
Colorectal unit	1.28	0.26 - 6.02	0.8	0.89	0.14 - 5.64	0.9
ENT	2.95	0.86 - 11.4	0.1	3.84	0.87 - 20.4	0.089
Gynaecology	6.83	2.23 - 24.2	0.001	2.01	0.45 - 10.4	0.4
Hepatobiliary	2.13	0.23 - 16.9	0.5	-	-	-
Maxillofacial	1.83	0.36 - 9.15	0.5	-	-	-
Neonatal	1.6	0.07 - 20.6	0.7	-	-	-
Obstetrics	75.2	20.2 - 358	<0.001	5.58	0.87 - 40.8	0.075
Orthopaedics	2.38	0.81 - 8.02	0.13	3.24	0.88 - 15.0	0.1
Paediatric surgery	4.57	1.43 - 16.7	0.014	9.73	2.28 - 51.6	0.004
Trauma	3.2	0.32 - 33.1	0.3	-	-	-
Urology	3.2	0.90 - 12.7	0.081	4.09	0.95 - 21.3	0.071
Vascular surgery	1.6	0.26 - 8.87	0.6	0.55	0.04 - 5.50	0.6

OR = odds ratio; CI = confidence interval; ACS = acute care surgery; ENT = ear, nose and throat.

economic models have demonstrated that prefilled syringes provide economic value by reducing costs, particularly for emergency drugs such as ephedrine and atropine.[18]

The concept of prefilled syringes originated in the 1990s, when AstraZeneca introduced 1% and 2% propofol in prefilled syringes.[19] However, this initiative failed to gain widespread adoption, despite recommendations from the National Patient Safety Agency and the International Safety Network on safety purchasing policies,[20] and studies highlighting the link between drug errors and human factors.[21,22] A major limitation of prefilled syringes is the shortened shelf life of pharmacy-prepared syringes, which typically only last a few weeks.[23] If not used within this time frame, the pharmacological agents may expire, and contribute to additional drug wastage. In contrast, industry-manufactured prefilled syringes have a longer shelf life, often up to 1 year.[23] While these may serve as a viable alternative, their cost is generally higher than that of pharmacy-prepared syringes.

Propofol, fentanyl and paracetamol are the most commonly used anaesthetic drugs at this institution. Fentanyl, an opioid, is primarily used for induction, pain management and sedation; propofol is the standard agent for induction and maintenance; and intravenous paracetamol is employed as part of a multimodal approach for intra- and postoperative pain management. Intravenous paracetamol is available as a standard 1 g vial at this institution. In paediatric patients and neonates, where dosing is 15 - 20 mg/kg, this often leads to significant drug wastage. However, it was observed that some clinicians at the institution practise 'sharing' a 1 g vial among multiple paediatric patients in an attempt to minimise wastage. This practice, however, contradicts the SA Society of Anaesthesia guidelines, as well as recommendations from the Centers for Disease Control and Prevention and the World Health Organization, which advise against sharing single-use vials.[24] This further supports the need for the availability of smaller vials specifically designed for

paediatric and neonatal use, which could help to reduce drug wastage and ensure adherence to infection control guidelines.

The 0.5% bupivacaine-hydrochloride with dextrose had one of the lowest preventable drug wastages. It is produced as a 4 mL volume vial of a 5 mg/mL concentration. This agent is commonly used in obstetric cases for caesarean sections performed under spinal anaesthesia. In SA hospitals, dosing is guided by the Essential Steps in the Management of Obstetric Emergencies (ESMOE) guidelines, which recommend the use of 1.8 mL of 0.5% bupivacaine hydrochloride with dextrose.[25] This results in routine wastage of 2.2 mL per obstetric case, and owing to infectious disease protocols, the ampoules are not shared. This provides another example where the availability of smaller volume ampoules could reduce both routine and preventable drug wastage.

The average cost per case of routine drug wastage was ZAR3.85, while preventable drug wastage was ZAR1.32. A total of 373 cases were included in this cohort, resulting in a total cost of ZAR1 436.05 for routine wastage and ZAR492.36 for preventable wastage during the study period. The estimated annual costs of routine and preventable drug wastage at this institution are ZAR11 816.64 and ZAR34 465.20, respectively. The amount might seem low, but when bearing in mind the number of cases per year, this amounts to a significant fraction of total healthcare expenditure.[3,7] The primary finding of a 2024 systematic review was that significant wastage of anaesthetic drugs is linked to decreased financial efficiency in healthcare institutions.[26] This was further supported by a review that demonstrated that the cost-effective utilisation of surgical supplies and anaesthetic agents reduces expenses while maintaining high-quality patient care.[27] Adopting these practices is essential, particularly in developing countries.

Study limitations

The current study has several limitations.

This audit was part of an MMed (Anaesthesia) research project conducted by PM, which involved a single researcher for the entire data collection period. While this may have introduced potential bias, a standardised protocol was followed, ensuring adherence to the study's inclusion and exclusion criteria. The data collection process was straightforward, with the researcher documenting only the remaining drug quantities. Calculations for percentage wastage and cost were performed at the end of the data collection phase, with assistance from the researcher's supervisors and a statistician.

Data points were collected over a 2-week period, a timeframe deemed sufficient for feasibility by the university's Postgraduate Committee for a Master's project. The study protocol included a sample size calculation, which determined a minimum of 173 observations and a maximum of 370 data points. However, we acknowledge that a longer study duration and a larger sample size would have reduced bias and provided a more accurate representation of drug wastage in the theatres at this institution. We propose that a similar study be conducted across multiple academic hospitals within the University of the Witwatersrand, as well as other university and state hospitals across the country, over an extended period, to yield a more comprehensive analysis of drug wastage.

Data were collected during daytime working hours (07h00 - 16h00), when the number of elective theatre cases typically exceeds that of emergency cases. Unfortunately, data were not collected during the after-hours period (16h00 - 07h00), which means that emergency surgical cases were not exclusively accounted for. This represents a limitation of the study.

The anaesthetists (who were not part of the research team) were blinded to the study; however, the data collection process in their theatres may have raised their awareness, potentially leading to a change in their practice. This is likely a factor that explains the low rate of preventable drug wastage observed in this audit.

Drug formulations and syringes discarded in the biohazardous sharps containers were excluded from the study, potentially leading to an underestimation of drug wastage. Additionally, some anaesthetists shared ampoules between cases, which may have resulted in an overestimation of the amount of drug wasted.

Conclusion

The cost and wastage of anaesthetic drugs are significant concerns in healthcare institutions, particularly in developing countries where resources are limited. Studies highlight that large-scale wastage of anaesthetic drugs negatively impacts financial efficiency. Routine wastage, often due to larger-than-required ampoules, is prevalent, especially in paediatric and neonatal cases where smaller doses are needed. This issue is compounded by practices such as the sharing of vials, which raises infection control concerns and goes against established guidelines.

Reducing drug wastage is crucial for improving operating room efficiency and controlling healthcare costs. Cost-effective practices, such as using smaller ampoules and prefilled syringes, have been shown to lower drug wastage without compromising patient care. Furthermore, studies emphasise the importance of adopting these practices in order to improve financial sustainability and maintain high-quality care, especially in resource-constrained settings. Overall, addressing anaesthetic drug wastage through thoughtful procurement, dosing and utilisation strategies can contribute significantly to both cost savings and enhanced patient safety.

Data availability. All relevant data are included within the manuscript, and the raw data are available upon request from the authors. The data are stored electronically in a password-protected format.

Declaration. This research was conducted to fulfil the requirements for PM's MMed (Anaesthesia) degree, as mandated by the University of the Witwatersrand.

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Author contributions. Conceptualisation: PM, GL. Methodology and protocol development: PM, GL. Project administration: PM. Investigation: PM, GL. Project supervision: GL. Writing original draft: PM, GL. Statistical analysis: PM, GL. Writing – review and editing: PM, GL.

Conflicts of interest. None.

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