ORIGINAL CLINICAL RESEARCH REPORT

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Evaluation of Drug Wastage in the Operating Rooms and Intensive Care Units of a Regional Health Service

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BACKGROUND: Pharmacological treatments for critical processes in patients need to be initiated as rapidly as possible; for this reason, it is a standard of care to prepare the main anesthesia and emergency drugs in advance. As a result, 20%–50% of the prepared drugs remain unused and are then discarded. Decreasing waste by optimizing drug use is an attractive strategy for meeting both cost containment and environmental sustainability. The primary end point of this study was to measure the actual amount of drug wastage in the operating rooms (ORs) and intensive care units (ICUs) of a Regional Health Service (RHS). The secondary end point was to analyze and estimate the economic implications of this waste for the Health Service and to suggest possible measures to reduce it.

METHODS: This prospective observational multicenter study was conducted across 12 hospitals, all of which belong to the same RHS in the north-east of Italy. Data collection took place in March 2018 and included patients admitted to ICUs, emergency areas, and ORs of the participating hospitals. Data concerning drug preparation and administration were collected for all consecutive patients, independent of case types and of whether operations were scheduled or unscheduled. Drug wastage was defined as follows: drugs prepared in ready-to-use syringes but not administered at all and discarded untouched. We then estimated the costs of wasted drugs for a 1-year period using the data from this study and the yearly regional pharmacy orders of drugs provided to the ORs and ICUs. We also performed a sensitivity analysis to validate the robustness of our assumptions and qualitative conclusions.

RESULTS: We collected data for a total of 13,078 prepared drug syringes. Drug wastage varied from 7.8% (Urapidil, an alpha-1 antagonist antihypertensive) to 85.7% (epinephrine) of prepared syringes, with an overall mean wastage rate of 38%. The estimated yearly waste was 139,531 syringes, for a total estimated financial cost of €78,060 ($92,569), and an additional quantity of medical waste amounting to 4968 kg per year. The total provider time dedicated to the preparation of unused drugs was predicted to be 1512 working hours per year.

CONCLUSIONS: The overall extent of drug wastage in ORs and ICUs is concerning. Interventions aimed at minimizing waste-related costs and improving the environmental sustainability of our practice are paramount. Effort should be put into designing a more efficient workflow that reduces this waste while providing for the emergency availability of these medications in the OR and ICU. (Anesth Analg 2021;132:1450–6)

KEY POINTS

- **Question:** What is the extent of drug wastage occurring in operating rooms (ORs) and intensive care units (ICUs) and what is its impact on the economy and the sustainability of the Health Service?
- **Findings:** Preventable drug wastage in our Regional Health Service varied from 7.8% to 85.7% of prepared ready-to-use syringes, depending on the drug, with an overall mean wastage rate of 38%.
- **Meaning:** Interventions aimed at minimizing waste-related costs and improving the environmental sustainability of our practice are paramount.

GLOSSARY

CI = confidence interval; **COVID-19** = coronavirus disease 2019; **ICU** = intensive care unit; **OR** = operating room; **PFS** = prefilled syringe; **RHS** = Regional Health Service; **SD** = standard deviation

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Anesthetists and intensivists are often called to react promptly to a patient's sudden pathophysiological variations, and pharmacological treatments for critical processes should be initiated as rapidly as possible. Intravenous drugs do not always come in prefilled syringes (PFSs), but need be drawn from a vial and diluted into a syringe. This is a time-consuming procedure and a potential cause of attention diversion from patient care. Furthermore, because of the stressful nature of intensive care situations, the risk of error is high, which may lead to undesired consequences. For this reason, it is a standard practice to prepare the main anesthesia and emergency drugs in advance. However, surveys have shown that 20%–50% of the unused prepared drugs have to be discarded, contributing to the production of hospital waste.[1]

Anesthesia departments spend 10%–13% of a hospital's total pharmacy budget,[1] and drug wastage contributes significantly to the cost of anesthetic care. Nowadays, in alignment with cost containment and environmental sustainability goals, the pressure to reduce costs and waste must be balanced against the need to maintain an optimal level of care.[2] The implementation of strategies to accomplish these goals is becoming increasingly compulsory. Decreasing waste and optimizing drug use is an attractive strategy that does not impose particular limits on doctors, and it does not compromise the quality of patient care. Moreover, medical waste has been identified as a significant contributor to environmental pollution, and several anesthetic drugs have direct environmental toxicity and contamination potential.[3,4] Hence, additional ethical considerations and ecological benefits may occur from the reduction of such waste.

Despite this, most anesthesia and care professionals are not aware of drug costs and the amount of waste that they personally generate,[5,6] although surveys show that the vast majority of them would like to reduce the environmental impact of their work.[7]

In addition, in the context of the coronavirus disease 2019 (COVID-19) pandemic, another interesting aspect must be considered: the surge of critically ill patients requiring prolonged sedation, intubation, and mechanical ventilation with continuous muscular paralysis has led to a critical shortage, not only of personal protective equipment, but also of emergency/anesthetic drugs.[8] Our hospital pharmacy issued an alert regarding difficulties in resupplying some drugs, despite the postponement of almost all scheduled surgical procedures.[9] Optimizing the use of these drugs has never been more critical.

The primary end point of this study was to measure the amount of drug wastage (defined as the percentage of drugs prepared into ready-to-use syringes but not administered at all and discarded untouched) occurring in the operating rooms (ORs) and intensive care units (ICUs) of a Regional Health Service (RHS). The secondary end point was to analyze and estimate the economic implications of drug wastage on the Health Service and to suggest possible measures to reduce it.

METHODS

This prospective observational multicentre study was conducted in March 2018. This month was chosen as it represents a "standard" month in terms of hospital activities, not being associated with any holiday periods. A total of 12 hospitals participated, including 2 academic tertiary care hospitals, 1 secondary care hub hospital, and 9 secondary care spoke hospitals in Friuli Venezia Giulia, a region in the northern-east of Italy with a population of approximately 1.2 million inhabitants. All the hospitals belong to the RHS, which sets the health policies and coordinates their action through the Regional Health Agency.

The ethics committee for the institutes involved deemed it unnecessary to proceed with a formal assessment, considering the economic nature of the research and the absence of any patient involvement.

In April 2017, before initiating the present study, we performed a feasibility pilot study over 1 month at the University Hospital of Udine—the main academic tertiary care hospital in the Region, containing 1095 beds. In this study, we collected data on a total of 3226 prepared syringes, obtained drug information pertaining to those most frequently wasted, and recorded the time used for syringe preparation (from vial opening to when the prepared and correctly labeled syringe was ready for use).

According to the literature, just a few drugs account for the majority of the total wastage[10]; this fact was confirmed by the results of the pilot study, from which the following 11 drugs were chosen for tracking and wastage analysis: atropine, cisatracurium, ephedrine, epinephrine, lignocaine, midazolam, normal saline, phenylephrine, propofol, rocuronium, and urapidil.

Data collection took place in all the participating hospitals at the same time and involved patients admitted to ICUs, emergency areas, and ORs. Data concerning drug preparation and administration were collected consecutively on all case types, independent of whether they were scheduled or unscheduled.

At our hospitals, all anesthetic and emergency drugs are available in each OR and the ICU itself, and dedicated nurses prepare the drugs each day according to patient characteristics and the instruction of the anesthesiologist in charge. Importantly, anesthesiologists were not involved in the study to avoid any bias from conscious restrictions in drug prescription.

Data collection was entrusted to the nurses. Each nurse involved was provided with a data sheet on

which to report the number of the selected drugs that were prepared, used, or discarded during their shift.

Preventable drug wastage was defined as drugs prepared into syringes (ie, ready to use), but not administered at all and discarded untouched. The direct cost estimation of the amount of preventable drug wastage was based on the price paid by the hospital pharmacy department for the drugs and related devices (syringes, caps, labels, saline vials) plus the cost of medical waste disposal. Thus, using the data collected in this study (duration: 1 month) and the yearly regional pharmacy orders of drugs provided to the ORs and ICUs, we estimated the total waste of the study drugs and the related cost of this wastage within our RHS for a 1-year period. Given that our RHS has a single purchasing agency with a centralized warehouse, the unit costs are the same for the different regional hospitals. Indirect costs for ordering, stocking, and distribution, both at the regional and local level, were not taken into account in the cost estimation.

From the feasibility study performed, we found that the average preparation time of emergency drugs by dedicated providers and nurses was 39 ± 25 (mean ± standard deviation [SD]) seconds for each drug. We used this mean value to estimate the provider time spent in the preparation of unused drugs.

Statistical Analysis

Statistical analysis was performed using a specifically designed Microsoft Excel 2010 spreadsheet (Microsoft, Redmond, WA) and GraphPad Prism, version 6.01, for Windows (GraphPad Software, San Diego, CA). Descriptive statistics (means and SD for quantitative variables and absolute and relative frequencies for qualitative variables) were calculated. The 95% confidence interval (CI) for the proportion of drug wastage was also calculated for each drug using the hybrid Wilson/Brown method.

Drug use is not constant during the year, but we expect the waste percentages to remain fairly stable; even as the workload increases or decreases (eg, in correlation with the holiday seasons), the relative percentages of waste should remain comparable to previous months (as every working OR will have its drugs prepared in advance as usual). Furthermore, data collected in the pilot study performed in April 2017 are comparable to those of the main study, providing anecdotal support to our supposition. Given these premises, we performed a sensitivity analysis to validate the robustness of our assumptions and qualitative conclusions regarding extrapolating the monthly consumptions to an annual estimate, taking into account possible monthly variations in waste patterns. We built 2 mathematical models in which monthly waste percentages vary randomly from 0% to −10% and from 0% to +10% compared to what was found in the study. We then ran these models for each drug, 5 times for each of the 11 months.

RESULTS

During the study period, we collected data on a total of 13,078 prepared drug syringes. Preventable drug wastage in our RHS varied from 7.8% (urapidil, an alpha-1 antagonist antihypertensive) to 85.7% (epinephrine), with an overall mean of 38% (95% CI, 37.2-38.9), corresponding to 4978 prepared syringes thrown away untouched. Details of the analysis for each drug are presented in Table 1.

The results of the sensitivity analysis show that the total annual wastage can vary from a minimum of 36.1% (95% CI, 35.9-36.2) to a maximum of 39.7% (95% CI, 39.6-39.9).

The cost analysis was performed applying our results to the annual consumption of drugs delivered to the ORs and ICUs in our RHS, obtained from hospital pharmacy reports (excluding normal saline since its end use could not be established from the records available; ie, whether it had been used or not for drug dilution or for other procedures).

The results indicate an estimated annual wastage of 139,531 prepared syringes in our RHS, for a total estimated financial cost of €78,060 ($92,569) per year (Table 2; Figure). Further analysis revealed that only a few drugs account for the majority of the waste cost: 54.3% of the waste cost can be ascribable to epinephrine, atropine, and ephedrine.

In addition to the costs of unused drugs, the estimated preventable medical waste resulting from the discarded drugs was 4968 kg for a single year, entailing an overall waste disposal cost of €10,000 ($11,862).

The average preparation time of a drug syringe by the nursing staff, from readily available materials, was on average 39 seconds per syringe. Thus, the total provider time dedicated to the preparation of unused drugs equals 1512 working hours per year.

DISCUSSION

The main finding of this study is that significant drug wastage occurs in ORs and ICUs, impacting the economy and sustainability of the RHS. We found that 38% of the prepared syringes were discarded without being used. These results are in line with other literature reports.[1] Interpersonal and "cultural" variations in the medications that are prepared prophylactically may be significant, but we found that the differences in drug wastages between the different hospitals were only of the magnitude of a few percentage points (especially atropine and vasopressors). Evidence of this cultural uniformity can also be seen in the literature, as it seems to be the case in the health systems of all developed countries.[1]

Table 1. Study Drugs, Syringe Dilutions, the Absolute Number of Prepared and Wasted Syringes, and the Overall Percentage of Wasted Prepared Syringes During the Study Period

Drug	Syringe dilution	Prepared (n)	Wasted (n)	Waste (%)	95% CI
Atropine	1 mg/10 mL	2248	1596	71	69-73
Cisatracurium	20 mg/10 mL	233	31	13	9-18
Ephedrine	25 mg/10 mL	1962	1121	57	55-59
Epinephrine	1 mg/10 mL	357	306	86	82-89
Epinephrine	5 mg/5 mL	76	65	86	76-92
Lignocaine	200 mg/10 mL	160	20	12	8-19
Midazolam	15 mg/15 mL	562	258	46	42-50
Midazolam	5 mg/5 mL	1749	341	19	18-21
Propofol	200 mg/20 mL	2515	395	16	14-17
Rocuronium	100 mg/10 mL	349	43	12	9-16
Rocuronium	50 mg/5 mL	837	66	8	6-10
Normal saline	10 mL	1258	499	40	37-42
Normal saline	20 mL	630	178	28	25-32
Urapidil	50 mg/10 mL	51	4	8	2-19
Total		13,078	4978	38	37-39

Drug waste is defined as drugs prepared into ready-to-use syringes but not administered at all and discarded untouched. Waste percentages and their 95% CI are rounded to the nearest integer.
Abbreviation: CI, confidence interval.

Table 2. Estimated Yearly Cost of Unused Drugs

Drug	Estimated annual waste (n of syringes)	Estimated annual waste cost (€)	% of total wastage cost
Atropine	38,704	16,204.72	20.8
Cisatracurium	2380	3941.21	5.0
Ephedrine	24,254	13,889.95	17.8
Epinephrine	27,990	12,273.21	15.7
Lignocaine	5360	1953.84	2.5
Midazolam 15 mg	18,100	9932.98	12.7
Midazolam 5 mg	9506	3271.33	4.2
Propofol	7916	6006.35	7.7
Rocuronium	4544	9137.53	11.7
Urapidil	776	1449.69	1.9
Total	139,531	78,060.80	100

Drug waste is defined as drugs prepared into ready-to-use syringes but not administered at all and discarded untouched.

The drugs accounting for the majority of the preventable waste are as follows: atropine, ephedrine, epinephrine, and midazolam. Drugs can be grouped according to the frequency of their waste: high acuity drugs, like epinephrine and atropine, are rarely used and almost always wasted. Vasopressors, like ephedrine, are wasted slightly less often (suggesting that a substantial number of patients receive vasopressors, especially in the operating theatre), but are almost always prepared. Other common medications, like propofol and neuromuscular blocking agents, are often prepared and used, but the leftover syringes are wasted.

On a cost-wise basis, despite their individual low unit costs, the same 4 drugs (atropine, ephedrine, epinephrine, and midazolam) were responsible for the majority of the financial cost incurred (71.2%). On the other hand, the overall contribution of propofol and rocuronium to preventable waste was low, but being among the most expensive drugs assessed, they had a significant impact (almost 20%) on the total financial cost. Propofol is both the most detrimental to the environment and one of the most expensive drugs we analyzed. It is highly toxic to aquatic organisms, has a high potential for bioaccumulation, and a high soil mobility. It is not biodegradable in water or under anaerobic conditions and requires incineration for its complete destruction.[3] During the study period, we recorded a waste of 7.9 L of propofol (158 estimated L annually, in our RHS). Given the high cost, environmental impact, and short shelf-life in the syringe, it is important to optimize its use, ideally only preparing it when actually needed.

The degree of total waste is alarming: we calculated that an estimated 139,531 syringes of these study drugs are discarded unnecessarily every year in our RHS, resulting in 4968 kg of preventable medical waste with an estimated financial cost of over €78,000 ($92,569). Given the surgical case volume of each Health Service, decreasing such waste holds the potential to save millions of euros every year on a national basis.

Similar issues have already been investigated in the literature, but obtaining accurate data on drug disposal is challenging, making it is difficult to determine the actual rate of drug wastage. Many studies[6,11–13] suffer from their retrospective design, which limits their validity since they calculate the amount of wasted drugs indirectly and inaccurately (eg, by using the difference between pharmacy supplies and compiled anesthesia records). Other prospective studies[10,14–16] have different limitations, such as being monocentric, restricted with regards to case selection and in data collection, of low sample size, using indirect observations of leftover drugs without checking the waste bin, etc. All these factors may cause a significant underestimation of the problem and result in error margins as wide as 40%.[10]

The novelty of our work consists in the fact that our prospective observational multicenter study was conducted in such a way to reduce all these limitations: it entailed the focused, direct observation of wasted drugs during real-life, everyday hospital routine, and with minimized selection bias by not involving the health care providers responsible for the drugs' prescription. To the best of our knowledge, this is the first multicentre study that analyses the impact of drug wastage on all the public hospitals of an entire RHS with a catchment area of more than 1.2 million inhabitants.

Our study does have some limitations, and we cannot exclude that we may have underestimated the preventable drug wastage. As an observational study, its execution was based on the good will of those collecting the data, and we noticed wide differences in the data collected from the different

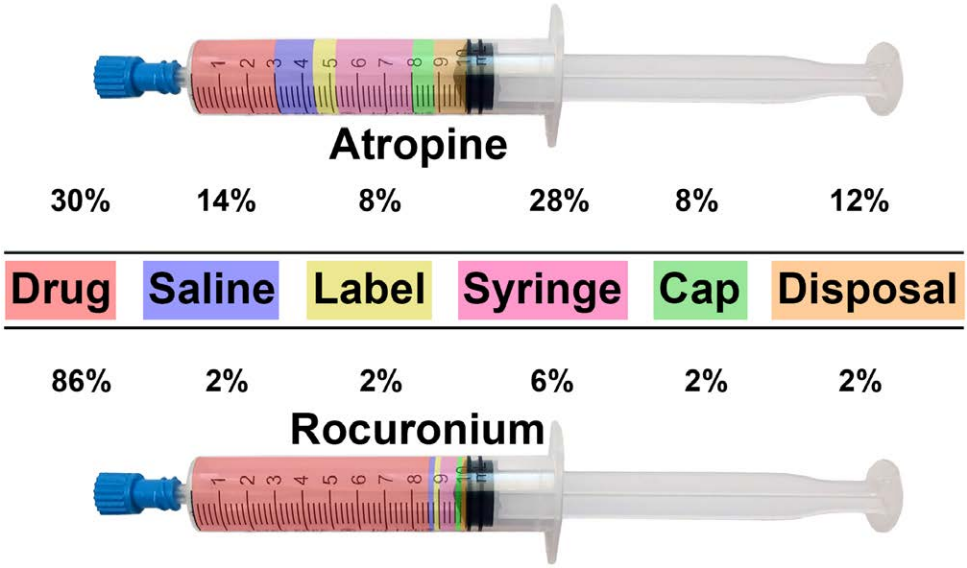

Figure. Graph showing the impact of each component on the final cost of the prepared and ready-to-use syringe. The cost of the drugs varies widely. Atropine is the cheapest drug, accounting for only 30% of the total cost of the prepared syringe. For rocuronium (one of the most expensive drugs), the total cost is almost exclusively due to the drug itself.

centers. This factor may have impacted the total numbers of wasted syringes detected in the study period, but we expect the relative percentages of waste to remain reliable.

We collected data over a 1-month time frame, then extrapolated it to obtain an estimate of the yearly drug wastage. We cannot exclude that wastage patterns may differ over the months but data collected in the pilot study (performed in April 2017) are comparable to those of this main study, providing some anecdotal support to this presumption. However, the sensitivity analysis (performed for this very reason) confirms that the amount of waste is still very high, even when considering the most conservative estimates (total waste 36.1% with 95% CI, 35.9-36.2).

The anesthesiologist on duty should not have been aware of the study, but some anesthesiologists were not completely blinded to the study; thus, there may have been a certain degree of Hawthorne effect (ie, behavior modification in response to being observed). However, we think that this should not have significantly changed the routine preparation of the study drugs, as they are generally considered life-saving. Furthermore, the possibility that the passing of prepared drugs occurred across different nursing shifts is possible, but the destination of these drugs should also have been reported.

Another important aspect regards the generalizability of our findings. While the results should apply in principle to every OR, their subsequent economic impact depends on the organization in question and drug costs. The biggest differences may arise from institutions in which the main drugs are prepared by the hospital pharmacy into ready-to-use sterile syringes; this can lead to a decrease in waste and provider time labor, but the actual cost-effectiveness of such a complex system has to be demonstrated. In our context—a public health system with a single regional purchasing agency covering many hospitals—the resulting cost of drugs is very low. In different health service organizations, especially private ones, the cost of drugs can be enormously higher, making drug wastage an even more important issue. In systems in which a third-party payer is charged for the medications, drug wastage might even be economically beneficial.

It is certainly not easy to reconcile the minimization of wastage costs and the optimization of resource allocation and environmental sustainability with the maintenance of the quality of care, but it should be a mandatory attitude in all health care organizations; also because, in addition to ethical contemplations, financial and environmental interests are often aligned.[17] We can recommend some general strategies for this purpose.

Every hospital has its own habits and policies, and their revision should be the first approach: it is possible to vastly optimize the routine preparation of the most wasted drugs. Another effective intervention is the education of the various providers involved (physicians and nurses), as most of them lack knowledge about wastefulness and the costs of wasted drugs. This can be effective, but their efficacy tends to be short lived and needs to be continually reinforced: providers tend to return to previous patterns and habits after just a few months.[18–20]

Potential savings may be achieved without having any impact on clinical availability through the use of commercially PFSs, especially for rarely used

or heavily wasted drugs, such as atropine, ephedrine, and epinephrine. Their use is also characterized by several other advantages because not only do they reduce waste, but they may also improve patient safety: PFS benefit from enhanced labeling and no dilution is necessary, thus reducing the risk of medication errors. Furthermore, industrially manufactured and quality controlled PFS allows for a greater certainty of concentration and improved compliance with stringent recommendations regarding sterility and particle contaminants (ie, glass fragments).[21]

Further studies are needed, especially to establish whether our findings are consistent across different health systems, organizations, and "cultural" settings. Subsequent studies may also measure wastage pattern variations through the year, by collecting data for shorter periods over different months. It is also of utmost importance to study the relative impact of different wastage reduction measures.

CONCLUSIONS

Some amount of drug wastage is inevitable, but its overall extent in ORs and ICUs is particularly concerning. Minimizing wastage constitutes an important point of intervention that may reduce the costs and improve the environmental sustainability of our practice. The combination of common sense, good work organization, and greater cost-consciousness will assure that costs and ethical considerations are respected.

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