MEDICAL WASTE: PROFILE AND COST ANALYSIS IN A SURGICAL SITE

Resíduos de serviços de saúde: perfil e análise de custos em um centro cirúrgico

Residuos de los servicios de salud: análisis de perfil y costos en un centro quirúrgico

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ABSTRACT: Objective: To determine the waste generation profile and measure the costs of materials used in medical waste management in a surgical site. **Method:** This is an exploratory-descriptive survey, with a quantitative approach, in the case study modality. The site was the surgical site of the University Hospital of Universidade de São Paulo. The stratified sample was of 1,120 surgeries, and the waste was weighed for 82 days. **Results:** The surgical site waste accounted for 6.38% of the total hospital waste. The most representative group was A-infectious (50.62%). The mean generation was 3.72 kg per surgery. Most of the waste was generated in the operating room (55.93%), and oral maxillary surgeries generated most of the waste in terms of mass. The cost per kilo was: Group A (R$ 1.10), Group B (R$ 5.70), Group D Recycled (R$ 0.96), Group D Nonrecycled (R$ 1.01) and Group E (R$ 3.23). **Conclusion:** The mean total cost per surgery was R$ 8.641, and its reduction depends on strategies of purchasing consumable supplies that had greater impact on costs.

KEYWORDS: Medical waste. Surgicenters. Costs and cost analysis.

RESUMO: Objetivo: Determinar o perfil de geração e mensurar os custos dos materiais utilizados no gerenciamento de resíduos de serviços de saúde em um centro cirúrgico. **Método:** Trata-se de pesquisa exploratória, descritiva, com abordagem quantitativa, na modalidade estudo de caso. O local foi o Centro Cirúrgico do Hospital Universitário da Universidade de São Paulo. A amostra estratificada foi de 1.120 cirurgias, e os resíduos foram pesados por 82 dias. **Resultados:** Os resíduos do Centro Cirúrgico representaram 6,38% do total hospitalar. O grupo mais representativo foi A-infectantes (50,62%). A média de geração foi de 3,72 kg por cirurgia. A sala de operação foi o local que mais gerou resíduos (55,93%), e as cirurgias buco-maxilares as que mais geraram resíduos, em termos de massa. O custo de um quilo foi: Grupo A (R$ 1,10), Grupo B (R$ 5,70), Grupo D Reciclado (R$ 0,96), Grupo D Não Reciclado (R$ 1,01) e Grupo E (R$ 3,23). **Conclusão:** O custo total médio por cirurgia foi de R$ 8,641, e sua redução depende da negociação de compra dos itens de consumo que tiveram maior representatividade nos custos.

Palavras-chave: Resíduos de serviços de saúde. Centros cirúrgicos. Custos e análises de custo.

RESUMEN: Objetivo: Determinar el perfil de generación y medir los costos de los materiales utilizados en la gestión de los Residuos De Los Servicios De Salud en un Centro Quirúrgico. **Método:** Esta es una investigación exploratoria, descriptiva, con un enfoque cuantitativo, en la modalidad de estudio de caso. El sitio fue el Centro Quirúrgico del Hospital Universitario de la Universidad de São Paulo. La muestra estratificada fue de 1.120 cirugías y los residuos se pesaron durante 82 días. **Resultados:** Los residuos del Centro Quirúrgico representaron el 6,38% del total del hospital. El grupo más representativo fue A-infeccioso (50,62%). La generación promedio fue de 3,72 kg por cirugía. El quirófano fue el lugar que generó la mayor cantidad de residuos (55,93%) y las cirugías orales-maxilares las que generaron la mayor cantidad de residuos, en términos de masa. El costo de un kilo fue: Grupo A (R$ 1,10), Grupo B (R$ 5,70), Grupo D Reciclado (R$ 0,96), Grupo D No Reciclado (R$ 1,01) y Grupo E (R$ 3,23). **Conclusión:** El costo total promedio por cirugía fue de R$ 8,641 y su reducción depende de la negociación de compra de los artículos de consumo que tuvieron mayor representatividad en los costos.

Palabras clave: Residuos sanitarios. Centros quirúrgicos. Costos y análisis de costo.

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INTRODUCTION

The medical waste (MW) has worried health managers in the third millennium, in which models of medical waste management must guide their decisions on environmental and social responsibility for economic development[1]. This implies the creation of public policies and legislation oriented towards environment sustainability and the protection of human health.

The MW encompass a wide range of waste, with different characteristics and classifications, including those produced in health facilities, administrative areas, kitchens, and gardens, including packaging and recyclable supplies, and those generated by workers and patients. By this mean, from 75 to 90% of MW can be comparable to households or general waste, or, non-hazardous. The rest, from 10 to 25%, are considered hazardous and represent a series of environmental and health risks that should be better managed worldwide[2].

Hazardous MW has assumed great importance in recent years, more because of the risk involved in poorly managed waste than for the volume generated, estimated between 1 and 3% of the total municipal solid waste in a municipality[2,3].

The two main laws in Brazil related to MW are the Resolution of the Board of Directors (*Resolução da Diretoria Colegiada* – RDC) No. 222, March 28, 2018, of the National Health Surveillance Agency (*Agência Nacional de Vigilância Sanitária* – Anvisa)[4], defining MW internal management, encompassing segregation, packaging, identification, internal transportation, temporary storage, treatment and external storage; and the Resolution of the National Council of Environment (*Conselho Nacional do Meio Ambiente* – CONAMA) No. 358, April 29, 2005, defining MW management that is external to the health facility with collection, external transport and final destination[5].

Waste is classified as Group A, B, C, D and E. Group A accounts for waste that may have the presence of biological agents; Group B, waste containing chemicals that may be hazardous to public health or to the environment; Group C includes radioactive waste; Group D, general recyclable and non-recyclable waste, similar to household type; and Group E covers sharps[4,5].

MW management is a process that involves many interconnected activities; it is related to the working condition, infrastructure, development of human resources involved in the management, disposal practices by all categories of health workers, and risk of workplace injury with sharps and chemical contaminants. Investments in the acquisition of specific safety boxes for each group, purchase of containers, waste compactors and the use of warning plates do not guarantee an adequate level of MW management[6].

The current challenge is to generate less waste. Data from 2016[7] showed an increase of 3% compared to the previous year, and this percentage has been increasing since 2012, even with the regulation of the National Policy on Solid Waste[8] and marketing and educational strategies to promote conscious consumption and to avoid wasting materials in healthcare services. Another challenge is to ensure the segregation at the actual source to make sure recycling is possible and hazardous waste is sent to a safe destination[6].

Although the importance of MW management is recognized, there is still some difficulty for the operationalization of the Medical Waste Management Plan (MWMP), as prescribed by law. So waste keeps being generated, affecting the population health and causing a negative impact on the environment.

In many hospitals, nurses are responsible for the MWMP and must have a broad management perspective focused on work process analysis and cost management, essential tools to seek support in obtaining resources for improvements.

The surgical site (SS) is an important and complex site with respect to costs due to the complexity of its logistic distribution, involving various equipment and materials, type of care provided and different processes and subprocesses, directly and indirectly related to surgeries[9].

The nurse clearly needs to have knowledge and involvement in the management of material resources that will result in MW, in order to develop a generation profile, to measure the costs and to manage this waste.

Until now, in Brazil, there has been no relevant publications that demonstrate the profile and the cost composition of the MW management process. Some demonstrate the expense with a final destination, which, in most of the healthcare institutions, is outsourced and has contracts per weight, kilos or tons.

The information produced in this study is expected to contribute to cost reduction proposals, possible resizing of containers, changes in collection and transport frequency, flows of materials and post-consumption packaging, waste classification and elimination criteria, as well to improving the management of healthcare organizations by drawing comparison with other institutions with the same profile.

Based on the very recommendations of the legislation, it is difficult to perform calculations and there is a concern

about how to make them, since, most of time, unknown costs are used.

OBJECTIVE

To determine the generation profile and measure the costs of the materials used in MW management in a SS.

METHOD

This is an exploratory, descriptive, quantitative survey, in the case study modality, carried out in the city of São Paulo, State of São Paulo, in the SS of the University Hospital of Universidade de São Paulo (UH-USP).

To measure the final cost of each subprocess (group of waste from the legislation) generated in the operating rooms (OR) of the SS, the number of surgeries performed was used as a target population.

Considering the number of surgeries performed in the last four years, the stratified probability sampling was calculated with statistical power of 95%, resulting in n=1,120 surgeries.

Data collection was carried out from September to November 2015. MW subprocesses have been mapped based on the classification of RDC no. 356/2004, that was in force until 2018, when the legislation of Anvisa was updated, and the RDC no. 222/2018[4] is now in force, which was used to discuss the data of this study because it did not change the previous classification.

For 82 days, the waste was weighed, and it was measured in kilograms (kg), considering the MW site of generation, before being placed in the containers. The bags received a sticker label with different colors for those from the OR, the postanesthetic recovery room and sites that generate common waste. The records were typed in spreadsheets from A to D, by shifts of work, with information about the OR, the patient's name, the surgery performed, the medical specialty, the weight of MW of Group A, the weight of plastics and of paper waste. This information was collected at the end of the surgeries, when the circulating nurse of the OR requested the cleaning service. The weighing took place in the SS facilities, inside the temporary storage, avoiding the possibility of mixing with waste from other sectors.

MW subprocesses were described for measuring cost, with the identification of the person in charge, the design of flowcharts, the inventory of material quantity and costs, the identification of the number of surgeries, and the calculation of the partial cost of each subprocess[6]. The acquisition cost of supplies and equipment were obtained from the stockroom and the property management.

Costs were calculated in Brazilian currency (real), which symbol is R$. For depreciation calculation of the equipment, it was considered its value divided by the period of 60 months and, after, divided by 30 days, obtaining the cost per day, that was still divided by the number of generation points of each subprocess. The value of a generation point was multiplied by the number of points of each subprocess of the groups of RDC no. 222/2018[4]. The generation points of each group of waste were considered division units, with their specificities.

All surgeries, at the end of the anesthetic-surgical procedure, generate infectious MW, plastic and paper segregated within the OR, which, in this survey, were called direct generation; sharps and chemical MW that are discarded in the same container for various surgeries and various anesthetic procedures were called indirect generation.

The categorical variables were descriptively analyzed, and comparisons were made by analysis of variance (Anova), or Kruskal-Wallis test. A Bonferroni post hoc test was performed to evaluate the inference about means or, still, their quality.

The study was previously approved by the Research Ethics Committee of UH-USP (Report no. 1251/12), complying with the Resolution no. 466/2012 of the National Health Council.

RESULTS

To present the data referring to the MW generation profile, it is important to consider that the SS facility represents 6.38% of the general production of MW of the UH-USP.

Table 1 presents the MW distribution of the UH-USP and the SS under study, by their classification into groups.

Regarding the site of generation of MW in the SS, of the total of 8,102.64 kg, 4,532.01 kg (55.93%) were from the OR; 325.68 kg (4.02%) from postanesthetic recovery room and 3,244.95 kg (40%) from the support area. Among MW generated in the latter area, 2,309.44 kg (28.5%) were non-recyclable, produced in toilets, leftover food from the pantry, paper-towel from station surgical sinks, and 935.51 kg (11.5%) were recyclable, coming from the administrative areas of the facility.

When the production of MW was analyzed, specifically in ORs, it was found that of the total chemical waste (132.900 kg) generated, 110.800 kg were originated in drug leftovers, 21.100 kg in the leftovers of formaldehyde vials, in addition to 1 kg of power cells and batteries. As for sharps (235.65 kg), 159.35 kg were discarded in 151 specific boxes (7 Liter), resulting in a mean of 1.94 kg per box, and 76.30 kg were discarded in 12 large boxes (Clean Box®) used for large-format materials in laparoscopic surgeries and orthopedic surgeries.

Table 2 shows the distribution of descriptive data of the total MW per specialty in the OR.

The mean of total MW in the OR was 3.72 kg per surgery. The specialty that most generated MW was Oral maxillary, with an average of 4.55 kg, followed by Gynecology, with 4.21 kg.

Due to the stratification in seven surgical specialties, there was a wide variation in the mean MW generation, because of the particularities of each one. Hence, the statistical test Anova (post hoc Bonferroni) was performed, presented in Figure 1.

Concerning the average total of MW produced among the specialties, a statistically significant difference was verified (Anova F20, 95, $p<0.01$). Oral maxillary surgeries,

Table 1. Distribution and classification of medical waste of the University Hospital of Universidade de São Paulo (UH-USP) and the surgical site (SS).

Waste Classification (Report nº 344/98 and RDC nº 306/05)	UH-USP		SS	
	(kg)	%	(kg)	%
Infectious (with sharps) A+E	38,865.40	30.62	4,101.34	50.62
General nonrecycled D	74,166.40	58.42	2,309.44	28.50
Chemical B	780.80	0.62	132.90	1.64
General recycled D	13,132.10	10.34	1,560.26	19.26
Total	126,944.70	100.00	8,103.94	100.02

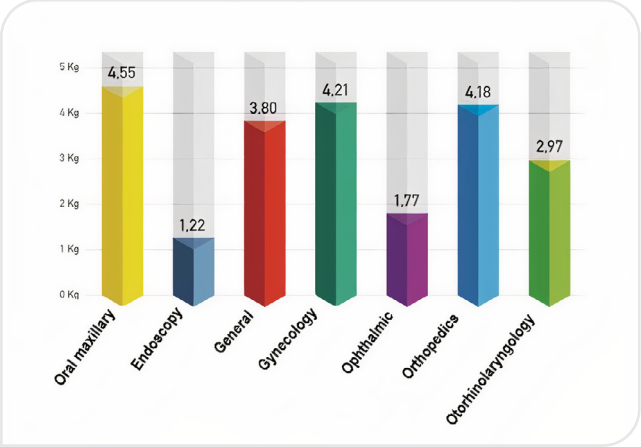

Figure 1. Distribution of the mean total of medical waste in operating rooms of the University Hospital of Universidade de São Paulo, according to medical specialties.

Table 2. Weight distribution (kg) of medical waste in surgical sites of the University Hospital of Universidade de São Paulo, according to medical specialties.

Medical specialty	Mean	Standard deviation	Median	Minimum	Maximum
Oral maxillary (n=40)	4.55	2.11	4.33	1.35	10.78
Endoscopy (n=28)	1.22	0.83	0.98	0.40	3.65
General (n=621)	3.80	2.12	3.38	0.20	18.15
Gynecology (n=114)	4.21	1.79	4.05	1.10	9.75
Ophthalmic (n=46)	1.77	0.85	1.70	0.50	4.70
Orthopedics (n=185)	4.18	2.24	3.85	0.35	12.80
Otorhinolaryngology (n=86)	2.97	1.05	2.75	1.35	5.70
Total (n=1,120)	3.72	2.09	3.35	0.20	18.15

on average, produced more total MW when compared to endoscopic, ophthalmological and otorhinolaryngological surgeries (post hoc Bonferroni $p<0.05$). Secondly, we have gynecological surgeries in relation to endoscopic, ophthalmological and otorhinolaryngological surgeries (post hoc Bonferroni $p<0.05$).

The distribution of material costs in OR by MW groups is presented in Table 3.

In Table 3, the fixed cost of R$ 5.526 per surgery was reached after the incorporation of the costs of each subprocess, so that subprocess A contributes with R$ 3.414 (61.78%), subprocess D with R$ 0.714 (12.92%), B with R$ 0.677 (12.25%) and E with R$ 0.721 (13.04%). It has been found that in the A-Infectious subprocess 94.90% of the costs are concentrated on the surgery supplies, that are the white collecting bags; in subprocess B-Chemical, the highest concentration was in common-use supplies, that are chemical containers, with a unit cost of R$ 12.50, plus bags, labels and seals, with a representative sample of 89.06%. In subprocess E-Sharps, the variable supplies, that are small and large-size containers, accounted for 91.53% of costs. The unit cost of the 7-Liter storage boxes, R$ 2, is below market values, possibly due to the hospital purchasing strategy; large sharps boxes cost R$ 32 per unity.

Figure 2 shows the MW cost per kilo.

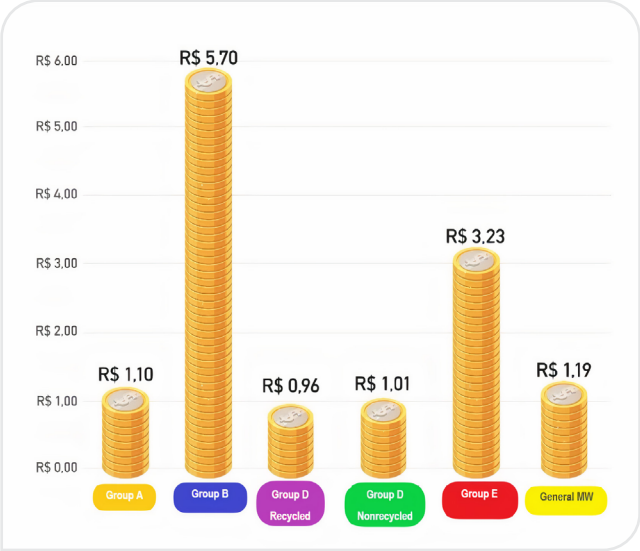

Figure 2. Distribution of cost calculations (R$) per kilo of medical waste of the University Hospital of Universidade de São Paulo, classified by groups of the Resolution of the Board of Directors no. 222/22/2018.

DISCUSSION

The proportion of SS waste in relation to the hospital was hardly representative when compared to that of international studies[10]. The proportion of waste from Group A-Infectious

Table 3. Distribution of the cost of materials in the management of medical waste in operating rooms in the University Hospital of Universidade de São Paulo.

Subprocess (groups of MW)	Direct costs (R$)				Indirect costs (R$)				Total cost per surgery (R$)		Total cost of the sample (n=1,120)	Total cost per day (n=82)
	Fixed supplies per surgery		Fixed equipment		Common use supplies per surgery		Common use equipment SS		R$	%	R$	R$
	R$	%	R$	%	R$	%	R$	%				
A-Infectious	3.240	94.90	0.029	0.849	-	-	0.145	4.24	3.414	100%	3,823.68	46.630
D-Recyclable Paper and plastic	0.606	84.87	0.002	0.289	-	-	0.106	14.84	0.714	100%	799.68	9.752
B-Chemical	--	--	0.014	2.067	0.603	89.06	0.06	8.86	0.677	100%	758.24	9.246
E-Sharps	---	--	0.001	0.138	0.660	91.53	0.060	8.321	0.721	100%	807.52	9.847
Total	3.846	69.56	0.046	0.83	1.263	22.88	0.371	6.72	5.526	100%	6,189.12	75.477

MW: medical waste; SS: surgical site.

was the expected due to the high concentration of invasive procedures and other surgical outcomes, such as blood transfusion, bladder catheterization and central venous puncture.

The percentage of recycled waste from the SS facility was higher than that of the rest of the hospital, that can be attributed to the recycling of paper and plastic within the OR, an innovative strategy in the perioperative area, and also to the disposal practices of the workers, who already had the practice of recycling in their work process during the surgery.

The data of this survey are similar to another study conducted in the SS of large hospitals, where infectious and sharps waste represented 52.60%, general waste 35.46%, and recycled waste 9.29%[11]. It was verified that the UH-USP presented a higher percentage of recycling, but the generation of chemical waste was lower. As the Group B-Chemical is considered a hazardous waste, the smaller its generation, the better the management performance of the service is considered.

The World Health Organization (WHO)[12] recommends that MW, that may be health and environmental hazard, should vary from 10 to 25% of the total generated in each institution. There is no international classification criterion; however, when analyzing MW of SS, Groups A, B and E meet the risk referred to, and the rate was high, exceeding the recommendation. However, the generation values of the UH-USP made a total of 31.24% and were slightly closer to the WHO recommendations.

The OR was the site that generated most of MW, according to a study published from Turkey, analyzing environmental-friendly practices in operating rooms[10]. It is important to know the representativeness of each site within the facility so that efforts are prioritized, and strategies formulated to combat waste and implement the reduction of MW generation, as well as the planning of educational actions in sites where it will have a greater impact.

Considering also that the OR is the site where surgeries take place, which are the SS products, and, consequently, where the revenues are generated, the degree of detail of the MW generation profile, related to the number of surgeries and the amount of waste generated in the period, showed that the specialty of General Surgery was the one that had the highest representative sample. This specialty generated most of MW in terms of mass; however, after the inference about means and after the statistical significance among the various specialties was proven, it was the oral maxillary and gynecological surgeries that produced most of such waste.

The mean generation of MW per surgery for infectious waste was 3.24 kg; for plastics, 0.28 kg; and paper, 0.20 kg. The mean of these three groups was 3.72 kg, coming directly from ORs. Whereas sharps contributed with 0.210 kg, and the chemicals with 0.119 kg per surgery, not coming directly from ORs, since the same container is used in several surgeries.

A study conducted in a medium-sized hospital concluded that the mean generation rate per SS surgery was 1.253 kg of MW of Groups A and E, and 0.337 kg of waste of Group D, making a total of 1.590 kg/surgery, values lower than in this survey. However, in this study, chemical waste was not included; the complexity of the surgeries is lower and, furthermore, the method of weighing the waste may have influenced the results because it was not done per surgery or at the generation site[3].

The higher concentration of costs could be visualized in fixed and common use supplies in the SS and leads to reflection on the importance of the microeconomic perspective in healthcare cost management. To model the processes and, consequently, reduce costs, the nurse's management actions may be connected to a better description of a material in the bidding processes, to larger purchases, with planning for delivery by installments, and purchasing strategies to minimize costs of items with greater representativeness in the cost composition.

The mean total cost per surgery was the sum of the costs of the OR and of the quantity of units of the other points of generation by the ratio of the survey sample (n=1. 120). Thus, the mean total cost would be R$ 8.641, receiving R$ 5.526 from the OR, R$ 0.531 from postanesthetic recovery room, R$ 0.485 from recycled general waste, and R$ 2.099 from the nonrecycled waste in the support area. Thus, such a cost could be transformed into a waste collection rate to be added to the collection rates of ORs or procedures per specialty, being the best way to pay for this service and then price it. If the calculation were based on the mean weight of surgeries (3.72 kg) and in the mean cost of MW (R$ 1.19), this value would be R$ 4.426, which would be 1.9 time lower.

The data of this study confirm the few results of the literature that chemical waste has the highest cost and the recyclable the lowest value, when compared to infectious waste[13].

The cost of disposing cost of hazardous waste is eight times higher than that of the disposal of general waste. Waste that is not adequately segregated should be treated as infectious waste, increasing significantly the overall disposal costs[14,15].

It should be considered that the alternatives of treatment and final destination of MW of Groups A, B and E are also

the highest, as described in international studies[1,14,15], which, although they have the limitation of not reporting the cost composition, show that these groups of waste have higher costs in all management process, highlighting the importance of segregation at the site of origin.

Most of the waste generated in the ORs is recyclable waste (Group D), such as paper, cardboard, and plastic. Waste of this category that is not contaminated by body fluids is typically easy to recycle[1,15].

The cost per kilo of each MW group can be used as an indicator of the process quality of management of such waste.

In this study, the advance in knowledge was the determination of the generation profile and the measurement of managing costs of MW, with detailing of items that have the highest representation in the total cost composition, which may be the proposition of a cost measurement model, based on costing methods, to be replicated in other services as an alternative to the pricing of a service that is not charged descriptively.

Surgical teams should include environmental issues in SS management decisions to work jointly with support services. In this sense, it is important to have a green team, that is a multidisciplinary group to think about institutional strategies to eliminate waste, prioritize the rational use of drugs, and improve costing methods and provision of services in the SS[3].

CONCLUSION

It was concluded that the mean MW generation was 3.72 kg per surgery, being Group A-infectious the most representative waste group; the OR was the site that generated most of the waste. The average total cost was R$ 8.641 per surgery, and its reduction depends on purchasing strategies to minimize costs of consumable items that had greater representativeness in costs.

The generation and management of MW will always be influenced by new economic, political, technological, social, and cultural circumstances of the healthcare team, such as consumption pattern, worker disposal practices and material resource management.

The positioning of health institutions in the face of sustainability principles will certainly be reflected in the management processes to achieve the efficiency of these processes, in which resources can be used consciously and adequately so that MW management goals can be achieved with quality and safety.

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