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EXPERIENCES ON THE MANAGEMENT OF HAZARDOUS WASTE GENERATED IN A LATIN AMERICAN HOSPITAL

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ABSTRACT:
The inadequate management of hospital waste is not only dangerous to the environment but can also affect your workers. It is essential to manage the waste generated in hospitals to avoid public health problems and environmental risks. The main objective of this paper is to show the experience in the management of hazardous waste generated by a Latin American hospital located in Quibdó city (Colombia). The results show that the external management (collection/transport/treatment/final disposal) of all hazardous waste generated represents 0.56% of the annual operating budget. This activity is also equivalent to $3.81 USD/month per kg of hazardous waste generated and $185 USD/year per available bed in the hospital. On average, the findings show that before the implementation of the management plan, the amounts generated from hazardous waste grow at a rate of 20.9%/year. The rate of hazardous waste generation after implementation of the management plan decreases to -16.9%/year. This study may be relevant for hospitals of similar characteristics in developing countries because it can be a reference point for visualizing the benefits of implementing a hospital waste management plan.

INTRODUCTION:

The hospitals are important sources of contaminants resulting from diagnostic, laboratory, and research activities, as well as from the excretion of patient medications, including active components and metabolites, chemicals, pharmaceuticals, radioactive markers, or iodized contrast media [1]. It is reported that 75% of the waste generated by hospitals corresponds to general sanitary waste, while the remaining 25% correspond to hazardous infectious waste [2]. Inadequate management of hospital waste is not only hazardous to the environment but can also affect your workers. Thus, it is essential to manage the waste generated in hospitals to avoid public health problems and environmental risks [3]. The hospital waste can contaminate soil, water, and air, and that is why it must be managed properly. Management is also necessary because humans fight infectious diseases such as Covid-19, HIV, or hepatitis. The variety of waste generated in a hospital is dangerous and needs to be properly transported and disposed. Latin American hospitals also generate a significant amount of waste, which by not being adequately managed can cause a negative impact on the environment associated with their cycle [4]. In other words, these wastes could affect generation sites, collection sites, transport systems, and final disposal facilities [5]. Hence, the classification, collection, storage, treatment, and final disposal of hospital waste is of great relevance due to its hazardous characteristics, and because they represent a potential threat to both public health and the environment [6]. The amount of Latin American hospital waste has increased in recent decades probably due to population growth and concentration, and the increased in the coverage of health services [7]. In addition, it is frequently reported that Latin American hospitals in small and intermediate cities do not yet have adequate management of these wastes, which is associated, on the one hand, with poor control by local environmental and public health authorities. On the other hand, hospitals associate these deficiencies with a low allocation of economic resources by central governments [8,9]. All this means that sometimes the final management and disposal of Latin American hospital waste is not being carried out on the basis of established technical safety protocols, which significantly affects public health and the environment. The proper treatment, control, and final disposal of hospital waste is an issue of urgent care for the entities providing this type of health services in Latin America. In addition, this management of hospital waste is of increasing interest to the different public health authorities, since such waste can put at risk the health of the personnel who have contact with them, directly or indirectly. These risks also warn of the need to reconnaissance and monitor the management of waste contaminated with biological, chemical, and radioactive material in hospitals. Knowing the management chain of hospital waste from the generation source to the final disposal, handling and sorting procedures, and the safety implements used by staff, will allow establishing technical protocols that contribute to the proper management of these wastes. This will not only benefit the community associated with hospitals but will also contribute to the improvement of the environment. The hospital wastes are solid, liquid, or gaseous substances, materials or by-products generated by a productive task resulting from the activity carried out by a generator [10]. These wastes could initially be classified as non-hazardous, i.e., biodegradable, recyclable, inert, and ordinary or common materials. Hospital waste could also be classified as hazardous waste, which has infectious, combustible, flammable,

explosive, radioactive, volatile, corrosive, or toxic characteristics, which can cause harm to human health or the environment [11]. Hazardous wastes are further classified into infectious or biohazardous wastes, which are those containing microorganisms such as bacteria, parasites, viruses, fungi, or oncogenic viruses. They can cause an infectious disease in susceptible guests [12]. Hazardous wastes can also be classified as chemical risk, such as remnants of chemicals and their packaging or any other residue contaminated with them, which, depending on their concentration and exposure time, can cause death, serious injury, or adverse effects on public health and the environment. Lastly, radioactive hazardous wastes are identified, corresponding to predictable and continuous energy-emitting substances in alpha, beta, or photon form, whose interaction with matter can result in the emission of X-rays and neutrons [13].

The main objective of this paper is to show the experience in the management of hazardous waste generated by a Latin American hospital located in Quibdó city (Colombia). The management of hazardous waste generated by the different areas or units of the hospital is studied. The harvesting, transport, and disposal phases of these hazardous waste inside the hospital are also analyzed. Lastly, the quantity of the different types of hazardous waste generated by the hospital under study is quantified.

MATERIALS AND METHODS

Study site

The study hospital is located in Quibdó city, Colombia (5°41'00" N; 76°38'45" W; see Figure 1). The city has a population of 109,121 inhabitants, surface area of 3,075 km^2, population density of 35.5 inhabitants/km^2, and average elevation of 43 m.s.n.m. The city has an average temperature of 28 °C and corresponds to life areas of very humid forest and tropical rainforest, with high rainfall. The total annual rainfall is 8,050 mm. The study hospital is primary health care or first level. This level is the closest to the population, i.e., the level of first contact with patients. This level of health care is about bringing health care as close as possible to the patient, whether it is to their community, their work, or where they require it [14]. The hospital has an annual budget of $4,765,000 USD. This for the last year of study.This hospital has an emergency department, 24 hours a day and for 7 days a week. There are also 144 hospitalization beds at the end of the last year of study. The hospital has the following service areas: external consultation, dentistry, vaccination, maternity, operating room, laboratory, pediatrics, x-ray, and functional rehabilitation. Indeed, the different areas of the hospital generate non-hazardous and hazardous waste. Among the hazardous waste generated are the following types: bio-sanitary, anatomopathological, sharps, and drugs [15]. For internal storage of this waste, the hospital has a central reservoir with a storage capacity of 10 tons. Infectious waste is not stored for more than 7 days, due to its characteristics and possible decomposition. The study hospital shows great coverage of users and patients, which generates a high level of hospital waste in its different areas. On average, 7,001 kg of hospital waste is being generated monthly. In the hospital the sharp waste is arranged in safety guards and deactivated with hydrogen peroxide, the 15 guardians are located in the medical offices and laboratory. The

anatomopathological waste is refrigerated (4 °C) and sent to an external company for deactivation and final disposal. The hospital has red containers of adequate resistance. These containers have pedal for the disposal of hazardous waste. Lastly, the hospital has an annual contract ($26,700 USD) with an external company to provide the service of collection, transportation, treatment, deactivation, and final disposal of all waste generated.

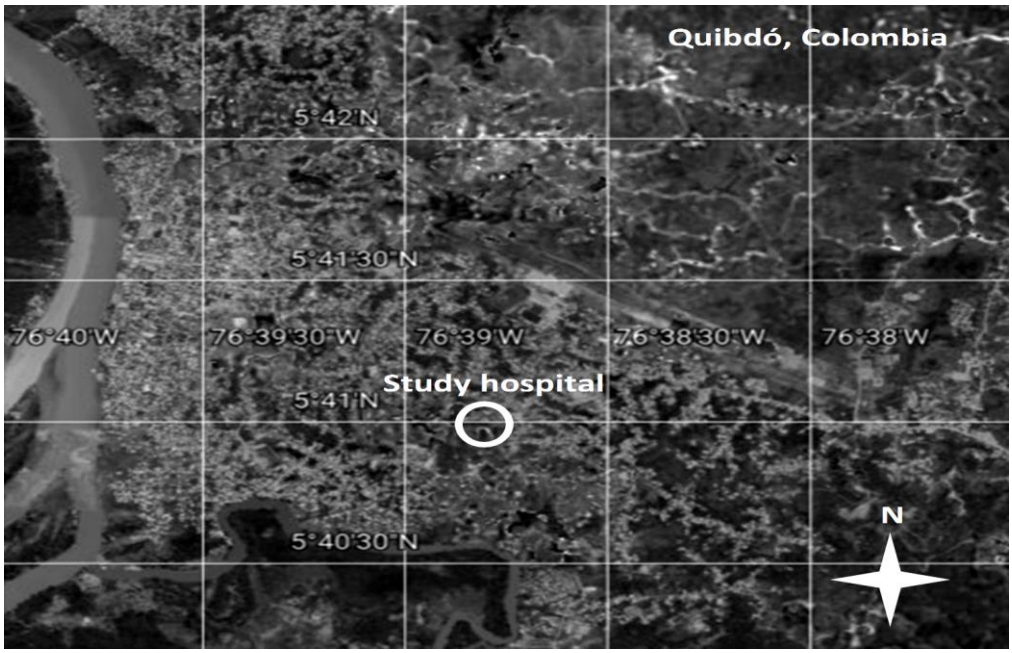


Figure 1. Location Of the Hospital Under Study (Google Earth Pro, 2021).

RESEARCH METHODOLOGY

The research methodology used in this study considered three phases. Phase 1: In this phase daily visits were made to the hospital facilities in order to characterize the stages of classification, management, transport, and storage of the waste generated. This characterization focused on hazardous waste generated by the different service areas of the hospital. During the characterization, the procedures carried out by the staff responsible for the internal management of hazardous waste were analyzed. The existence of signaling associated with each stage of hazardous waste management was also reviewed. The route of hazardous waste inside the hospital, from each of the service areas to their final storage in the hospital, was analyzed. Lastly, it was assessed whether the hospital followed the protocols established by Colombian health authorities for the collection, transport, and storage of hazardous waste.

Phase 2: In this phase the quantities and types of hazardous waste generated by the hospital were determined. To estimate the amounts and types of waste generated, the analog and digital information available at the hospital was reviewed. In this regard, the study hospital used the format established by the Colombian health authorities for the recording of hospital waste generation information (Figure 2) [15]. This format was diligence by each of the service areas, and subsequently, the information was consolidated for the entire hospital. The format used considered the following main study variables: Type of waste (biological and chemical), amount of waste (kg/day), number of bags delivered, storage time (hours), official responsible for delivery, and collection

time. The format did not consider radioactive waste because it was not generated by the study hospital.

	FORMAT RH 1. DAILY REGISTER OF THE GENERATION OF HOSPITAL WASTE																				
Institution Name:																		Collection Company:			
Address:													Telephone:								
Level:													Area - dependency:					Telefono:			
Responsible PGIRSH:													Number of beds					Business contact:			
Date	Type of waste								Total day (KG)	Number of bags delivered	Storage (In hours)	Responsible for delivery to the route	Collection Time	Registration of the Collector Vehicle	Driver's Name - Collection Company	Manifest code - collection support					
	Biological risk			Chemical risk																	
	A	B	C	D	E	F	G	H													
Observation:																					
Type of waste																					
infectious	A: anatomopathological												Chemical:	D: expired medicines							
	B: bio-sanitary													E: laboratory reagents							
	C: sharps													F: heavy metals							
														G: empty bottles							
														H: other waste (e.g., maintenance: lamps, oils, paints, etc.).							

Figure 2. Format For Daily Registration of Hazardous Waste Generated.

Phase 3: The period of information analysis was between 2012- 2016. During the information analysis, the generation of hazardous waste was compared with respect to the evolution in the number of beds available, discharged patients, specialized medical consultations, surgeries, and births [16]. Additionally, the turn-bed indicator was considered. Namely, this indicator was a measure of the number of discharged patients who, on average, committed the use of each available bed [17]. A descriptive analysis of the data was carried out and statistical tests were applied using the SPSS software V.18.0. A comparative analysis was also carried out to study the behavior in the production of hazardous waste: biological and chemical. In this study, the biological risk wastes considered were as follows: anatomopathological, bio-sanitary, and sharps. The chemical hazard wastes considered were expired medicines, laboratory reagents, heavy metals, empty bottles, and containers, and other waste (e.g., maintenance: lamps, oils, paints, etc.).

RESULTS AND DISCUSSION

Internal management of hazardous waste

The results of the general diagnosis showed that in the different hospital areas there were informative warnings (signage) to indicate the collection schedule and the transport routes of the hazardous waste generated. In addition, information notices for the correct initial disposal of waste (i.e., at the generation source) were observed in the hazardous waste generation areas. This signage referred to information sheets that indicated the type of waste that should be deposited in each of the containers installed in the hospital (Figure 3a). The hospital had red containers for the disposal of hazardous waste in each of its service areas. The containers of bio-sanitary waste were of two types: 20 liters, with pedal lid; and 35 liters, with swaying lid. It was also observed that

these containers had properly labeled red bags inside depending on the service area of the hospital where they were located. The bags were changed on average every four hours according to the frequency of waste collection. Separation at the source of waste generation was the fundamental basis for proper waste management in hospitals. This consisted of the initial selective separation of waste from each of the specific generation sources, which also initiated a chain of activities and processes whose efficiency depended on the appropriate initial classification of waste [18].

Three-liter guards were observed in the nursing offices and in the healing carts, which were used for the deposit of sharp material (Figure 3b). The sharp wastes were deactivated with hydrogen peroxide. In total of 15 guards were detected for sharp wastes. The results showed that hazardous hospital waste was not deactivated with sodium hypochlorite. According to what was considered by the Colombian Health Ministry [15], among the different disinfectants that could be used to deactivate hazardous waste, hypochlorite should not have been used in waste materials to be incinerated, because chlorine was one of the precursors in the formation of highly toxic agents (e.g., dioxins). It was also reported that in hospitals where hypochlorite was misused to deactivate waste, it was common for waste not to be incinerated as a final disposal technique. In other words, these hazardous wastes were probably deposited in landfills or, in their absence, in uncontrolled dumps [19].

a) b)

Figure 3. Containers For Waste A) Bio-Sanitary and B) Sharp [20].

The results showed that the economic component was essential to be able to carry out hazardous waste management work in the study hospital. For example, it was observed that the cost of collection, transportation, treatment, and final disposal of all hazardous waste generated at the hospital was about $26,700 USD per year. This does not include management within the hospital. This item only represented 0.56% of the hospital's total operating budget ($4,765,000 USD). However, in this study, a great concern was reported regarding the proper handling of hazardous waste from its origin to its final disposal, since sometimes and due to the budget scarcity, it was not possible to guarantee an adequate technical management. The results also showed an average production of hazardous waste throughout the hospital of 7,001 kg per month. The previous

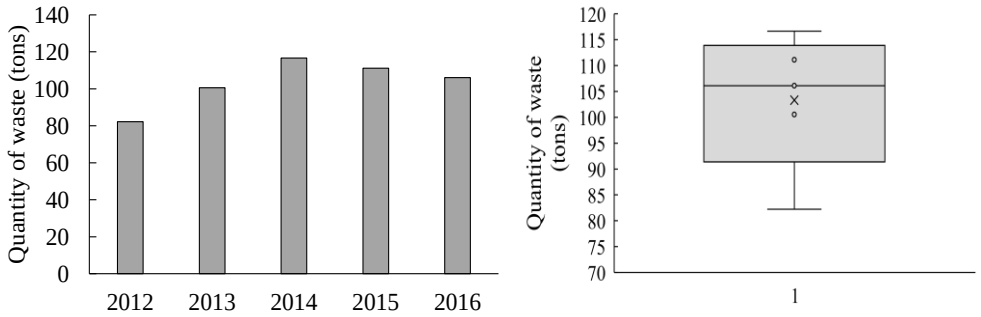
findings made it possible to calculate economic indicators of hazardous waste management that could be useful for other similar Latin American hospitals. The indicators were as follows: $3.81 USD/month per kg of hazardous waste collected, transported, treated, and finally deposited; and $185 USD/year per bed available for these same management activities. Lastly, Table 1 shows other indicators of interest obtained during the diagnosis of the hospital under study.

Table 1. Indicators Of Service Efficiency in The Hospital Under Study (Adapted from [16]).

INDICATOR	**2012**	**2016**
Hospitalization beds	90	144
Egress of patients	5,172	10,186
Turn-bed	57.5	70.7
Specialized medical consultation	10,847	12,027
Surgery (No births or cesarean sections)	1,956	3,910
Births	1,636	3,256
Hazardous waste (kg)	63,888	46,111

Characterization of hazardous waste

The results showed that during the first three years of study (2012-2014) the total amount of waste generated (hazardous and non-hazardous) by the hospital was increasing. An interannual increase of 17.2 ton/year (+20.9%/year) was observed. Subsequently, a decrease in the total amount of waste generated was observed during the remaining period (2014-2016) (Figure 4). An annual decrease of 5.23 ton/year (-4.75%/year) was observed. This decrease was probably due to the hospital implementing a waste management plan in 2014. On average, an annual waste production of 0.894 ton per available bed (range: 0.737 – 0.997 ton/bed) and 0.0139 ton per patient discharged from the hospital (range between 0.0104 – 0.0159 ton/patient discharged) was observed throughout the study period. The above results should consider the increase in the turn-bed indicator during the study period, from 57.5 to 70.7 (Table 1). This indicator was a measure of the patient number discharged who on average compromised the use of each available bed [17]. In other words, the hospital was improving its efficiency during the study period.



a) b)

Figure 4. Annual Quantity of Hospital Waste During the Study Period. A) Annual Variation And B) Box and Whisper Diagram.

The findings showed that during the first two years of study (2012-2013) the amount of hazardous waste generated by the hospital was increasing. An annual increase of 20.3 ton (20.9%/year) was observed. Subsequently, a decrease in the amount of hazardous waste generated was observed during the remaining period (2013-2016) (Figure 5). On average, an annual decrease of 12.7 ton/year (-16.9%/year) was observed. Indeed, this decrease was probably due to the hospital implementing a hazardous waste management plan in 2014. In this study, an average annual hazardous waste production of 0.533 tons per available bed was observed (range: 0.320 – 0.814 ton/bed), and 0.0105 tons per patient discharged from the hospital (range: 0.0045 – 0.0163 ton/patient discharged). Again, the previous results should consider the increase in the turn-bed indicator during the study period, from 57.5 to 70.7 (Table 1). Namely, the hospital was improving in its operating efficiency during the study period.

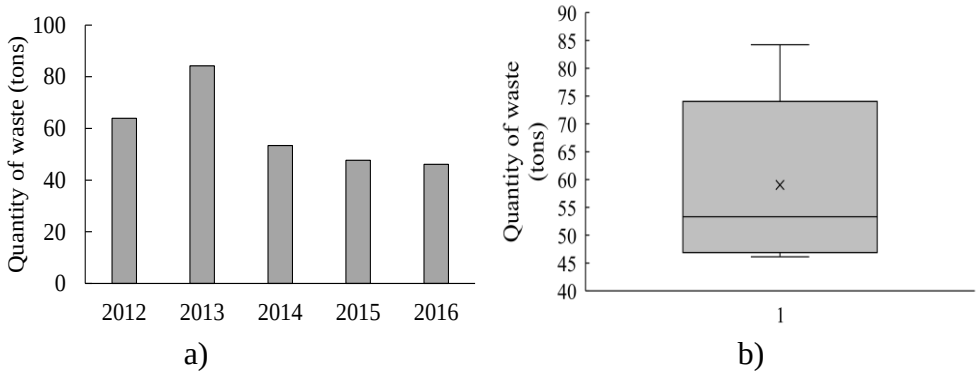


Figure 5. Annual Quantity of Hazardous Waste During the Study Period. A) Annual Variation And B) Diagram of Boxes and Whiskers.

The results showed that during the first two years of study (2012-2013) the amount of hazardous waste generated was higher compared to the amount of non-hazardous waste (Figure 6a). On average, 61.5% (56.7 ton/year) more hazardous waste was generated annually compared to non-hazardous waste. Subsequently, this trend was reversed when the waste management plan was implemented inside the hospital. The results suggested that prior to the implementation of the waste management plan, mistakes were possibly being made in the management of non-hazardous waste. Namely, a significant amount of this waste was probably mixed with hazardous waste. This possibly increased the operating costs of the system, because managing a ton of hazardous waste was more expensive compared to managing the same amount of non-hazardous waste. As mentioned, after the implementation of the hospital waste management plan in 2014 the trend was opposite. On average, it was observed that the amount of hazardous waste was 11.9% (13.2 ton/year) lower compared to non-hazardous waste (total = 62.3 ton/year). Indeed, this suggested a reduction in the operating costs of the system due to a decrease in the percentage of hazardous waste to be managed. In this study, it was evidenced that the percentage of non-hazardous waste to be managed corresponded to recyclable material (paper, cardboard, plastic, and glass) and biodegradable (food waste).

In relation to the 295.2 tons of hazardous waste generated in the hospital during the study period, it was observed that the largest proportion corresponded to biological risk waste (98%). Within this category the composition was as follows: bio-sanitary wastes = 90%, anatomopathological wastes = 5.0%, sharp wastes = 2.0%, and pharmaceutical wastes = 3.0% (Figure 6b). During the study period, no cytotoxic and radioactive wastes were observed. The bio-sanitary waste showed the same temporal trend observed for all hazardous waste. That is, a peak production was visualized in 2013 (74.3 ton/year), and subsequently its quantities tended to decrease to 47.0 ton/year (2016). This peak in production occurred during the period in which the waste management plan had not been implemented in the hospital under study. Anatomopathological wastes showed a similar temporal trend. The production range of this type of waste was between 2.26 – 4.13 ton/year. The sharp wastes showed a different behavior, because in 2012, 1.25 tons were generated and at the end of the study period only 0.349 tons were generated. This could indicate a better management and awareness during the generation of this type of hazardous waste inside the hospital. In relation to chemical wastes, the drugs had a variable behavior during the study period. The production range of this type of waste was between 1.36 – 2.48 ton/year. Lastly, no cytotoxic and radioactive wastes were observed in the study hospital.

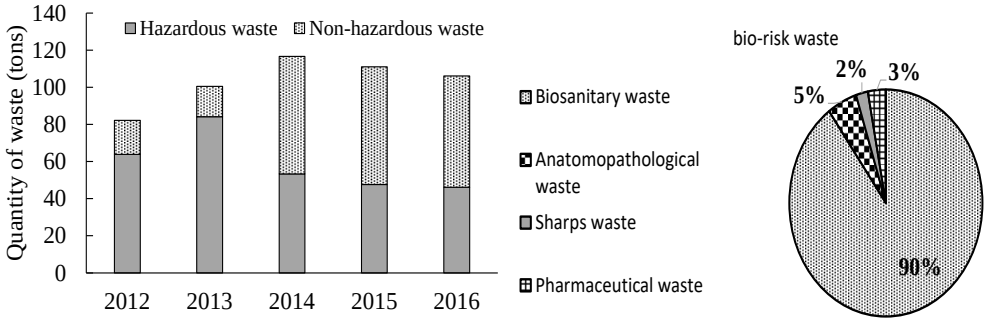


Figure 6. Annual Quantity of Hazardous and Non-Hazardous Waste During the Study Period. A) Annual Variation And B) Composition of Bio-Sanitary Wastes.

CONCLUSIONS

The findings of this study on the experience in the management of hazardous waste generated by a Latin American hospital allow us to visualize the following conclusions.

- The results show that the external management (collection, transport, treatment, and final disposal) of all hazardous waste generated by the hospital represents 0.56% of its annual operating budget. This activity is also equivalent to $3.81 USD/month per kg of hazardous waste generated, and $185 USD/year per available bed.
- It is observed that before the implementation of the management plan the quantities of hospital waste grow at a rate of 20.9%/year. After their application, they begin to decline at a rate of -4.75%/year. This evidences the effectiveness of the waste management plan implemented in the hospital

under study. It can be suggested that with this management plan the effectiveness of the system increases by 25.7%.

- On average, the findings show that prior to the implementation of the management plan the amounts generated of hazardous waste are growing at a rate of 20.9%/year. The rate of hazardous waste generation after implementation of the management plan decreases to -16.9%/year. Thus, an increase of 37.8% in the effectiveness of the hazardous waste management system in the study hospital can be suggested.
- In this study, the ineffectiveness of the system is evidenced by a higher production of hazardous waste compared to non-hazardous waste. Namely, before the implementation of the management plan, 61.5% more hazardous waste is generated compared to non-hazardous waste. This suggests a cost overrun during system operation because non-hazardous waste is possibly mixed with hazardous waste. After the implementation of the management plan the trend was opposite. The amount of hazardous waste is 11.9% lower compared to non-hazardous waste.
- Finally, this study may be relevant for hospitals of similar characteristics in developing countries because it can possibly constitute a guide to visualize the benefits of implementing a hospital waste management plan. It can also serve as a reference for agencies responsible for the monitoring and control of hazardous waste generated in hospitals.

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Conflict of interest

The authors state that there are no conflicts of interest.

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