SHORT COMMUNICATION

Carbon footprint of waste generated in orthopaedic cases in Pakistan: a pilot descriptive study

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Abstract

Most of the literature on reducing carbon emissions is from the developed world, which does not represent the realities of the developing world. Therefore, the current study was planned to gauge the carbon footprint generated by total knee and hip arthroplasty at the Aga Khan University Hospital, Karachi, between November 2023 and July 2024. The trash was sorted into biohazardous, packaging, and discarded equipment categories. The institutional Carbon Management Tool was used to estimate the carbon footprint. Of the 45 cases, the mean total trash per case was 29.3±13.9kg. In the current practice, the mean carbon footprint was 26.3±12.5kg carbon dioxide equivalents per case. Packaging represented 14.0±4.2% of the total carbon footprint from the waste. Even if this waste is sent to landfill sites, the carbon footprint is not reduced, indicating that the zero-emission solutions from the developed world may not work well in low- and middle-income countries, and innovative local solutions are urgently required.

Keywords: Carbon footprint, Greenhouse gasses, Hospital, Medical, Surgical, Pollution..

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Introduction

Climate change is a major concern leading to food shortages, health issues and increased risk of death.[1] Pakistan has been facing unusual climate events, such as floods, droughts, cyclones and storms, at an unprecedented scale. This change has led to water shortages, high temperatures and droughts, causing food insecurity and poverty in the country.[2] Urgent action is required to preserve the climate, and mitigate its untoward consequences.

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Greenhouse gases (GHGs) are a major source of climate change. Up to 10% of GHG emissions are linked to the healthcare sector, with surgical departments contributing up to six times more than the other departments.[3.] Therefore, reducing the carbon footprint from surgeries appears to be the most impactful place to make a start.

Some studies have looked at the environmental impact of orthopaedic procedures. One study estimated that the mean average carbon footprint of carpal tunnel decompression was 12.0kg carbon dioxide equivalents CO2e, and 85.5kg CO2e for knee arthroplasty.[4] A study in France estimated that the carbon footprint of arthroscopic rotator cuff repair was 334.61±18.82kg CO2e per procedure, with GHG production occurring mainly due to anchor usage, single-use equipment, conventional hospitalisation, and contaminated water management.[5]

Most such studies have been conducted in the developed world, which has markedly different healthcare practices and a much better civic infrastructure. Due to little resemblance to the developed world, Pakistan needs local evidence to assess the scale of impact of surgical procedures on climate, and come up with locally applicable solutions. The current study was planned to gauge the carbon footprint of orthopaedic cases in a Pakistani tertiary care setting.

Materials and Methods

The cross-sectional study was conducted at the Aga Khan University Hospital (AKUH), Karachi, from November 2023 to July 2024, and comprised cases of unilateral total knee arthroplasty (TKA), bilateral TKA, and unilateral total hip arthroplasty (THA) samples. Complex cases, such as revision surgeries and multiple procedures in a single anaesthesia, were excluded.

After each case, the trash was sorted into four categories; biohazardous, packaging (paper and plastic), discarded equipment, and linen. The first step was to separate all the biohazardous waste (i.e. any waste that was in direct contact with the patient's bodily fluid, blood, or the surgical field). The remaining waste was sorted into packaging, discarded equipment, and linen. The sorted trash and linen were weighed. The institutional carbon management tool[6], which has been developed using local data and is endorsed by the World Health Organisation (WHO), was used to estimate the carbon footprint of the waste from these cases. The output was presented as CO2e units.

The carbon footprint was estimated for the current practice of waste management at the institution, where all surgical waste, except linen, is incinerated. There are no green bags available. The study also evaluated a hypothetical estimation of non-biohazardous waste sent to landfills, and gauged its impact on carbon emissions. The carbon footprint for recycled waste was not done, since the country does not have an effective recycling infrastructure at the time of the study.

Data was analysed using Stata 17. Weight and CO2e values for each procedure were presented as mean ± standard deviation. Exemption was obtained from the institutional ethics review committee.

Results

Of the 45 cases sampled, 15(33.3%) each related to unilateral TKAs, bilateral TKAs, and unilateral THAs. The overall mean waste generated was 29.3±4.8kg. The highest mean waste generated was in bilateral TKA 48.0±4.8kg), followed by unilateral TKA 20.5±3.1kg, and unilateral THA 19.4±3.3kg (Table 1).

Table-1: Mean waste produced by unilateral TKA, bilateral TKA and unilateral THA.

Waste Category	Unilateral TKA	Bilateral TKA	Unilateral TKA	Total
	15 (33%) cases	15 (33%)	15 (33%)	45 (100%)
Linen	11.7 ± 3.8 kg	24.3 ± 3.0 kg	13.6 ± 4.9 kg	16.5 ± 6.9 kg
Biohazardous	12.2 ± 1.9 kg	30.9 ± 5.0 kg	11.8 ± 3.2 kg	18.3 ± 9.7 kg
Packaging	2.4 ± 1.0 kg	7.5 ± 1.3 kg	2.9 ± 0.9 kg	4.2 ± 2.6 kg
Discarded Equipment	5.7 ± 0.6 kg	9.7 ± 1.7 kg	4.8 ± 0.7 kg	6.7 ± 2.4 kg
Total Waste*	20.5 ± 3.1 kg	48.0 ± 4.8 kg	19.4 ± 3.3 kg	29.3 ± 13.9 kg

* Excluding linen
TKA: Total knee arthroplasty, THA: Total hip arthroplasty.

The carbon footprint estimated for incineration of all surgical waste was estimated at 26.3±12.5 CO2e. The largest contribution was from biohazardous waste, 16.4±12.5 CO2e which comprised 61.9% of the total carbon footprint. Packaging contributed 3.8±2.3 CO2e , or 14.3% of the total carbon footprint per case (Table 2).

In a hypothetical scenario of the carbon footprint if non-hazardous waste was sent to a landfill instead of incineration would have increased the overall carbon footprint to 27.6±13.0CO2e per case. If non-biohazardous packaging was sent to landfill instead of on-site incineration, its carbon footprint would have increase to 15.5% of the carbon footprint (Table 2).

Table-2: Mean carbon footprint of unilateral TKA, bilateral TKA and unilateral THA estimated in carbon dioxide equivalent (CO2e) terms.

Waste Category	Carbon Footprint (CO2e)			
	Setting: current institutional Practices		Setting: Landfill use for Non-Hazardous Waste	
Linen	0.3 ± 0.1	1.1%	0.3 ± 0.1	1.1%
Biohazardous	16.4 ± 8.7	61.9%	16.4 ± 8.7	59.0%
Packaging	3.8 ± 2.3	14.3%	4.3 ± 2.6	15.5%
Discarded Equipment	6.0 ± 2.2	22.6%	6.8 ± 2.5	24.5%
Total	26.3 ± 12.5	100.0%	27.6 ± 13.0	100.0%

TKA: Total knee arthroplasty, THA: Total hip arthroplasty, CO2e: Carbon dioxide equivalent.

Discussion

Most evidence on the climate impact of surgical procedures, and solutions to mitigate it, has been published in the developed countries. The current pilot study, to our knowledge, is the first to estimate the carbon footprint of orthopaedic arthroplasty cases in Pakistan. The mean total waste per case was 29.3kg, generating a mean carbon footprint of 26.3 CO2e.

Literature from Germany reported the carbon footprint from arthroplasty cases to be 125.9kg CO2e, while it was reported to be 100.2kg CO2e in the United Kingdom.[7,8] Although the current numbers are significantly less than these studies, they were able to incorporate more institutional data on energy consumption, transport, aesthetic gases, and other variables. When accounting for these additional variables, it can be hypothesised that the carbon footprint of surgical cases in Pakistan will also increase. Unfortunately, estimates from other countries do not match the ground realities of Pakistan due to vast differences in the energy infrastructure and institutional practices. Therefore, a lot of work is required to generate baseline estimates for other sources of carbon emissions in an operating room.

There are three possible solutions to mitigate the environmental impact of the operating room. The first of them involves recycling non-biohazardous waste. Pakistan does not have any effective recycling facilities currently. Developing the infrastructure for large-scale recycling will need serious policy and economic efforts, which is outside the scope of hospital administrators and medical professionals. Therefore, more pragmatic solutions are needed that can be implemented using the already available resources.

The second possible solution could be to use a landfill for non-biohazardous waste. However, based on the current estimates, the carbon footprint will increase with the use of landfills. One reason for this increase is the additional carbon emissions from the vehicles transporting waste from hospitals to landfill sites, instead of on-site incineration. Therefore, it seems unreasonable to incur these additional emissions.

Lastly, a reduction may be targetted in the waste generated per case. Naturally, the bulk of this reduction may come from reducing the packaging of the equipment and operating tools, and by re-using single-use disposable equipment. Packaging currently represents 14% of the non-biohazardous waste. A major portion of this 'packaging' is used to ensure the sterility of the equipment, therefore, it may not be possible to eliminate it. The push to use disposable surgical equipment was backed by evidence that single-use items reduce the risk of infection[9], which is a major cause of morbidity in developing countries. Therefore, reverting to re-useable equipment may do more harm than good.

The current study has limitations of being a single-centre, convenience pilot study, and, as such, the findings may not be generalisable to all hospitals in Pakistan. Despite the limitations, the pilot data is important to establish a baseline, and provides impetus to the task of developing locally relevant solutions.

Conclusion

Zero-emission solutions from the developed world are not likely to be effective in developing countries due to differences in civic infrastructure. Innovative, low-ost, and infrastructure-compatible solutions are needed to mitigate the environmental impact of the operating rooms in developing countries.

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