

RESEARCH ARTICLE **HAND**

Waste management in hand surgery: a quantitative and qualitative analysis

Anna J Neriamparambil MBBS  0000-0002-3532-6997,^{1,a} Joyce Antony MBBS, PhD  0000-0002-9871-8496²

¹Auckland Regional Centre for Plastic, Reconstructive and Hand Surgery, Middlemore Hospital, Ōtāhuhu, Auckland, NEW ZEALAND. ²Department of Neurosurgery, Gold Coast Hospital, Southport, Queensland, AUSTRALIA.

Keywords: hand, operative surgical procedures, medical waste, carbon footprint, cost saving

Submitted: December 5, 2024 AEST Revised: April 8, 2025 AEST Accepted: August 20, 2025 AEST

DOI: 10.34239/ajops.143594

Australasian Journal of Plastic Surgery

Vol 9, Issue 1, 2026

Abstract

Introduction: The healthcare sector accounts for 5–10 per cent of global carbon emissions with a significant contribution from operating theatres. This study aims to comprehend the carbon footprint of waste generated in hand surgery.

Methods: Waste generated from 21 surgical procedures done both in operating theatres under general anaesthetic and procedural suites under local anaesthetic was segregated into clean paper, contaminated paper, clean plastic and contaminated plastic, and weighed before routine disposal. The waste management policy of the institution was examined to estimate the financial and emissions burdens.

Results: This study found a mean of 1.922 kg of waste was generated per procedure. More complex procedures, such as open reduction and internal fixation, generated more waste (mean = 5.182 kg) compared to less complex procedures, such as incision and drainage of abscess, tendon repair or nail bed repair (mean = 1.382 kg). A mean reduction in total waste of 0.86 kg per procedure was achieved by performing eligible, less complex procedures in the procedural suite under local anaesthetic. This translated to an annual reduction of 0.77 tonnes of total surgical waste with a cost saving of NZ\$376.70 for disposal and a reduction of 252 kgCO₂e in carbon emissions.

Conclusion: This study sheds light on the carbon footprint of waste generated from hand surgery. A collaborative effort is required to mitigate the deleterious impact of surgical waste on climate change. Judicious use of procedural suites is a simple strategy to reduce waste and carbon emissions.

^a Corresponding author: Anna J Neriamparambil MBBS; annajoywork@gmail.com

Introduction

Healthcare activities are intended to protect and restore health and save lives. However, hospitals and other healthcare institutions generate substantial waste and contribute significantly to greenhouse emissions and climate change. Of this waste, 85 per cent is categorised as general, non-hazardous in nature, while the remaining 15 per cent may be infectious, toxic or radioactive with the potential to adversely impact health.¹ The theatre suite of a hospital is believed to contribute between 20 and 33 per cent of healthcare waste.² Up to 90 per cent of waste generated from the theatre suite is improperly sorted and sent for expensive and unnecessary hazardous waste processing, which can increase the carbon footprint of each procedure by up to 50-fold.³ This has prompted the healthcare sector to explore the implications of management of waste generated from theatre suites and develop means of waste reduction to minimise the sector's carbon footprint. The aim of this cross-sectional study was to estimate the carbon footprint of hand surgery in a single, high-volume institution, establishing a baseline benchmark for future sustainability auditing, engaging local stakeholders, and elucidating strategies for waste minimisation.

Methods

Study design

This was a prospective study examining waste generated by routine procedures performed within the department of hand surgery at a single institution over a period of four months. The primary investigator attended operating lists between August 2024 to December 2024, collecting waste data from 21 procedures performed by proceduralists with varying levels of operative experience. The 21 procedures included:

- seven complex procedures in the operating theatre under general anaesthetic, such as distal radius open reduction and internal fixation or arthroplasty
- seven non-complex procedures in the operating theatre under general anaesthetic, such as tendon repair, nail bed repair, and incision and drainage for abscess
- seven similar non-complex procedures in the procedural suite under local anaesthetic.

The hand surgery procedures were selected to ensure a representative sample, both elective and emergency, and the proceduralists had varying degrees of experience from junior registrars to senior consultants.

Intraoperative waste was segregated into clean paper, contaminated paper, clean plastic and contaminated plastic. Contaminated waste was defined as waste material generated from direct patient care or contact. To provide an example, it does not include the product wrappers, but does include each item in a multipack surgical set. The waste was sorted by the nursing staff involved in the procedure as routine. The sorted waste was weighed using a theatre scale (Seca 334 Mobile Digital Baby Scale; Seca GMBH & Co) and relevant emission coefficients were applied to determine the overall emissions. The method used has been extensively documented in existing literature.⁴

Following Shah and colleagues' examples, the waste management policy of the hospital was examined closely, in addition to the tariff for waste management and carbon dioxide (CO₂) emissions for different types of waste.⁴ The cost and carbon emissions for processing each type of waste were calculated.

Ethics approval

Ethics approval was obtained from the local human research ethics committee—Te Whatu Ora Counties Manukau Research Registration Number: SAK 1844. This study was undertaken in accordance with the Declaration of Helsinki and adhered to Good Clinical Practice guidelines.

Results

This study generated a mean of 0.467 kg (95% CI, 0.403–0.530) of clean paper, 0.440 kg (95% CI, 0.264–0.616) of contaminated paper, 0.239 kg (95% CI, 0.196–0.281) of clean plastic and 0.777 kg (95% CI, 0.548–1.006) of contaminated plastic waste from various hand procedures in different settings (operating theatre compared to procedural suite). This translated to a mean of 1.922 kg (95% CI, 1.440–2.405) of total waste per procedure. **Table 1** summarises the amount of waste generated, stratified by various hand procedures and different settings.

More complex operations, such as open reduction and internal fixation for distal radius fractures or arthroplasty, generated more waste with a mean of 5.162 kg (95% CI, 4.693–5.631) compared to non-complex procedures, such as incision and drainage of abscess, tendon repair or nail bed repair, with a mean of 1.382 kg (95% CI, 1.224–1.541). By performing eligible, non-complex procedures in the procedural suite under local anaesthetic, rather than in the operating theatre under general anaesthetic, a mean reduction in

total waste of 0.827 kg (95% CI, 0.788–0.866) per procedure was noted.

The hospital pays NZ\$146.50 per tonne for the management of clean waste and NZ\$828 per tonne for the management of contaminated waste. **Table 2** estimates the financial and emissions burden of waste generated per procedure. **Table 3** estimates the annual financial and emissions burden of surgical waste generated over a year by the department of hand surgery.

Discussion

This study explores waste management in hand surgery at a single, high-volume, combined orthopaedic and plastic surgery hand unit in New Zealand. Complex procedures, such as open reduction and internal fixation of distal radius fractures and arthroplasty, generate a mean of 5.162 kg of total waste, including 2.326 kg (95% CI, 2.290–2.362) of paper and 2.836 kg (95% CI, 2.387–3.285) of plastic waste. This compares favourably with a previous study from the United Kingdom

generating a mean of 0.8 kg of paper and 6.3 kg of plastic waste.⁴ While the waste generated in our study is comparable to the United Kingdom study, the subtle differences could be attributed to draping preferences and the generation of larger volumes of waste with more complex distal radius fracture fixations.

Another pivotal finding of this study is the mean reduction in total waste of 0.86 kg (95% CI, 0.788–0.937) per procedure by performing eligible, non-complex procedures (such as incision and drainage of abscess, tendon repair or nail bed repair) in the procedural suite under local anaesthetic, rather than in the operating theatre under general anaesthetic. This difference could be attributed to the use of major surgical packs in the operating theatre compared to minor packs in the procedural suite. While this translates to an annual reduction of 0.77 tonnes of total surgical waste with a cost saving of NZ\$376.70 for disposal and a reduction of 252 kgCO₂e in carbon emissions, these savings need to be balanced against the financial expenses

Table 1. Range (95% CI) of plastic and paper waste and mean weight of clean and contaminated waste for the procedures in the different operative settings

Procedure	Paper waste (kg)			Plastic waste (kg)			Overall waste (kg)
	Total	Clean	Contaminated	Total	Clean	Contaminated	Total
Complex GA	2.30–2.37	0.67	1.67	2.49–3.34	0.52	2.32	4.69–5.63
Simple GA	0.86–0.98	0.63	0.29	0.81–0.99	0.23	0.68	1.69–1.94
Simple LA	0.42–0.46	0.26	0.18	0.50–0.56	0.17	0.36	0.94–1.01

GA = general anaesthetic; LA = local anaesthetic

Table 2. Economic and environmental costs for procedures in the different operative settings

	Complex GA	Simple GA	Simple LA
Clean waste (kg)	1.19	0.86	0.43
– Cost/tonne (NZ\$)	146.50	146.50	146.50
– Cost/procedure (NZ\$)	0.17	0.13	0.06
– Emissions coefficient (kgCO ₂ e/tonne)	232	232	232
– Carbon emissions/procedure (kgCO ₂ e)	0.28	0.20	0.10
Contaminated waste (kg)	3.99	0.97	0.54
– Cost/tonne (NZ\$)	828.00	828.00	828.00
– Cost/procedure (NZ\$)	3.30	0.80	0.45
– Emissions coefficient (kgCO ₂ e/tonne)	422	422	422
– Carbon emissions/procedure (kgCO ₂ e)	1.68	0.41	0.23
Overall cost/procedure (NZ\$)	3.47	0.93	0.51
Overall carbon emissions/procedure (kgCO₂e)	1.96	0.61	0.33

GA = general anaesthetic; LA = local anaesthetic; kgCO₂e = kilograms of carbon dioxide equivalent

Table 3. Annual financial and environmental cost of waste generated in hand surgery

	Complex GA	Simple GA	Simple LA	Total
Number of procedures	1847	460	899	3206
Cost/procedure (NZ\$)	3.47	0.93	0.51	–
Carbon emissions/procedure (kgCO₂e)	1.96	0.61	0.33	–
Total annual cost (NZ\$)	6409.09	427.80	458.49	7295.38
Total annual emissions (kgCO₂e)	3620.12	280.60	296.67	4197.39

GA = general anaesthetic; LA = local anaesthetic; kgCO₂e = kilograms of carbon dioxide equivalent

of running a procedural suite and the unforeseen cost of postoperative infections or complications. Therefore, appropriate patient selection when considering surgical management in procedural suites under local anaesthetic is crucial.

Given the imminent threat from climate change, the healthcare community should advocate for and participate in emissions reduction and improved sustainability practices. Healthcare has a considerable carbon footprint, accounting for 7 per cent of Australia's carbon dioxide emissions, and the operating theatre contributes a significant proportion (20–30%) of this carbon footprint.⁵ The Royal Australasian College of Surgeons has adopted the Canadian approach to efficient waste management, summarised as the 5Rs—Reduce, Reuse, Recycle, Rethink and Research.⁶ This study supports the judicious use of procedural suites and local anaesthetic for eligible patients and procedures to reduce waste generation and carbon emissions. There is sufficient evidence to support the use of reusable drapes and gowns to achieve a 66 per cent reduction in carbon emissions without increasing infection risk or compromising comfort.⁴

Despite the theatre staff segregating clean plastic waste, it was later combined with clean paper waste and none of the hospital waste contractors provide a service that can separate the two for recycling, so this waste is incinerated with energy capture.⁴ An amalgamation of advanced systems is utilised such as static electricity to remove dust and smoke particles, acid gas scrubbers, catalytic converters and fabric filters with the remaining bottom ash and fly ash used in making concrete and other construction material. This is not a unique problem and others have reported the failure of recycling in theatre due to improper waste segregation in the hospital or a lack of service provision by waste contractors.⁴

This study has shed some light on the impact of waste generation in the operating theatre as well as current waste management practices. Several interventions have been proposed and are currently under review within our department, including the potential modification of surgical packs to reduce unnecessary consumables, increased use of the procedural suite and improved segregation of recyclable waste. The healthcare community needs to actively rethink our practices to minimise our carbon footprint. Further research in this area is pivotal to the provision of sustainable healthcare practices.

Limitations

This study has numerous limitations. First, it estimates the carbon footprint of hand surgery by calculating waste generation from various procedures performed in a high-volume institution. Other factors significantly contributing to carbon footprint include power consumption, travel for patients and staff, and procurement of equipment. Waste generation accounts for only 20–30 per cent of the carbon footprint.⁵ However, power consumption, travel and procurement are relatively non-modifiable contributors of carbon footprint and hence research is more heavily weighted on reducing waste generation. Second, this study does not account for anaesthetic gases, many of which are ozone-depleting. Only 5–20 per cent of anaesthetic gases are metabolised by patients and without recovery systems, the majority of these gases are inadvertently released into the atmosphere with a global warming potential over 2000 times that of carbon dioxide.⁶ Third, there is a potential bias from surgeons being aware of the study being undertaken, as they would endeavour to judiciously utilise resources and minimise waste affecting the results of the study, the well-recognised Hawthorne effect.

Conclusion

This study sheds light on the environmental impact of waste generated in hand surgery. Given the detrimental effects of climate change and both national and international mandates to achieve reduced emissions, it is timely to draw this to the attention of clinicians and hospital administrators. Mitigating the carbon footprint of the operating theatre requires a collaborative endeavour to change the culture and mindset within healthcare institutions towards sustainability and social responsibility. Judicious use of procedural suites and local anaesthetic would help minimise waste generation and inadvertent release of anaesthetic gases to reduce emissions.

Conflict of interest

The authors have no conflicts of interest to disclose.

Funding declaration

The authors received no financial support for the research, authorship and/or publication of this article.

References

- 1 Borowy I. Medical waste: the dark side of healthcare. *Hist Cienc Saude Manguinhos*. 2020;27(suppl 1):231–251. <https://doi.org/10.1590/s0104-59702020000300012> PMID:32997065
- 2 Robinson PN, Surendran K, Lim SJ, Robinson M. The carbon footprint of surgical operations: a systematic review update. *Ann R Coll Surg Engl*. 2023;105(8):692–708. <https://doi.org/10.1308/rcsann.2023.0057> PMID:37906978 PMCid:PMC10626532
- 3 MacNeill AJ, Lillywhite R, Brown CJ. The impact of surgery on global climate: a carbon footprinting study of operating theatres in three health systems. *Lancet Planet Health*. 2017;1(9):e381–e388. [https://doi.org/10.1016/S2542-5196\(17\)30162-6](https://doi.org/10.1016/S2542-5196(17)30162-6) PMID:29851650
- 4 Shah S, Morris H, Thiagarajah S, et al. Handling ‘carbon footprint’ in orthopaedics. *Ann R Coll Surg Engl*. 2024;106(6):498–503. <https://doi.org/10.1308/rcsann.2023.0052> PMID:38563077 PMCid:PMC11214852
- 5 Malik A, Lenzen M, McAlister S, McGain F. The carbon footprint of Australian health care. *Lancet Planet Health*. 2018;2(1):e27–e35. [https://doi.org/10.1016/S2542-5196\(17\)30180-8](https://doi.org/10.1016/S2542-5196(17)30180-8) PMID:29615206
- 6 Kagoma Y, Stall N, Rubinstein E, Naudie D. People, planet and profits: the case for greening operating rooms. *CMAJ*. 2012;184(17):1905–1911. <https://doi.org/10.1503/cmaj.112139>



CC-BY-4. This is an open access article distributed under the Creative Commons Attribution 4.0 International License (CC-BY-4) which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited. View this license's legal deed at <http://creativecommons.org/licenses/by/4.0> and legal code at <http://creativecommons.org/licenses/by/4.0/legalcode> for more information.