Staff education compared with active real-time waste segregation to reduce the environmental impact of hip and knee arthroplasty

a multicentre study

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Aims
Arthroplasty has been shown to generate the most waste among all orthopaedic subspecialties, and it is estimated that hip and knee arthroplasty generate in excess of three million kg of waste annually in the UK. Infectious waste generates up to ten times more CO2 compared with recycled waste, and previous studies have shown that over 90% of waste in the infectious stream is misallocated. We assessed the effect of real-time waste segregation by an unscrubbed team member on waste generation in knee and hip arthroplasty cases, and compared this with a simple educational intervention during the 'team brief' at the start of the operating list across two sites.

Methods
Waste was categorized into five categories: infectious, general, recycling, sharps, and linens. Each category was weighed at the end of each case using a digital weighing scale. At Site A (a tertiary orthopaedic hospital), pre-intervention data were collected for 16 total knee arthroplasy (TKA) and 15 total hip arthroplasty (THA) cases. Subsequently, for ten TKA and ten THA cases, an unscrubbed team member actively segregated waste in real-time into the correct streams. At Site B (a district general hospital), both pre- and post-intervention groups included ten TKA and ten THA cases. The intervention included reminding staff during the 'team brief' to segregate waste correctly.

Results
Active real-time waste segregation reduced infectious waste by a mean of 2.51 kg (95% CI 1.492 to 3.542) in TKA, and 1.83 kg in THA cases ($p = 0.004$). Educational intervention reduced infectious waste by a mean of 3.52 kg in TKA and 2.09 kg in THA cases ($p = 0.026$). Total waste was significantly reduced in both groups post-intervention for TKA cases.

Conclusion
Simple educational measures alone can significantly reduce the amount of infectious waste. Extrapolated nationally, our results would yield a reduction of approximately 315,004 kg to 594,577 kg of CO2 annually, which equates to 70 to 132 gasoline-powered passenger vehicles driven for a year.

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Take home message

- Simple educational interventions can have a significant impact on reducing the amount of infectious waste generated, and thus the carbon footprint of knee and hip arthroplasties.

Introduction

The need for the medical community globally to define and reduce its impact on climate change has never been more pressing. Recently in the UK, the Health and Care Act (2022)[1] outlined the commitment for the NHS to achieve a "net zero" carbon footprint by 2045 – an immense task considering the NHS emits more than 25 megatonnes of CO2 annually, equating to more than one-third of the UK's public sector emissions.[2,3]

When compared with other specialties, Rizan et al[4] highlighted that surgery is three to six times more energy-intensive than any other department. Within orthopaedics, operating theatre waste, transportation, carbon emissions from object manufacture, anaesthetic gases, and water use have recently been highlighted as areas to target to reduce our carbon footprint.[5] Arthroplasty has been shown to generate the most waste among all orthopaedic subspecialties,[6] and it is estimated that hip and knee arthroplasties generate in excess of three million kg of waste annually in the UK.[7]

In a study of waste generated from hip and knee arthroplasty in the UK, it was found that the majority of waste was disposed as infectious waste: 69.2% in total knee arthroplasty (TKA) and 73.4% in total hip arthroplasty (THA).[7] Similar figures were found in a waste audit in Baltimore (Maryland, USA).[8] Previous studies on operating theatre waste segregation have suggested that over 90% of waste in the infectious stream is misallocated, and should have been disposed of in alternative, less energy-intensive waste streams.[9,10] Rizan et al[11] also highlight that disposing of infectious waste generates approximately ten times more CO2 compared to recycled waste. With over 190,000 knee and hip arthroplasties performed in the UK annually,[12] small improvements in waste segregation can have a significant impact in reducing overall CO2 production.

The authors aim to assess the effect of real-time waste segregation by an unscrubbed team member in knee and hip arthroplasty cases. Recognizing that active waste segregation by a separate team member may not be practically achievable in many healthcare systems due to limited resources and personnel, the authors also assess the effects of a simple educational intervention during the 'team brief' at the start of the operating list on waste segregation.

Methods

Two sites were selected for the study, a tertiary orthopaedic hospital (Site A: Royal Orthopaedic Hospital NHS Foundation Trust, Birmingham, UK) and a district general hospital (Site B: Royal Wolverhampton NHS Foundation Trust, Wolverhampton, UK). At both sites, primary hip and knee arthroplasty cases were included, with complex primary, revision, and trauma cases excluded.

Waste was categorized into five categories: infectious, general, recycling, sharps, and linens. Each category was weighed at the end of each case using a digital weighing scale accurate to 0.01 kg. The same manufacturer's weighing scale was used across both sites throughout the study. Waste produced in the anaesthetic room, anaesthetic gases, anatomical waste, and fluid from suction tubing were excluded. In each case, data collection began as soon as preparation for the case began in theatre, corresponding to the opening of new waste bags, and concluded once the final waste bags were closed at the end of the procedure.

At Site A, data collection took place between April 2022 and May 2023. Pre-intervention data were collected prospectively for 16 TKA and 15 THA cases. Subsequently, data for ten TKA and ten THA cases were collected, with an unscrubbed team member in theatre actively segregating waste in real time into the correct streams according to established local and national guidelines. The Trust's waste management lead also provided guidance on optimal waste segregation practice.

At Site B, data collection took place between August 2023 and January 2024, with initial pre-intervention data collection including ten TKA and ten THA cases. Subsequently, for the post-intervention group of ten TKA and ten THA cases, at the beginning of each operating list during the 'team brief' all team members were simply reminded of the need to use the correct waste streams for waste disposal and the environmental impact of this.

The study was approved locally at each site. Institutional review board or ethical approval was not required.

Statistical analysis

Data were collected and stored using Excel 2019 (Microsoft, USA), and SPSS v. 28 (IBM, USA) was used to perform independent-samples *t*-test to determine significance of differences pre- and post-intervention in both groups, with a significance level of 0.05.

Results

At Site A, 31 cases were included pre-intervention (16 TKAs and 15 THAs). Overall, ten TKAs and ten THAs were then studied with a team member (RP) actively segregating waste in real time. The mean weights of the different waste streams pre- and post-active waste segregation are indicated in Table I. Infectious waste was reduced by a mean of 2.51 kg (21.2%) (95% CI 1.492 to 3.542) in TKA cases, and 1.83 kg (17.3%) in THA cases. This reduction was significant in both cases (TKA: $p < 0.001$, and THA: $p = 0.004$), as illustrated in Figure 1.

At Site B, the pre-intervention group consisted of ten TKA and ten THA cases. Overall, these cases were then studied with an educational intervention at the start of each operating list (without active waste segregation). Mean weights of the different waste streams pre- and post-intervention are summarized in Table II and Figure 2. The mean infectious waste was reduced by 3.52 kg (30.6%) in TKA cases ($p < 0.001$) and 2.09 kg (19.9%) in THA cases ($p = 0.026$).

Site A recycled small amounts of waste in TKA (0.93 kg) and THA (0.42 kg), with no significant change following active waste segregation. Site B did not recycle any waste, highlighting the variation in waste management between different trusts.

Total waste was significantly reduced in both groups post-intervention for TKA cases. This trend was similarly seen

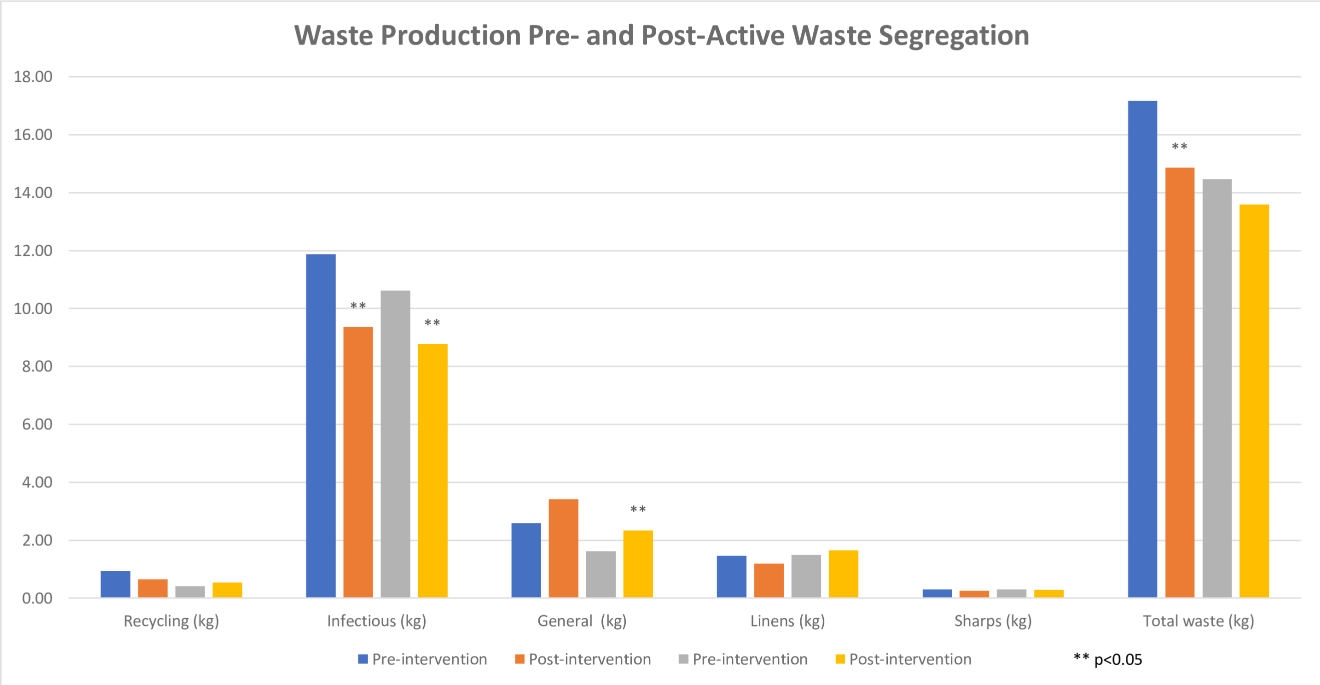

Fig. 1
Waste production pre- and post-active waste segregation.

Table I. Site A's active waste segregation.

Waste, kg	Pre-intervention (TKA)	Post-intervention (TKA)	Change, %	p-value*
Recycling	0.93	0.65	-30.43	0.245
Infectious	11.87	9.36	-21.16	< 0.001
General	2.59	3.41	31.79	0.556
Linens	1.46	1.20	-17.95	0.236
Sharps	0.31	0.25	-18.37	0.661
Total waste	17.16	14.87	-13.36	0.0102
Waste, kg	**Pre-intervention (THA)**	**Post-intervention (THA)**	**Change, %**	**p-value***
Recycling	0.42	0.54	29.60	0.158
Infectious	10.61	8.78	-17.27	0.004
General	1.63	2.34	43.85	0.001
Linens	1.50	1.65	10.00	0.722
Sharps	0.31	0.28	-8.70	0.793
Total waste	14.46	13.59	-6.04	0.208

*Independent-samples *t*-test.
THA, total hip arthroplasty; TKA, total knee arthroplasty.

for THA cases at both sites but did not reach statistical significance (Figure 1 and Figure 2).

Discussion

Active real-time waste segregation was effective and significantly reduced infectious waste, confirming that a significant proportion of waste was being misallocated. The authors noted that the majority of packaging and surgical tray wrapping was being disposed of in the infectious stream (typically in orange bags), despite the items being clean and disposed of prior to surgical incision. The infectious waste stream (orange bags in NHS hospitals) should only be used for cases where there is concern for infectious agents, such as methicillin-resistant *Staphylococcus aureus* (MRSA), COVID-19, or carbapenemase-producing *Enterobacterales* (CPE), otherwise the offensive waste stream (tiger-stripe

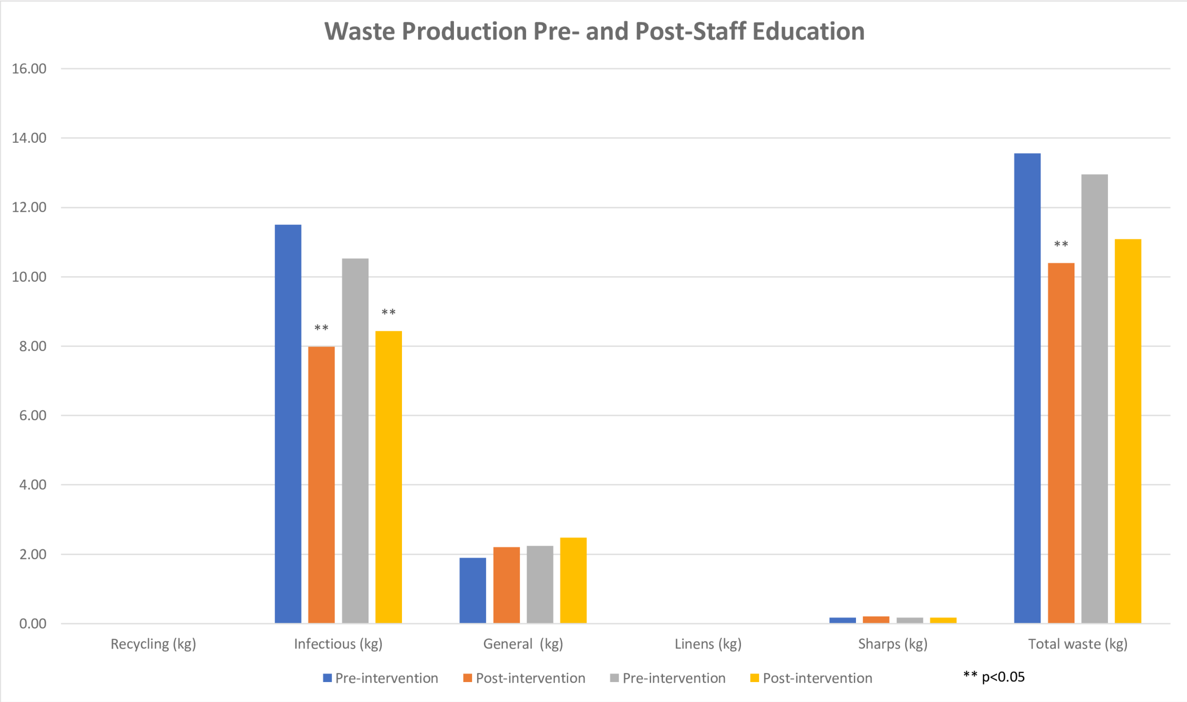

Fig. 2
Waste production pre- and post-staff education.

Table II. Site B's staff education.

Waste, kg	Pre-intervention (TKA)	Post-intervention (TKA)	Change, %	p-value*
Recycling	0.00	0.00	0.00	NA
Infectious	11.50	7.98	-30.57	< 0.001
General	1.89	2.20	16.51	0.969
Linens	0.00	0.00	0.00	NA
Sharps	0.17	0.21	22.35	0.169
Total waste	13.56	10.39	-23.35	0.002
Waste, kg	**Pre-intervention (THA)**	**Post-intervention (THA)**	**Change, %**	**p-value***
Recycling	0.00	0.00	0.00	N/A
Infectious	10.53	8.44	-19.90	0.026
General	2.24	2.48	10.63	0.680
Linens	0.00	0.00	0.00	N/A
Sharps	0.17	0.17	0.59	1.000
Total waste	12.95	11.08	-14.41	0.091

*Independent-samples *t*-test.
N/A, not applicable; THA, total hip arthroplasty; TKA, total knee arthroplasty.

bags) and general waste should be used. In our study, neither trust used the tiger-stripe bags (offensive waste). Rizan et al[11] studied the carbon footprint of the different waste streams and found that infectious waste generates 569 kg to 1,074 kg of CO2e/t waste due to incineration processes, compared to 249 kg CO2e/t for offensive waste and 172 kg CO2e/t for general domestic waste.

Our results demonstrate that a significant reduction in infectious waste can be achieved with simple educational measures alone. Given limited resources, it is not practical to allocate the responsibility of appropriate waste segregation to an individual team member, and thus the effect of an educational intervention during the 'team brief' at the start of the list was studied. Our results have confirmed that simple educational measures, if implemented on a large scale, could prove a simple yet powerful tool to significantly reduce CO_2 emissions from theatre waste. Educational intervention resulted in a 3.52 kg mean reduction in infectious waste for TKA cases, and 2.09 kg in THA cases. If this were replicated nationally, extrapolating using figures from the National Joint Registry (NJR), which covers data from England, Wales, Northern Ireland, the Isle of Man, and Guernsey,[12] the result would be a reduction of approximately 315,004 kg to 594,577 kg of CO_2, which equates to between 70 and 132 gasoline-powered passenger vehicles driven for a year.[13]

More accurate waste segregation also has significant cost implications. Local trust data from Site A show the cost of disposing of infectious waste is three times that of general waste. Thus, the authors recommend a particular focus on reducing the amount of unnecessary infectious waste generated in theatre, and the use of tiger-stripe (offensive) and general waste streams should be encouraged and made available in theatre.

Only a small percentage of waste was recycled in Site A for TKA (4.37%) and THA (3.97%) cases. Given the high proportion of papers and plastics that make up packaging, manufacturers should be taken to task to ensure all their packaging is not only recyclable but clearly labelled as such;[7] currently this does not occur.

Site B did not recycle any waste, highlighting the variation in waste management between different trusts. Further large-scale studies are required to assess this variation in more detail. Ultimately, a greater emphasis is required on a national scale to not only standardize but also optimize waste management in theatre, to ensure optimal waste segregation and increased recycling.

Limitations

The authors recognize that the study focuses on improving waste segregation, which represents just one of many measures required to reduce the carbon footprint of surgery, including reducing overall consumption of single-use items, streamlining surgical trays, use of reusable gowns, and moving towards alcohol-based scrub techniques.[14] While CO_2 is considered an important contributor to global warming via the greenhouse effect, it is one of several greenhouse gases.[15] Our study evaluates the impact of waste generation on CO_2 production, however does not investigate its effect on other drivers of climate change. Our study involved two sites, and further work is required to establish the variation in practices nationally and implement large-scale interventions to improve waste segregation on a larger scale. The authors acknowledge that while the segregation of waste in hospital was directly assessed, the final destination and treatment of the waste was assumed to have taken place as per hospital policy.

In conclusion, our pilot data have demonstrated the efficacy of simple educational measures in reducing the CO_2 generated from waste inappropriately discarded in the infectious waste stream. Large scale initiatives are required to implement educational measures on a national and international level to reduce the overall carbon footprint of orthopaedic surgery.

References

1. **No authors listed**. Health and Care Act 2022. HM Government. https://www.legislation.gov.uk/ukpga/2022/31/contents/enacted (date last accessed 28 November 2024).
2. **Tennison I**, **Roschnik S**, **Ashby B**, **et al**. Health care's response to climate change: a carbon footprint assessment of the NHS in England. *Lancet Planet Health*. 2021;5(2):e84–e92.
3. **Phoon KM**, **Afzal I**, **Sochart DH**, **Asopa V**, **Gikas P**, **Kader D**. Environmental sustainability in orthopaedic surgery: a scoping review. *Bone Jt Open*. 2022;3(8):628–640.
4. **Rizan C**, **Steinbach I**, **Nicholson R**, **Lillywhite R**, **Reed M**, **Bhutta MF**. The carbon footprint of surgical operations: a systematic review. *Ann Surg*. 2020;272(6):986–995.
5. **Saleh JR**, **Mitchell A**, **Kha ST**, **et al**. The environmental impact of orthopaedic surgery. *J Bone Joint Surg Am*. 2023;105-A(1):74–82.
6. **Kooner S**, **Hewison C**, **Sridharan S**, **et al**. Waste and recycling among orthopedic subspecialties. *Can J Surg*. 2020;63(3):E278–E283.
7. **Prakash R**, **Abid H**, **Wasim A**, **Sharma A**, **Agrawal Y**. The environmental impact and sustainability of total hip and knee arthroplasty. *Arthroplast Today*. 2023;24:101254.
8. **Lee RJ**, **Mears SC**. Reducing and recycling in joint arthroplasty. *J Arthroplasty*. 2012;27(10):1757–1760.
9. **Kwakye G**, **Brat GA**, **Makary MA**. Green surgical practices for health care. *Arch Surg*. 2011;146(2):131–136.
10. **Laustsen G**. Reduce--recycle--reuse: guidelines for promoting perioperative waste management. *AORN J*. 2007;85(4):717–722.
11. **Rizan C**, **Bhutta MF**, **Reed M**, **Lillywhite R**. The carbon footprint of waste streams in a UK hospital. *J Clean Prod*. 2021;286:125446.
12. **Ben-Shlomo Y**, **Blom A**, **Boulton C**, **et al**. The National Joint Registry 20th annual report. National Joint Registry. 2023. https://reports.njrcentre.org.uk/Portals/0/PDFdownloads/NJR%2020th%20Annual%20Report%202023.pdf (date last accessed 11 November 2024).
13. **No authors listed**. Greenhouse gas equivalencies calculator. United States Environmental Protection Agency. 2024. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator?unit=vehicles&amount=556#results (date last accessed 11 November 2024).
14. **McNamee C**, **Rakovac A**, **Cawley DT**. Sustainable surgical practices: a comprehensive approach to reducing environmental impact. *Surg*. 2023;S1479-666X(23)00093-8.
15. **No authors listed**. Basics of climate change. United States Environmental Protection Agency. 2024. https://www.epa.gov/climatechange-science/basics-climate-change#keygases (date last accessed 11 November 2024).

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Data sharing

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