Operating room waste management: A case study of primary hip operations at a leading NHS hospital in the United Kingdom

Abstract

Objective: This research examines current waste management within an operating room at a large United Kingdom (UK) National Health Service (NHS) hospital. The study measured the volume and type of waste produced for primary hip operations (PHOs) and estimated the total waste produced across the UK by the procedure.

Methods: Three PHOs were audited to measure and compare the waste volumes generated.

Results: The average volume of waste per surgical procedure was 10.9kg, consisting of clinical (84.4%), recyclable (12.8%) and Bio-bin (2.8%) waste. This research also found that single-use devices contribute significantly to operating room waste. In addition, it was estimated that there is a missed opportunity to reduce clinical waste volume in each procedure, where approximately 15% of clinical waste disposal consisted of visibly clean recyclable waste material, including cardboard and plastics.

Conclusions: It was estimated that in the NHS approximately 1043 tonnes of waste is produced annually by PHOs alone. A significant volume of this waste could be prevented through improved recycling and reduced use of single-use devices.

Keywords

waste management, operating room, sustainability

Introduction

Climate change is a significant global health threat.[1] The Intergovernmental Panel on Climate Change's Sixth Assessment Report 2021 states that global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions occur in the coming decades.[2] This includes a decrease of GHGs of 45% by 2030 compared with 2010, and a target to reach net zero by 2050,[3] requiring all industries to develop strategies to reduce environmental effects.[2]

As the United Kingdom's (UK) leading health care provider to a population of 66.8 million, the National Health Service (NHS) is the largest publicly funded health system in the world and the fifth largest workforce globally.[4] In 2019, NHS Digital,[5] reported the NHS in England generates approximately 538,600 tonnes of waste per year and contributes approximately 6% carbon footprint of the UK emissions.[6] Waste in health care is not only linked to materials and CO_2 emissions, but also to clinical practice, service delivery and care.[7] Waste in the NHS is estimated to account for 20% of health expenditure,[6] although the current researchers have found that there is a paucity of data reporting a monetary value associated with waste in the NHS overall. Similarly, in the United States (US) it is estimated that approximately 30% of health care spending may be considered waste, with an estimated cost of up to $935

billion.[9,10] This suggests US health care is also wasting a huge volume of resources and money, and significantly attributing to environmental harms.

Surgical health care is resource intensive and one of the major contributors to climate change within the health care sector.[11] The Greener NHS strategy[6] has thrown down a significant challenge for surgery within the NHS to meet a target of net zero GHG by 2045, including pledging to drive action on key areas including reducing waste and reducing single-use plastic consumption. The NHS has also committed to an ambitious but achievable Long-Term Plan, describing a wide variety of strategies and world-leading climate change mitigation objectives.[12]

Approximately 315 million surgical procedures are performed worldwide annually.[13] In the UK, the NHS Confederation reported a volume of 10.119 million surgeries for the financial year 2015-2016, an increase of 40% from 2005-2006.[14] Research reports that the burden of waste generated by surgery accounts for up to 70% of a hospitals' total waste volume.[13] Worldwide, the volume of surgical procedures is expected to increase to an estimated half a billion a year by 2030.[15] Highlighting the significance of this increase in surgical procedures, Rizan et al.[16] report the carbon footprint of a single operation ranges from 6-814 kg CO_2 equivalents, illustrating the burden of environmental impact of surgery within health care.

Primary hip operations (PHOs), also known as hip replacement procedures, are a relatively common surgical procedure, with approximately 96,000 PHOs undertaken in the NHS each year.[17] This number is expected to rise in future due to an increasingly aging society globally.[17,18] PHOs are considered to be one of the largest generators of waste in surgery, with one study reporting a single PHO generates greater than 13kg of waste.[19]

Other research has noted a lack of published data on the proportion of waste disposed of via the various waste streams and, similarly, a paucity of research reporting adequate infrastructure for waste segregation within NHS surgical departments.[1,20] This is remarkable, given that the choice of waste stream has up to a 50-fold impact on a procedure's carbon footprint.[20]

The current research aims to highlight the burden of waste produced by PHOs. It hypothesises that there is significant potential for reducing waste through improved waste recycling practices and reduced use of single-use devices (SUDs).

Methods

Waste audit data collection

Surgical waste audits of three PHOs were undertaken within a single orthopaedic department based at Freeman Hospital, run by the Newcastle upon Tyne Hospitals NHS Foundation Trust. The audits were conducted over two consecutive days in March 2018. The collection of waste was undertaken from PHOs using a cemented surgical technique, performed by two orthopaedic surgeons operating in separate operating rooms (ORs) and with different circulating staff members. It was expected that the waste audits of each operation would find the procedures produced similar volumes of waste, as all three PHOs would be conducted using a standardised surgical technique. There was, however, potential for the waste produced to vary due to the surgeon preference of either a cemented or uncemented surgical technique requiring different surgical instruments to be used. The surgical waste audits will be referred to as Surgery A, Surgery B and Surgery C. The OR staff had

previously received internal NHS OR waste management and waste segregation training. In order to obtain real world data, the staff agreed to manage the waste as they normally would for each operation. All OR personnel (including the scrub team, circulating nurses and custodial staff) were asked to ensure that every waste bin was empty at the start of the surgical procedure, and that all waste was accounted for.

Contaminated and uncontaminated waste was separated by staff as per protocol into the following waste streams:

(i) Clinical waste; yellow and black striped ‘non-offensive’ tiger-striped bags. Examples of ‘non-offensive’ waste includes soft health care waste, dressings and swabs with bodily fluids, and personal protective equipment (i.e. hats, gloves, and aprons);

(ii) Recyclable waste collected in clear plastic bags. Examples of recyclable material includes non-confidential paper, soft and hard plastics, and metal packaging;

(iii) Bio-bin waste (sharps and anaesthesia) collected in a container to be weighed, prior to being safely deposited in a dedicated Bio-bin;

(iv) Hazardous waste, e.g. batteries used to power single use devices

(v) Pink plastic bags containing dirty laundry.

As explained below, the final two categories were not included in our audits.

Clinical waste bags and clear recycling bags were collected and moved to a secure storage location for sorting and weighing, immediately following the surgical procedures. The volume of each waste stream was calculated. Significant waste items such as SUDs, waste segregated in plastic bags and evidence of contamination were photographed (an example is given as Online Supplement Figure S1).

It became clear from intraoperative observation of Surgery A and Surgery B that significant volumes of visibly clean recyclable waste were being disposed of via the clinical waste stream. Current procedural protocol for waste management, predominantly dictated by the point in time of the operation called “knife to skin” means that recycling is no longer collected after this time and this waste is disposed of in clinical waste. These methods were undertaken by staff to minimise the risk of contamination from bodily fluids. However, it was observed that most of the recyclable waste was being handled away from areas of potential contamination. During the Surgery B audit the researchers realised there was an opportunity to quantify the full potential volume of recyclable waste during the final waste audit. Thus, prior to the Surgery C waste audit, the researchers modified the methodology and asked the staff to collect all the recyclable waste as usual until the point in time when they would normally stop collecting the recyclable waste. From that moment onwards, the staff collected the rest of the recyclable waste in a separate plastic bag labelled as ‘additional recyclable waste’ for separate weighing.

Waste audit data analysis

All data was stored and analysed in Excel. The total volume (kg) and average amount per operation of clinical, recyclable and Bio-bin waste streams from all three audits were calculated. The figures were rounded to one decimal point and recorded using calibrated scales accurate to 0.1kg. The audit excluded dirty laundry, as it would have contributed a disproportionate volume of reusable waste to the analysis. Anatomical, medicinal, confidential and hazardous waste were also excluded due to the sensitive and dangerous nature of the waste.

This study adopted a similar methodology to Stall et al.,[21] who undertook waste audits of large joint arthroplasty to quantify the annual environmental impact of the surgical waste produced in Canada for a specific procedure. Stall et al. conducted real time waste audits of total knee arthroplasty (TKA), a similar large joint replacement surgery to PHOs, and extrapolated the audit waste volumes by the total number of TKA procedures reportedly performed in a year as reported by the Canadian Joint Replacement Registry. In the UK, the equivalent registry is the National Joint Registry (NJR)[17]. The NJR has been reporting joint replacement data since 2003, reporting a total of approximately 95% of all procedures for joint replacement surgery data.[17] Data was used from the 17th NJR Annual Report 2020 rather than the 18th NJR 2021 Report due to an unusually low and unrepresentative volume of annual PHOs undertaken in 2020 due to the effects of the Covid-19 pandemic on healthcare services. According to the NJR, in 2019 there were 95,677 PHOs conducted[17]. Therefore, applying the principles from the Stall et al.[21] methodology, this study estimated the annual environmental impact of PHOs within

the NHS by multiplying (a) the total average waste audit volumes from the three PHO surgeries observed by (b) the total 2019 volume of NHS PHOs, 95,677.

Results

Surgical waste from the three waste audits (Surgery A, Surgery B and Surgery C) totalled 32.5kg (see Figure 1). This equated to an average of 10.9kg of waste per operation, consisting of 9.2kg clinical (84.4%), 1.4kg recyclable (12.8%) and 0.3kg Bio-bin (2.8%) waste. The volume of recyclable waste collected in Surgery A (2.0kg) was double that collected in Surgery B (1.0kg) with minor differences in surgical technique witnessed by the researchers intraoperatively, suggesting the reason for the difference in collecting recycling may be due to staff waste management. During the Surgery C waste audit an additional 1.5kg of recyclable waste material was collected after the time of “knife to skin” and adherence to standard waste collection protocol, to highlight any recycling of material currently lost (Table 1). In order to adhere to “knife to skin” protocol, the 1.5kg of additional recyclable waste collected in Surgery C had to be disposed of in clinical waste, making up a total weight of 8.8kg of clinical waste as seen in Figure 1.

Estimated NHS annual waste volumes of primary hip operations

The volume of waste produced each year by PHOs undertaken within the NHS is estimated to be 1043 tonnes. This was calculated using the reported figure of 95,677 PHOs undertaken within the NHS,[17] multiplying this by the average volume of waste per operation of 10.9kg and dividing the result by 1000.

Estimated recycling potential and reduction of clinical waste in primary hip operations

Table 1 shows the potential that over a quarter of the total waste produced by a PHO could be recycled. Furthermore, this means that with improved recycling the volume of clinical waste can be reduced by approximately 15%.

Single-use devices and waste volumes

Our waste audit results revealed that SUDs used during the surgical procedures contributed significantly to the waste produced. For example, a SUD called a pulse lavage (PL), routinely used during a PHO to clean the patients' wound area, weighs 0.7kg (including the sterile packaging and eight AA batteries, contributing 0.2kg). Following its use for approximately three minutes during the procedure, the batteries were disposed of in hazardous waste and the PL disposed of in clinical waste. The orthopaedic department previously used reusable PLs, suggesting less waste had been produced and indicating the potential to move back to this option in support of more sustainable waste management. A photograph of the SUD in question is available as Online Supplement Figure S2.

Using the NJR[17] figure of 95,677 PHOs undertaken within the NHS during 2019, it was estimated that if all NHS centres were using single-use PL devices during every PHO, this would produce an estimated 66,974kg (95,677 x 0.7kg) of waste annually. This would comprise 47,845kg (95,677 x 0.5kg) in non-recyclable waste contributing to the clinical waste stream and 19,135kg (95,677 x 0.2kg) in batteries requiring costly hazardous waste disposal.

Discussion

This study highlights that a significant volume of waste is produced through current practices undertaken during PHOs. We found that an average of 10.9kg of waste is generated per procedure, consisting of 84.4% clinical, 12.8% recyclable and 2.8% Bio-bin waste. We estimate that approximately 1043 tonnes of waste is produced by PHOs in the NHS annually. Corroborate this with commonly performed operations including hysterectomies and large joint arthroplasty which generate on average, per operation 9.2kg[28] and 13.8kg[19,22] respectively. Moreover, the NHS reportedly performs over 10 million surgical operations annually,[14] and has a total annual volume of 538,600 tonnes of waste[5]. To that end, this study supports research proposing surgery is a large waste generator in health care, and there is significant opportunity to reduce waste volume.

At present, there are significant missed opportunities to reduce clinical waste through improved recycling of waste and reduced use of SUDs. Furthermore, the demand for surgery overall - and, in particular, large joint replacement surgical procedures - is increasing,[15,17] potentially heightening its future environmental impact.

In line with the initiatives set out internationally within the United Nations Sustainable Development Goal 3; *to ensure health and well-being for all, at every stage of life* [24] and the UK Royal College of Surgeons' sustainability strategy 2021,[25] this study highlights the importance of addressing a paucity of evidence globally addressing factors attributing to environmental harms.[20] The strength of this study also addresses a lack of published data reporting the proportion of waste disposed of via the different waste streams within surgery.[26]

Our results mirror those of Stall et al.[21] who utilised NJR data to calculate total national waste volumes of TKA produced in Canada. In that study, 47,429 TKAs produced about 400 tonnes of waste. This was comparatively similar to the findings in this study, considering the number of TKA procedures were half the number of PHOs reported by the NJR.[17]

Our study's findings also align with the results of a UK NHS multi-centre quality improvement report,[19] which suggested it was possible to reduce the amount of clinical waste generated within an operating theatre by roughly 50%. Indeed, in our study a total of 1.5kg recyclable waste was routed for disposal via the clinical waste stream, meaning under 50% of the total potential recyclable material is currently being recycled. Moreover, clinical waste requires high temperature incineration and generates the highest carbon footprint at 1074 kg CO_2 equivalent per tonne.[16] Where there is evidence of waste segregation, the choice of waste stream has an up to 50-fold impact on the carbon footprint.[26] Regarding cost implications, it is reported that surgical waste streams with the lowest estimated carbon footprint have the lowest financial cost.[16] Therefore, the optimal recycling of the waste materials captured in this study would not only reduce the volume of clinical waste by 15% but also reduce the carbon footprint and costs of waste disposal.

This study also highlights the burden of using a SUD routinely in the OR. Research widely reports the manufacture and use of SUDs contribute significantly to climate change.[21] Typically used in emergency departments and surgical outpatients, SUDs are mostly comprised of plastic, and considered the most carbon-intense products procured in health care.[21,20] Moreover, plastics and SUDs are increasingly being used in health care, accounting for approximately 30% of all health care waste.[27] The

device represents 0.7kg of clinical waste volume, including using 8 x AA batteries per operation plus the device's associated packaging (online Supplement Figure S2). The PL had previously been a reusable device utilising an electricity supply, suggesting the positive potential of moving back to a reusable PL.

The Association of Surgeons of Great Britain and Ireland's are in support of cost-effective surgery.[29] The association said, 'the risk of cross infection with the use of reusable devices is infinitely small. However, hysteria about this leads to colossal waste'.[29(p12)] The Association estimated that, as well as reducing waste generation within surgery, shifting the reliance on SUDs towards reusable items had the potential to reduce the cost of using the medical device by about half. In the US, Sherman, Raibley and Eckleman[30] demonstrate a clear benefit to both the environment and cost reduction from using reusable medical devices over SUD alternatives.

In its Long-term Plan and Plastics Reduction Pledge, the NHS has committed to reducing the use of SUDs.[6] To date, over 145 NHS trusts have signed the pledge.[6] Conducting full life-cycle assessments and contamination risks of reusable versus SUDs will further strengthen the evidence supporting a return to reusable, reduced environmental impact, and lower cost instrumentation within surgical procedures.[9,26,27,28]

Limitations

The main limitation of this study is its small size. The study involved only three waste audits, performed by two orthopaedic surgeons at a single NHS site. Wider research into other commonly performed procedures where surgical registry data may be available to calculate annual waste volumes in the NHS will further support calls to reduce waste in operating procedures.

Conclusions

This research sheds new light on the environmental impact of waste management in the OR. It found that a large volume of waste is produced during PHO surgical procedures and, moreover, a significant volume of this waste can be reduced by transitioning to more resource efficient strategies, assisting in the development of more sustainable surgery.

Mitigating the environmental impact of surgical services requires a collective drive for cultural change regarding sustainability and social responsibility.[1] The results of this study strongly suggest a modification to the current OR protocol for waste management is required within the OR department to support optimal waste reduction. In addition, this study supports the view by Rizan et al.[20] that manufacturers should look to optimise the material used in their products and packaging to reduce environmental harms and to support of the NHS's net zero target.

Declaration of conflicting interests

The Authors declare that there are no conflicts of interest.

Ethics approval

The Authors declare that all the research meets the ethical guidelines.

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References

1. MacNeill AJ, Lillywhite R and 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: e381-8.

2. IPCC, 2021: Climate Change 2021: *The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. [Masson-Delmotte, V, Zhai P, Pirani A, et al (eds.)]. Cambridge University Press. In Press.

3. IPCC: Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte V., Zhai P, Pörtner H-O, et al (eds.)]. IPCC, World Meteorological Organization, Geneva, Switzerland, 2018, 32 pp.

4. Tennison I, Roschnik S and Ashby B et al. Health care's response to climate change: a carbon footprint assessment of the NHS in England. *The Lancet* Planetary Health. 2021; 5: e84-92.

5. NHS Digital. *Estates Return Information Collection (ERIC) 2018/19. Data Quality Report 2019.* NHS Digital: October 2019.

6. National Health Service. Delivering a ‘Net Zero’ National Health Service. NHS England, UK: February 2021.

7. Minogue V and Wells B. Reducing waste in the NHS: an overview of the literature and challenges for the nursing profession. *J. Nurs. Manag* 2016; 23: 20-25.

8. Voudrias EA. Healthcare waste management from the point of view of circular economy. *J. Waste Manag* 2018; 75: 1-2.

9. Eckelman MJ and Sherman J. Environmental impacts of the US healthcare system and effects on public health. *PloS one* 2016; 11: e0157014.

10. Shrank WH., Rogstad TL and Parekh N. Waste in the US healthcare system: estimated costs and potential for savings. *JAMA* 2019; 15 322: 1501-9.

11. Roa L, Velin L, Tudravu J et al. Climate change: challenges and opportunities to scale up surgical, obstetric, and anaesthesia care globally. *Lancet Planet Health* 2020; 4: e538-43.

12. National Health Service. *NHS Long term Plan.* Report. NHS, UK, January 2019.

13. Kwakye G, Brat GA and Makary MA. Green surgical practices for health care. *Arch Surg* 2011 1; 46:131-6.

14. National Statistics. *Hospital Admitted Patient Care Activity.* Report. Health and Social Care Information Centre, UK: November 2016.

15. Shrime MG, Daniels KM and Meara JG. Half a billion surgical cases: Aligning surgical delivery with best-performing health systems. *Surgery* 2015 1;158: 27-32.

16. Rizan C, Steinbach I, Nicholson R, et al. The carbon footprint of surgical operations: a systematic review. *Ann. Surg* 2021; 272: 986-95.

17. National Joint Registry. 17th Annual Report 2020. Surgical data to 31 December 2019. Registry for England, Wales, Northern Ireland and Isle of Man https://reports.njrcentre.org.uk/2019 (2020, accessed 10 August 2021).

18. Patel A, Pavlou G, Mújica-Mota RE, et al. The epidemiology of revision total knee and hip arthroplasty in England and Wales: a comparative analysis with National projections for the United States. A study using the National Joint Registry dataset. *Bone Joint J*. 2015; 97: 1076-81

19. Southorn T, Norrish AR, Gardner K, et al. Reducing the carbon footprint of the operating theatre: a multicentre quality improvement report. *J Periop. Pract*. 2013; 23: 144-6.

20. Rizan C, Mortimer F, Stancliffe R, et al. Plastics in healthcare: time for a re-evaluation. *J. R. Soc. Med* 2020; 113: 49-53.

21. Stall NM, Kagoma YK, Bondy JN, et al. Surgical waste audit of 5 total knee arthroplasties. *Can. J. Surg* 2013; 56: 97.

22. Lee RJ and Mears SC. Reducing and recycling in joint arthroplasty. *J. Arthroplasty* 2012; 27: 1757-60.

23. Burnett RSJ and Abos D. Total hip arthroplasty: techniques and results. *BC Med J* 2010; 52:e64.

24. United Nations. Sustainable Development Goals. Goal 3: Ensure healthy lives and promote wellbeing for all at all ages, https://www.un.org/sustainabledevelopment/health/ (2021, accessed 10 August 2021).

25. Royal College of Surgeons of England. Sustainability in Surgery Strategy 2021. RCSE, UK: April 2021.

26. Rizan C, Bhutta MF, Reed M. et al. The carbon footprint of waste streams in a UK hospital. *J Clean Prod* 2021; 286:125446

27. McGain F, Story D, Lim T. et al. Financial and environmental costs of reusable and single-use anaesthetic equipment. BJA: *Br Journal Anaes*. 2017 Jun 1;118:862-9.

28. Thiel CL, Eckelman M, Guido R, et al. Environmental impacts of surgical procedures: life cycle assessment of hysterectomy in the United States. *Environ. Sci. Technol* 2015; 49: 1779-86.

29. Association of Surgeons of Great Britain and Ireland. Consensus statement on cost-effective and sustainable surgery, https://www.asgbi.org.uk/userfiles/file/consensus/asgbi_consensus_statement_on_cost-effective_surgery.pdf (2012, cited February 2022).

30. Sherman JD, Raibley IV LA and Eckelman MJ. Life cycle assessment and costing methods for device procurement: comparing reusable and single-use disposable laryngoscopes. *Anesth. Analg* 2018; 127: 434-43.