Surgical waste audit of 5 total knee arthroplasties

Nathan M. Stall, BSc, MD*
Yoan K. Kagoma, BASc, MD*
Jennifer N. Bondy, MSc, MD*
Douglas Naudie, BSc, MD†

From the *Schulich School of Medicine and Dentistry, Western University, and the †Department of Orthopaedic Surgery, London Health Sciences Centre, London, Ont.

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Correspondence to:
D. Naudie
London Health Sciences Centre
University Hospital
A9-028, 339 Windermere Rd.
London ON N6A 5A5
douglas.naudie@lhsc.on.ca

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Background: Operating rooms (ORs) are estimated to generate up to one-third of hospital waste. At the London Health Sciences Centre, prosthetics and implants represent 17% of the institution's ecological footprint. To investigate waste production associated with total knee arthroplasties (TKAs), we performed a surgical waste audit to gauge the environmental impact of this procedure and generate strategies to improve waste management.

Methods: We conducted a waste audit of 5 primary TKAs performed by a single surgeon in February 2010. Waste was categorized into 6 streams: regular solid waste, recyclable plastics, biohazard waste, laundered linens, sharps and blue sterile wrap. Volume and weight of each stream was quantified. We used Canadian Joint Replacement Registry data (2008–2009) to estimate annual weight and volume totals of waste from all TKAs performed in Canada.

Results: The average surgical waste (excluding laundered linens) per TKA was 13.3 kg, of which 8.6 kg (64.5%) was normal solid waste, 2.5 kg (19.2%) was biohazard waste, 1.6 kg (12.1%) was blue sterile wrap, 0.3 kg (2.2%) was recyclables and 0.3 kg (2.2%) was sharps. Plastic wrappers, disposable surgical linens and personal protective equipment contributed considerably to total waste. We estimated that landfill waste from all 47 429 TKAs performed in Canada in 2008–2009 was 407 889 kg by weight and 15 272 m^3 by volume.

Conclusion: Total knee arthroplasties produce substantial amounts of surgical waste. Environmentally friendly surgical products and waste management strategies may allow ORs to reduce the negative impacts of waste production without compromising patient care.

Level of evidence: Level IV, case series.

Contexte : On estime que les blocs opératoires génèrent jusqu'au tiers des déchets hospitaliers. Au Centre des sciences de la santé de London, les prothèses et les implants représentent 17 % de l'empreinte écologique de l'établissement. Pour analyser la production de déchets associés aux arthroplasties totales du genou (ATG), nous avons procédé à une vérification des déchets générés lors de ces chirurgies, afin d'en mesurer l'impact environnemental et de proposer des stratégies d'amélioration de la gestion des déchets.

Méthodes : Nous avons réalisé l'analyse des déchets produits lors de 5 ATG effectuées par un même chirurgien en février 2010. Les déchets ont été regroupés en 6 catégories : déchets solides normaux, plastiques recyclables, déchets présentant un biorisque, linge lavé en buanderie, objets tranchants et emballages stériles bleus. Nous avons mesuré le volume et le poids de chaque catégorie. Nous avons utilisé les données du Registre canadien des remplacements articulaires (2008–2009) pour estimer le poids et le volume totaux des déchets générés par toutes les ATG effectuées au Canada.

Résultats : La quantité moyenne de déchet chirurgicaux (à l'exclusion du linge lavé en buanderie) par ATG a été de 13,3 kg, dont 8,6 kg (64,5 %) étaient des déchets solides normaux, 2,5 kg (19,2 %), des déchets présentant un biorisque, 1,6 kg (12,1 %), des emballages stériles bleus, 0,3 kg (2,2 %), des substances recyclables et 0,3 kg (2,2 %), des objets tranchants. Les emballages de plastique, le linge chirurgical jetable et le matériel de protection personnelle jetable contribuaient énormément au volume total de déchets. Selon notre estimation, les déchets qui ont abouti au dépotoir suite aux 47 429 ATG effectuées au Canada en 2008–2009 totalisaient un poids de 407 889 kg et un volume de 15 272 m^3.

Conclusion : Les arthroplasties totales du genou engendrent des quantités substantielles de déchets chirurgicaux. Des produits plus écologiques et de meilleures stratégies de gestion des déchets permettraient aux blocs opératoires de réduire l'impact négatif des déchets produits, sans compromettre les soins aux patients.

Niveau de preuve : Niveau IV, série de cas.

In 2001, the Canadian health care sector generated 2.1% of Canada's total greenhouse gas (GHG) emissions and 1% of total solid waste.[1] In the United States, health care activities in 2007 contributed 8% of total U.S. GHG emissions and 7% of total U.S. carbon dioxide emissions.[2] Alarmingly, health care facilities in the United States continue to dispose of more than 4 billion pounds of waste annually, making the U.S. health industry the second-largest industrial contributor to landfills after the food industry.[3] Within a hospital, operating rooms (ORs) contribute disproportionately to health care waste production.[4] Although ORs occupy a proportionally smaller area of a health care facility, they are estimated to generate 20%–33% of total hospital waste.[5,6] In fact, a routine operation at a hospital produces more waste than a family of 4 produces in an entire week.[7]

Large joint arthroplasty is major contributor to OR waste production.[8] Prosthetics and implants contributed to 17% of the London Health Sciences Centre's ecological footprint in 2006.[9] Moreover, total joint arthroplasty is a frequently performed surgical procedure, with 47 429 total knee arthroplasties (TKAs) performed across Canada in 2008–2009.[10] Given the susbtantial ecological footprint associated with joint arthroplasties and the high frequency with which TKAs are performed, we sought to investigate waste production through a waste audit of 5 TKAs performed by a single surgeon. We hoped that the results of this audit would allow us to identify strategies to improve waste management practices.

Methods

A waste audit is a qualitative and quantitative assessment tool that examines the types, quantities and sources of waste produced. The results of a waste audit allow an institution to identify opportunities for improved waste management practices and to measure the impact of waste reduction strategies.[11] We performed a waste audit of 5 TKAs conducted at the London Health Sciences Centre, University Hospital, London, Ont. In this 343-bed hospital, 603 primary TKAs were performed in 2009. The Western University Research Ethics Board stated that this study did not require their approval.

The 5 TKAs were completed in February 2010 by a team led by the same orthopedic surgeon (D.N.). Operating room personnel varied among the TKAs, but they were informed of the procedure's inclusion in the waste audit to ensure all waste was disposed of in the OR for complete collection and analysis. For all 5 TKAs, the scrub team comprised the consultant surgeon, an orthopedic fellow, an orthopedic resident, a medical student and a scrub nurse.

We categorized surgical waste into 6 streams: normal solid waste, recyclable plastics, biohazard waste, laundered linens, sharps and blue sterile wrap (polypropylene wrap used to cover surgical products during sterilization). All discarded items were catalogued during the procedure in real time (see Table 1 for a complete catalogue from 1 TKA). Data collection commenced as soon as OR personnel began preparing for the TKA and concluded when personnel disposed of their surgical attire and personal protective devices.

After the TKA was completed and the patient left the OR, we weighed each waste stream and measured bag volumes. Waste was weighed on a digital scale accurate to 0.1 kg, and bag volume was approximated using a measuring stick accurate to 1 mm.

Statistical analysis

All data were stored and analyzed in Excel 2007 (Microsoft Corp.). We calculated the average weights of each waste stream and the average volume of the solid waste stream for the 5 TKAs. Data from the Canadian Joint Replacement Registry, of the Canadian Institute for Health Information, were used to extrapolate weight and volume estimates for all TKAs performed in Canada during 2008–2009.[10]

Results

The surgical waste (excluding laundered linens) from the 5 TKAs totaled 66.7 kg, of which 43.1 kg (64.5%) was normal solid waste, 12.8 kg (19.2%) was biohazard waste, 8.1 kg (12.1%) was recyclable blue sterile wrap, 1.5 kg (2.2%) was recyclables and 1.4 kg (2.0%) was sharps (Table 2). The average mass of surgical waste per TKA is provided in Table 3. The volume of normal solid waste (which is ultimately disposed of in landfills) from the 5 TKAs totaled 1.6 m^3. When extrapolated to all 47 429 TKAs performed in Canada in 2008–2009,[10] the estimated landfill waste was 407 889 kg by mass and 15 272 m^3 by volume (Table 3).

A variety of items were prepared and opened for surgery but remained unused at the end of the procedures. These items are referred to as "overage."[12] The total overage from the 5 TKAs comprised 45 green sterile towels, 16 sterile surgical gloves, 5 disposable surgical gowns, 4 inner wrappers from surgical gloves, 2 lengths of tubing and 1 small unsterile towel.

Several items contributed disproportionately by number to surgical waste. Per TKA, there was an average of 64 (range 59–73) plastic wrappers, 41 (range 37–52) sterile surgical gloves, 29 (range 30–43) green sterile towels and 10 (range 0–29) vinyl gloves. There were also disproportionate volume contributions from disposable surgical linens and personal protective equipment. Per TKA, there was an average of 5 (range 4–8) surgical gowns, 5 (range 2–8) surgical drapes and 3 (range 1–4) table covers.

Discussion

The results of this waste audit demonstrate that TKAs produce substantial amounts of waste (Fig. 1). We report that per TKA, an average of 64.5% of waste per weight was normal solid waste requiring transport and dumping in a landfill and 19.2% was biohazard waste requiring high-energy treatment processes, including incineration. Only 14.3% of waste by weight was recycled (12.1% was recyclable blue sterile wrap and 2.2% was recyclable clear plastics). These

Table 1. Catalogue items from 1 total knee arthroplasty

Waste	Units	Waste	Units
Plastics		**Paper/cardboard**	
1000 mL bag (empty) of Ringer's lactate solution	1	Cardboard box with paper manual for Cement Erythromycin Kit	2
2% chlorhexidine antiseptic solution bottle (empty)	1	Cardboard box with paper manual for joint spacer (articular insert)	1
20 mL Luer Lock syringe	2	Miscellaneous paper	5
50 mL antibiotic fluid bag (empty)	1	Wrapper (inner) for surgical gloves	23
500 mL bag (empty) of NaCl solution	1	**Biohazard waste**	
Cement mixing stick	1	12″ × 12″ sponge	7
Cement mixing system and tubing	1	2250 mL suction fluids (filled)	1
Cement mixing system gun	1	8″ × 4″ gauze	6
Cement powder bags	2	Electrocautery and suction irrigator with tubing	1
Face shield	2	NaCl bag and tubing	1
Facial oxygen mask with tubing	1	**General nonrecyclable waste**	
Glove liners	2	Adhesive backings	5
Marking pen	2	Blue sterile wrap	1
Moulded inner packaging for joint prosthesis	8	Bulb syringe (for irrigation)	1
Sterile light handle covers	2	Disposable surgical gown	4
Tubing	1	Elastocrepe dressing	1
Vicryl suture pack	9	Excess cement (mixed and activated)	—
Wrapper (outer) for surgical gloves	23	Extremity drape	1
Wrapper for 1 L Tis-U-Sol container	1	Foley catheter kit	1
Wrapper for 1000 mL bag of Ringer's lactate solution	1	Gauze pads	5
Wrapper for 20 mL Luer Lock syringe	2	Gauze roll	1
Wrapper for 500 mL bag of NaCl solution	2	Mayo stand cover	1
Wrapper for cast padding	1	Miscellaneous tips	2
Wrapper for Cement Erythromycin Kit	2	Shoe cover	1
Wrapper for cement mixing system	1	Spinal anesthesia kit	1
Wrapper for disposable surgical gown with inner paper	4	Sterile surgical gloves	46
Wrapper for elastic bandage	1	Stockinette	1
Wrapper for filter straw	1	Surgical air warming blanket	1
Wrapper for flat epidural	1	Surgical face mask	3
Wrapper for glove liners	4	Table cover	3
Wrapper for hypodermic needle	1	U-drape	1
Wrapper for jet lavage tip	1	Virox wipe	2
Wrapper for limb positioning device	1	**Recyclables**	
Wrapper for marking pen	1	Moulded inner packaging for joint prosthesis	3
Wrapper for saw blade	1	Tis-U-Sol 1 L container	1
Wrapper for skin stapler	1	Irrigation tubing container	1
Wrapper for sterile knee pack	1	**Sharps**	
Wrapper for sterile light handle covers	1	Bovie tip	1
Wrapper for stockinette	1	Drain trochar	1
Wrapper for suction irrigator	1	Glass vial	6
Wrapper for suction irrigator tip	1	Needle	12
Wrapper for syringe	1	Needle tip	5
Wrapper for tourniquet	2	Red sharps container	1
Wrapper for U-drape	1	Scalpel blades	3
Wrapper for surgical air warming blanket	1	Stapler	1
Wrapper for Webril	1	Suture needles	13
Wrapper for wound drain	1	Syringe	4
Laundry		**Sterile blue wrap**	
Bed sheet	7	Extra-large	5
Gortex sheet	4	Large	5
Green sterile towel	31	Medium	3
Small unsterile towel	1	Small	1
Surgical gown	1		

results suggest that TKA waste at our institution is not being maximally recycled, as some hospitals have achieved recycling rates of more than 40% of their total waste stream.[13] A failure to maximally recycle increases the amount of waste ending up in landfills and increases hospital hauling and disposal costs. A hospital's disposal cost for a single ton of solid waste is about US$121.[14] Efficient recycling reduces waste disposal costs, and recycling has allowed some institutions to acquire lucrative revenue from industry for recycling paper, plastics and other materials.[13]

Our results also reveal that TKA waste at our institution is being improperly segregated into normal waste and biohazard waste streams. According to waste management experts, biohazard waste should not exceed 15% of total hospital waste.[15] In this study, we report that biohazard waste contributed 19.2% by weight of total TKA waste. This finding is consistent with those from previously published reports indicating that 50%–85% of waste that should be disposed of as normal solid waste is actually disposed of as biohazard waste.[13,16] In fact, a recent study of OR waste reported that nonhazardous waste contributed 92% of the weight of what was discarded as biohazard waste.[17] A failure to improperly segregate waste increases the amount of waste requiring special treatment by high-energy processes. These processes, including incineration, are harmful to the environment and human health and cost 10–20 times more than the disposal of normal solid waste.[13] In fact, some experts state that proper segregation of waste in the OR may have the single most substantial impact on the cost of disposal.[5] It is essential that awareness of improper surgical waste segregation is heightened to reduce waste production and operation costs.

We also report that TKAs at our institution are associated with considerable surgical overage. Overage refers to surgical items that are readied and opened for surgery but remain unused and are thereby wasted.[12] Surgical overage increases the turnover of OR inventory and results in increased waste output and disposal costs. A 1997 study projected that overage from all 14 719 000 surgical procedures performed in the United States in 1993 resulted in a loss of US$125 million.[12] The investigators of this study were able to reduce overage by 45% per surgical case by implementing an intervention that included an education program, reduction of overage generating setups and redesign of surgeon-specific supply pick lists.[12] We suggest that OR teams use a "just-in-time" industrial model for surgeons' nonemergent instrumentation and supply needs.[18] This would involve only opening surgical materials and instrumentation when there is a reasonable probability of these items actually being used. Considering that ORs must function efficiently to maximize a surgeon's operating time, the generation of overage is inevitable despite any encouraged reduction interventions. To divert these materials from landfill and reduce hospital disposal costs, several donation projects have collected these materials and distributed them as aid to the developing world. These projects include Project REMEDY at Yale University (www.remedyinc.org) and Operation Green, a program that we have initiated at our own institution (www.operationgreen.ca).

Our waste audit also reveals that certain surgical items contribute disproportionately by number to TKA surgical waste. We report an average of 64 plastic wrappers, 41 sterile surgical gloves, 29 green sterile towels and 10 vinyl gloves per TKA. The excessive amount of vinyl and surgical gloves used per procedure may be explained in part by the consultant surgeon's individual preference to use unsterile vinyl gloves for all members of the team assisting in patient positioning, particularly in situations requiring contact precautions. Moreover, it was the consultant surgeon's preference to double glove for all arthroplasties and to put on fresh sterile surgical gloves after draping and immediately before cementing components. The consultant surgeon also practices in an academic environment in which fellows, residents and medical students commonly scrub in for his cases. The excessive amount of waste produced by plastic wrapping may also be attributed to inefficient industrial packaging. Many surgical products delivered by industry are excessively packaged and double-wrapped in plastic. Hospitals must recognize that wasteful

Table 3. Average mass of waste streams and Canadian extrapolations for total knee arthroplasties (TKA), 2008–2009

Waste stream	Mass, kg/TKA	2008–2009 Canadian extrapolation, kg
Normal/landfill	8.6	407 889
Recyclables	0.3	14 229
Biohazard waste	2.5	118 572
Blue wrap	1.6	75 886
Laundered linens	7.8	369 946
Sharps	0.3	14 229

Table 2. Mass of waste streams for each total knee arthroplasty

Waste stream	Surgery 1, kg	Surgery 2, kg	Surgery 3, kg	Surgery 4, kg	Surgery 5, kg
Normal/landfill	9.3	8.3	9.2	7.7	8.5
Recyclables	0.2	0.4	0.0	0.5	0.5
Biohazard waste	1.4	1.8	2.8	3.6	3.2
Blue wrap	1.5	1.7	1.7	1.9	1.2
Laundered linens	6.5	6.9	7.3	8.6	9.7
Sharps	0.4	0.5	0.5	0.0	0.0

packaging increases both procurement and disposal hauling costs. Health care institutions have considerable purchasing power and should insist that companies modify their packaging practices to increase environmental and financial efficiency.[19] The sizeable usage of surgical gloves and green sterile towels should be further investigated, especially since these items accounted for much of the surgical overage associated with TKAs. It is plausible that the turnover of these items is excessive and that increased awareness and education about the waste produced by TKAs may decrease their usage.

Finally, we noted that surgical linens consisting of surgical gowns, surgical drapes and table covers contributed disproportionately to the volume of waste. Volume of waste is an important consideration in pushing a landfill to capacity.[5] Surgical linens are available as either disposable or reusable products, and our institution uses disposable products. About 80% of hospitals in the United States use disposable gowns, and surgical linens contribute 2% of all hospital waste.[20] One study reported that substituting reusable for disposable linen could reduce surgical waste volume by 53%.[5] Unfortunately, existing life cycle analyses comparing disposable and reusable surgical linens based on environmental and financial superiority are conflicting.[20–25] However, many of these studies are outdated, and a 2010 life cycle analysis reported that reusable surgical linens showed a clear environmental and financial advantage over disposable linens.[26] Although further research on this topic is needed, hospitals, including ours, should consider transitioning to reusable surgical linens to reduce the volume of surgical waste produced.

Limitations

We recognize that the major limitation of this study is that the results are largely specific to our institution, and even to the consultant surgeon's individual preferences. Nonetheless, we believe that this waste audit demonstrates that TKAs generate unacceptably large amounts of surgical waste. We identified that surgical waste associated with TKAs at our institution was not maximally recycled,[1] was improperly segregated[2] and was associated with substantial surgical overage.[3]

Fig. 1. Waste produced from 1 total knee replacement. Waste from left to right: 1 bag of blue sterile wrap, 2 bags of reusable linens, 1 bag of recyclable clear plastics, 1 sharps container, 1 bag of biohazard waste and 4 bags of regular solid waste.

Conclusion

Based on our study results, we have initiated several strategies, including establishing recycling programs, ensuring proper waste segregation, initiating overage recovery programs, educating our industrial partners about reducing excessive packaging and considering a transition to reusable surgical linens.

It is imperative that efforts to promote sustainable OR practices are strengthened worldwide.[4] The fundamental principles of decreasing waste in the OR are the same as the cornerstone strategies of waste minimization: reduce, reuse and recycle.[27] Successful waste reduction strategies rely on the establishment of an environmental stewardship team. This team allows all stakeholders to put forward their input in the greening process by involving cross-departmental membership from perioperative nursing staff, physicians, ancillary staff, environmental services, and the managers and administrators who oversee perioperative services.[17] There are also a number of organizations dedicated to "greening health care," including Health Care Without Harm (www.noharm.org), Practice Green Health (www.practicegreenhealth) and the Canadian Association of Physicians for the Environment (www.cape.ca). Leaders within the medical community have called for individual clinicians to educate themselves about green health care and promote more sustainable health care delivery.[28] It is critical to recognize that heightened environmental awareness delivered by dedicated organizations and clinicians will underlie the success of future endeavours to green ORs and health care in general. The emergence of sustainable waste management strategies combined with a growing interest in greening health care may allow ORs to reduce the negative impacts of waste production without compromising patient care.[4]

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