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Research Paper

Assessing the environmental impact of an anastomotic leak care pathway

Stephan Bischofberger [a,*], Fiona Adshead [b], Keith Moore [b], Mesut Kocaman [c], Gianluca Casali [c], Cindy Tong [d], Sanjoy Roy [d], Michael Collins [e], Walter Brunner [a]

[a] *Department of Surgery, Colorectal Unit, Kantonsspital St. Gallen, Switzerland*
[b] *Sustainable Healthcare Coalition, Devon, UK*
[c] *Johnson & Johnson MedTech, Berkshire, UK*
[d] *Johnson & Johnson MedTech, New Brunswick, NJ, USA*
[e] *Environmental Resources Management Consulting, London, UK*

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ABSTRACT

Background: The healthcare sector faces increasing pressure to improve environmental sustainability whilst continuing to meet the needs of patients. One strategy is to lower the avoidable demand on healthcare services, by reducing the number of surgical complications, such as anastomotic leak (AL). The aim of this study was to assess the environmental impact associated with the care pathway of AL.

Methods: An environmental impact assessment was performed according to the Sustainable Healthcare Coalition (SHC) guidelines. A care pathway, describing the typical steps involved in the diagnosis and treatment of AL was developed. Activity and emission data for each stage of the care pathway were used to calculate the climate, water and waste impact of the treatment of AL patients.

Results: The environmental impact assessment shows that AL is associated with an average climate, water and waste impact per patient of 1303 kg CO_2-eq, 1803 m^3 of water and 123 kg waste, respectively. Grade C leaks are associated with the greatest environmental impact, contributing to 89.3 %, 79.4 % and 97.9 % of each impact, respectively. A breakdown of the environmental impact of each activity shows that stoma home management is the largest contributor to the total climate (46.6 %) and waste (47.3 %) impact of AL patients, whilst in-patient hospital stay contributes greatest to the total water impact (46.7 %).

Conclusions: The treatment of AL is associated with a substantial environmental impact. This study is, to our knowledge, the first to assess the environmental impact associated with the treatment of AL.

Introduction

In 2016, the World Health Organisation attributed 12.6 million (23 %) deaths globally to modifiable environmental factors and further estimated that nearly a quarter of global disease burden could be prevented through healthier environments [1]. The healthcare sector as a whole produces major streams of emissions and waste, either directly or indirectly through the materials and services it procures, uses and disposes of [2–4]. Hospitals contribute disproportionately to healthcare's climate impact as they are highly energy intensive, consuming more electricity and energy for heating per square meter than any other non-residential buildings [5,6]. In addition, hospitals consume large amounts of resources and generate huge quantities of waste [4,6].

Accordingly, healthcare systems globally face a challenge to improve their environmental sustainability and reduce their carbon footprint, whilst continuing to meet the needs of patients and communities. In 2020, a precedent was set by the National Health Service (NHS) in England, one of the world's largest healthcare systems, who published their commitment and targets to reduce the NHS carbon footprint to net zero by 2040, with the aim of reaching an 80 % reduction of the current footprint by 2032 [7].

One strategy to improve environmental sustainability of healthcare is to reduce the avoidable demand on services whilst maintaining or improving health outcomes [8–10]. Anastomotic leak (AL) is a common complication of colorectal surgery, in which a defect in the anastomosis leads to the leakage of luminal contents from the bowel into the abdomen and is associated with an increased risk of infection, and increased morbidity and mortality rates [11–15]. As a result patients experiencing AL face a higher incidence of hospital readmissions, increased length of stay and a greater number of surgical reinterventions

* Corresponding author.
E-mail address: Stephan.Bischofberger@kssg.ch (S. Bischofberger).

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[16,17]. Whilst the clinical burden and economic impact of AL have been well studied, its environmental impact is less understood.

The aim of this study was to assess the climate, waste and water footprint associated with the care pathway of AL.

Methods

AL care patient pathway

Using the study protocol of the European Society of Coloproctology (ESCP) audit [25] and information from relevant literature [17–22], a care pathway, describing the typical steps involved in the diagnosis and treatment of patients experiencing AL was developed, shown in Fig. 1. The grading of AL (Grade A, B and C) and treatment methods for each grade were defined from the study protocol of the ESCP audit, a two-month prospective audit performed in hospitals across Europe to collect data on the demographics, operative details and outcomes of patients undergoing colorectal resections [21]. The pathway was scaled to represent 100 patients, and follows each step of the care pathway, from initial diagnosis through to treatment and hospital discharge. It details the treatment pathways for patients with Grade A, Grade B and Grade C anastomotic leak, including the number of in-patient stay days for all patients and the additional stoma home management required for Grade C patients. Data from the 2017 audit by the ESCP [21] were used to determine the incidence of each Grade of AL and the length of hospital stay. The proportion of patients undergoing CT scan and the split of Grade C patients undergoing Hartmann's procedure or ileostomy were based on data from relevant literature [17–20,22].

All patients suspected of having an AL undergo full blood tests, following which they are either sent for surgery or undergo a CT scan for confirmation of an AL diagnosis [20,22]. Grade A patients are defined as those with relatively minor leaks, who do not require radiological or surgical intervention [21,22]. Grade B are those that require radiological intervention, in the form of a CT-guided drain [21,22], to remove the perianastomotic fluid that collects as a result of AL [20]. Grade C are those with the most serious leaks, that require further surgical intervention in the form of an anastomotic revision with protective ileostomy or a Hartmann's procedure [11,20,21].

Total parental nutrition (TPN; involving a central venous catheter, cannula, tubing and TPN bags) is used for patients who cannot be fed orally and was estimated to be required in a small proportion (5 %) of all AL patients. It was assumed that all patients receive intravenous (IV) antibiotics followed by oral antibiotics [23]. Grade C patients requiring stoma home management receive this for the relevant duration, with a further proportion of those (patients with a protective stoma) requiring an additional stoma closure operation. Length of hospital stay was also considered in the pathway for all patients. This was stratified by the number of general in-patient days and intensive care in-patient days and accounted for both initial treatment and readmission(s). No care pathway modules were excluded from the care pathway, and all known activities are included in the scope of each module.

Environmental impact assessment

The Sustainable Healthcare Coalition (SHC) has created an innovative set of guidelines that allows users to consistently appraise

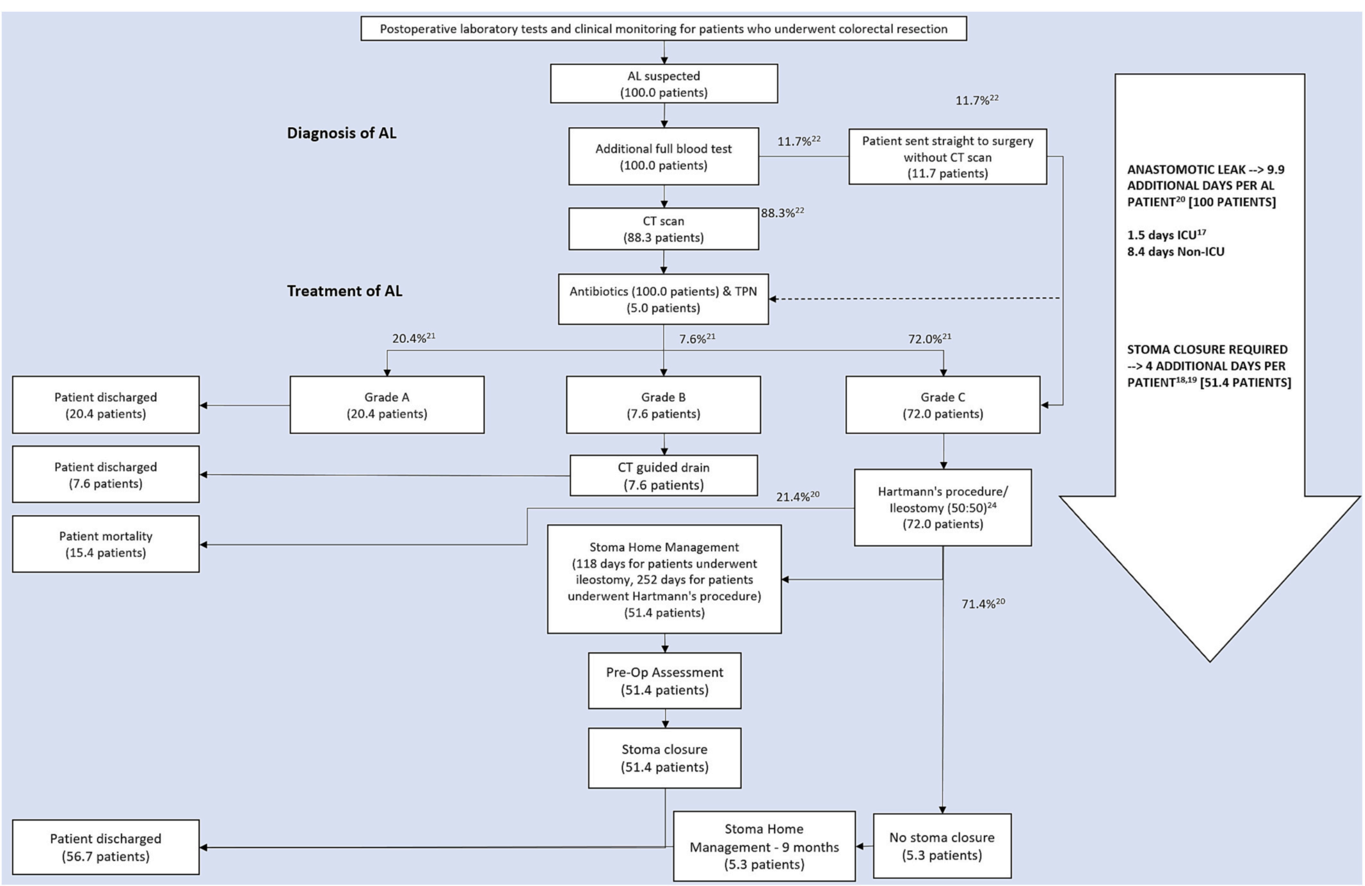

Fig. 1. Care pathway for the treatment of patients with AL.
Based on 100 patients experiencing AL.
Abbreviations: AL: anastomotic leak; CT: computed tomography; ICU: intensive care unit; TPN: total parenteral nutrition.

environmental impacts of healthcare treatment pathways [24]. These guidelines provide a method for evaluating the environmental (climate, water and waste) impact of different care pathway modules using three key metrics: greenhouse gas emissions (climate impact), fresh water use and waste generated [24].

An environmental impact assessment was performed using the patient pathway (Fig. 1) for AL. All healthcare activities associated with each distinct step of the patient pathway were identified. As detailed in the SHC guidelines, all distinct activities or services grouped within a stage of the pathway were only included if they were required to achieve the objective of the stage [24]. Activity and emission data pertaining to each stage of the care pathway were then used to calculate the climate, water and waste impact of the treatment of AL patients. Emission factors for each stage and activity in the care pathway were also obtained from a number of different sources, including the SHC Care Pathways guidance [24], the ecoinvent Database (for some consumable materials) [25], and the Association of the British Pharmaceutical Industry (ABPI) Blister Pack Carbon Evaluation Tool [26]. Climate impact was assessed by evaluating the greenhouse gas emissions (carbon footprint) associated with treatment of AL, and measured using a carbon dioxide equivalent metric (kg CO_2-eq), which describes the amount (in kilograms) of CO_2 that would have the same global warming potential as the given mixture and amount of greenhouse gas emitted. Water impact was assessed by evaluating freshwater usage (m^3) associated with AL treatment and waste impact by evaluating the amount of waste generated during the treatment of AL (measured in kg).

The total climate, water and waste impact associated with the treatment of Grade A, B and C patients was calculated using the impact values associated with each individual activity and item in the care pathway. The relative incidence of each grade of leak was then taken into consideration and used to calculate the mean climate, water and waste impact of an adult patient undergoing treatment of AL, by averaging the overall impact of the number of patients included in the pathway.

A detailed breakdown of the activity data and emissions data used for each item in the care pathway, and information on the data source, can be found in Supplementary Table 1. All data were sourced from published sources, with the exception of the length of CT-guided drain and the proportion of patients receiving TPN. In the absence of published data for these activities, estimates from clinical experts were used.

Results

Anastomotic leak care pathway

The pathway showed that the majority (72.0 %) of these patients undergo treatment for Grade C leaks, with 20.4 % of patients experiencing Grade A leaks and 7.6 % experiencing Grade B leaks. Compared with those who do not experience leaks, AL patients were associated with an increased length of hospital stay, spending an additional 8.36 days in general inpatient care and additional 1.50 days in intensive care, on average (9.86 additional days in total). Grade C patients who required stoma closure, spent a further 4.00 days in hospital following readmission.

Overall environmental impact

The environmental impact assessment shows that AL is associated with an average climate, water and waste impact per patient of 1303 kg CO_2-eq, 1803 m^3 of water and 123 kg waste, respectively. Of the three grades of leak, Grade C is associated with the greatest environmental impact. The treatment of Grade C leaks contributes to 89.3 %, 79.4 % and 97.9 % of the climate, water and waste impact, respectively, relative to the other two grades (Table 1).

A breakdown of the environmental impact of each activity included in the care pathway is shown in Table 2. Stoma home management represents the largest contributor to the climate impact of AL patients, contributing to 46.6 % (607 kg CO_2-eq) of the total respective impacts, followed by in-patient days (40.8 %, 531 kg CO_2-eq) and surgical and radiological intervention (8.2 %, 107 kg CO_2-eq). Stoma home management made the greatest contribution to the total waste impact as well, accounting for 47.3 % (58.1 kg) of the total waste footprint of AL patients. Given its large contribution to the overall environmental impact of AL, stoma home management was analysed separately. A detailed breakdown shows that the majority of the climate and water impact of this item is associated with the manufacture of the ostomy bag material (Table 3). A full breakdown of the results can be found in Supplementary Table 2, and details of the sources used in Supplementary Table 1.

The care pathway item that made the greatest contribution to the total water impact was in-patient days, accounting for 46.7 % (841.1 m^3) of the total water footprint of AL patients. A more detailed breakdown of in-patient stay shows that the climate, water and waste impact

Table 1
Environmental impact of AL patients.

Stage	Environmental impact of treatment for Grade A, B and C leaks			Contribution to the total environmental impact of treatment of all Grades of AL			Incidence	Environmental impact per AL patient		
	Climate impact (kg CO_2-eq)[a]	Water impact (m^3)[a]	Waste impact (kg)[a]	Climate impact	Water impact	Waste impact		Climate impact (kg CO_2-eq)[b]	Water impact (m^3)[b]	Waste impact (kg)[b]
Treatment of Grade A leaks	47.92	138.47	0.87	4.10 %	8.75 %	0.90 %	20.38 %	9.77	28.22	0.18
Treatment of Grade B leaks	77.63	187.63	1.20	6.64 %	11.86 %	1.24 %	7.58 %	5.89	14.23	0.09
Treatment of Grade C leaks	1043.54	1256.03	94.63	89.26 %	79.39 %	97.86 %	72.04 %	751.75	904.81	68.17
AL diagnosis & monitoring								4.60	14.67	0.48
In-patient days								530.97	841.13	53.89
Total environmental impact per AL patient								1302.97	1803.06	122.80

Abbreviations: AL: anastomotic leak; kg CO_2-eq: carbon dioxide equivalent (kilograms).
[a] Depicts the environmental impact associated with the treatment of each grade of leak.
[b] Depicts the contribution of each treatment to the overall environmental impact per AL patient.

Table 2
Breakdown of the environmental impact of each care pathway stage per patient.

Stage	Impact per anastomotic leak patient			% contribution to total		
	Climate impact (kg CO_2-eq)	Water impact (m^3)	Waste impact (kg)	Climate impact	Water impact	Waste impact
Monitoring and diagnosis	**4.60**	**14.67**	**0.48**	**0.35 %**	**0.81 %**	**0.39 %**
CT scan	2.20	7.00	0.14	0.17 %	0.39 %	0.11 %
Full blood test	2.40	7.66	0.34	0.18 %	0.42 %	0.28 %
Antibiotics & TPN treatment	**47.92**	**138.47**	**0.87**	**3.68 %**	**7.68 %**	**0.71 %**
Tablet antibiotics	10.79	28.03	0.03	0.83 %	1.55 %	0.03 %
IV antibiotics	32.82	103.45	0.17	2.52 %	5.74 %	0.14 %
IV antibiotics bags	0.27	0.09	0.02	0.02 %	0.01 %	0.02 %
Syringes	1.30	4.03	0.45	0.10 %	0.22 %	0.37 %
IV cannula	0.36	0.08	0.02	0.03 %	0.00 %	0.01 %
IV tubing	0.06	0.05	0.02	0.00 %	0.00 %	0.02 %
TPN	0.67	0.55	0.11	0.05 %	0.03 %	0.09 %
Central venous catheter	1.14	2.01	0.01	0.09 %	0.11 %	0.01 %
TPN - cannula	0.03	0.01	0.00	0.00 %	0.00 %	0.00 %
TPN - tubing	0.01	0.01	0.00	0.00 %	0.00 %	0.00 %
TPN bags	0.47	0.16	0.04	0.04 %	0.01 %	0.03 %
Surgical & Radiological intervention	**106.73**	**187.68**	**9.44**	**8.19 %**	**10.41 %**	**7.68 %**
CT guided drain	2.25	3.73	0.03	0.17 %	0.21 %	0.02 %
Hartmann's procedure	43.48	76.56	2.75	3.34 %	4.25 %	2.24 %
Ileostomy	14.18	24.96	2.75	1.09 %	1.38 %	2.24 %
Stoma closure operation	46.82	82.44	3.92	3.59 %	4.57 %	3.19 %
Stoma home management	**606.78**	**620.02**	**58.13**	**46.57 %**	**34.39 %**	**47.34 %**
Stoma home management: Ostomy bag (stoma-closure patient)	528.52	540.05	50.64	40.56 %	29.95 %	41.23 %
Stoma home management: Ostomy bag (no-stoma closure patient)	78.26	79.97	7.50	6.01 %	4.44 %	6.11 %
Patient travel	**5.97**	**1.09**	**–**	**0.46 %**	**0.06 %**	**–**
Patient travel to elective care due to stoma closure operation	5.97	1.09	–	0.46 %	0.06 %	–
In-patient days	**530.97**	**841.13**	**53.89**	**40.75 %**	**46.65 %**	**43.88 %**
ICU	135.00	205.50	19.50	10.36 %	11.40 %	15.88 %
General ward	317.76	510.08	27.60	24.39 %	28.29 %	22.47 %
General ward (due to stoma closure operation)	78.21	125.55	6.79	6.00 %	6.96 %	5.53 %
Total	**1302.97**	**1803.06**	**122.80**	**100.00 %**	**100.00 %**	**100.00 %**

Abbreviations: CT: computerised tomography; kg CO_2-eq: carbon dioxide equivalent (kilograms); ICU: intensive care unit; IV: intravenous; TPN: total parenteral nutrition.

Table 3
Detailed breakdown of the contribution of stoma home management to environmental impact.

Stage	Impact per AL patient		
	Climate impact (kg CO_2-eq)	Water impact (m^3)	Waste impact (kg)
Ostomy bag material	541	169	0
Ostomy bag processing	61.9	450	3.50
Ostomy bag transportation	0.185	0.015	0
Ostomy bag waste management	3.69	0.229	54.6
Total	607	620	58.10

Abbreviations: AL: anastomotic leak; kg CO_2-eq: carbon dioxide equivalent (kilograms).

can be mainly attributed to general in-patient (non-ICU) days (Table 2). The environmental impact of in-patient care is largely associated with the use of energy and consumables, and is therefore directly related to hospital length of stay. AL patients require a greater number of general in-patient days, compared with days in the ICU, resulting in these days contributing to the majority of the environmental impact associated with in-patient stay overall.

Discussion

The results of this environmental impact assessment demonstrate that the treatment of AL is associated with a substantial environmental impact. Reducing one AL could result in an average climate saving of 1303 kg CO_2-eq (equivalent to 5 return flights from London to Rome) [27], a water saving of 1803 m^3 (equivalent to 17 times the annual water use of an average European household) [28] and a waste saving of 123 kg (equivalent to almost 3 times the monthly waste generation of an average European individual) [29].

The care pathway analysis described herein demonstrates that AL is associated with an increased length of hospital stay and this factor makes a substantial contribution to the overall environmental impact of the AL care pathway. This finding is aligned with another life cycle assessment that demonstrated the association between in-patient hospital stay and environmental footprint [30]. The WHO defines an environmentally sustainable health system as one which improves, maintains or restores the health of its patients, whilst minimising its negative impact on the environment and leveraging opportunities to restore and improve it [2]. By identifying and taking action to reduce the incidence of AL, hospitals and wider healthcare systems can not only improve clinical outcomes for patients, but also make progress towards becoming more economically and environmentally sustainable. Increased drive amongst healthcare systems to improve their sustainability has led to a growing body of research being conducted around the environmental impact associated with activities in the healthcare sector [30]. This includes a substantial number of life cycle assessments focusing on the impact associated with the use of specific resources and equipment, and the environmental impact associated with specific medical procedures, such as medical interventions during child birth, dialysis and a variety of different types of surgery [30,31].

Whilst this research is essential in enhancing our understanding of where improvements can be made, there is also a need to identify ways in which sustainability targets can be integrated into healthcare operations. The integration of environmental performance metrics into the existing quality and safety reporting frameworks is one way in which to introduce sustainability benchmarking and accountability within healthcare systems [31]. Integrating environmental sustainability into value-based healthcare reform, through identifying evidence-based best practices which take into account environmentally preferable and waste sparing practices, will help to introduce environmental stewardship into the healthcare quality discourse [31]. In order to do this, clinical best practices will need to include considerations of resource efficiency and pollution prevention, in addition to optimisation of patient outcomes [9,32]. Development of a set of robust and standardised metrics that define environmental performance at a number of levels, including for individual products, clinical care pathways, providers and entire hospitals and health systems, is therefore required [31].

This study is, to our knowledge, the first study to assess the environmental impact associated with the treatment of AL. Results from studies like these may encourage clinician engagement in order to not only reduce the clinical burden on patients, but also make environmental savings [9,32].

Limitations

Whilst this impact assessment was conducted in line with SHC guidelines [24], identification of more specific data relating to some of the care pathway activities could improve the overall accuracy of the environmental impact assessment. Generic drug substance environmental intensity data were used to evaluate the environmental impact of the production of antibiotics, and secondary life cycle emission factor data were used to characterise the impact of the manufacture of consumables, such as catheters, IV sets, cannulas and ostomy bags (Supplementary Table 1) [25]. Using specific environmental impact data relating to the manufacture and supply of antibiotics, TPN and consumables, in addition to gaining an improved understanding of individual variation in the use of ostomy bags in home management, could improve the accuracy of this assessment. In addition, carrying out specific audits of material, energy and staff requirements associated with AL treatment may further improve the accuracy.

Emission factors sourced from the ecoinvent database incorporate a mix of different electricity sources, based on a European wide average [25]. However, impacts associated with energy consumption of specific clinical activities (e.g. in-patient stay) were sourced from the Sustainable Care Pathways Guidance, which are based on UK electricity sources [24]. Therefore, climate impacts from energy consumption for other countries could vary due to differences in national electricity grid mixes. The AL patient pathway was also developed based on European data from the ESCP audit [21] and relevant literature [17–20,22]. In practice, the estimations for environmental impact may vary based on the specific care pathways of individual hospitals, due to the use of different surgical techniques and varying amounts of consumables. The SHC guidelines recommend that, where data availability allows, hospitals perform their own analyses based on their specific care pathway. However, it is likely that the general findings of this study regarding the contribution that specific activities of the pathway make to the overall environmental impact are likely applicable to wider settings.

Whilst this study focused specifically on colorectal surgery, the findings can be applied more broadly to conclude that efforts to reduce the incidence of surgical complications and their severity may lead to improvements in the overall environmental sustainability of surgical departments. In order to understand how significant these improvements would be, future studies evaluating the environmental impact associated with patients undergoing colorectal surgery without complications could be performed.

The findings from this analysis also provide an indication of the environmental impact of patients without surgical complications, who still experience aspects of the AL treatment pathway. For example, patients with left-sided colorectal resection, especially those undergoing ultra-low anterior resection would typically receive a protective ileostomy, regardless of whether they experience AL [33]. As this analysis has shown, ostomy bags are associated with a significant impact, and it is therefore likely that these patients would also have a substantial impact on the environment.

Conclusions

The treatment of AL is associated with a substantial environmental impact. Overall, Grade C leaks are associated with the greatest environmental impact of all patients who experience a leak. Within the AL care pathway, stoma home management, in-patient days and surgical and radiological intervention make the largest contribution to the overall climate impact of AL patients.

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Ethics approval

As this study made use of published data sourced from the ESCP audit and relevant literature, IRB approval was not required.

CRediT authorship contribution statement

Substantial contributions to study conception and design: MK, CT, SJ, GC, MC, SB, FA, KM, WB; substantial contributions to analysis and interpretation of the data: MK, CT, SJ, GC, MC, SB, FA, KM, WB; drafting the article or revising it critically for important intellectual content: MK, CT, SJ, GC, MC, SB, FA, KM, WB; final approval of the version of the article to be published: MK, CT, SJ, GC, MC, SB, FA, KM, WB.

Declaration of competing interest

MK, CT, SJ, GC are employees of Johnson & Johnson. SB, FA, KM and WB declare no conflict of interest.

Data sharing statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. More details on Johnson & Johnson's commitment to transparency are available via the following link: https://www.jnj.com/coronavirus/our-commitment-to-transparency/.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sopen.2023.07.001.

References

[1] Prüss-Üstün A, Wolf J, Corvalán C, et al. Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks. World Health Organization; 2016.
[2] World Health Organization. Environmentally sustainable health systems: a strategic document. World Health Organization. Regional Office for Europe; 2017.
[3] Karliner J, Slotterback S, Boyd R, et al. Health care's climate footprint: how the health sector contributes to the global climate crisis and opportunities for action. Health Care Without Harm 2019. https://noharm-global.org/sites/default/files/documents-files/5961/HealthCaresClimateFootprint_092319.pdf.
[4] Brown LH, Buettner PG, Canyon DV. The energy burden and environmental impact of health services. Am J Public Health 2012;102:e76–82.
[5] Gaglia A, Balaras C, Mirasgedis S, et al. Empirical assessment of the Hellenic non-residential building stock, energy consumption, emissions and potential energy savings. Energ Conver Manage 2007;48:1160–75.
[6] Wyssusek KH, Keys MT, van Zundert AAJ. Operating room greening initiatives – the old, the new, and the way forward: a narrative review. Waste Manag Res 2019;37:3–19.
[7] National Health Service. Delivering a 'net zero'. National Health Service; 2020.
[8] National Health Service. Reducing the environmental impact of equipment, medicines and resources. availble at: https://www.england.nhs.uk/ahp/greener-ahp-hub/specific-areas-for-consideration/reducing-the-environmental-impact-of-equipment-medicines-and-resources/. [Accessed 7 December 2023].
[9] Mortimer F, Isherwood J, Wilkinson A, et al. Sustainability in quality improvement: redefining value. Future Healthc J 2018;5:88–93.
[10] Royal College of Surgeons of England. Sustainability in the operating theatre: a guide to good practice. May 2022.
[11] Rahbari NN, Weitz J, Hohenberger W, et al. Definition and grading of anastomotic leakage following anterior resection of the rectum: a proposal by the International Study Group of Rectal Cancer. Surgery 2010;147:339–51.
[12] Kirchhoff P, Clavien PA, Hahnloser D. Complications in colorectal surgery: risk factors and preventive strategies. Patient Saf Surg 2010;4:5.
[13] Krarup PM, Nordholm-Carstensen A, Jorgensen LN, et al. Association of comorbidity with anastomotic leak, 30-day mortality, and length of stay in elective surgery for colonic cancer: a nationwide cohort study. Dis Colon Rectum 2015;58:668–76.
[14] Midura EF, Hanseman D, Davis BR, et al. Risk factors and consequences of anastomotic leak after colectomy: a national analysis. Dis Colon Rectum 2015;58:333–8.
[15] Schiff A, Brady B, Ghosh S, et al. Estimated rate of post-operative anastomotic leak following colorectal resection surgery: a systematic review. J Surg Surgical Res 2016;2:060–7.
[16] Ribeiro Jr U, Tayar DO, Ribeiro RA, et al. The clinical and economic burden of colorectal anastomotic leaks: middle-income country perspective. Gastroenterol Res Pract 2019;2019:2879049.
[17] Élthes E, Török Á, Dénes M, et al. Primary medical effects and economic impact of anastomotic leakage in patients with colorectal cancer. A middle-income country perspective. J Interdiscip Med 2020;5:152–7.
[18] Van Loon T, Clermonts S, Wasowicz D, et al. Feasibility of single-port reversal of left-sided colostomy in the presence of incisional hernia; promising results. Turk J Colorectal Dis 2021:32.
[19] van Dellen J, Carapeti EA, Darakhshan AA, et al. Intrinsic predictors of prolonged length of stay in a colorectal enhanced recovery pathway: a prospective cohort study and multivariate analysis. Colorectal Dis 2019;21:1079–89.
[20] Basilico V, Griffa B, Radaelli F, et al. Anastomotic leakage following colorectal resection for cancer: how to define, manage and treat it. Minerva Chir 2014;69:245–52.
[21] ESCP Cohort Studies and Audits Committee. The 2017 European Society of Coloproctology (ESCP) international snapshot audit of left colon, sigmoid and rectal resections – study protocol. Colorectal Dis 2018;20:5–12.
[22] Gessler B, Eriksson O, Angenete E. Diagnosis, treatment, and consequences of anastomotic leakage in colorectal surgery. Int J Colorectal Dis 2017;32:549–56.
[23] Milito G, Lisi G, Venditti D, et al. Endoluminal vacuum therapy as treatment for anastomotic colorectal leakage. Surg Technol Int 2017;30:125–30.
[24] Sustainable Healthcare Coalition. Care pathways: guidance on appraising sustainability. Available at: https://shcoalition.org/sustainable-care-pathways-guidance/; 2015.
[25] Ecoinvent database version 3.8. Available at: https://ecoinvent.org/the-ecoinvent-database/.
[26] ABPI blister pack carbon footprint tool. Available at: https://www.abpi.org.uk/r-d-manufacturing/abpi-blister-pack-carbon-footprint-tool/.
[27] International Civil Aviation Organization. Carbon emissions calculator. Available at: https://www.icao.int/environmental-protection/carbonoffset/pages/default.aspx.
[28] EurEau. Europe's water in figures: an overview of the European drinking water and waste water sectors. Available at: https://www.eureau.org/resources/publications/eureau-publications/5824-europe-s-water-in-figures-2021/file; 2021.
[29] Eurostat. Muncipal waste statistics. Availabe at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Municipal_waste_statistics; 2021.
[30] Prasad PA, Joshi D, Lighter J, et al. Environmental footprint of regular and intensive inpatient care in a large US hospital. Int J Life Cycle Assess 2022;27:38–49.
[31] Sherman JD, Thiel C, MacNeill A, et al. The green print: advancement of environmental sustainability in healthcare. Resour Conserv Recycl 2020;161:104882.
[32] Marimuthu M, Paulose H. Emergence of sustainability based approaches in healthcare: expanding research and practice. Procedia Soc Behav Sci 2016;224:554–61.
[33] Wu SW, Ma CC, Yang Y. Role of protective stoma in low anterior resection for rectal cancer: a meta-analysis. World J Gastroenterol 2014;20:18031–7.