Original research

Targeted intervention to achieve waste reduction in gastrointestinal endoscopy

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ABSTRACT

Objective Endoscopy is healthcare's third largest generator of medical waste in hospitals. This prospective study aimed to measure a single unit's waste carbon footprint and perform a pioneer intervention towards a more sustainable endoscopy practice. The relation of regulated medical waste (RMW; material fully contaminated with blood or body fluids or containing infectious agents) versus landfill waste (non-recyclable material not fully contaminated) may play a critical role.

Design In a four-stage prospective study, following a 4-week observational audit with daily weighing of both waste types (stage 1), stage 2 consisted of a 1-week intervention with team education of waste handling. Recycling bins were placed in endoscopy rooms, landfill and RMW bins were relocated. During stages 3 (1 month after intervention) and 4 (4 months after intervention), daily endoscopic waste was weighed. Equivalence of 1 kg of landfill waste to 1 kg carbon dioxide equivalent (CO_{2e}) and 1 kg of RMW to 3kgCO_{2e} was assumed. Paired samples t-tests for comparisons.

Results From stage 1 to stage 3, mean total waste and RMW were reduced by 12.9% (p=0.155) and 41.4% (p=0.010), respectively, whereas landfill (p=0.059) and recycling waste increased (paper: p=0.001; plastic: p=0.007). While mean endoscopy load was similar (46.2 vs 44.5, p=0.275), a total decrease of CO_{2e} by 31.6% (138.8kgCO_{2e}) was found (mean kgCO_{2e} 109.7 vs 74.9, p=0.018). The annual reduction was calculated at 1665.6kgCO_{2e}. All these effects were sustained 4 months after the intervention (stage 4) without objections by responsible endoscopy personnel.

Conclusion In this interventional study, applying sustainability measures to a real-world scenario, RMW reduction and daily recycling were achieved and sustained over time, without compromising endoscopy productivity.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Previous studies showed that endoscopic procedures make use of a substantial number of single-use consumables and are energy intensive. Too much of the waste may be declared as special medical waste with obligation to apply more energy-consuming waste processing.

⇒ Recycling and other green initiatives (reusable vs disposable material) have been applied in some healthcare sectors. Still, awareness on sustainable endoscopy remains largely unaddressed.

WHAT THIS STUDY ADDS

⇒ Waste segregation and implementation of recycling together with proper education of endoscopy staff lead to a significant reduction of the waste carbon footprint generated by endoscopic procedures.

⇒ Sustainable endoscopy regarding waste handling was achievable and sustained over time, did not compromise productivity and may be cost-effective for stakeholders.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Reduction of the regulated medical waste production and carbon footprint in the field of endoscopy may have an environmental impact and lower the associated economic burden, helping to improve health of future generations.

INTRODUCTION

Healthcare is responsible for 4.4% of the world's carbon footprint, being one of the major culprits of increasing greenhouse gas emissions worldwide.[1] In particular, endoscopy is considered healthcare's third largest generator of medical waste in a hospital, mainly due to the routine use of single-use consumables.[1–4] Nonetheless, data on overall and periendoscopic procedure carbon footprint is still sparse.[4] It is estimated that approximately 1.5 kg of plastic waste is produced per endoscopic procedure, but only 0.3 kg is recyclable.[4 5] However, most endoscopy units are not equipped with recycling bins, which leads to the disposal of waste solely as landfill or regulated medical waste (RMW).[5] Siddhi *et al* identified various strategies to reduce the carbon footprint associated with endoscopy, and considered recycling waste, waste segregation and raising endoscopy staff awareness as 'easy wins' due to their low cost and easiness of implementation.[4] However, the lack of awareness by most endoscopy staff regarding the expenses and correct categorisation of endoscopic waste is the primary barrier to recycling in many endoscopy units.[6 7]

Green endoscopy has recently been defined as an association of multiple strategies to reduce waste, readdress equipment and supplies for the benefit of patients, healthcare facilities and the community.[3 7] Still, it is crucial to amplify strategies to further mitigate the global carbon footprint of endoscopy units, since sustainability in endoscopy remains an unaddressed issue, explored by a small group of enthusiasts.

This study aimed to be the first real-world interventional project to implement measures towards a more sustainable endoscopy practice and perform an audit on its waste carbon footprint and processing expenses at three distinct timepoints: preintervention, 1 month and 4 months after the intervention. Lastly, it aimed to perform an assessment of the waste carbon footprint generated by single diagnostic upper endoscopy and colonoscopy.

MATERIALS AND METHODS

Study design

This was a four-stage prospective, single-centre, interventional study, designed to quantify the environmental impact of a single endoscopic unit and to implement a strategy to reduce it.

The study was conducted between October 2021 and March 2022 at the Portimão endoscopy unit of Algarve University Hospital Centre (Portugal).

The Revised Standards for Quality Improvement Reporting Excellence guidelines were used to report the study.[8]

Aims and outcome measures

The primary aims of the study were: (1) to assess and compare the waste carbon footprint and waste processing expenses induced by endoscopic procedures before and after the intervention and (2) to reorganise the endoscopy unit to reduce and recycle endoscopic waste (intervention).

The secondary aims were: (1) to evaluate the project's impact on the unit's productivity and staff daily labour; (2) to assess the waste carbon footprint generated by a single diagnostic upper endoscopy before and after the intervention; (3) to assess the waste carbon footprint generated by a single diagnostic colonoscopy before and after the intervention and (4) to assess whether the behavioural changes implemented were still in practice 4 months after the intervention.

The primary outcome measures were (1) waste carbon footprint—carbon dioxide equivalents (CO_{2e}): CO_{2e} measured in kilograms; waste processing expenses—disposal of landfill and RMW in € per kg and (2) presentation of retrieved data and seminars regarding waste handling, segregation and disposal in the endoscopy unit; acquisition and placement of recycling bins within endoscopy rooms, and relocation of landfill and RMW bins.

The secondary outcome measures were: (1) anonymous survey on the impact of the study on the daily work routine filled by the entire medical, nursing and auxiliary staff; (2) waste carbon footprint of a single diagnostic upper endoscopy—CO_{2e}: CO_{2e} measured in kilograms before and after the intervention and (3) waste carbon footprint of a single diagnostic colonoscopy—CO_{2e}: CO_{2e} measured in kilograms before and after the intervention.

Phases of the study

Stage 1: preintervention

During the preintervention phase of the study, a 4-week observational audit was conducted. It intended to identify the origins of waste within endoscopy that could be modified by applying simple measures in a stepwise manner, such as correct segregation and recycling. Only 2 out of the 14 members of the endoscopy unit were involved in the data collection so that the endoscopy staff were unaware of this audit. Following usual practice, daily endoscopic waste produced in the endoscopy rooms was separated into two different categories (landfill, RMW).[7] Over this period, all waste bags were weighed at the end of the working day. The number of bags, their weight in kilograms and the total number of endoscopic procedures were registered in daily record sheets designed for the intended purpose. Additionally, on the first day of this stage, the waste bags generated by both a diagnostic upper endoscopy and colonoscopy were separately weighed at the end of each procedure. Waste from sharps containers, waste generated in the preprocedure and postprocedure areas and that due to endoscope reprocessing were not accounted for in any of the study stages. The weighing process was rendered with an engineer-calibrated scale, with a stated accuracy (e) of 5 g (SimãoVaz). Data registration was recorded after calculating the mean of three consecutive weight measurements for each waste bag, always performed by the same two physicians (JACN and JR).

Stage 2: intervention

After collecting data from stage 1, a 1-week intervention was held. The entire endoscopy unit team (medical, nursing and auxiliary staff) was involved. It concerned the presentation of retrieved data from the study's first stage and two seminars regarding waste handling, segregation and disposal in endoscopy units. Additionally, recycling bins were acquired at a cost of approximately €60, labelled and placed within endoscopy rooms and landfill and RMW bins were relocated to avoid landfill and RMW systematic misclassification (figure 1 and table 1).

Stage 3: 1 month after intervention

The first postinterventional phase comprised a 4-week period, during which daily endoscopic waste produced in the endoscopy rooms was again categorised[7] and weighed. As in stage 1, the number of bags, their weight in kilograms and the total number of endoscopic procedures were registered in daily record sheets designed for the intended purpose. On the first day, the waste bags generated on both a diagnostic upper endoscopy and colonoscopy were separately weighed at the end of each procedure. The two interveners (JACN and JR) used the same engineer-calibrated scale, weighing method and standardised registration.

Stage 4: 4 months after intervention

This phase comprised a 4-week period, 4 months after the first postinterventional stage, during which daily endoscopic waste produced in the endoscopy rooms was once again categorised[7] and weighed. Before this stage, no other staff awareness initiatives took place. As in stages 1 and 3, the number of bags, their weight in kilograms and the total number of endoscopic procedures were registered in daily record sheets designed for the intended purpose. Measurements were performed by the same two interveners (JACN and JR), with the same engineer-calibrated scale, weighing method and standardised registration.

Survey: impact of the study on the daily work routine

On completion of stage 3, the authors designed a four-question categorical (yes/no) query to assess the impact of this study on the daily work of the staff within the unit: question 1: 'did you feel the study interfered with your daily work routine?'; question 2: 'did you think the study was helpful in raising awareness about waste sorting within the unit?'; question 3: 'do you think recycling waste allows for more sustainable activity within the endoscopy unit?'; question 4: 'do you agree that the achievements of this study are to be maintained in the future?'

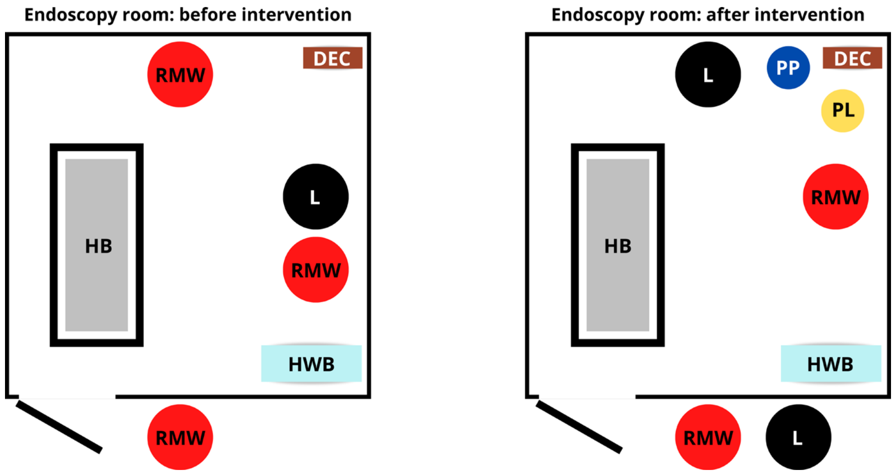

Figure 1 Placement and relocation of bins within endoscopy rooms: before and after intervention. DEC, disposal endoscopic cabinet; HB, hospital bed; HWB, hand washbasin; L, landfill waste; PL, plastic waste; PP, paper waste; RMW, regulated medical waste.

Surveys were printed and delivered to every member of the endoscopy unit (medical, nursing and auxiliary staff) and anonymously filled. Answers were collected and analysed by JACN and JR.

Definitions

Diagnostic endoscopy

Non-interventional procedure, without any type of device usage (no biopsies or polyp resection).

Landfill waste

Non-recyclable endoscopy-related material not fully contaminated with blood or body fluids[7] (figure 2).

Recycled paper and plastic

All paper, cardboard and the majority of plastic types (resin identification codes 1–5) were considered recyclable material.[7 9 10] If consisting of both paper and plastic, and not contaminated, these would be detached and separated accordingly (figure 2).

Regulated medical waste

Endoscopy-related material saturated with blood or body fluids or containing infectious agents, including suction canisters[7] (figure 2).

Table 1 Stage 2: intervention

Step 1	Meeting with the team (medical, nursing and auxiliary staff)
Step 2	Presentation of data 1. Amount of overall waste produced 2. Alert the team to systematic waste misclassification and misplacement (eg, personal protective equipment erroneously discarded as regulated medical waste (RMW)) 3. Raise awareness about recycling + Seminars 1. Strategies to reduce overall waste production (eg, opening one pack of gauze at a time) 2. Correct waste handling, segregation and disposal 3. Identification of potential recyclable components
Step 3	Acquisition, labelling and placement of recycling bins within the endoscopy suite + Removal and relocation of landfill and RMW bins

Waste carbon footprint measured in CO_{2e}

CO_{2e} was used as a measurement unit to calculate the waste carbon footprint. Equivalence of 1kg of landfill waste to 1kgCO_{2e} and 1kg of RMW to 3kgCO_{2e} was applied.[11–16]

Waste processing expenses

Disposal of landfill and RMW cost was estimated to be 1€ per kg and 10€ per kg, respectively.[11] These amounts were applied to calculate the overall economic burden of waste processing and disposal.

Statistical analysis

Sample size calculation

To the author's knowledge, no studies with similar aims or outcomes have been published so far. In a study concerning the environmental impact of single-use endoscopes, Namburar *et al* measured endoscopic waste in a similar unit where recycling was already established. The authors demonstrated that approximately two-thirds of the waste were attributed to landfill waste, while RMW accounted for about 30% of the total generated waste mass.[9]

Herein, a power of 80% (type 2 error β of 20%) was used for sample-size estimation. It was expected that in the preinterventional stage of the study, RMW would account for approximately 60% of total waste mass. It was anticipated that recycling would reduce 50% in hazardous production, so that RMW would account for around 30% of the unit's waste mass, similar to the Namburar *et al* study. This assumption led to the calculation that 40 endoscopic procedures per group (before and after the intervention) would be needed.

All statistical analysis was conducted using the Statistical Package for the Social Sciences, V.27.0. A level of significance at 5% was established. Descriptive data are described as absolute (n) and relative frequencies (%) for categorical variables. Continuous variables are summarised as mean with SD or median with IQR, depending on the statistical distribution. Throughout the manuscript, one decimal place was used for result presentation and three decimal places were used to express p values. Comparison of continuous variable outcomes was performed using paired-samples t-test or Wilcoxon test, based on statistical distribution.

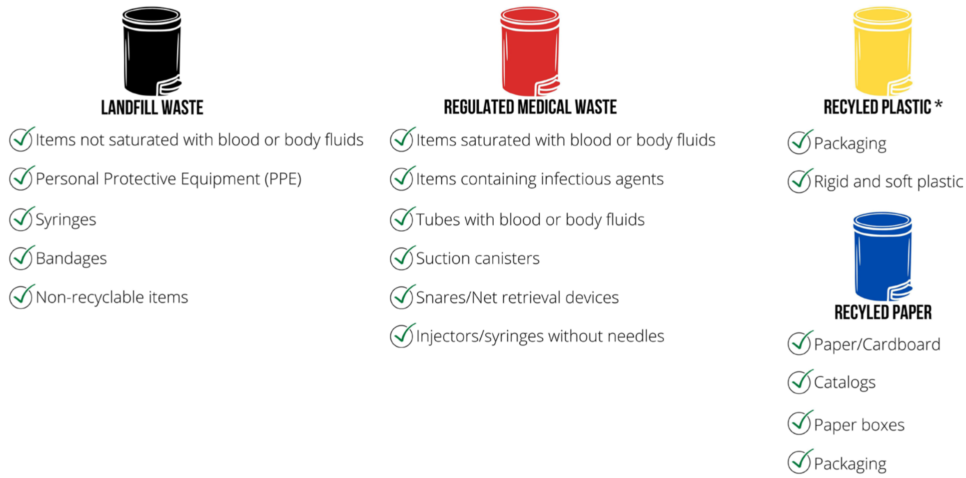

Figure 2 Waste sorting grid for endoscopy. *Including resin identification codes 1–5 (PET, HDPE, PVC, LDPE, PP). HDPE, high-density polyethylene; LDPE, low-density polyethylene; PET, polyethylene terephthalate; PP, polypropylene; PVC, polyvinyl chloride. Adapted from de Melo *et al*.[7]

Patient and public involvement statement

Patients were not involved in the design or implementation of the study. Patients were not included as participants of the study and there is no plan in place to involve them in the dissemination of results.

RESULTS

Stage 1: preintervention

During the first stage of the study, 185 endoscopic procedures (85 upper endoscopies and 100 colonoscopies) were performed over 4 weeks. More than 75% were rendered under superficial sedation provided by a gastroenterologist, approximately 15% executed under deep sedation with propofol, with the assistance of an anaesthesiologist, and the remaining were performed without sedation. A total 197.3 kg of waste (including personal protective equipment (PPE) and packaging material) were generated, including 76.6 kg of landfill and 120.7 kg of RMW. (table 2). Neither recycled paper nor plastic waste was collected.

Regarding diagnostic procedures (table 3), in this non-recycling scenario, an upper endoscopy generated 0.2 kg of landfill waste and 0.3 kg of RMW, corresponding to a total of 1.1kgCO_{2e}. A colonoscopy produced 0.4 kg of landfill waste and 0.5 kg of RMW, reaching 1.9kgCO_{2e}.

At the end of the preinterventional period, the waste carbon footprint generated by all endoscopic procedures within the unit was 438.7kgCO_{2e} (table 4).

Stage 2: intervention

During the 1-week intervention, two seminars were held, with an overall 100% staff participation (medical, nursing and auxiliary staff).

Stage 3: 1 month after intervention

After the 1-week intervention, a 4-week first postintervention phase of the study took place. During this period, 178 endoscopic procedures (84 upper endoscopies and 94 colonoscopies) were performed, of which more than 70% were rendered under superficial sedation, approximately 20% under deep sedation with propofol, and the remaining were performed without sedation. A total 171.4 kg of waste (including PPE and packaging material) were generated, comprising 87.8 kg of landfill and 70.7 kg of RMW. After these 4 weeks, 4.7 kg of recycled paper and 8.2 kg of recycled plastic waste were collected (table 2).

At the end of the first postinterventional period, the waste carbon footprint generated by all endoscopic procedures within the unit was 299.9kgCO_{2e} (table 4).

Stage 4: 4 months after intervention

Four months after the end of the first postinterventional period, a 4-week phase was conducted to assess whether the behavioural changes were still in practice. During this period, 172 endoscopic procedures (75 upper endoscopies and 97 colonoscopies)

Table 2 Retrieved data

	Preintervention	One month after intervention	Four months after intervention		
	Total	Total	Total	P value*	P value†
Landfill waste, kg (%)	76.6 (38.8)	87.8 (51.2)	82.6 (50.9)	0.059	0.781
RMW, kg (%)	120.7 (61.2)	70.7 (41.2)	68 (41.9)	**0.010**	0.866
Recycled paper, kg (%)	0 (0)	4.7 (2.8)	3.8 (2.3)	**0.001**	0.266
Recycled plastic, kg (%)	0 (0)	8.2 (4.8)	8 (4.9)	**0.007**	0.920
Total waste, kg	197.3	171.4	162.4	0.155	0.806
Endoscopies (n)	185	178	172	0.275	0.892

Bold means statistically significant.
*P value for preintervention versus 1 month after intervention based on paired-samples t-test.
†P value for 1 month after intervention versus 4 months after intervention based on paired-samples t-test.
RMW, regulated medical waste.

Table 3 Diagnostic standard endoscopic procedures

	Preintervention		One month after intervention		Four months after intervention	
	Upper Endoscopy	Colonoscopy	Upper Endoscopy	Colonoscopy	Upper Endoscopy	Colonoscopy
Landfill waste, kg (%)	0.2 (40)	0.4 (44.5)	0.5 (62.5)	0.5 (50)	0.4 (57.1)	0.5 (50)
RMW, kg (%)	0.3 (60)	0.5 (55.5)	0.1 (12.5)	0.2 (20)	0.1 (14.3)	0.2 (20)
Recycled paper, kg (%)	0 (0)	0 (0)	0.1 (12.5)	0.1 (10)	0.1 (14.3)	0.1 (10)
Recycled plastic, kg (%)	0 (0)	0 (0)	0.1 (12.5)	0.2 (20)	0.1 (14.3)	0.2 (20)
Total waste, kg	0.5	0.9	0.8	1	0.7	1
Carbon footprint, $kgCO_{2e}$	1.1	1.9	0.8	1.1	0.7	1.1

$kgCO_{2e}$: carbon dioxide equivalents—equivalence of 1kg of landfill waste to 1$kgCO_{2e}$ and 1kg of RMW to 3$kgCO_{2e}$ was applied.[11–16]
RMW, regulated medical waste.

were performed. More than 70% were rendered under superficial sedation, approximately 17% executed under deep sedation with propofol and the remaining 13% were performed without sedation. A total 162.4 kg of waste (including PPE and packaging material) were generated, comprising 82.6 kg of landfill, 68 kg of RMW, 3.8 kg of recycled paper and 8 kg of recycled plastic waste (table 2).

At the end of this stage, the waste carbon footprint generated by all endoscopic procedures within the unit was 286.6$kgCO_{2e}$ (table 4).

Waste production

Preintervention versus 1 month after intervention

Overall, mean total waste was reduced by 12.9% (49.3 kg vs 42.9 kg, p=0.155). Mean RMW was significantly reduced by 41.4% (30.2 kg vs 17.7 kg, p=0.010), while mean landfill waste increased by 12.3% (19.2 kg vs 21.9 kg, p=0.059). Regarding recycling debris, both mean paper and plastic waste significantly increased (0 kg vs 1.2 kg, p=0.001; 0 kg vs 2.1 kg, p=0.007, respectively) (figure 3). Mean endoscopy load was identical between stages (46.2 vs 44.5, p=0.275). In both assessment periods, total waste produced by diagnostic standard endoscopic procedures was similar, but both RMW and overall carbon footprint were reduced (table 3).

One month after intervention versus 4 months after intervention

Mean total waste (42.9 kg vs 40.6 kg, p=0.806), RMW (17.7 kg vs 17 kg, p=0.866), landfill waste (21.9 kg vs 20.7 kg, p=0.781), recycled paper waste (1.2 kg vs 1 kg, p=0.266), recycled plastic waste (2.1 kg vs 2 kg, p=0.920) (figure 3) and mean endoscopy load (44.5 vs 43, p=0.892) were similar between stages.

Table 4 Waste carbon footprint

	Preintervention	One month after intervention	Four months after intervention		
	Total	Total	Total	P value*	P value†
Landfill waste, $kgCO_{2e}$ (%)	76.6 (17.5)	87.8 (29.3)	82.6 (29.9)	0.059	0.781
RMW, $kgCO_{2e}$ (%)	362.1 (82.5)	212.1 (70.7)	204 (70.1)	**0.010**	0.866
Total carbon footprint, $kgCO_{2e}$	438.7	299.9	286.6	**0.018**	0.841

Bold means statistically significant.
$kgCO_{2e}$, carbon dioxide equivalents— equivalence of 1 kg of landfill waste to 1$kgCO_{2e}$ and 1 kg of RMW to 3$kgCO_{2e}$ was applied.[11–16]
*P value for preintervention versus 1 month after intervention based on paired-samples t-test.
†P value for 1 month after intervention versus 4 months after intervention based on paired-samples t-test.
RMW, regulated medical waste.

Waste carbon footprint and waste processing expenses

Preintervention versus 1 month after intervention

An overall reduction of the waste carbon footprint of 31.6% (138.8$kgCO_{2e}$) was obtained (109.7$kgCO_{2e}$ vs 74.9$kgCO_{2e}$, p=0.018), corresponding to a waste carbon footprint's yearly reduction of 1665.6$kgCO_{2e}$ (figure 4).

The intervention also allowed for a significant reduction in mean waste processing and disposal costs (€320.9 vs €198.7, p=0.012), with savings of approximately €500, which represents a yearly reduction of the economic burden of endoscopic procedures of approximately €6000 at the authors' institution.

One month after intervention versus 4 months after intervention

Mean waste carbon footprint (74.9$kgCO_{2e}$ vs 71.7$kgCO_{2e}$, p=0.841) (figure 4) and mean waste processing and disposal costs (€198.7 vs €190.7, p=0.857) were similar between stages.

Tables 4 and 5 summarise the data regarding waste carbon footprint and waste processing expenses.

Impact of the study on the daily work: survey

Concerning the four-question query designed to assess the impact of the study on the daily work of staff within the unit, a 100% response and completion rate was obtained. The entire team agreed that the study did not interfere with the daily work routine and was helpful in raising awareness about waste sorting within the unit. They also acknowledged that recycling waste allowed for more sustainable activity within the endoscopy unit, and that the achievements of the study were to be maintained in the future.

DISCUSSION

Recently, attention has been drawn to the significant carbon footprint of operating theatres, warranting intervention. Assessments are unanimous that there are several factors involved, such as the nature of the surgical procedure, electricity and ventilation requirements, anaesthesia protocols and extent of consumables used during surgery.[17 18] In the same way as operating theatres, endoscopic procedures consume a significant number of single-use material and energy.[4 19] As such, endoscopy represents a versatile healthcare area where sustainability enhancement interventions are also pertinent.[1] However, published literature on sustainable endoscopy is still sparse, and sustainability and environmental concerns are not a priority to most political administrations.[4]

This prospective real-world interventional study assessed the waste carbon footprint generated by endoscopic procedures, with a standardised, quality-improvement approach. In this project, the endoscopic unit was reorganised according to the

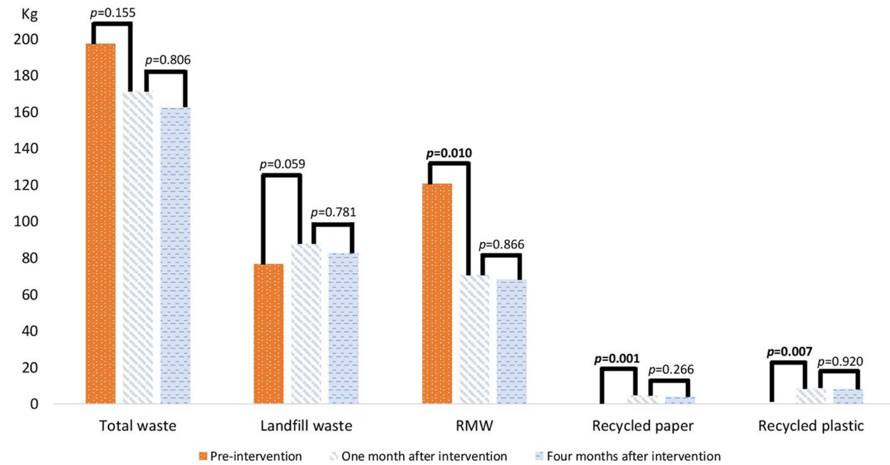

Figure 3 Waste production and allocation. RMW, regulated medical waste.

most recent waste sorting grid for endoscopic procedures.[7] These measures clearly reduced RMW generation. Moreover, the study did not impact work productivity or staff dynamics. Notably, an overall significant decrease in the waste carbon footprint was verified, translating into an economic burden reduction.

During the preinterventional period of the study, 61% of the generated waste mass was RMW, whereas the remaining portion comprised landfill waste; no recycling was performed during this first stage, as no clear recycling plan was in place before the project took place. In the first month after intervention, landfill waste accounted for 51.2% and RMW production was reduced to 41.2%; the remaining fraction (7.6%) consisted of recycled paper and plastic. The authors believe that RMW reduction was accomplished due to (1) relocation of landfill and RMW bins, to avoid systematic waste misclassification; (2) raising staff awareness regarding the disposal of non-contaminated PPE as landfill waste rather than RMW; and (3) establishment of recycling. This overall improvement remained 4 months after the intervention, despite no other staff awareness initiatives taking place, with landfill waste accounting for 50.9%, RMW 41.9% and recycled waste 7.2% of total waste mass. In a study by Namburar *et al* 65% of generated endoscopic waste was direct landfill waste, while RMW represented nearly 30% and the remaining fraction was recycled waste.[9] There is a disparity between the two studies, both in overall total mass and RMW percentage. This may be explained by variations in practice within different endoscopy units. Regarding total mass, in our study, the entire endoscopy pathway carbon footprint was not assessed (eg, waste generated in preprocedure and postprocedure areas, waste from sharps containers and that from endoscope reprocessing were not accounted for). Additionally, in Portugal, not all endoscopic procedures are conducted under deep sedation with propofol, as illustrated in the study's results. Therefore, materials used by anaesthesiologists were not always part of our unit's daily waste register. These could explain total mass dissimilarities between studies. As for RMW differences, at the authors' unit, at the end of a working day, suction canisters containing aspiration fluids are disposed as RMW, even if not reaching their total capacity. Moreover, all endoscopists wear PPE, which were disposed of after every procedure as RMW to comply with the COVID-19 pandemic contingency plans.[20] One of the messages emphasised to staff during this study was the correct disposal of non-contaminated PPE as landfill waste. Still, some PPE may have accounted for RMW generation. During the last stage of the study, the authors conducted a subanalysis on the proportion of total waste represented by PPE. This represented 35.5% of the overall waste, surpassing the 8% referred by Namburar *et al*[9] most likely as a reflection of different realities concerning PPE regulations. Also, in our unit, supplies composed of both metal and plastic, including devices used during endoscopic

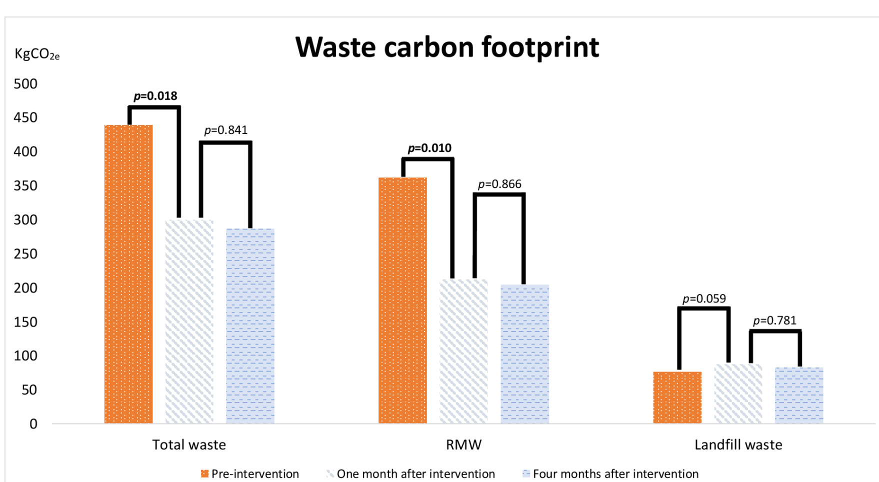

Figure 4 Waste carbon footprint. RMW, regulated medical waste.

Table 5 Waste processing expenses

	Preintervention	One month after intervention	Four months after intervention		
	Total	Total	Total	P value*	P value†
Landfill waste, € (%)	76.6 (6)	87.8 (11.1)	82.6 (10.8)	0.059	0.781
RMW, € (%)	1207 (94)	707 (88.9)	680 (89.2)	**0.010**	0.866
Total, €	1283.6	794.8	762.6	**0.012**	0.857

Bold means statistically significant.
€—disposal of landfill and RMW cost 1€ per kg and 10€ per kg, respectively.[11]
*P value for preintervention versus 1 month after intervention based on paired-samples t-test.
†P value for 1 month after intervention versus 4 months after intervention based on paired-samples t-test.
RMW, regulated medical waste.

procedures are either single use (eg, polypectomy snares, net retrieval devices) or reusable (eg, biopsy forceps). These items are considered to be fully contaminated with infectious agents, blood or body fluids from the patients, precluding its recycling. Therefore, if devices are single use, these are classified as RMW.

Potential areas of intervention, such as reducing single-use devices, may modify the carbon footprint generated by endoscopic waste. As stressed by Namburar *et al* the use of single-use endoscopes may increase the overall carbon footprint burden related to endoscopic procedures.[9] In our unit, all endoscopes are reprocessed. Still, we may speculate that this analysis could be extended to certain devices such as biopsy forceps, since the amount of waste created by disposable biopsy forceps is also significantly higher in comparison to reusable forceps.[7] In the same line of thought, endoscopic therapeutic procedures mainly use single-use and non-recyclable accessories, such as polypectomy snares, diathermy pads and net retrieval devices. Most of these products are considered non-recyclable, being directly disposed as landfill or RMW.[1] According to Siau *et al* only through manufacturers' disclosure will it be possible to directly assess the carbon footprint associated with these single-use devices.[1] Nevertheless, future studies are required to assess the potential benefit of reusable devices within endoscopy.

This study conclusively showed that endoscopy waste carbon footprint can be reduced by implementing simple actions such as recycling and educating endoscopy staff. It is established that nearly 40% of healthcare-related waste is recyclable, but culminates in incineration or disposal as landfill waste.[1,21] It is important to state that the destination of recyclable materials was guaranteed. Our hospital centre is provided with an adequate recycling partner (Stericycle Portugal/Ambimed) that guarantees that all recyclable hospital waste is accurately sorted, dismantled and led to the correct process.

De Melo *et al* highlighted that educating endoscopy staff on how to adequately dispose of endoscopic debris, to achieve a target percentage of RMW, would probably have a major repercussion on waste reduction.[7] In the current study, after the intervention, a 41.4% decrease in RMW production was observed, which corresponded to a €500 waste disposal cost reduction. This demonstrates that an educational intervention has a major impact, not only on the environment but also on the endoscopy-related expenses associated with unnecessary RMW disposal.[7] As stated, the main culprits that led to the reduction of RMW were the significant number of inappropriately placed PPE, endoscopy disposables and paper from hand washing and drying, due to container index locations before the intervention, which were leading to systematic waste misclassification. Unit reorganisation regarding more intuitive waste handling (recycling bins near the disposal endoscopic cabinets, or RMW away from washbasins), correct waste segregation and raising endoscopy staff awareness were easily implemented, low-cost and effective. These should probably be the first steps towards 'greener' endoscopy units. Importantly, these goals were achieved without interfering with the overall endoscopic productivity or daily work routine of staff members. After the intervention, gradual attention towards recycling was noted, staff members were unanimously enthusiastic and recycling is now definitely set up for long-term application at the authors' unit, as observed in stage 4 that took place 4 months after the intervention.

Estimates reveal that one endoscopic procedure generates an average of 2.1 kg of waste.[9] Still, Namburar *et al* did not specify whether this amount of waste was only applicable to diagnostic endoscopic procedures.[9] The current study quantifies the exact amount of waste and respective carbon footprint of both diagnostic upper endoscopies and colonoscopies. This analysis and data may be of importance for several reasons, for example, to define the sustainability of a colorectal cancer screening program. Comparing both diagnostic upper endoscopy and colonoscopy, total waste production was similar and potential recycling waste ranged from 0.2 to 0.3 kg.

In this study, the authors found that with adequate waste handling and segregation, waste carbon footprint could suffer a reduction after the intervention of 138.8kgCO_{2e}, and 1665.6kgCO_{2e} over the course of 1 year. This reduction is equivalent to 349 and 4186 miles driven by an average passenger vehicle, respectively.[22] Global scale studies are required to accurately analyse not only the environmental, but also the overall economic impact of reducing CO_{2e} related to endoscopic procedures within endoscopy units worldwide.

Our study has limitations that should be acknowledged. As this study was performed during the COVID-19 pandemic, PPE were accounted for waste production, therefore waste generation may not be reproducible in a different scenario.

The results obtained in our study may reflect an underestimate of the total carbon footprint related to endoscopic procedures, as this study focusses on waste generation, which is a particular and modest aspect of the overall endoscopy carbon footprint. According to Chua *et al* waste disposal represented approximately 2% of the carbon footprint generated by interventional radiology procedures.[23] Similarly, Whiting *et al* study on the carbon footprint generated per hour of surgery (excluding anaesthetic gases), concluded that waste was responsible for less than 1% of the total carbon footprint.[24] Although waste production and disposal are one of the key and easy-to-note carbon footprint drivers, there are many other contributors to account for. Both these studies raise awareness to the fact that energy (total heating, ventilation, and air conditioning) and single use consumables represent approximately 90% of the carbon footprint, in these specific settings.[23,24] These data might be extrapolated to the field of endoscopy, not only because it is a very energy-intensive healthcare area, but also due to the large number of single-use consumables used in every endoscopic procedure. Indeed, waste represents a small proportion of the carbon footprint and to estimate the total CO_{2e} generated by endoscopy several other aspects would have to be considered. Carbon emissions related to energy consumption, such as operational resource use (lighting, heating, air conditioning) and equipment reprocessing depict important example sources of carbon dioxide emissions, which were not assessed in our study. In addition, the waste in the preprocedure and postprocedure areas was also not accounted. The study exclusively included the waste generated within the endoscopy suite. Assessing waste produced in the preprocedure and postprocedure areas of our endoscopy unit would reduce reproducibility and increase heterogeneity (eg, endoscopic procedures with and without deep sedation). Future studies assessing the entire endoscopy pathway could further elaborate on the preprocedure and post-procedure carbon footprint. Similarly to Namburar *et al* we also did not account for the waste in sharps containers.[9] Lastly, this is a single-centre project and workload at the authors' endoscopy unit cannot be considered of high volume, which may hamper generalisation to high volume endoscopic units. However, the implementation of such a study in a smaller public endoscopy unit allowed a rigorous control of all variables to be collected and the educational intervention in 100% of the staff, thus assuring their maximal compliance.

Our study has other strengths that should be highlighted. To the authors' knowledge, this is the first prospective interventional study assessing the waste carbon footprint of an endoscopy unit, before and after reorganisation and implementation of recommended waste sorting grid for endoscopic procedures; this also included assessment of endoscopy unit staff's awareness, enthusiasm and compliance regarding a greener practice. Performance bias was eliminated by rendering the weighing process with an engineer-calibrated scale, and data registration was always performed by the same two physicians. Importantly, the results of the reassessment phase, 4 months after the intervention, stress that the behavioural conducts persist and that staff are motivated and continue to allocate waste in the appropriate streams. This reassures the authors that the intervention was successful in maintaining the staff highly engaged, and that these appear to be, in fact, feasible first-line strategies to reduce the carbon footprint of endoscopic procedures.

In conclusion, this study demonstrated that it is possible to decrease the waste carbon footprint, by establishing step-by-step actions, such as correct waste segregation and disposal. While some aspects of the carbon footprint of endoscopy units may be unavoidable, the vast majority of obstacles are universal and should be faced conscientiously.

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