



# Measuring Medical Waste from Gastrointestinal Endoscopies in South Korea to Estimate Their Carbon Footprint

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**Background/Aims:** Although gastrointestinal endoscopy (GIE) is a major contributor to the carbon footprint of national healthcare, the amount of medical waste generated by GIE procedures is not reported in South Korea. This study aimed to measure the amount of medical waste generated from GIE procedures in South Korea.

**Methods:** We conducted a 5-day audit of medical waste generated during GIEs at seven hospitals. During the study period, medical waste in the endoscopy examination rooms was measured twice daily and documented as mass (kg). To calculate the mean mass of disposable waste generated during one esophagogastroduodenoscopy (EGD) and one colonoscopy, the mean mass of medical waste generated from seven examinations was calculated. The mean mass of medical waste generated during GIEs was calculated by dividing the total mass of medical waste generated by the number of GIE procedures.

**Results:** Overall, 3,922 endoscopies were performed and 4,558 kg of waste was generated. The mean weight of medical waste generated per endoscopy was 1.34 kg. Each EGD and colonoscopy generated a mean of 0.24 kg and 0.43 kg of disposable waste, respectively. Applying the mean waste estimates from this study to annual GIE procedures performed in South Korea in 2022 showed that the total medical waste produced from GIE was 13,704,453 kg. In addition, the total masses of medical waste produced during EGD and colonoscopy procedures were 819,766 kg and 2,889,478 kg, respectively.

**Conclusions:** Our quantitative measurement showed that a large amount of medical waste is generated from GIE procedures. However, further research is warranted to reduce medical waste generated during GIE, which is an urgent unmet need. (*Gut Liver* 2025;19:43-49)

**Key Words:** Carbon footprint; Gastrointestinal endoscopy; Medical waste; Green endoscopy; Sustainability

## INTRODUCTION

The planet is experiencing climate crisis, which can have catastrophic consequences for human beings unless greenhouse gas emissions fall dramatically. Carbon footprint (CF) is defined as the total amount of greenhouse gas emissions caused directly and indirectly by an individual, event, organization, or production process, and

is expressed as carbon dioxide equivalent (CO<sub>2</sub>e).<sup>1</sup> CF is relevant to all fields, healthcare being no exception. On a global level, in 2014, the healthcare industry was responsible for 5.5% of the total national CFs of Organization of Economic Co-operation and Development countries.<sup>2</sup> During the past 10 years from 2007 to 2016, healthcare CF has increased by 75% in South Korea.<sup>3</sup> One reason for this is the growing number of gastrointestinal endoscopy (GIE)



procedures being performed. By its very nature, GIE is a major contributor to the national healthcare CF.<sup>4</sup> Endoscopy emits the third highest amount of waste in hospital.<sup>5</sup> The procedure leads to huge amounts of non-recyclable medical waste.<sup>6</sup> Recent preliminary studies also suggested that GIE is one of the largest polluters and waste generators.<sup>1</sup>

However, few reports have revealed the amount of medical waste generated by GIE (hereafter referred to as “GIE waste”), and these reports are mostly from the USA.<sup>7,8</sup> Gayam<sup>7</sup> reported that a single GIE procedure generates 1.5 kg of plastic waste in West Virginia University Medicine Hospital West Virginia, USA. Namburur *et al.*<sup>8</sup> also measured GIE waste through a 5-day audit of all GIEs performed at two academic medical centers in the USA with a low and a high endoscopy volume. They found that each endoscopy generated 2.1 kg of disposable waste, and 64% of this waste was sent to the landfill. GIE waste may differ by country as per the specific practices involved.

Considering that GIE waste has a significant impact on CF, it is important to formally quantify GIE waste in South Korea. In this study, we measured GIE waste at seven hospitals to estimate the GIE waste generated in South Korea.

## MATERIALS AND METHODS

### 1. Study design

We performed an audit of GIE waste at seven university or tertiary hospitals over 5 working days (October 2023) in South Korea. We documented the number and type of GIE procedures performed and calculated the disposable waste generated by them. The following GIE procedures were audited: esophagogastroduodenoscopy (EGD), colonoscopy, sigmoidoscopy, endoscopic retrograde cholangiopancreatography (ERCP), and endoscopic ultrasound. Specific therapeutic interventions, such as endoscopic resection and stent insertion, were not audited as the number of procedures for such interventions varies widely between hospitals. During the study period, medical waste in the endoscopy examination rooms was documented as mass (kg) after the last endoscopic procedure scheduled in the morning and afternoon, twice daily. Medical waste was measured using the same pre-determined method in each hospital with the same scale, which was provided to each hospital before the start of this study. We measured the mass of medical waste kept in trash bags in grams and converted it to kilograms. Each day, medical waste was collected in a designated trash bag. We measured the mass of medical waste in the pre-procedure and post-procedure areas and in the endoscopy examination rooms. And we

also obtained waste from endoscope reprocessing. Therefore, the total mass of medical waste is the sum of all these measurements. Waste from the patient waiting area or staff break rooms and instruments that were collected as sharp objects in separate containers were not included in the measurement. The mean weight of medical waste generated by each endoscopy was calculated by dividing the total mass of GIE waste generated by the number of GIE procedures performed during the 5-day audit. To calculate the mean disposable waste generated during one EGD and colonoscopy, the mean value of medical waste generated from seven examinations was calculated. Therefore, weight per one EGD and colonoscopy includes only the waste weight from own examination.

This study was approved by the Institutional Review Board of Kyung Hee University Hospital at Gangdong, Seoul, Republic of Korea (IRB number: KHNMC 2023-12-036). Written informed consent was waived as this study did not require personal identity data.

### 2. Annual nationwide endoscopy volume

We used the mean waste generated per endoscopy at each hospital as the representative value to calculate the annual GIE waste in South Korea. We used the latest annual data on endoscopies performed in South Korea in 2020 and 2022. Annual nationwide endoscopy volume was obtained from the Health Insurance Review and Assessment (HIRA) Bigdata Open portal (<https://opendata.hira.or.kr/>). HIRA data are generated in the process of reimbursing providers under the National Health Insurance program and contain comprehensive information on the relevant healthcare services, including procedures, operations, examinations, treatments, and prescriptions.<sup>9</sup> Procedure codes in physician claims databases had a considerably high level of agreement with data in medical charts. The index date for extracting the study data from the HIRA database was April 13, 2024.

### 3. Definition of endoscopic procedures

We used the most recent annual data of GIEs performed in South Korea in 2020 and 2022. As the most common GIE procedures are EGD, colonoscopy, and ERCP, their annual procedure volumes were calculated from the HIRA database. Based on the definition of HIRA Bigdata Open portal, endoscopic procedures were defined as follows: EGD without (E7611, E7612) or with tumor resection (Q7651, Q7652, QZ933, QQ7653, Q7654); colonoscopy without (E7660, E7680, E7670) or with tumor resection (Q7701, Q7702, Q7703, QX706); ERCP without (E7621 or E7622) or with therapeutic intervention (Q7761, Q7762, Q7763, Q7764, Q7765, Q7766, Q7767).

**Table 1.** The Number of Endoscopies and Their Mass of Medical Waste from Seven Hospitals during 5-Day Audit

Variable	Severance Hospital	Kyung Hee University Hospital at Gangdong	Inje University Sanggye Paik Hospital	Cha Bundang Medical Center	Bundang Jesaeng General Hospital	Seoul National University Hospital	Soonchunhyang University Cheonan Hospital	Total
No. of procedures								
EGD	486	339	103	200	472	456	284	2,340
Colonoscopy	205	69	70	102	272	190	153	1,061
Sigmoidoscopy	39	8	12	19	9	49	20	156
ERCP	69	9	8	32	9	75	15	217
EUS	52	14	12	16	3	37	14	148
Total	851	439	205	369	765	807	486	3,922
Mass of medical waste, kg	1,367	467	259	382	562	1,221	300	4,558
Mean medical waste of GIEs	1.61	1.38	1.26	1.04	0.73	1.51	0.62	1.34
Waste per endoscopy, kg								
EGD	0.28	0.15	0.05	0.19	0.32	0.33	0.35	0.24
Colonoscopy	0.35	0.35	0.12	0.45	0.61	0.67	0.44	0.43

EGD, esophagogastroduodenoscopy; ERCP, endoscopic retrograde cholangiopancreatography; EUS, endoscopic ultrasound; GIE, gastrointestinal endoscopy.

#### 4. Statistical analysis

No specific statistical analyses were conducted.

## RESULTS

### 1. Endoscopic procedure waste

During the 5-day audit, 3,922 endoscopies (2,340 EGD, 1,061 colonoscopy, 156 sigmoidoscopy, 217 ERCP, and 148 endoscopic ultrasound) were performed at seven hospitals and total waste produced (including personal protective equipment) weighted 4,558 kg (Table 1). Table 2 enumerates materials discarded following a single endoscopic procedure and after reprocessing the endoscopy. The mean daily mass of medical waste in each endoscopy unit was 651.1 kg, and the weight of medical waste in each hospital varied from 259 to 1,367 kg. The mean weight of medical waste generated by each endoscopy was 1.34 kg, and each EGD and colonoscopy generated a mean of 0.24 kg (range, 0.05 to 0.35 kg) and 0.43 kg (range, 0.12 to 0.61 kg) of disposable waste per procedure, respectively.

### 2. Endoscopic procedure waste in South Korea

The annual number of GIE procedures increased from 8,829,121 in 2020 to 10,311,225 in 2022 in South Korea (Table 3). In 2022, hospitals in South Korea performed 3,499,713 EGD; 6,719,716 colonoscopy; and 91,795 ERCP procedures. When applying the mean waste estimates from this study to GIE procedures performed in 2022, the total medical waste produced from GIE (including EGD, colo-

**Table 2.** Waste Generated by an Endoscopic Procedure and the Reprocessing of the Endoscope

Waste generated by an endoscopic procedure	Waste generated by reprocessing the endoscope
Plastic box that contains 4×4 gauze	Gloves
Plastic water bottle	Gown
Plastic mouthpieces*	Face shield
Plastic suction canister	Hair covering
Plastic suction tubing used for endoscopy	Sponge and wipe for precleaning
Plastic Isolysr bottle	Container for transport the endoscopy
Plastic packaging of biopsy forceps	Sponge and wiper for cleaning
Plastic packaging of disposable scope buttons	Channel brush
Gloves	Valve cylinder brush
Gown	Flushing tube
Face shield	Germicidal wipe transport container
Hair covering	Germicidal wipe sink

\*Not needed for colonoscopy.

noscopy, and ERCP) was 13,704,453 kg. In addition, the total medical waste produced from EGD and colonoscopy procedures were 819,766 kg, and 2,889,478 kg, respectively. Since EGD and colonoscopy are relatively straightforward procedures, we assumed that the total amount of medical waste generated would not vary significantly based on the specific indications for the procedures or individual patient factors such as diagnosis/treatments or various comorbidities. Therefore, medical waste generated from EGD and colonoscopy was measured separately. Based on calculations in Gayam's study,<sup>7</sup> the total GIE waste in 2022 in South Korea was about 36.0% of that in the USA and

could cover approximately 42.1 soccer fields to a height of 1 m (Fig. 1A). Considering the number of endoscopic procedures performed in 2022 in South Korea, previous calculations estimate a CF of 11,456,238 tCO<sub>2</sub>e based on the National Green House Inventory Report of Korea in 2022,<sup>10</sup> which is equivalent to the CF of 2,727 gasoline-powered passenger vehicles driven for 1 year in the USA; consumption of 4,879,247 L (1,289,101 gallons) of gasoline; burning 5,726,899 kg (12,625,652 lbs) of coal; or the electricity usage of 2,261 homes in the USA for 1 year in 2024.<sup>11</sup> Sequestering that amount of CO<sub>2</sub> would require 54 km<sup>2</sup> (13,375 acres) of U.S. forests over 1 year (Fig. 1B). Notably, these simple calculations do not include waste that is incinerated, such as from containers with sharp edges/objects, or the environmental impact from producing endoscopy supplies.

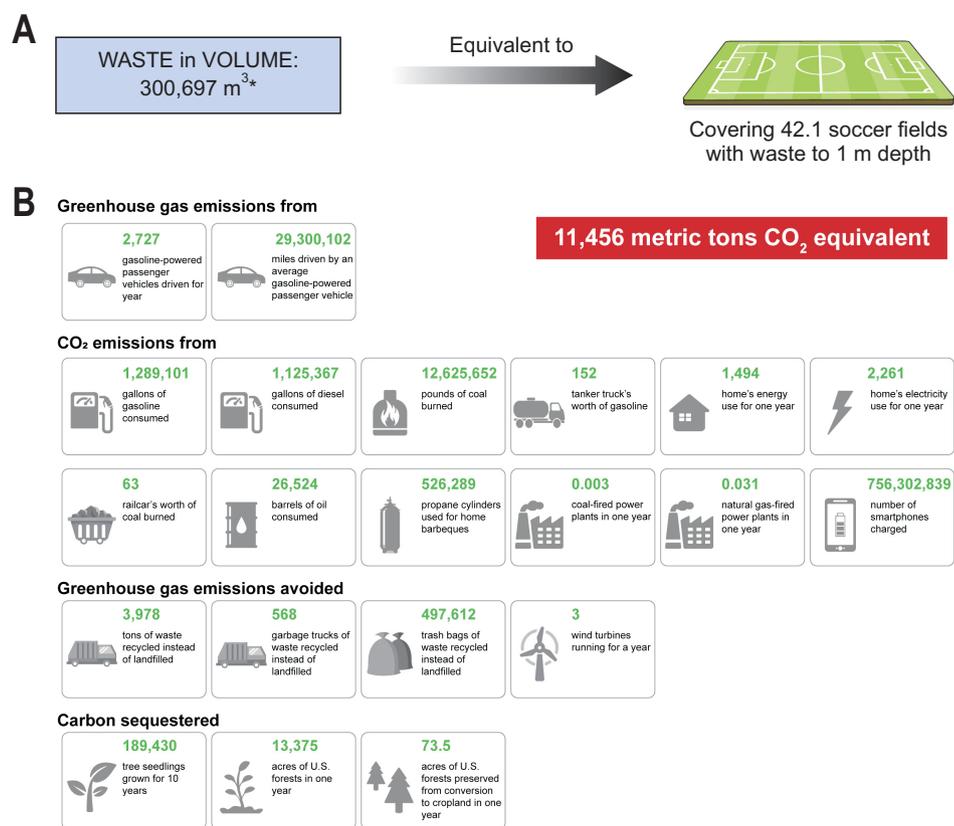
**Table 3.** Annual Number of Gastrointestinal Endoscopy Procedures Performed in 2020 and 2022

Type of endoscopy	Annual volume of endoscopy		
	2020	2021	2022
EGD	3,391,563	3,470,783	3,415,692
EGD with tumor resection	65,556	79,104	84,021
Colonoscopy	2,948,049	3,251,666	3,219,347
Colonoscopy with tumor resection	2,340,953	3,003,363	3,500,369
ERCP	13,236	13,607	15,038
ERCP with therapeutic intervention	69,764	76,711	76,757
Total	8,829,121	9,895,234	10,311,225

EGD, esophagogastroduodenoscopy; ERCP, endoscopic retrograde cholangiopancreatography.

## DISCUSSION

To the best of our knowledge, this is the first study to quantify GIE waste in South Korea. Our study is essential as it can raise awareness of green endoscopy. In our previous report,<sup>12,13</sup> we showed the low awareness of green endoscopy for GIE procedures in South Korea. In the current study, the amount of GIE waste was about 1.34 kg per



**Fig. 1.** Endoscopic procedure waste in South Korea. (A) Estimates of disposable waste generated annually during endoscopic procedures in South Korea. (B) The annual carbon footprint of endoscopy in the South Korea. Estimates are based on energy use and calculations of plastic waste disposal. \*Not including waste from reprocessing of endoscopes.

endoscopy, 0.24 kg per EGD, and 0.43 kg per colonoscopy, respectively. The mean weight of medical waste (1.34 kg) generated by each endoscopy in this study was slightly lower than that (1.5 kg) in a study conducted in the USA.<sup>7</sup> In our study, the amount of generated waste was similar between the participating hospitals, which may indicate that our estimate of GIE waste is fairly accurate. However, there were some differences in endoscopic practices between the participating hospitals, including use of disposable gowns. When applying the mean waste estimates from this study to annual volume of GIE procedures performed in South Korea, the total medical waste produced from GIE was 13,704,453.4 kg. In addition, the total medical waste produced from EGD and colonoscopy procedures were 819,766 kg and 2,889,478 kg, respectively, in 2022. When comparing South Korea with USA, the total amount of medical waste produced by GIEs in South Korea is estimated to be about 36.0% of that in the USA.<sup>8</sup> This is quite a large amount of waste production considering the population size and economic scale of South Korea compared to those of the USA. In addition, the annual medical waste from GIE of South Korea could cover several soccer fields.<sup>8</sup> However, annual endoscopy figures of this study only captured reimbursement data billed through the HIRA system and do not include non-reimbursed cases, such as health check-up endoscopies. Therefore, the actual figures of GIE volume and associated medical waste may have been underestimated.

According to Gayam's study in the USA, materials disposed of after one endoscopic procedure and one GIE procedure generated 1.5 kg of plastic waste.<sup>7</sup> However, that assessment was limited as the study did not include all components related to performing an endoscopy and the pre- and post-GIE procedures. Namburath *et al.*<sup>8</sup> conducted a 5-day audit in high- and low-volume hospitals in the USA and reported that one GIE procedure generated 2.1 kg of disposable waste. They comprehensively captured all pre-procedure and post-procedure wastes as well as intra-procedure wastes. Therefore, they reported a larger volume than Gayam's study<sup>7</sup> and the current study. When these amounts of GIE waste are applied to the annual endoscopy volume in the USA, which is 18 million procedures, the weight of total endoscopic waste would be equivalent to 25,000 passenger cars, enough to cover approximately 120 soccer fields to 1 m depth.<sup>8</sup> However, both studies were published in the USA, and it should be noted that GIE practices may differ between the USA and South Korea.

Although this study is only a small step ahead for GIE CO<sub>2</sub>e research, it could be a giant leap for green endoscopy in South Korea as it can bring awareness to the importance of green endoscopy.<sup>12,13</sup> Recently, a position statement to

reduce the environmental footprint of GIE was released by the European Society of Gastrointestinal Endoscopy and the European Society of Gastroenterology and Endoscopy Nurses and Associates.<sup>14</sup> In this statement, immediate actions to reduce the environmental impact of GIE were recommended. They also recommended rational use of GIE to avoid unnecessary procedures, digitalization, an outpatient basis procedure rather than inpatient procedure, and minimization of single-use devices. To make endoscopy sustainable, these interventions can be applied at the national, hospital, and individual levels.<sup>1</sup> At the individual level, the recommendations include use of reusable caps, reusable clothes and shoes, avoiding use of plastic cup, adequate waste segregation, use of telemedicine, using bike or public transport, virtual training, and switching off computers.<sup>14</sup> In particular, it is important to implement these changes at an individual level; a step-by-step change will ultimately reduce the CF of the healthcare system.

It is clear that a reuse and recycle approach is more environmentally sustainable; therefore, green endoscopy interventions recommend minimizing the use of single-use devices as well as single-use scopes. For example, at least 2,000 procedures may be performed with one reusable endoscope.<sup>8</sup> However, doing so does involve some risk of infection transmission during GIE procedures. The estimated rate of healthcare-associated infection from GIE is about 1 out of 1.8 million procedures.<sup>15</sup> In addition, 400 cases of multidrug-resistant organism outbreaks and over 20 deaths were reported between 2000 and 2017, which translates into an overall death risk of 1 out of 150,000 ERCPs.<sup>16</sup> More recently, however, the infection rate has been decreasing owing to the rigorous reprocessing protocol of GIE.<sup>17</sup> A single-use endoscope was shown to be associated with up to 40% increase in medical waste mass after accounting for the lack of waste from reprocessing.<sup>8</sup> Therefore, the balance between the environmental impact and transmission risk of infection from GIE procedures is complex, and further research is required on this complicated issue.

This study has several limitations. First, our data were based on GIE waste collected from seven hospitals, which may not adequately represent the GIE procedures conducted across different types of hospitals throughout South Korea. Depending on the characteristics of the medical institution, the amount of medical waste generated from EGD and colonoscopy seems to vary. In this study, only the amount of medical waste in each hospital was measured; however, the reasons for the deviation were not identified. Therefore, further research is warranted from varied GIE procedures and hospitals of various sizes. Second, a 5-day audit may not be a sufficiently long period to obtain a

reliable measure of GIE waste. A longer-term audit is necessary as GIE practices may vary day by day. We did not capture all endoscopic procedures from endoscopy rooms during our audit. Specific therapeutic interventions such as endoscopic resection and stent insertion were not measured. However, annual endoscopy figures obtained from the HIRA system do not include non-reimbursed cases; thus, the actual mass of medical waste from endoscopies may be much higher. Third, we could not measure energy use and water consumption, which is also essential for GIE procedures. Reprocessing of GIE requires energy along with a large amount of clean water and chemicals, which generates potentially toxic water.<sup>7</sup> Disposal of waste during reprocessing may particularly vary in each hospital, warranting further study. In addition, the recyclable portion of the total GIE waste could not be measured in our study. To know the disposition of waste, including recycling material, may help to minimize waste. Finally, the impact of single-use endoscopes on waste generation was not considered in this study, as it is not still available in South Korea. Considering the particular relevance of single-use endoscopes to the national CF,<sup>18</sup> this issue should be included in future studies.

In conclusion, our quantitative measurement showed that a large amount of medical waste is generated by GIE procedures. We should direct our efforts toward environmentally sustainable endoscopy to align with global environmental concerns. Further research on green endoscopy is warranted to reduce CFs from GIE.

## CONFLICTS OF INTEREST

H.J.L. is an editorial board member of the journal but was not involved in the peer reviewer selection, evaluation, or decision process of this article. No other potential conflicts of interest relevant to this article were reported.

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## AUTHOR CONTRIBUTIONS

Study concept and design: D.H.J., J.M.C. Data acquisition: D.H.J., H.J.L., T.J.J., Y.S.C., B.R.K., N.S.Y., J.M.C. Data analysis and interpretation: D.H.J., J.M.C. Drafting of the manuscript: D.H.J., J.M.C. Critical revision of the manuscript for important intellectual content: J.M.C. Statistical analysis: J.M.C. Study supervision: J.M.C. Approval of final manuscript: all authors.

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