

## ORIGINAL ARTICLE

# Environmental sustainability in the operating room

## *A worldwide survey among anaesthesiologists*

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**BACKGROUND** The healthcare industry carbon footprint is 5.2% of total CO<sub>2</sub> equivalent emissions worldwide. The operating rooms are the most resource demanding areas in hospital care and the higher energy demands, lack of effective waste management, and inhaled anaesthetic use, lead to a high carbon footprint. There is wide variation in the carbon footprint of inhaled gases, with desflurane ranking 40 times higher than sevoflurane. Other inhaled agents, including N<sub>2</sub>O and isoflurane, have additional ozone-depleting properties.

**OBJECTIVE** To describe what factors influence the implementation of sustainable anaesthetic strategies.

**DESIGN** An international survey.

**SETTING** Anaesthesia clinicians worldwide between April 2021 and April 2022.

**PARTICIPANTS** One thousand two hundred and thirty-seven anaesthesia clinicians from 75 countries.

**MAIN OUTCOME MEASURES** The primary outcome was a determination of the most used anaesthetic plans among anaesthesia practitioners. Secondary outcomes included an assessment of the influence of various socioeconomic variables on anaesthetic decision-making, and on the level of the practitioners' awareness of peri-operative environmental sustainability.

**RESULTS** Sixty-four percent of respondents use inhaled anaesthetics on a daily basis, with 83% preferring sevoflurane, and only 5% using N<sub>2</sub>O regularly. Forty-five percent do not know which halogen gas has the highest carbon footprint. Fifty-one percent do not use low flow anaesthesia regimes (<1.0 l min<sup>-1</sup>) due to concerns about CO<sub>2</sub> rebreathing (30%), hypoxia (25%), compound A related renal failure (12%) or CO generation (10%). Only 15% use minimal flow anaesthesia (<0.5 l min<sup>-1</sup>). There is a correlation between higher income countries and implementation of more sustainable strategies, probably due to better access to updated technology and sustainability education programmes. Desflurane is used in 6 to 12% of the cases regardless of the GDP index.

**CONCLUSIONS** Halogen gases are the most frequently used anaesthetic drugs worldwide. The majority of respondents are unaware of their global warming impact, or are not influenced in their anaesthetic choices by environmental concerns. More sustainable alternatives of anaesthesia are under-implemented, and vary significantly among countries depending on their GDP index. Further education and training in sustainability is needed.

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## KEY POINTS

- Worldwide, a significant number of anaesthesiologists are unaware of their daily carbon footprint.
- Inhaled anaesthetics have different levels of global warming potential, and are the most frequently used anaesthetic drugs worldwide.
- High-income countries have better access to technology that provides for more environmentally sustainable care.
- Raising awareness and improving education, despite differences in national socioeconomic backgrounds, is essential to reduce the peri-operative carbon footprint.

## Introduction

Anthropogenic Green House Gas (GHG) emissions have continued to rise rapidly in the last decade<sup>1</sup> in spite of increased public and political awareness of climate change. Even though the COVID-19 pandemic resulted in a temporary drop of fossil fuel and industry emissions in the first half of 2020, they rebounded by the second half of 2020.<sup>2</sup> The Intergovernmental Panel on Climate Change (IPCC) report states a likely exceedance of global temperatures above 1.5°C by 2030. Therefore, a significant reduction of GHG emissions in the upcoming century is urgently needed.<sup>3,4</sup> Healthcare contributes to global net emissions with a share of 4.7% in the European Union, which ranks as the third largest contributor to the global healthcare industry footprint, with a share of 12% after the United States (27%) and China (17%).<sup>5,6</sup> As rising planetary temperatures are one of the biggest threats to health this century,<sup>7</sup> healthcare systems should have an intrinsic motivation to lead by example.

Volatile anaesthetic agents have been estimated to be responsible for 0.01 to 0.10%<sup>8–10</sup> of total global carbon dioxide equivalent (CO<sub>2</sub>e) emissions contributing to global warming. On the basis of atmospheric sampling of volatile anaesthetics, their accumulation is increasing, particularly desflurane,<sup>10–13</sup> which has the highest warming potential among all anaesthetic gases.<sup>10</sup> Although these are a seemingly small contribution to total global emissions, inhaled anaesthetics account for 5% of acute hospital CO<sub>2</sub>e emissions, and up to 50% of peri-operative department emissions in high-income countries.<sup>10–13</sup> Use of these anaesthetics is directly within the control of anaesthesia providers, with often more sustainable alternatives available. Thus, environmental stewardship is an important opportunity for GHG mitigation and professional sustainability leadership.<sup>10</sup> A significant global variability exists in anaesthetic practice due to differences in the socioeconomical, infrastructural, and medical

situation, which might compromise sustainability programmes for anaesthesia.

There are only a handful of surveys<sup>14–18</sup> addressing the impact of peri-operative practice on sustainability, circumscribed on a national level. Therefore, the main objective of this questionnaire is to benchmark anaesthetic practice worldwide in order to determine its potential impact on sustainability, and the need to increase education programmes. Moreover, we wanted to assess the influence of socioeconomic variables in our anaesthetic practice, and the potential influence in sustainability outcomes.

## Materials and methods

We obtained prospective ethical approval for our survey (Ethical Committee No. PI-4630) from La Paz University Hospital Ethics Committee, Madrid, Spain (Chairperson Prof A. Castro Conde) on 23 March 2021.

The European Society of Anaesthesia and Intensive Care (ESAIC) and the Spanish Society of Anaesthesia and Critical Care (SEDAR) endorsed the survey in June 2021. Both institutions validated the questions asked, and provided feedback for this survey.

The questionnaire was preceded by a short text explaining that the survey was being conducted under ESAIC purview and General Data Protection Regulation (GDPR) protection. Consent was implied with survey completion.

The survey is an international cross-sectional study, distributed online over one year (April 2021 to April 2022) by different ways and means in order to reach anaesthesiologists worldwide (Supplementary File 1, <http://links.lww.com/EJAIC/A49>). Once the link was received, the respondent was allowed to anonymously answer the questionnaire, which was available in English and Spanish. Incomplete or repeated surveys were discarded as invalid answers.

The survey consisted of 14 sustainability questions, and seven more to assess demographic data. We gathered opinions from anaesthesiologists (residents and specialists), anaesthesia nurses and veterinary anaesthesiologists about their choice of anaesthetic agents, use of low-flow anaesthesia and anaesthetic carbon footprint awareness (full questionnaire available in Supplementary File 2, <http://links.lww.com/EJAIC/A50>). Questions 1 to 3 enquired about anaesthetic agent choice. Questions 4 to 9 asked about low flow anaesthesia and the potential risks involved. Questions 10 to 14 gathered information about the carbon footprint of anaesthesia. Questions 15 to 21 collected demographic data.

Data obtained from this survey were geographically distributed by continents and cross-matched against three different World Development Indicators from the World Bank Database: CO<sub>2</sub> emissions (metric tons

per capita), Gross Domestic Product (GDP per capita: current US\$) and current health expenditure (% of GDP). In order to compensate for sampling bias from under-represented regions, we aggregated countries into continents, and distributed their socioeconomic results into quintiles. Thus, comparisons are based on groups of countries with similar geographical and socioeconomic indices, instead of on purely national basis (Supplementary Tables 1S, 2S and 3S, <http://links.lww.com/EJAIC/A46>).

### Statistical analysis

Data were processed using the SAS programme, version 9.4 (SAS Institute Inc. 2013, Cary, North Carolina, USA). Incomplete answers were discarded. Statistically significant differences were considered with a probability of error less than 5% ( $P < 0.05$ ). For the description of continuous quantitative variables, mean value was used together with standard deviation. Qualitative variables were described by absolute frequencies, and relative frequencies expressed as a percentage. Comparisons between continuous quantitative variables among independent groups were assessed using Student's *t*-test, or ANOVA when the analysis involved three or more groups. Statistical significance was obtained using non-parametric tests, Kruskal–Wallis or Mann–Whitney *U* when, in absence of normal distribution, use of discontinuous quantitative variables, or when stratification of subgroups implied a sample size of less than 30 individuals. The analysis of frequencies between qualitative variables was carried out using the Chi-square test (with Yates' correction) or Fisher's exact test when necessary.

### Results

One thousand two hundred and eighty-five online responses were received between April 2021 and April 2022 from 75 different countries. Forty-eight responses were not valid due to missing values (96% valid rate).

Among respondents, 878 (71%) were anaesthesiologists (consultant level), 219 (18%) anaesthesia residents, 7 (1%) anaesthesia nurses, 97 (8%) shared management and clinical duties (chairperson or section chief), and 36 (3%) were veterinary anaesthesiologists. The survey was completed by 657 men (53%), 572 women (46%) and eight respondents who preferred not to declare sex (1%). Age had a pyramidal representation with fewer responses in both extreme groups. One thousand and fifty-four (85%) of responses came from Europe and South America (Table 1). Seven hundred and fifty-five (61%) of respondents worked in countries with a GDP higher than p50.

### Type of anaesthesia

Sixty-four percent of the respondents preferred inhaled anaesthetics and 23% total intravenous anaesthesia (TIVA), with the latter being more frequently used by experienced anaesthesiologists than by less experienced

**Table 1** Survey demographics

Age	Percentage	Number
< 25	0.2	3
25 to 29	8.7	108
30 to 39	30.2	374
40 to 49	24.9	308
50 to 59	23.4	290
> 60	12.4	154
Unit		
Day surgery	7.6	94
General surgery, urology & ENT	43.9	546
Neurosurgery	4.2	52
Cardiothoracic surgery	7.3	91
Paediatric surgery	13.5	168
OB / GYN surgery	4.8	60
Trauma & Orthopaedics surgery	8.0	99
Research & experimental surgery	0.2	3
Veterinary clinic	3.2	40
Other	6.8	85
Sex		
Male	53	658
Female	46	572
Prefer not to say	1	8
Role		
Resident/Fellow	17.6	219
Consultant	70.6	878
Managers	8.0	97
Anaesthesia nurse	0.6	7
Veterinary anaesthesiologist	3.2	40
Years of experience		
< 5	18.6	232
5 to 9	16.7	208
10 to 14	14.5	180
15 to 19	10.9	136
20 to 25	15.6	194
> 25	23.2	288
Geographic distribution		
Europe	59	735
South America	26	320
North America	6	80
Middle East	3	38
Asia	2	22
Africa	2	21
Central America	1	12
Australia & New Zealand	< 1	9

clinicians ( $P < 0.01$ ). The remaining 13% used other options on a common basis. Interestingly, veterinary surgery (85%), general surgery (73%), paediatric surgery (72%) and cardiothoracic surgery (70%) are the areas wherein inhaled anaesthetics are used most frequently, whereas neurosurgery (48%) is the area where TIVA is most commonly used (Figure 1S, <http://links.lww.com/EJAIC/A38>). Supplemental Figure 2S, <http://links.lww.com/EJAIC/A39>, shows anaesthetic preference according to clinical role ( $P < 0.001$ ).

With regards to the geographic distribution of preferences (Table 2), inhaled anaesthetics are the preferred option worldwide, and have the highest use rate in Africa. According to our data, Central America is the region where inhaled anaesthetics are used the least ( $P < 0.001$ ) (Supplemental figure 3S, <http://links.lww.com/EJAIC/A40>). Interestingly, if we filter our results per national CO<sub>2</sub> emissions criteria, we observe that the

**Table 2** What anaesthetic plan do you use more often?

Data in %	TIVA	Anaesthetic gases	Regional without sedation	Regional with sedation	i.v. sedation	Inhaled sedation	Number
Europe	27	65	2	6	1	0.5	736
North America	16	76	1	5	1	0	80
South America	18	60	3	16	2	2	319
Central America	8	33	17	33	8	0	12
Africa	5	81	5	10	0	0	21
Middle East	16	74	5	5	0	0	38
Asia	9	77	0.0	14	0	0	22
Australia & New Zealand	22	56	11	11	0	0	9
Number	278	796	31	110	14	8	1237

Preferred anaesthetic plan according to geographical region represented in percentages with absolute numbers in the last column and row. i.v., intravenous.

preference for inhaled anaesthetics is similar across the board (55–65% preference in all quintiles), whereas TIVA is used mostly in countries with a higher CO<sub>2</sub> footprint ( $P < 0.001$ ), and regional anaesthesia with sedation is used more in less CO<sub>2</sub> emitting countries ( $P < 0.001$ ). The same pattern arises if the data are filtered per GDP *per capita* (Fig. 1) and health expenditure (% of GDP).

#### Type of anaesthetic agent

Among those using inhaled anaesthetics, 83% preferred sevoflurane, 10% desflurane and 6% isoflurane in their clinical practice. Desflurane is most used in cardiothoracic (18%), otolaryngologic and general surgery combined (12%), and preferred by anaesthesiologists in management positions (20%). On the contrary, desflurane is seldom selected in neurosurgery (6%) or paediatric anaesthesia (3%), and was not used in this survey by anaesthesia nurses (0%), research anaesthesiologists (0%) or veterinarians (0%). This information is summarised in supplemental Figures 4S, <http://links.lww.com/EJAIC/A41> and 5S, <http://links.lww.com/EJAIC/A42>.

Sevoflurane is the most frequently preferred anaesthetic gas worldwide except in Africa, where its use (43%) equals isoflurane (43%). Interestingly, desflurane maintains a 10% use in this continent as well ( $P < 0.001$ ) (Table 3 and Fig. 2). There is little correlation between the national CO<sub>2</sub> footprint and the use of anaesthetic gas. There is a slightly higher isoflurane consumption (15%) in countries with fewer CO<sub>2</sub> emissions *per capita*, whereas sevoflurane is more often used in countries that produce more CO<sub>2</sub> *per capita*. Desflurane shows a constant preference across the board (6 to 12%) regardless of the level of CO<sub>2</sub> production *per capita*.

These differences are also shown when analysing GDP and health expenditure ( $P < 0.001$ ), with a higher isoflurane use in countries with the least GDP and healthcare expenditure *per capita* (26 and 19%, respectively). There is less desflurane use only in countries that belong to the lowest GDP quintile: 2 versus 10% average use in countries in the top four quintiles. Information regarding anaesthetic gas preference according to CO<sub>2</sub> emissions and GDP is summarised in Fig. 3.

Regarding N<sub>2</sub>O, 5% use it on a regular basis and 95% mix oxygen with air. Middle East (21%) and Africa (10%) are the regions in the world where N<sub>2</sub>O is most used. There is also a correlation between lower CO<sub>2</sub> emissions *per capita* (p10) and higher N<sub>2</sub>O use (19%) ( $P < 0.05$ ). Regarding which anaesthetic gas is considered the most pollutant to the atmosphere, 53% of respondents answered desflurane, 11% isoflurane, 7% sevoflurane and 29% did not to know.

#### Fresh gas flow

Forty-nine percent of the respondents use low flow anaesthesia (FGF < 1.0 lpm) when inhaled anaesthetics are being used, and only 15% of anaesthesiologists use minimal flow anaesthesia (FGF < 0.5 lpm). Regions where a FGF less than 0.5 lpm is used more often are Australia and New Zealand (44%), North America (19%) and Europe (18%) ( $P < 0.001$ ). Interestingly, there is a clear correlation in which countries with higher rates of CO<sub>2</sub> emissions, higher GDP *per capita* and higher healthcare expenditure *per capita* are more prone to apply lower FGF rates ( $P < 0.001$ ), whereas higher FGF rates (>2.0 lpm) are more common in low-income countries (Fig. 4).

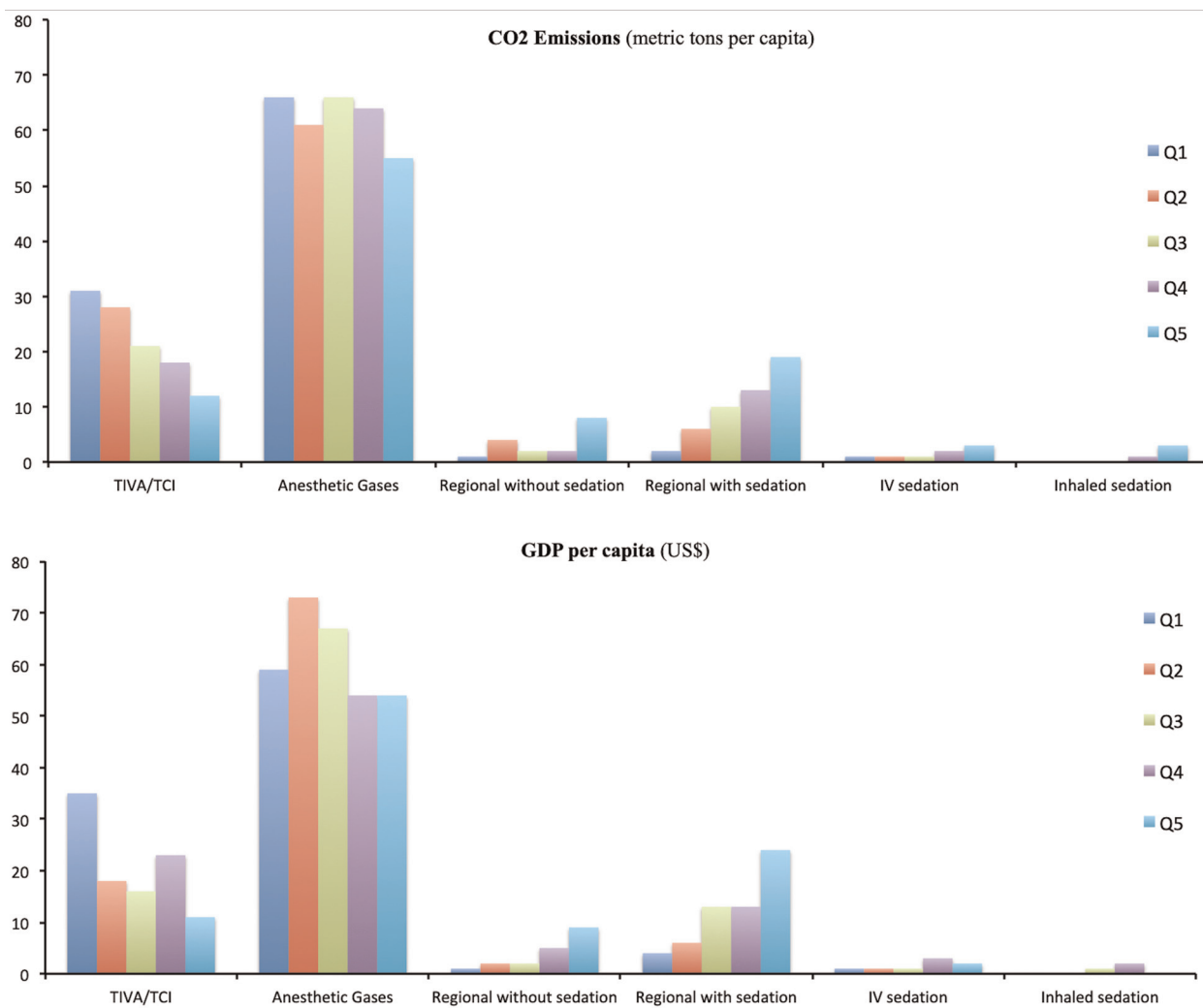
Reasons to avoid low flow anaesthesia were concerns for CO<sub>2</sub> rebreathing (30%), hypoxia (25%), compound A related renal insufficiency (12%) and CO formation (10%). Interestingly, 36% of respondents answered that they did not foresee any risks during low flow anaesthesia. Regarding question number 7, 66% of anaesthesiologists were more reluctant to use low flow anaesthesia in healthy infants than in healthy adults (34%).

#### Performance of anaesthesia ventilators

Fifty percent of the anaesthesiologists answered that they did not know whether the CO<sub>2</sub> absorber used in their institution contained NaOH or KOH. Forty-two percent confirmed that their absorber had one or other of these two components, and only 8% confirmed that they use NaOH/KOH-free CO<sub>2</sub> absorbers.

Regarding fresh gas flow efficiency information displayed by ventilators, 52% of respondents said that this information was available, among which 79% actually use it in

**Fig. 1** Anaesthetic plan preference according to CO<sub>2</sub> emissions and GDP *per capita*. Data expressed in percentages.

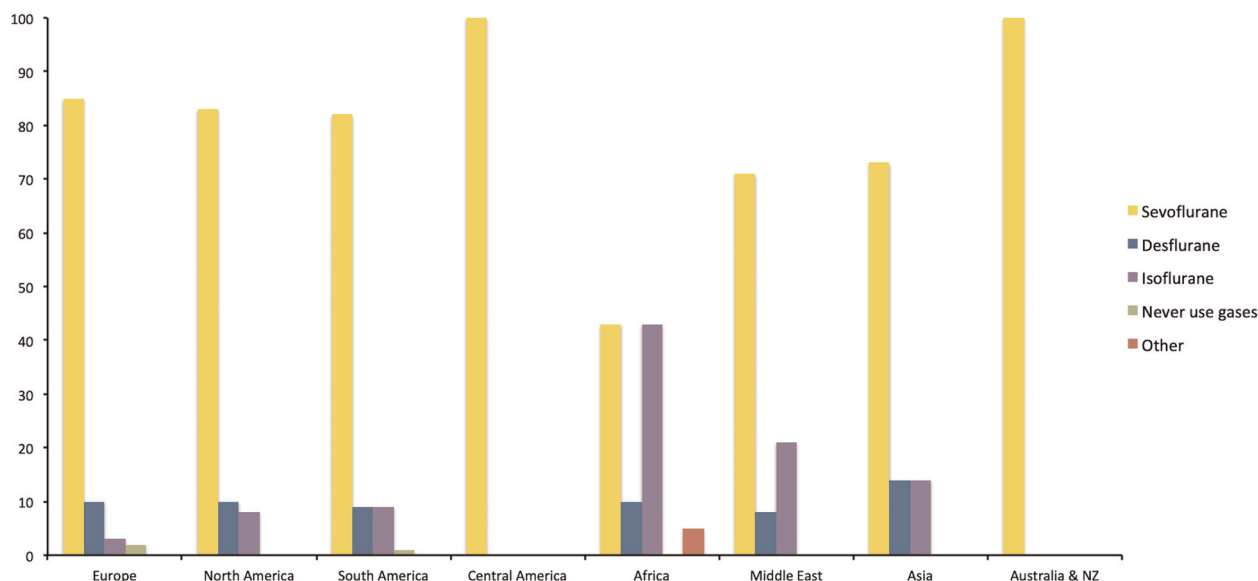


The upper graph shows the anaesthetic preference according to CO<sub>2</sub> emissions (metric tons *per capita*). The lower graph shows anaesthetic preference according to GDP *per capita* in each country. In order to compensate for sampling bias from under-represented regions, we aggregated countries into quintiles (Q1-Q5) of a given value: CO<sub>2</sub> emissions in the upper graph and GDP per capita in the lower graph. Thus, comparisons are based on groups of countries with similar socioeconomic indices ( $P < 0.001$ ).

**Table 3** What anaesthetic gas do you use more often?

Data in %	Sevoflurane	Desflurane	Isoflurane	Never use gases	Other	Number
Europe	85	10	3	2	0	736
North America	83	10	8	0	0	80
South America	82	9	9	1	0	319
Central America	100	0	0	0	0	12
Africa	43	10	43	0	5	21
Middle East	71	8	21	0	0	38
Asia	73	14	14	0	0	22
Australia & NZ	100	0	0	0	0	9
Number	1021	119	77	19	1	1237

Preferred anaesthetic gas according to geographical region represented in percentages with absolute numbers in the last row and column.

**Fig. 2** Anaesthetic gas preference according to region. Data expressed in percentages ( $P < 0.001$ ).

every day clinical practice. From the remaining group, 85% said that such information was not displayed, and 15% were not sure that they had it available.

#### Anaesthetic contribution to carbon footprint

Questions 11 to 13 investigated the practitioners' views about the potential influence that anaesthetic practice, healthcare industry and surgical activity has on the national carbon footprint of each country. These three questions show a broad distribution of answers covering from no impact (0%) to full responsibility (100%), with 50, 49 and 52% as median values, respectively (Supplemental Figures 6S–8S, <http://links.lww.com/EJAIC/A43>, <http://links.lww.com/EJAIC/A44>, <http://links.lww.com/EJAIC/A45>).

Question 14 asked if inhaled anaesthetic drugs are regulated under the Kyoto protocol, to which 70% answered don't know, and 15% expressed equally both yes and no.

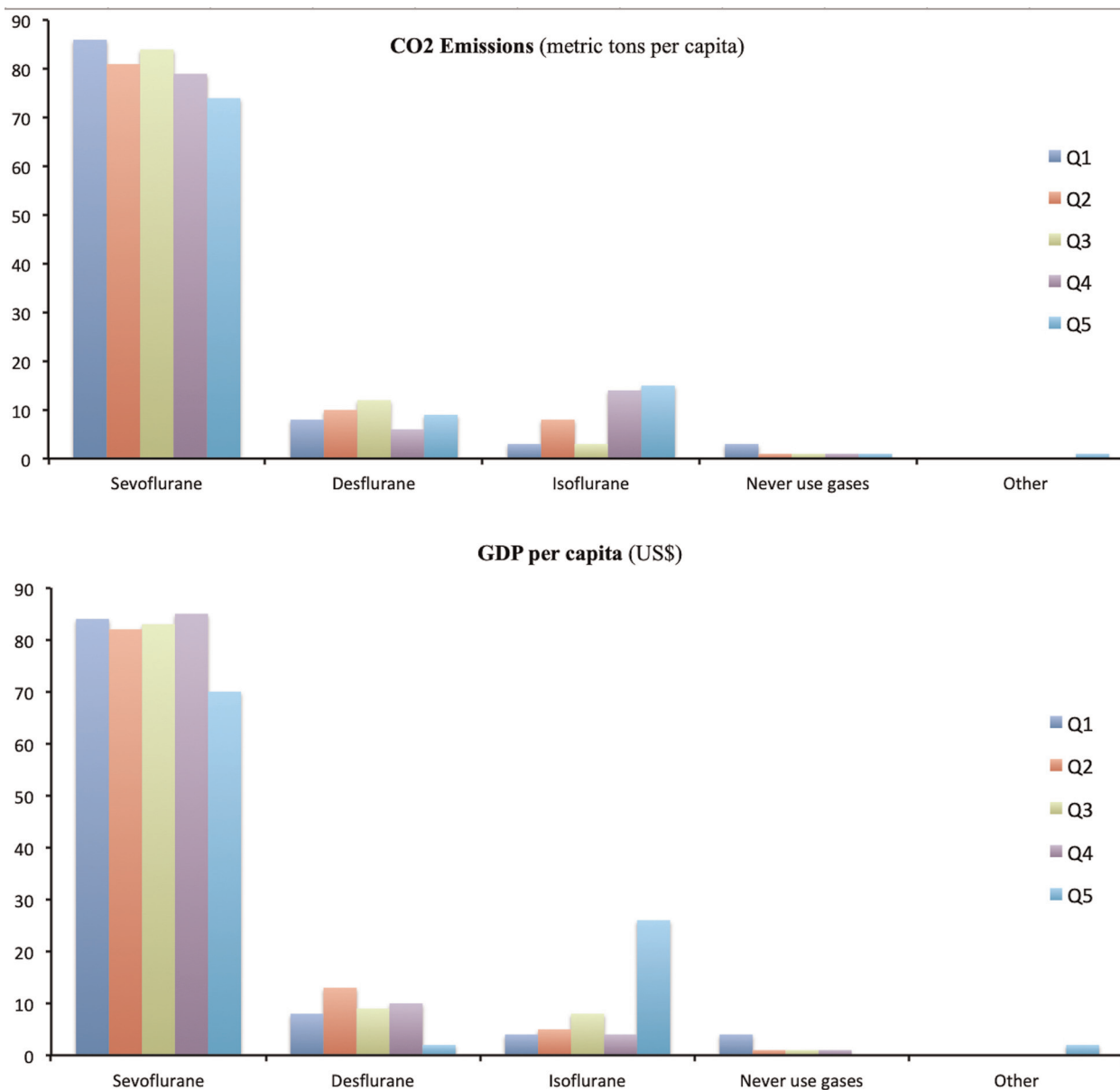
#### Discussion

The healthcare industry is a major polluter worldwide, responsible for 5.2% of all global GHG emissions.<sup>7</sup> Moreover, the operating rooms are the most resource demanding areas in hospital care and the higher energy demands, lack of effective waste management, and inhaled anaesthetic use, lead to a high intrinsic carbon footprint.<sup>7,19</sup> Volatile anaesthetics can be responsible for 50% of the peri-operative emissions, with an increasing concern over the use of these gases in the ICU and emergency settings, and by veterinary services: these out-of-the-operating-room sites often lack efficient anaesthesia ventilators and scavenging systems.<sup>21</sup> Therefore, it is relevant to

benchmark the use of different types of anaesthetic drugs, and ascertain if there are significant correlations with the level of CO<sub>2</sub> emissions, population wealth or healthcare expenditure. Although there are a handful of surveys dealing with sustainability during the peri-operative process, this is the first to examine the problem worldwide, with 75 participating countries. It is also the first survey that compares its gathered data with socio-economic indicators (CO<sub>2</sub> emissions, GDP index and healthcare expenditure).

According to our data, 64% of anaesthesiologist use halogenated gases on a daily basis during general anaesthesia maintenance, with sevoflurane ranking first, followed by propofol based TIVA / TCI (23%), and regional anaesthesia (11%). These results resemble data shown in previous studies.<sup>14–17</sup> It is worth noting that in African countries, isoflurane, an ozone-depleting drug with a higher warming potential than sevoflurane, is as frequently used as the latter (43%). Despite its higher cost, desflurane shows a 10% preference among African anaesthesiologists, although this result can be influenced by the fact that 29% of respondents from this continent came from South Africa. Inhaled anaesthetics are used by 93% of veterinary anaesthesiologists, with isoflurane ranking first (85%). Interestingly, senior consultants (32%) choose desflurane more often than less experienced consultants (9%) or residents (7%), showing a possible exposure to marketing strategies. Strikingly, only 49% of the anaesthesiologists use low flow anaesthesia (<1.0 lpm) on a daily basis: it is used more frequently in high-income countries, probably due to better access to premium ventilators, and education programmes on sustainability

**Fig. 3** Anaesthetic gas preference according to CO<sub>2</sub> emissions (metric tons *per capita*) and GDP *per capita* in each country. Data expressed in percentages.

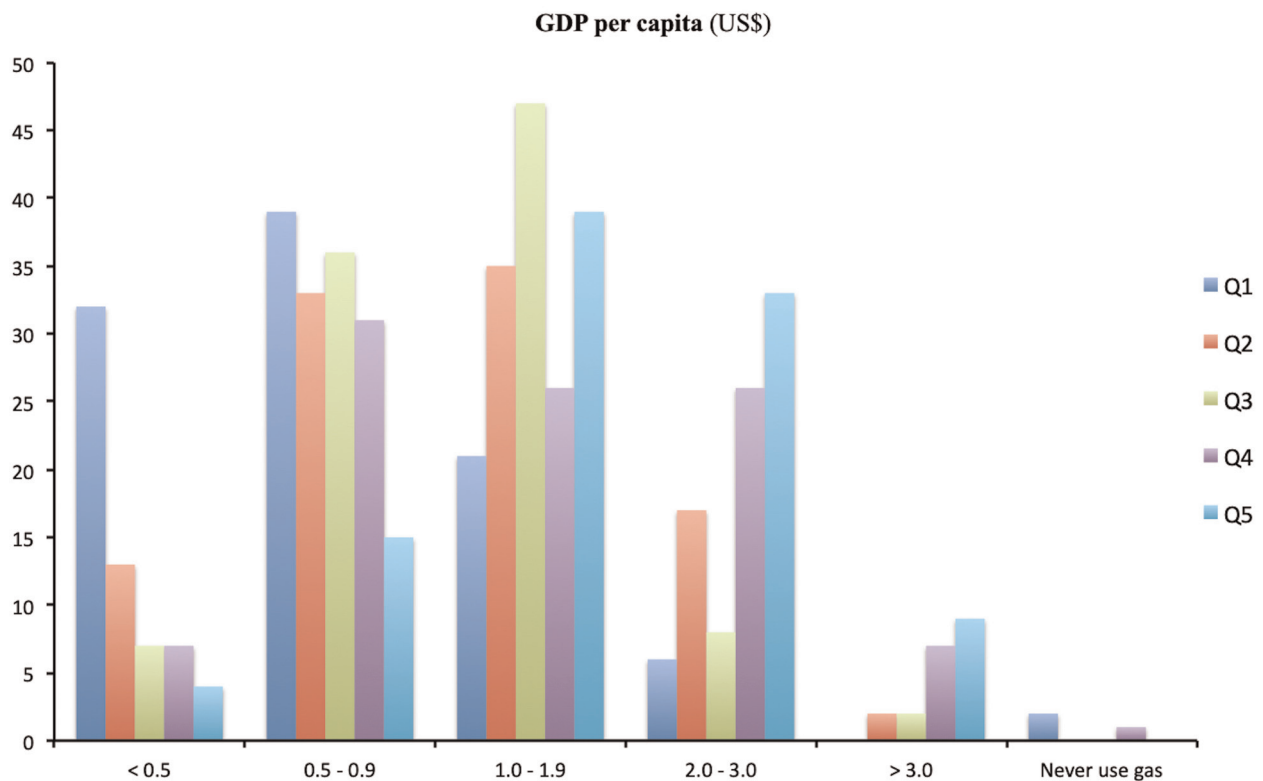


The upper graph shows the anaesthetic gas preference according to CO<sub>2</sub> emissions (metric tons *per capita*). The lower graph shows anaesthetic gas preference according to GDP *per capita* in each country. In order to compensate for sampling bias from under-represented regions, we aggregated countries into quintiles (Q1-Q5) of a given value: CO<sub>2</sub> emissions in the upper graph and GDP per capita in the lower graph. Thus, comparisons are based on groups of countries with similar socioeconomic indices ( $P < 0.001$ ).

and environmental health. The fact that 48% of respondents do not use, or do not have available the necessary visual displays in the ventilators, adds to this hypothesis. We also observed TIVA preference was significantly higher in countries with a higher GDP index and healthcare expenditure *per capita*. Possible explanation for such behaviour is again better access to technology (infusion pumps, Target-Controlled-Infusion software

and EEG Neuromonitors) and education from Scientific Societies.

N<sub>2</sub>O, a gas with a high greenhouse effect and ozone-depleting properties, is still used in peri-operative medicine, especially in middle and low-income countries, probably due to its low price and unawareness of its environmental effects. More education is needed in this

**Fig. 4** Fresh gas flow preference according to GDP *per capita*. Data expressed in percentages.

Countries are stratified into GDP quintiles. Anaesthesiologists working in countries in the first quintile in GDP *per capita* tend to use lower fresh gas flows than fellow colleagues working in countries with less GDP *per capita* ( $P < 0.001$ ).

regard to encourage a global N<sub>2</sub>O ban, including areas outside the operating room such as in dentistry and the labour ward. Therefore, stakeholders with implemented N<sub>2</sub>O-free healthcare plans should lead the transition and share their experience.

Concerns expressed for not using low flow anaesthesia are most likely preventable by properly programming alarms (inspired CO<sub>2</sub> and O<sub>2</sub> levels) according to local safety protocols in order to prevent CO<sub>2</sub> rebreathing and hypoxia. Surprisingly, Compound A related renal insufficiency still is a matter of concern for nearly 12% of the clinicians, despite lack of available evidence supporting its clinical repercussion in humans.<sup>20,21</sup> On the contrary, only 10% believe that CO formation might have unwanted effects, which is possible if CO<sub>2</sub> absorbers containing NaOH/KOH are used, which according to this survey, are the most prevalent worldwide. Therefore, patients at risk for exogenous (smoke inhalation, polytransfusion and children <2 years of age with anaesthetic gas recirculation >50%) or endogenous CO formation (sepsis, trauma, shock or haemolysis) might benefit from COHb monitoring in POCT gas analysis if blood sampling is available, or noninvasively by using pulse co-oximetry devices.<sup>22-24</sup>

Regarding low flow anaesthesia in paediatric population, 66% of the anaesthetists were more reluctant to apply it in healthy infants, which have a lower minute volume than healthy adults. Infants typically have less dilution effect in the gas mixture delivered by the ventilator than adults, who have higher MV and lower recirculation fraction (FGF/MV). Therefore, it is not surprising that infants are often ventilated in an 'open circuit' scheme due to recirculation fractions above 1 (FGF > MV), which delivers fresh nonused anaesthetic gas directly to the atmosphere. This FGF setting increases the economic and environmental burden of our practice. Therefore, we propose that FGF should never exceed the patient's minute volume, and we strongly encourage anaesthesiologists to use low flow anaesthesia even in the paediatric setting.

Our study shows a significant need for further educational programmes on environmental health and sustainability. Figures 1S to 3S, <http://links.lww.com/EJAIC/A38>, <http://links.lww.com/EJAIC/A39>, <http://links.lww.com/EJAIC/A40> depict how little knowledge there is about the impact of healthcare practice to the national carbon footprint. We strongly agree with existing recommendations to include educational initiatives both at a



preclinical and clinical level.<sup>14,25,26</sup> Furthermore, our daily anaesthetic choices are free from any audit in most centres worldwide, despite inhaled anaesthetics belonging to a cluster of chemicals (N<sub>2</sub>O and fluorinated greenhouse gases) regulated by different international protocols (Kyoto, Paris, Montreal and Kigali). Despite these facts, 70% of respondents did not know if these drugs are in fact regulated by these Conventions. Similar lack of awareness among anaesthesiologists worldwide has been previously reported.<sup>14–17</sup>

Limitations of our study include a possible selection bias where more motivated clinicians took the effort to share and respond to the survey, and social media distribution likely took place among groups of anaesthesiologists already interested in sustainability and environmental health. Moreover, many countries were under-represented, and we only obtained answers from 75 countries (from a total of 193 according to the United Nations) mainly from European and South American countries. In order to compensate for this issue and improve the applicability of our study, we grouped countries into continents, and divided their socioeconomic indexes into quintiles to compare answers from similar geographical and socioeconomic origins, instead of on purely national criteria. In fact, the number of responses is more balanced when GDP criteria are applied, with 61% of clinicians working in countries with a GDP over the median value distribution. Nevertheless, the use of professional networks and online methods to disseminate the survey may have excluded a wider participation from low-income countries. This effect becomes more evident with the fact that only 0.1% of respondents answered that they use a gas different to sevoflurane, desflurane or isoflurane on a daily basis, most probably halothane, which is still commonly used in low-income countries. Relevant countries with high CO<sub>2</sub> emissions participated very little in this survey, especially within Asia. Further surveys in the future should strive to better describe the sustainability situation in this region.

The broad distribution of answers for questions 11 to 13 into a homogenous cloud of data might not only be interpreted as an absolute lack of knowledge about the healthcare footprint, but also because the questions were poorly understood by the participants. Should the latter be the prevailing reason, again, a lack of awareness in healthcare sustainability facts might contribute to the poor understanding of these questions.

We did not find differences in sex or experience, but the 30 to 39-year-old segment was slightly over-represented.

## Conclusion

Halogen gases are the most frequently used anaesthetic drugs worldwide, and the majority of respondents are unaware of their global warming impact, or are not influenced in their anaesthetic choices by environmental

concerns. There is an under-implementation of more sustainable strategies of anaesthesia, especially in countries with less access to updated technology. A clear need exists for further education and training worldwide, both at the preclinical and clinical level, in order to make informed decisions that warrant the best possible balance between patient safety and planet health. Furthermore, the availability of adequate technology is essential for both a well tolerated and low carbon care.

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AT, JDS and FRB have no conflicts to declare.

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