Reducing the greenhouse gas emissions from halogenated agents in daily clinical practice: an audit at the University Hospital of Bordeaux

Jean-Claude PAUCHARD [a,b] , Gauthier GRESS[b], Matthieu BIAIS [b,d], Hélène BELOEIL[e], Karine NOUETTE-GAULAIN[b,f]

[a]Polyclinique Aguilera Groupe Ramsays GDS, Anesthésie Réanimation, 64200 Biarritz, France

[b]CHU Bordeaux, Service d'Anesthésie Réanimation Pellegrin, Hôpital Pellegrin, Place Amélie Raba Léon, F-33000 Bordeaux, France

[c]CHU Bordeaux, Department of Anaesthesia and Critical Care, Magellan Medico-Surgical Center, F-33000 Bordeaux, France

[d]Univ. Bordeaux, INSERM, UMR 1034, Biology of Cardiovascular Diseases, F-33600 Pessac, France

[e]Université Rennes, Inserm NUmecan CIC 1414, CHU Rennes, F-35033 Rennes, France

[f]Univ. Bordeaux, INSERM U12-11, Laboratoire de Maladies Rares : Génétique et Métabolisme (MRGM), 176 Rue Léo Saignat, F-33000 Bordeaux, France

Corresponding author : Karine Nouette-Gaulain

Anaesthesiology and Critical Care Department, Hôpital Pellegrin, CHU de Bordeaux, Place Amélie Raba Léon, 33 076 Bordeaux Cedex, France.

Email:karine.nouette@gmail.com

Keywords: Anaesthetics; Greenhouse gases; Fresh gas flow

Dear Editor,

Halogenated agents, widely used for maintenance of general anaesthesia in the operating room (OR) have a significant greenhouse gas effect with a notorious ecological impact [1, 2]. Sevoflurane, desflurane and nitrous oxide have a global warming potential greater than 200 times that of carbon dioxide (CO_2). Volatile gas leakage in the OR can be explained by factors such as type of ventilator, fresh gas flow (FGF) into the rebreathing system, airway devices, absorbers. Thus, decreasing the source of greenhouse gas emissions and reducing halogenated agent consumption play a major role in controlling the carbon footprint in healthcare. Therefore, we tested the ability of anaesthetists to change their daily clinical practice after the implementation of an anaesthesia educational program (AEP) considering the control of greenhouse gas emission.

The audit was performed between February, 2017 and April, 2018 in a teaching French hospital (Bordeaux. This study was approved by the Publication of Ethics Committee of the University Hospital of Bordeaux (2019-22) and was approved by the local committee for audit of clinical practice (Cellule d'Aide Methodologique à l'Evaluation des Pratiques Professionnelles et à la Pertinence des Soins, CAMEPPS) and registered as audit of clinical practice n° 455.
Consecutive patients scheduled for elective and emergency surgery under general anaesthesia requiring controlled mechanical ventilation were prospectively included

in the audit. Patients were not included if the duration of general anaesthesia was <10 minutes or if patients were ventilated using a facial mask. Patients scheduled for cardiac surgery were not included.

The audit was based on a three-stage protocol: “Institutional practice phase”, called Phase I (February to April 2017), “Intermediate education Phase” and after implementation “Result phase”, called Phase II (November 2017 to January 2018), evaluating the AEP entitled ‘‘Control of greenhouse gas emission”. All the anaesthesia healthcare workers (physicians, trainees, nurses) were involved in the audit. Implementation of the AEP included different actions: (i) the use of the automated control of volatile delivery mode if available; (ii) a decrease in FGF if automated control of volatile delivery mode was not available (induction: 6-8 L/min, maintenance: <1 L/min); (iii) lung protective ventilation in adults (tidal volume: 6-8 ml/kg ideal body weight (IBW); positive end-expiratory pressure (PEEP): 6-8 cm of water, and recruitment manoeuvres) [3] and (iv) the well-reasoned choice of halogenated agent (sevoflurane rather than desflurane, desflurane used in patients with BMI> 35 or surgery with expected duration >2 h).

The primary outcome was mean FGF (L/min) used for maintenance of general anaesthesia. When maintenance was performed using automated control of volatile delivery mode, FGF was considered to be 0.5 L/min.

Volatile agent consumption was recorded by the pharmacy department. The sources of greenhouse gas emissions were calculated using global warning potential (GWP_{100}), expressed as ‘carbon dioxide equivalent’ in kilogram (kg CO2-eq):

Kg CO2-eq= HA consumption (L) x HA volumetric weight (kg/L) x $HAGWP_{100}$ [2, 4]

Data were presented as mean ± standard deviation or median (interquartile range) as appropriate. Continuous variables were compared with independent samples

Student's t test, or with Wilcoxon test if the distribution was skewed. Categorical variables were analysed by Chi Square test or Fisher's Exact test as appropriate.

The final dataset consisted in 350 consecutive patients in Phase I and 420 patients in Phase II (Table 1). Nitrous oxide was not used for maintenance of general anaesthesia.

The mean FGF was significantly lower in the Phase II group than in the Phase I group (1.1 ± 0.8 L/min vs 1.7 ± 1.6 L/min, respectively; $p<0.001$). FGF (including manually selected and automated control of volatile delivery mode) < 1L/min for maintenance of general anaesthesia was observed in 108/307 (35.2%) patients in Phase I and in 145/315 (46%) patients in Phase II ($p=0.006$).

There were 36% and 23% decreases in desflurane and sevoflurane consumption between Phase I and Phase II, respectively. This reduction in halogenated agent consumption led to a 51 542 kg CO2-eq decrease for a 3-month period in general anaesthesia-induced ecological cost (Table 2).

This audit was based on the implementation of AEP entitled 'Control of greenhouse gas emission' and is associated with a change in the daily practice in anaesthesiologists. Halogenated agents are one of the largest sources of greenhouse gas emissions in healthcare systems [2]. Therefore, a global decrease in FGF led to a significant decrease in halogenated agent consumption and in greenhouse gas emissions. Halogenated agents are scavenged and emitted by anaesthesia machines with little or no degradation as medical waste directly out of the buildings or thrown away with absorbers. Therefore, controlling greenhouse gases emissions is also associated with a better choice of volatile agent. However, halogenated compounds are still used in ORs without any regulations, even if, the use of a reasoned FGF based on patient metabolic demand has been recommended for 40 years. Introducing automated control of volatile delivery mode in the standard of care was associated with a reduction in volatile agent cost per hour >25% and a 40% reduction of greenhouse gas emissions. Automated control of volatile delivery mode (when available on anaesthesia stations) was underused during Phase II, suggesting the need for education of anaesthesia providers on the environmental impact. When automated control of volatile delivery is not available, strategies for managing FGF during induction, maintenance and emergence should be applied in order to minimize waste and environmental contamination. Operating rooms generate 20-30% of total hospital waste and volatile agents are major contributors [2], even if these gases contributes only 0.02% of the climate effect [5].

In conclusion, after an implementation of AEP based on 'control of greenhouse gas emission', a global decrease in FGF led to a significant decrease in halogenated agent consumption and in greenhouse gas emissions. This strategy was also associated with improvements in daily practice of anaesthesiologists. The impact of anaesthesia on climate change needs to be monitored so that we can choose the most "climate friendly" anaesthesia protocol.

Funding

None

Disclosure of interest

None

References

1. Benhamou D, Constant I, Longrois D, Molliex S, Nouette-Gaulain K, Bull A. Use of volatile anaesthetic agents in anaesthesia: A survey of practice in France in 2012. Anaesth Crit Care Pain Med. 2015;34:205-9.
2. MacNeill AJ, Lillywhite R, Brown CJ. The impact of surgery on global climate: a carbon footprinting study of operating theatres in three health systems. Lancet Planet Health. 2017;1:e381-e8.
3. Futier E, Constantin JM, Paugam-Burtz C, Pascal J, Eurin M, Neuschwander A, et al. A trial of intraoperative low-tidal-volume ventilation in abdominal surgery. N Engl J Med. 2013;369:428-37.
4. Sulbaek Andersen MP, Sander SP, Nielsen OJ, Wagner DS, Sanford TJ, Jr., Wallington TJ. Inhalation anaesthetics and climate change. Br J Anaesth. 2010;105:760-6.
5. Shine KP. Climate effect of inhaled anaesthetics. Br J Anaesth. 2010;105:731-3.

Variable	Phase I	Phase II	p

Table 1. Characteristics of the patients

	Feb-April2017 n=350	Feb-April2018 n=420	
Sex			
Female	174 (50)	176 (42)	0.03
Weight (kg),	62 ±25	62±25	0.94
Height (cm),	163±21	162±21	0.9
BMI (kg/m^2),	24±6	24±5	0.75
Age (years),	44±24	41±26	NS
ASA physical status,			
I-II	278 (34)	383 (37)	0.87
III-IV	71 (45)	65 (53)	
unknown	1 (0)	2 (0)	
Emergency			
Yes	28 (8)	72 (17)	< 0.01
SOAS			
Yes	17 (5)	20 (5)	0.17
Asthma			
Yes	20 (6)	24 (6)	0.93
COPD			
Yes	12	24	0.7
Anesthesia station used			< 0.001
Félix/Taema®	84 (24)	60 (14)	
Félix AINOC/Taema®	84 (24)	60 (14)	
Zeus/Dräger®	23 (6.6)	33 (8)	
Julian/Dräger®®	71 (20.3)	6 (1.5)	

Flow-I/Maquet®	54 (15.4)	117 (28)	
Primus/Drager®	18 (5.2)	21 (5)	
Aisys/GE®	4 (1.2)	0 (0)	
Cato/Dräger®®	2 (0.5)	1 (0.2)	
Perseus/Dräger®®	2 (0.5)	99 (24)	
Infinity/Dräger®	0 (0)	12 (2.9)	
Unknown	8 (2)	11 (2)	
Anaesthesia duration (min)	118 ± 78	137 ± 87	0.01
Lung protective ventilation in adults (n= 260 Phase I, 250 Phase III)			
Tidal volume (ml/kg IBW)	7.4 ±1.1	7.2 ± 0.86	0.03
PEEP (cm H_2O),	3.4 ± 2.8	6 ±1.7	<0.001
Recruitment maneuvers (yes),	39 (16.7)	135 (57.7)	<0.001

Data are presented as mean±SD or n (%) when appropriate BMI: body mass index,
COPD : *Chronic obstructive pulmonary disease*
SOAS : sleep obstructive apnea syndrome
IBW: ideal body weight ,
PEEP: positive end-expiratory pressure

Table 2. **Consumption and related ecological cost of volatile agents during Phase I and Phase III**

Variable	Phase I	Phase II	% reduction
Interventions	11 414	11 192	
DESFLURANE			
Bottles (n)	113	72	36

Volume (L)	28	18	
Cost (€)	2 209	1 408	
CO_2-eq (kg)	104 515	66 620	
Driving distance (Km)	941 576	600 180	
SEVOFLURANE			
Bottles (n)	1 208	932	23
Volume (L)	302	233	
Cost (€)	25 061	19 329	
CO_2-eq (kg)	59 663	46 016	
Driving distance (Km)	537 504	414 558	

Results are expressed as number (n), Liter (L), euros (€), kilogram (kg), Km : kilometre CO_2-eq: carbon dioxide equivalent . Calculation of carbon dioxide equivalent can be converted into driving distance expressed in kilometre. In France in 2017, passenger cars currently emit an average 111 g CO_2 emissions/km