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Initiatives to broaden safety concerns in anaesthetic practice:

The Green Operating Room

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Abstract

Health sector is a major contributor to climate change through its carbon footprint. Hospitals are highly energy and resource intensive. Operating rooms (ORs) contribute for a major part to these emissions because of anaesthetic gases, energy-intensive equipment and waste. Besides initiatives aimed to mitigate hospitals' climate footprint, healthcare professionals need to be involved in this process by changing their professional and personal behaviours without compromising the quality of care. Education on metrics (greenhouse gases), concepts (life cycle) and strategies to reduce healthcare footprint would help professionals to commit themselves. The 5R's rule (reduce, reuse, recycle, rethink and research) used to promote an environmentally friendly way of life can be applied to the medical field and specifically to the operating room and anaesthesia. When applied in the ORs, these strategies help question the use of disposable devices, attires, packaging as well as our professional and personal behaviour. Greening the ORs need the engagement of all professionals as well as other departments (pharmacy, hygiene) and management. Economic and social co-benefits are expected from this process.

Introduction

The Bruntland Report defines sustainable development as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’ [1]. Sustainability must be addressed, monitored and evaluated in its three pillars: economic, social and environmental.

Health sector has a traditional role of delivering quality healthcare. However, health sector is actually facing a unique paradox. Indeed, it has to face climate change consequences on human health but it is also an important actor substantially contributing to climate change. Hospitals are highly energy and resource intensive. Procurement, resource use, transportation and other policies and practices contribute to the health sector’s significant carbon footprint.

To mitigate that impact on the planet, programs from international (World Health Organization-WHO; Healthcare without harm-HCWH) and national bodies have been issued [2]. Basic steps the health sector can take include improving hospital design, reducing and sustainably managing waste, using safer chemicals, sustainably using resources such as water and energy, and purchase environmental-friendly products. Since operating room activities contribute greatly to hospital carbon footprint, healthcare professionals have a role to play in transforming their own activities in an environmentally friendly manner without compromising quality of care. Awareness, commitment, professional and personal behaviour changes will contribute to mitigate hospital carbon footprint. Moreover, this change in professional behaviour should contribute to improve professional quality of life and sustainability.

Awareness about the health sector carbon footprint among healthcare professionals is an essential aspect for a collective engagement. Many publications and statements on the ORs burden on the environment and initiatives to mitigate that impact have already been published [3,4].

The aim of this review is to support and encourage operating room professionals to take an active role in implementing sustainability as an integral part of their practice.

Health sector paradox

The effects of global warming include soil degradation, loss of productivity of agricultural land, reduced fresh-water resources and the disruption and depletion of stratospheric ozone. These changes have a significant impact on human health, causing a change in the distribution of infectious diseases and outbreaks with warming, injuries during natural disasters (heat waves, floods, tornados) and malnutrition. Direct exposure to natural disasters has also an impact on mental health [5]. The World Health Organization (WHO) predicts for 2030 an excess in mortality due to climate change of 250.000 fatalities per year, including 38.000 due to heat, 48.000 to diarrhoea, 60.000 from malaria and 95.000 due to child malnutrition [6] as a consequence of direct effects of extreme weather events and indirect effects such as food production, water resources, air pollution and infectious diseases.

Paradoxically health sector is contributing to climate change through its major contribution to carbon footprint. Health care on average accounts for 5% of the national carbon footprint [7] with a large variability from 3% in England to 10% in the USA [8]. Health care activities are also responsible for air pollution, acid rain emissions, and smog-forming emissions.

The health sector can develop seven key strategies to become more climate-friendly, while at the same time generating significant health, environmental and social co-benefits: promoting energy efficiency programs, green building design, alternative sources of energy, low carbon transportation, local food, waste reduction and water sparing [2]. Many of these strategies can be implemented by a shift in the health sector's procurement policies and practices. Health co-benefits can result from reducing the health sector's climate footprint. Hospitals contribute to air pollution, water contamination, and other forms of environmental degradation. Fossil fuel combustion associated with energy use in buildings and transportation produces not only global warming gases such as carbon dioxide, but also a series of other pollutants that add to the environmental burden of disease [9]. The potential economic benefits of improving the health sector's climate footprint are significant. For instance, alternative energy measures carry long-term financial benefits.

Regarding social benefits, growing evidence demonstrates that health professionals are eager to do their part. For instance, when England's NHS launched its ambitious plan to reduce its climate footprint, it won 95% support from NHS staff [10]. The International Council of Nurses, a federation of national nurses' associations representing nurses in more than 128 countries, has identified climate change as an important issue for the nursing profession, and "Recognises the opportunity to take advantage of the massive potential to implement mitigation and adaptation policies that also have co-benefits to health" [11]. Along with action and research, education on climate change is also an important part of the commitment of future healthcare providers. The International Federation of Medical Students' Associations has called upon medical schools to integrate teaching related to climate change into their curricula [12].

Health care professionals should both 1) advocate for strategies to address climate change and 2) reduce the emissions of their own medical establishments and practices.

Health care facilities are a major contributor of waste. Operating rooms (ORs) are major contributors to carbon emissions. Operating room waste alone account for approximately 70% of hospital waste. [13]. Moreover, ORs waste management needs to comply with the need for sterility. Hospitals dispose of waste using disinfection protocols (from autoclaves to chemicals), incineration, or dumping waste into landfills [14] [15]. ORs contribute also to carbon emissions through the release of anaesthetic gases into the atmosphere, the use of energy-intensive medical equipment, and a 24-hour operating schedule [16].

Basic knowledge and metrics

Metrics

The potency of a greenhouse gas (GHG) depends on its atmospheric life and its capacity to absorb infrared light. The Global warming potential (GWP) has been created to allow comparisons of the global warming impact of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO₂). CO₂, by definition has a GWP of 1 regardless of the time period. For other GHGs, the larger the GWP, the more that a given gas warms the Earth compared to CO₂ over that time period. The time period usually used for

GWPs is 100 years. GWP₁₀₀ provide a common unit of measure, which allows to compare emissions. For example, Nitrous Oxide (N₂O) has a GWP 265–298 times that of CO₂ for a 100-year timescale. Moreover, the tropospheric life time of GHGs has to also be considered when comparing GHGs. N₂O emitted today remains in the atmosphere for more than 100 years, on average. The GWP₁₀₀ and tropospheric lifetime of anaesthetic gases are provided in Table 1. [17][18].

Another important metric is the Carbon dioxide equivalence (CO₂e), which is a way of describing the overall warming potential of individual GHGs, by converting amounts of other gases to the equivalent amount of CO₂ with the same GWP. The CO₂e is derived by multiplying the tons of the gas by the associated GWP. For example, a single bottle of isoflurane, volume 250 ml = 190 kg CO₂e = 1.188 km in a small car.[19]

The 5 R's

The well-known 5R's rule used to promote an environmentally friendly way of life can be applied to the medical field and specifically to the ORs and the anaesthesia field (Figure 1). [20]

Life cycle

Devices should always be chosen depending on their life-cycle assessment (LCA). LCA is a method for the environmental assessment of products, covering their life cycle from raw material extraction to waste treatment. For example, Eckelman et al. [21] reported that reusable laryngeal mask airways as used at their institution have a more favourable environmental profile than disposable ones. This type of analysis should be provided by manufacturer's and /or assessed by every institution before choosing a medical device.

The green operating room

Waste

Hospitals in developed countries generate 1% of a nation's solid waste, and 2.1 % of its GHGs emissions annually [22]. ORs contribute for a major part to these emissions because of

anaesthetic gases, energy-intensive equipment and waste. Indeed, the transportation and the incineration of waste is responsible for a big amount of GHGs emissions. Incinerating 1kg of clinical waste produces 3 kg of CO₂ [23]. However, according to WHO, around 85% of the hospital waste and 90 % of OR waste is non-hazardous comparable to domestic waste and potentially recyclable. Interestingly, as much as 25% of OR waste is generated by anaesthetists [24][25]. Many reasons can explain this huge amount of OR waste: the need to maintain sterility, the switch from reusable to single-use plastic devices in the 1980s; the “overage” i.e. opening sterile packs that may not be used: 80% of the OR waste is generated before the patients arrive for their operation [23]; pre-packaged supply kits containing unnecessary materials that will be discarded as waste; misclassification of OR waste as hazardous waste because of misunderstanding of the need to segregate waste or fear for incorrectly allocating waste as non-hazardous; lack of recycling while of general OR waste 40 % is paper, 58 % plastics and 2% aluminium and glass [25]. Mc Gain et al. [26] reported that 40 to 60 % of the OR waste generated by anaesthetists is recyclable, that includes glass, laryngoscope blades, plastics, paper / cardboard.

When the 5Rs rule is applied to ORs waste management, improvement towards a reduction of the environmental footprint of the ORs has been reported.

Reduce.

Like at home, reducing the quantity of waste generated is the best way to improve OR's environmental footprint. Simple ideas have already been tested with success: reduction of paper waste by not printing, paper towel and water waste by using hand sanitisers, overage by redesigning pre-packaged kits, etc... Appropriate segregation of waste is also an important way to reduce the volume of hazardous waste requiring special treatment. If segregation is not properly done, the amount of waste eliminated through the expensive high-energy processing of hazardous waste increases and the GHGs emission associated with it too [20]. In order to appropriately sort out the OR waste, 2 strategies can be implemented: 1) the definition of hazardous or clinical waste has to be clearly stated: unless waste is visibly soiled, dripping or caked with blood or body fluids, it is classified as general waste [27] 2) reorganising bins in the OR and clearly identify each one: hazardous waste, non-recyclable general waste, glass, plastic, laryngoscope blade and paper/cardboard. Reducing the number

of hazardous waste bins (one per OR and not so easily accessible) is also part of the strategy [20].

Reuse

The easiest way to start reusing materials in the OR is to switch for reusable care givers attires. Six studies analysed (1–6) in a review published in 2012 (7), compared the life cycle and therefore the environmental impact of reusable and disposable OR suits. These large-scale and methodologically rigorous studies have all shown that the environmental impact of disposable clothing is much greater than that of reusable clothing: + 200 to 300% for the carbon footprint secondary to energy expenditure, + 250 to 330% for water needs, + 750% in solid waste production. Vozzola et al. (8) compared the life cycles of gowns used for isolation patients: reusable gowns consume 28% less energy, emit 30% less greenhouse gases and 50% less water. Same has been shown for reusable surgical linens [22].

Specifically, in anaesthesia, many devices can be reusable. Ventilation and laryngeal mask airways are a good example as they used to be reusable. Hospitals switched for disposable in the 1980s after blood-borne diseases concerns [20] and pressure from the industry. During a typical anaesthesia procedure, a ventilation mask is touching the patient's face for 3 to 4 minutes before intubation. It is then discarded because it is not needed anymore. Unless the mask is obviously soiled with body fluids (which is extremely rare), why can we not disinfect and clean the mask and reuse it ? Same holds for reusable laryngeal mask airways, which have a much better environmental profile than disposable ones [21].

Recycle

Like at home, recycling is an important way of reducing the volume of waste in the OR. However, as for recycling outside the OR, recycling is advantageous only if it offsets its related impacts associated with collection and reprocessing on the environment. First, we can recycle the obvious: paper / cardboard and batteries for which all facilities already have specific bins and specific collecting systems like for household garbage. Plastics and metals can also be recycled. However, specific collecting and reprocessing systems have to be put in place by liaising with local recyclers. Laryngoscope blades, copper, aluminium and stainless-steel recycling can save both carbon and money [28]. One successful example is the

association called “les petits doudous” in France, which is financing electronic tablets and apps for children having surgery by recycling OR’s metals [29]. Medical glass can also be recycled in specific facilities. It cannot be recycled with household glass. Such facilities are still rare and should be developed and supported by authorities.

Rethink

...or refuse! Indeed, we have to refuse new devices that are unnecessarily wrapped in plastic, unnecessarily disposable (blood pressure cuffs) or simply unnecessary! Purchasing should be sustainable. The life cycle of a device, but also the collection and recycling of the used material by the manufacturer should be integrated into the items considered when buying a new device. Healthcare facilities have a responsibility to set an example by promoting sustainable purchases. As aforementioned, pre-packaged kits have to be rethought and unnecessary tools and materials removed.

We can also question our habits, which are not always necessary but can have a huge environmental impact. One example is the flu shot required for health care workers. Colleagues giving the shot usually wear single-use gloves even if recommendations do not require using gloves for routine vaccine administration because there is little risk involved. A medical facility with 30,000 employees that requires everyone to be vaccinated using gloves would release over three metric tons of GHGs emissions if landfilled, and six metric tons if incinerated.

The use of telemedicine for preoperative consultation can also reduce the carbon footprint of healthcare even if the net results of GHGs has to acknowledge the CO₂ emissions of internet and electronic devices.

Rethinking is also based on education. Education, training and therefore staff involvement can reduce waste by 6.5 % per month [30]. Moreover, when considering the development of a new hospital and/ or OR, the environmental impact has to be on the front page of the requirements for the construction company. Waste management strategies have to be taken into account.

Research

Data are still scarce on the environmental effects of different health care systems, different ORs organisations, new devices or technologies etc. Research should also include the development of more “green” devices like compostable tray or drapes.

Anaesthetic gases

Volatile anaesthetic agents represent 0.1 % of all GHGs. All of them participate to global warming. Their climate impact is comparable with that from the CO₂ emissions from one coal-fired power plant or 1 million passenger cars [18]. Nitrous oxide (N₂O) has a GWP₁₀₀ of 298, a tropospheric life time of 114 years and depletes the ozone layer, which protects the Earth from solar radiation (Table 1). Despite a recent controversy in the literature [31][32], we have enough evidences to declare that within anaesthetic gases, N₂O is by far polluting the most. Reducing the carbon footprint of anaesthesia can only be achieved by reducing the use of N₂O. A 50% mix of N₂O and oxygen with a fresh gas flow of 1l/min emitters 53.2 g of N₂O/ h which is 15.8 kg of CO₂/h which is the equivalent of driving a European car 120 km.

Unlike N₂O, halogenated gases do not have any impact on the ozone layer. However, as described in Table 1, their impact on GHG is so important that it cannot be neglected by anaesthesiologists. The GWP₁₀₀ and the atmosphere life time of the 3 most used halogenated agents are very different; desflurane being by far the most polluting agent. When accounting for the full life-cycle of the anaesthetic drugs, desflurane has the largest life cycle GHG impact when administered with both, O₂/air or N₂O/O₂ carriers [33]. The common idea that the carbon footprint of halogenated gases is negligible has been proven wrong. Indeed, when comparing the carbon foot print of operating theatres in 3 different hospitals, halogenated gases can be the primary source of GHG emissions [34]: In the operating theatre not using desflurane, the main source of emissions was energy (84%) followed by supply chain waste (12%) and anaesthetic gases (4%). On the opposite, in operating theatres using desflurane, halogenated gases accounted for 51 to 63 % of GHG emissions, supply chain waste for 13 to 20 % and energy for 17 to 36%. The use of desflurane resulted in a ten-fold difference in anaesthetic gas emissions between hospitals.

Analysing these results, authors stated that desflurane should be restricted to cases where it may reduce morbidity and mortality over alternative drugs [33]. Of course, we have to do so!

Beyond this statement, we could question the evidence-based proofs of the benefit for patients of using desflurane over sevoflurane or IV anaesthetic drugs. The only benefit of desflurane that has been shown by the large amount of literature available on the subject is a recovery few minutes earlier with desflurane [35]. Anaesthesiologists should have this in mind when choosing their halogenated gas.

Implementing a strategy of reduction of GHG emissions in the operating theatres also implies to work with low-flow anaesthesia. Modern anaesthesia ventilators allow to safely work with a fresh gas flow lower than 1l/min. This simple action can decrease the quantity of volatile agents used and spread in the atmosphere [36].

Finally, companies are actually developing processes to capture, extract and purify halogenated gases. These technologies are still experimental but could be available in the near future.

IV Drugs

The procurement chain of intravenous agents (as well as other medications) (methods of manufacture, packaging, transport to the hospital, energy and materials required for drug delivery) accounts for the major part of carbon emission from health care facilities. Impact on the environment is also due to the release of drugs and their metabolites into the aquatic environment [37][38].

Anesthetic drugs are unused and discarded in more than 50% of the time according to Atcheson et al [39]. Among them propofol is the costliest drug wasted and the worst for the environment accounting for up to 45% of wasted anaesthetic medication. Propofol is considered toxic to aquatic organisms (and is used to anesthetize fish![40]), has a high potential for bioaccumulation and high mobility in the soil, is not biodegradable in water under aerobic and anaerobic conditions and requires incineration to be fully destroyed. [41]

In a life cycle assessment of propofol versus anaesthetic gases, Sherman et al. showed that the environmental impact of propofol was nearly four orders of magnitude lower than desflurane or nitrous oxide [33].

Personal behaviour

After detailing the impact of our profession on the environment, we have to question our personal behaviour. We need to be consistent and lower our daily environmental impact. Barriers are usually a lack of knowledge and educational programs have shown to help implement more environmentally friendly attitudes [42]. Indeed, it is not that difficult! You can implement the following non-exhaustive list of simple changes as recommended in the European Society of Anaesthesiology (ESA) “tool kit for beginners” [43].

- For food and beverages: Use a reusable mug for coffee / tea, refuse plastic silverware and dishes at work, promote organic and local food in reusable dishes, eliminate plastic bottles, implement reusable and washable glasses for patients and yourself
- When attending a national or international conference: Refuse flyers, plastic goodies, single-use badge holders and plastic bottles
- Be e-green: Promote green-transportation for meetings (train not plane), audio-video conferences and stop emails to all (0.21g of CO₂ /email)
- Transportation: Consider commuting with a low carbon emission transportation mode (train, bike, feet)

Conclusion

Since ORs are the most important energy and resource intensive location in the hospital, reducing its carbon footprint would dramatically help reduce the global environmental impact of hospitals. Reduction of waste and greenhouse gas emissions are the major goals. 5R's rule (reduce, reuse, recycle, rethink and research) used to promote an environmentally friendly way of life can be applied to the medical field and specifically to the operating room to question the use of disposable devices, attires, packaging as well as our professional and personal behaviour. Greening the ORs needs the engagement of all its professionals as well as other departments (pharmacy, hygiene) and management. Economic and social co-benefits are expected from this process.

Practice points

- ORs contribute for a major part to hospitals carbon footprint because of anaesthetic gases, energy-intensive equipment and waste.
- The well-know 5R's rule used to promote an environmentally friendly way of life can be applied to the medical field and specifically to the operating room and the anaesthesia field. 5Rs applied to ORs waste management reduces environmental footprint of the ORs.
- The use of disposable devices should be questioned by comparing their benefits and costs (financial as well as environmental) versus the reusable options.
- Since anaesthetic gases (nitrous oxide, halogenated) contribute significantly to the OR carbon footprint, implementing a strategy of reduction of GHG emissions in the operating theatres implies to avoid the use of nitrous oxide, to choose the halogenated gas with the lowest impact and to work with low fresh gas flow techniques.
- The procurement chain of drugs and medical devices (methods of manufacture, packaging, transport to the hospital, energy and materials required for drug delivery) accounts for the major part of carbon emission from health care facilities.
- Awareness, commitment, professional and personal behaviour changes will contribute to mitigate hospitals' carbon footprint.
- Education in basic principles shared by all OR personnel is paramount to reduce carbon footprint.
- Implementation of eco-friendly practices depends on partnership with other specialties (pharmacist, hygiene), engineers and management.

Research agenda:

- Comprehensive studies on life cycle of drugs and devices.
- Address benefits/risks and costs (financial and environmental) of disposable versus reusable devices. Assess contamination and sterility of disposable versus reusable protective clothing.
- Develop and assess efficacy, efficiency and safety of anaesthetic gases scavenging techniques.
- Address toxicology of perioperative drugs on wastewater.
- Address safety of reprocessing devices.
- Evidence based proofs of the benefit for the environment of individual and collective efforts to implement eco-friendly practices.

Legend of the figures and tables

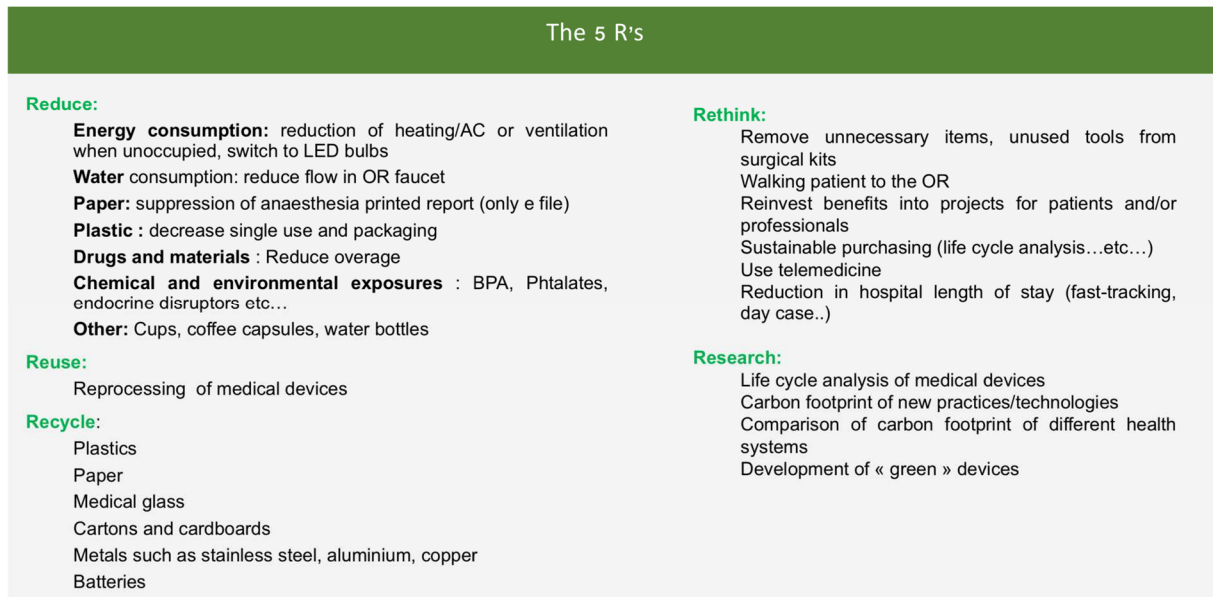
Table 1: Impact of anaesthetic inhaled agents on GHG emissions

Figure 1: The 5R's in the operating room (from ESA tool kit for beginners [43])

Table 1:

Agent	GWP₁₀₀ (CO₂=1)	Atmosphere lifetime (years)	CO₂ e (tCO₂e/litre)
Nitrous oxide	298	114	
Sevoflurane	130	1.1	0.20
Desflurane	2540	14	3.72
Isoflurane	510	3.2	0.76

Figure 1:



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