SUSQI PROJECT REPORT

Minimizing desflurane use and decreasing fresh gas flows

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Background:

Anesthetic volatile agents are used almost everyday by anaesthesiologists to provide general anesthesia to patients for various medical procedures, including surgeries and certain diagnostic tests. There are a range of anesthetic volatile agents available for clinical use, all of which are potent greenhouse gases as they are released unchanged into the atmosphere. In the UK, Anaesthetic gases alone contribute 2% of National Health Service (NHS) England's carbon footprint. (1) The impact is much larger in North America where anesthetic gases were the primary source of operating room (OR) emissions of up to 63% of the carbon footprint of the OR. (2) Recent published practice guidelines from the Canadian Anesthesiologists Society (CAS) recommends environmentally responsible use of volatile anesthetic agents that are potent greenhouse gases. (3)

Not all anesthetic volatile agents have the same environmental impact. Evidence from life cycle analysis has shown that desflurane is more carbon-intensive when compared to sevoflurane (2540 times for desflurane versus 130 times for sevoflurane the global warming potential (GWP) over 100 years. (4-5) Furthermore, desflurane is less potent, which means more than 3 times as much agent mass is required to produce the same clinical effects. Recent literature also demonstrated occupational exposure poses a potential health hazard to healthcare personnel, with associated genetic damage and oxidative stress. (6-7) A recent quality improvement project showed a reduction of desflurane use has an associated usage cost reduction of 58%.(8)

The NHS in the UK has committed to stop using desflurane by early 2024 due to its significant environmental impact and comparable alternatives that have no negative clinical outcomes or added patient safety risks. Discontinuation of desflurane will significantly lower the carbon footprint of anesthesia practices and will benefit wider public health aims.

It has been outlined in previous publications that desflurane has very minimal perceived benefits of faster emergence time from anesthesia with questionable meaningful clinical benefits, however, the adverse effects of desflurane will far outweigh its use. (9-10) The CAS recommends the lowest global warming potential volatile agent i.e. sevoflurane/isoflurane to be used unless clinically indicated to do otherwise (3).

> "*Responsible use of volatile anesthetic agents that are potent greenhouse gases. Considerations should include choosing agents with the lowest global warming potential and using low total fresh gas flow rates of 1 Lmin-1, ideally minimal flows of 0.5 Lmin-1, where appropriate.*"

During maintenance of general anesthesia, the ventilator/anesthetic machine will use fresh gas flow (usually a mixture of oxygen and air) to 'carry' the anesthetic volatile agent as the 'fresh gas' flows over the vaporizer in the anesthetic machine to deliver the anesthetic gas to the patient. The flow rate of the fresh gas affects how much anesthetic vapor is consumed. With advanced and efficient closed circuit anesthetic machines, the fresh gas flow rate can be as low as 0.1L/min to provide effective anesthetic volatile agent to patients.

At South Health Campus, semi-closed circuit ventilators are used and the fresh gas flow rate can be set as low at 0.3L/min for anesthetic delivery, without any clinical harm. By using low fresh gas flow, the volume of any anesthetic volatile agents consumed can be greatly reduced, as the fresh gas flow is a carrier gas, and with such efficient machines that we have to prevent leakage of gases and advanced monitoring to measure the volatile agents the patients receive, minimal fresh gas flow rate can easily be implemented without any adverse effects. This can ultimately lead to reduction in carbon footprint as well as costs for volatile anesthetics.

This project took place in the South Health Campus surgical suites unit, which includes an Operating room and anesthesia supply room where anesthetic is being delivered daily, and where anesthetic equipment is stored. The project has predominantly affected anesthesiologists as they are the primary staff to deliver the anesthetic to patients, however respiratory therapists have been involved as they are responsible for the anesthetic equipment.

Specific Aims:

To assess the sustainable value of replacing desflurane with sevoflurane and to reduce the overall volatile consumption by encouraging the use of low fresh gas flow during general anesthetic delivery. We anticipate these changes will reduce the carbon footprint and realise costs savings for the department.

Methods:

This is a quality improvement project at South Health Campus in alliance with the Green Team Competition, therefore, no ethics approval is required.

To implement changes, an email outlining the changes was sent out to get feedback from all anesthesiologists within the South Health Campus anesthesia department. 6 of 28 anesthesiologists were identified to use desflurane. The 6 desflurane users were individually approached to discuss the Green Team Competition project aim and methodology. Email followed by discussion at a business meeting were used to address change resistance. Therefore, we quickly learned that a sudden change in removing the desflurane from the anesthetic machine straight away would not be a good initial strategy to bring everyone in the department on board. Thus, it was felt that a stepwise approach would be warranted, along with staff education, i.e., raise awareness, deliver education and then process change.

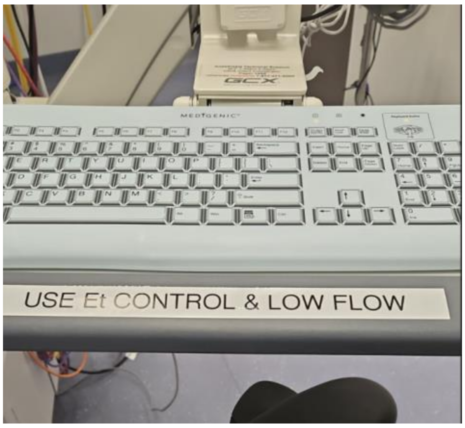
Firstly, a lecture was delivered by the project lead to outline the environmental sustainability practice and various carbon intense practices. Three days later, a sticker outlining the large difference of greenhouse gas emissions of different anesthetic gases made by AHS was placed onto the anesthetic machine. Four days later, the aim, purpose and methodology of the changes for the Green Team Competition was outlined at the departmental meeting. The following week, tape was placed around the desflurane vaporizers (Figure 2), and stickers to remind people to lower the fresh gas flow by selecting end-tidal control. These stickers were placed onto the anesthetic machines and the computers for electronic charting (Figure 1). This was done to reduce fresh gas flow rate and use end-tidal control (which is an automatic setting on the anesthesia machine to reduce gas flow rates). Finally, the desflurane vaporizers cassettes, which are normally situated on the anesthetic machine in the operating room, were moved to the anesthesia supply room where extra or supplementary anesthetic equipment is kept so to increase an inconvenience barrier for using desflurane (further distance to travel in order to obtain the desflurane vaporiser cassettes, rather than the vaporisers cassettes already situated within the anesthetic machine for the anesthetists to just turn it on).

These changes were communicated via email to the anesthesia site chief, the respiratory technician Lead, and the OR nursing lead. The resources that were required were a label printer which was borrowed from the Operating room administrative staff. The respiratory technicians were involved in clearing a cupboard for us to store the desflurane vaporizers in, as well as helping to affix the reminder stickers onto the anesthetic machines. The data analysis staff from the pharmacy department, as well as the information technology team from the operating room will help us with the collection of data.

Data on total volume of desflurane consumption, total volume of sevoflurane consumption, and the number of cases performed under general anesthetic, will be collected before and after the changes are implemented to evaluate carbon and financial impacts.

Figure 1. Figures showing 'use end tidal control and low fresh gas flow' placed onto

a) the computer keyboard, and



b) just below the dial for fresh gas control on the monitor.

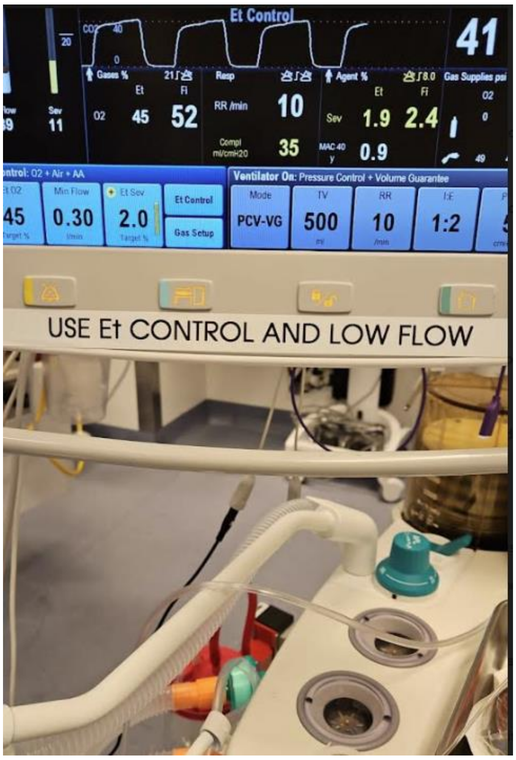


Figure 2. A tape is placed over the desflurane vaporizer that is inserted into the slot within the anesthetic machine

Measurement:

Patient outcomes:
There are no immediate changes to health outcomes for patients as the two drugs are comparable in terms of clinical effects. The standard of patient care will not be negatively impacted because whether desflurane or sevoflurane was used is largely anesthetic provider preference and both are clinically comparable agents. While outside of the scope of the project to measure, some potential benefits of switching to sevoflurane are outlined in the results section.

Population outcomes:
While outside the scope of our project to measure, there is potential to improve population health through the reduction in greenhouse gas emissions and slowing climate change, which in turn will positively affect the health of the global population from reducing the secondary health problems caused by climate change. Through cost savings by switching to sevoflurane, this may improve general access to care for the entire population, especially the extremes of ages.

Environmental sustainability:
Data on total volume of desflurane consumption, total volume of sevoflurane consumption, and the number of cases performed under general anesthetic, was collected in 2023 (before) and after the changes were implemented in 2024. Greenhouse gas (GHG) emission savings have been calculated using the carbon emission factors for desflurane and sevoflurane, taken from The Sustainable Development Unit database. Table 1 details the Global Warming Potentials and carbon dioxide equivalent (CO_2e) conversion factor per litre of anesthetic gas.

	Desflurane	Sevoflurane
Global Warming Potential (GWP 100 year)	2540	130
Carbon dioxide equivalent factor (tonnes CO_2e/litre)	3.72	0.20

Changes in CO2e from the project will reflect reduced procurement and consumption of desflurane and an increased procurement and consumption of Sevoflurane. Disposal was excluded from calculations as it was assumed disposal of the different volatile agents is the same.

Our CO2e saving has been translated into the equivalent of kilometers driven using an emission factor of 0.259 kgCO2e/km for an average passenger vehicle the Canadian Fuel consumption ratings search tool (nrcan-rncan.gc.ca).

Economic sustainability:
Desflurane, when compared to Sevoflurane, is more costly. It is also less potent and needs 3 times more of the dose for the same clinical effect as sevoflurane. Furthermore, there is only 1 supplier in Canada for desflurane which means that it is at an increased risk of supplier chain disruption. The financial data was obtained from the pharmacy drug use and stewardship team at Alberta Health Services. Only differences in costs have been shared in this report as per Contracting, Procurement and Supply Management (CPSM) advice.

Social sustainability:
A survey was sent to all staff in the department to explore their understanding of the environmental impact of anesthetic gases, their practice and perception of the change.

Results:

Patient outcomes:
Clinically, there is no risk to switch from desflurane to sevoflurane, or to use low fresh gas flow. In fact, there are more risks of adverse effects from using desflurane than sevoflurane. For instance, desflurane is an irritant and may cause bronchospasm, increase sympathetic response, increased cerebral blood flow and increase cerebral spinal fluid pressure which are deleterious in certain situations. (11) As it has a reduced potency, an increased amount is necessary to produce the same clinical response compared to sevoflurane.

There is a small potential perceived benefit of earlier wake-up from desflurane compared to sevoflurane, however the undesirable effects outweigh the purported benefit of earlier recovery. With better understanding of the pharmacokinetic properties of sevoflurane, anesthesiologists can learn to adjust the dosage of sevoflurane towards the end of surgery and equalize the recovery times between desflurane and sevoflurane.

Environmental and Economic sustainability:
Table one summarizes average annual desflurane use prior to implementing our changes (based on 6 months of data in each year, as the data obtained may show a lagged time, therefore, an increased data set may be more representative).

Table 1

Absolute changes without accounting for an increase in case volume from 2023- 2024	Desflurane	Sevoflurane
Usage Change (%)	-8	+17.4
CO_2e Change (Tonnes)	-0.45	+0.24
Monthly CO_2e savings (Tonnes)		0.21
Annual CO_2e savings (Tonnes)		2.52
Changes taking into the account an 11% Operating Room case increase from 2023-2024	Desflurane	Sevoflurane
Usage Change (%)	-17	+5.7
CO_2e Change (Tonnes)	-1.07	+0.09
Monthly CO_2e savings (Tonnes)		1
Annual CO_2e savings (Tonnes)		12

Following our changes, when taking into account the increased case volume in 2024, we have seen a 17% reduction in desflurane usage and a 6% increase in sevoflurane usage when compared to the average monthly usage in 2023. This is a saving of 1 Tonne CO_2e in one month. Projected across a year, assuming similar/consistent usage, this is a saving of 12 Tonnes CO2e, equivalent to driving 46,332 km in an average car.

Unexpectedly, the use of sevoflurane is showing to be a cost increase of $30.49 per month instead of a saving despite savings being demonstrated in other Hospitals / literature. The team will continue to collect data over the coming 6 months to offer a better reflection of the financial (and carbon) impacts of this project. This unexpected outcome has been flagged with our Surgery Strategic Clinical Network (SCN) who plan to further review the findings. Cost calculation is not shared due to confidentiality of AHS contract pricing.

Social sustainability:
Upon surveying the 28 anesthetists within the anesthetic department at South Health Campus before implementing the change, 6 anesthesiologists were identified to use desflurane (approx., 22% of staff). Only a very small proportion (<10%) of the staff anesthesiologists opposed the change. Two staff voiced strong opinion regarding the changes of moving desflurane into the anesthetic supply room. The resistance to these changes was mainly due to the perception of impacting professional autonomy. Others felt indifferent regarding the change and most thought that they rarely use desflurane. A post change survey can be repeated towards the end of the year after allowing staff having some time to adjust to the changes.

The changed strategy of a stepwise approach enables anesthetists who were opposed, to slowly get used to the change, and benefit from a deeper understanding / knowledge regarding the various anesthetic practices (in addition to desflurane and the importance of low fresh gas flow, and end-tidal control), as well as the other adverse clinical effects of desflurane for the small potential perceived benefit of earlier wake-up from desflurane compared to sevoflurane.

It was also mentioned that since the pharmacokinetics of these two drugs are different, there should be different approaches in how to use them in clinical practice. The updated CAS practice guidelines were also mentioned as well as anesthetic practice change in response to the need to provide environmentally sustainable anesthesia care in other provinces of Canada. This has a significant impact on the social circumstances and broadcasting and implementing potential wider health benefits.

We engaged other health allied members who were largely supportive. One of the reasons is that this initiative is directly affecting anesthesiologists only, especially when considering that majority of staff are using sevoflurane or willing and able to switch to sevoflurane without much delay to emergence from surgery. Of course, it is very important to consider the social aspects of keeping a healthy working environment, for both staff wellness, retention and recruitment. Furthermore, recent literature also demonstrated occupational exposure of volatile agents poses a potential health hazard to healthcare personnel, with associated genetic damage and oxidative stress (6-7), therefore, other modalities to provide anesthetic, wherever possible, e.g., using regional nerve block techniques or total intravenous anesthetic in the form of propofol infusion (both with lower carbon footprint), would be important to explore in order to minimize exposure of volatile agents in the work place for a healthy working environment. Therefore, a slow stepwise approach to change after extensive education and notification was implemented.

Discussion:

When considering the case volume increase in 2024, desflurane use decreased by 17% and the overall monthly volatile consumption was reduced by 1.7%. This denotes an annual CO2e saving of 12 tonnes which is equivalent to driving 46,332km in an average car. In terms of cost savings, the cost savings are realized from decreased desflurane use. As more sevoflurane will be consumed instead, even taking into account of encouraging low flow strategy, there is an additional monthly cost of 30 CAD. This outcome was unexpected and costs will continue to be reviewed over time. The 'actual' cost also needs to be considered in terms of the Triple Bottom Line.

We identified the barriers to implementing changes such as relocating the desflurane vaporizers from the operating room to the anesthetic supply room. We recognized that this social element needed to be addressed, therefore, we took advantage of the AHS sticker program which outlined the environmental impact of volatile agents. Those were placed just beside the volatile agents. We (the leader) presented at the Educational City Rounds to educate anesthetists across the whole of Calgary zone regarding environmentally sustainable anesthetic practices and the urgency of action. Hopefully, this widens the spread and scale of raising awareness and education.

We understand that the culture of a department is difficult to change, however, the overall culture is positive.

This project will be relevant in encouraging the use of total intravenous anesthetic (TIVA) which is more environmentally sustainable than use of volatile anesthetic agents. The main barrier to TIVA is the lack of target-controlled infusion (TCI) pumps within each of the operating rooms to enable its use. The next step would be to ask AHS for funding support and purchase more TCI pumps for TIVA use, potentially creating a business case proposal to use the money saved from reducing/eliminating desflurane use. These pumps can be placed within each operating room as an enabler to encourage its use. Therefore, this will be a reverse of the principle of relocating the more polluting volatile agents away from the operating room.

Conclusions:

This project has been extremely helpful in team bonding, educating other anesthetists, and realizing the importance of social aspects for implementing changes. The key elements that contribute to the successes and learning in this project is the need to assess the emotion of the department or team about changes, then implement changes in a stepwise approach after discussion.

City-wide education, which were attended by anesthesiologists and respiratory therapists at all 5 hospitals across the city of Calgary, plays an important part in raising awareness with a wider audience, and to ensure lasting effect of the change will be to show the department the data, empowering them to be part of the positive change while respecting them as individual and independent practitioners.

This project has ignited interests in identifying potential areas for improvement in terms of environmentally sustainable practices within our department through speaking with individuals.

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Critical success factors Please select one or two of the below factors that you believe were most essential to ensure the success of your project changes.			
People	**Process**	**Resources**	**Context**
☐ Patient involvement and/or appropriate information for patients - to raise awareness and understanding of intervention **√ Staff engagement** ☐ MDT / Cross-department communication ☐ Skills and capability of staff ☐ Team/service agreement that there is a problem and changes are suitable to trial (Knowledge and understanding of the issue) **√Support from senior organizational or system leaders**	**√clear guidance / evidence / policy to support the intervention.** ☐ Incentivization of the strategy – e.g., QOF in general practice ☐ systematic and coordinated approach ☐ clear, measurable targets ☐ long-term strategy for sustaining and embedding change developed in planning phase **√ integrating the intervention into the natural workflow, team functions, technology systems, and incentive structures of the team/service/organization**	☐ Dedicated time ☐ QI training / information resources and organization process / support ☐ Infrastructure capable of providing teams with information, data and equipment needed ☐ Research / evidence of change successfully implemented elsewhere ☐ Financial investment	☐ aims aligned with wider service, organizational or system goals. ☐ Links to patient benefits / clinical outcomes ☐ Links to staff benefits ☐ 'Permission' given through the organizational context, capacity and positive change culture.