Sustainability Workgroup Meeting

Date: April 28, 2025, 10am EST via Zoom

Attendance

Henrietta Addo, MSN, RN MPOG QI Specialist	Eva Lu-Boettcher, MD University of Wisconsin
Kate Buehler, MS, RN MPOG Clinical Program Manager	Katie O' Connor, MD, MBA Johns Hopkins
Nick Delasio, MD Johns Hopkins	Nirav Shah, MD MPOG Quality Director
Tony Edelman, MD, MBA MPOG Associate QI Director	Ben Stam, MD Corewell West and UM West
Lucy Everett, MD Massachusetts General	Meridith Wade, MSN, RN MPOG Pediatric Program Manager

Summary of meeting:

SUS 01 and 04

- Group generally supported a low flow measure (ie flow < 1 l/min), should be accompanied by a lower carbon footprint measure (update to SUS 02). Consider retiring SUS 01
- Group generally agreed that we should remove exclusion for < 30 minutes so that we can encourage lower flows for short cases

SUS 02

- Cuveele method – more accurate but likely fewer sites can participate. Coordinating center to see if more sites can send MV and end tidal agent concentration
- Change GWP from GWP 100 to GWP 20. Group agreed with plan to change to GWP 20, given that relative performance and trend over time should not change much as this doesn't change recommendations about the choice of anesthetic agents or flows administered.
- The group generally agreed that we should figure out a way to analyze shorter cases (ie less than hour) in a more granular way. One way is for shorter cases to compare against the recommended per minute (instead of per hour) kg CO2 equivalents of 2% sevoflurane at 2 l/min.

SUS 05 - PEDS

- Consider trying to isolate inhalation induction cases from IV induction
- Update rationale to include information about why nitrous shouldn't be used during induction (ie inability to adequately preoxygenate)
- Meridith to look through Peds SC notes regarding SUS 05

Next Meeting:

- SUS-03: Global Warming Footprint, Induction
- SUS-06-Peds: Low Fresh Gas Flow, Pediatric Induction
- SUS-07: Nitrous Oxide Avoided

Meeting Transcript:

Meeting Start: 1004

I) Measure Review: SUS-01: Fresh Gas Flow, less than or equal to 3 L/min
   a. Description: Percentage of cases with mean fresh gas flow (FGF) equal to, or less than 3 L/min, during administration of halogenated hydrocarbons and/or nitrous oxide
   b. Threshold: 90%
   c. Exclusions:
      i. Cases without an ETT or LMA placed
      ii. Cases without halogenated hydrocarbons and/or nitrous oxide administration
      iii. Cases with < 30 minutes of halogenated hydrocarbons or nitrous oxide administered between intubation and extubation
      iv. Cases with documentation of Nitric Oxide use
      v. Cases with only manually documented fresh gas flow values (fresh gas flow values must be automated to be considered for this measure)
   d. Success: Mean FGF equal to, or less than 3 L/min when inspired halogenated hydrocarbons is > 0.2% or nitrous oxide FGF > 0.2 L/min, during the maintenance period of anesthesia
   e. Other Measure Details:
      i. If Fresh Gas Flow Total (Concept ID:3214) is documented for the case, this concept will be used to determine success of halogenated agents or nitrous oxide use
      ii. If Fresh Gas Flow Total (Concept ID:3214) is not documented for the case, MPOG will calculate Fresh Gas Flow: Flows Oxygen (ID:3215) + Flows Air (ID:3220) + Flows Nitrous Oxide (ID:3225)
   f. Current SUS-01 Performance across All MPOG Institutions between April 2024 and March 2025: 15% - 100%

II) Measure Review: SUS-04: Fresh Gas Flow, less than or equal to 2 L/min
    a. Description: Percentage of cases with mean fresh gas flow (FGF) equal to, or less than 3 L/min, during administration of halogenated hydrocarbons and/or nitrous oxide
    b. Threshold: 90%
    c. Exclusions:
        i. Cases without an ETT or LMA placed
        ii. Cases without halogenated hydrocarbons and/or nitrous oxide administration
        iii. Cases with < 30 minutes of halogenated hydrocarbons or nitrous oxide administered between intubation and extubation
        iv. Cases with documentation of Nitric Oxide use
        v. Cases with only manually documented fresh gas flow values (fresh gas flow values must be automated to be considered for this measure)
    d. Success: Mean FGF equal to, or less than 2 L/min when inspired halogenated hydrocarbons is > 0.2% or nitrous oxide FGF > 0.2 L/min, during the maintenance period of anesthesia
    e. Other Measure Details:
        i. If Fresh Gas Flow Total (Concept ID:3214) is documented for the case, this concept will be used to determine success of halogenated agents or nitrous oxide use
        ii. If Fresh Gas Flow Total (Concept ID:3214) is not documented for the case, MPOG will calculate Fresh Gas Flow: Flows Oxygen (ID:3215) + Flows Air (ID:3220) + Flows Nitrous Oxide (ID:3225)
    f. Current SUS-01 Performance across All MPOG Institutions between April 2024 and March 2025: 1% - 98%
III) Measure Review: SUS-02: Global Warming Footprint, Maintenance
    a. Description: This measure analyzes the percentage of cases where carbon dioxide equivalents (CO_2 eq) normalized by hour for case receiving inhalational anesthetic agents (desflurane, isoflurane, or nitrous oxide) is less than CO_2 eq 2% sevoflurane at 2L FGF = 2.83 kg CO2/hr or the total CO_2 eq is less than 2.83 kg CO_2 for the maintenance period of anesthesia
    b. Threshold: 90%
    c. Exclusions:
        i. Cases without an ETT or LMA placed
        ii. Cases without inhalational agent (desflurane, sevoflurane, isoflurane, or nitrous oxide)
        iii. Cases with documentation of Nitric Oxide use
        iv. Cases with only manually documented fresh gas flow values (fresh gas flow values must be automated to be considered for this measure)
    d. Success: For maintenance phase of anesthesia:

i. Mean CO_2 equivalents for a case is < 2.83 kg $C0_2$/hr. This is equivalent to 2% sevoflurane at 2 L/min FGF
ii. Total CO_2 equivalents are less than or equal to 2.83 kg/CO_2

e. Other Measure Details:
i. If Fresh Gas Flow Total (Concept ID:3214) is documented for the case, this concept will be used to determine success of halogenated agents or nitrous oxide use
ii. If Fresh Gas Flow Total (Concept ID:3214) is not documented for the case, MPOG will calculate Fresh Gas Flow: Flows Oxygen (ID:3215) + Flows Air (ID:3220) + Flows Nitrous Oxide (ID:3225)

f. Current SUS-02 Performance across All MPOG Institutions between April 2024 and March 2025: 1% - 100%

g. Discussion:
i. *Ben Stam (Corewell West &UM West*): If you pass SUS-01 you then you pass SUS-01. When you look at SUS-02 and SUS-04, what does the Venn diagram look like for mutual inclusivity and exclusivity? Are there cases where SUS-04 is passed but failed in SUS-02? And vice versa? Do we need to do that analysis?
ii. *Tony Edelman (MPOG Associate QI Director)*: Conceptually, think about using desflurane at 2 L/min - desflurane has a high global warming potential, so your CO2 eq would still be high even if you pass SUS-04. They are similar measures, but not the same because they target different metrics
iii. *Kate Buehler (MPOG Quality Manager)*: SUS-01 and SUS-04 have a 30-minute exclusion, but SUS-02 does not. So, there could be cases that are excluded from SUS-01 and SUS-04 but included in SUS-02 that could impact passing rates, especially for short cases depending on which anesthetic agent you use.

IV) Measure Review: SUS-05-Peds: Nitrous Avoided, Induction

a. Description: Percentage of pediatric patients < 18 years old undergoing general anesthesia where nitrous oxide was avoided during induction
b. Threshold: 90%
c. Exclusions:
i. Age ≥ 18 years
d. Success: Nitrous oxide was not administered during the induction period of anesthesia
e. Modifications to consider: pass cases with nitrous oxide used during induction AND
i. Flows lower than _____
ii. For less than _____ minutes
iii. Patients < 3 years
iv. Rationale: "....can justify avoiding nitrous oxide for pediatric inhalational inductions when preop versed is administered or for patients 2/2.5 years old

and younger but would prefer to continue using it for older children who do not receive preop anxiolytic/amnestic agent"

f. Current SUS-05-Peds Performance across All MPOG Institutions between April 2024 and March 2025: 17% - 100%

g. Discussion:

i. *Lucy Everett (Mass Gen)*: For nitrous use in peds, since the age cut off is under 18, are we targeting only inhalation inductions? A lot of teens would have IV inductions, meaning no nitrous by default.

ii. *Tony Edelman (MPOG Associate QI Director):* No, it is not specific to inhalational induction; it is for the induction period in general

iii. *Lucy Everett (Mass Gen)*: Including all teens in the measure might skew performance rates higher because many undergo IV inductions without nitrous

iv. *Eva Lu-Boettcher (University of Wisconsin)*: Yes, many patients 12 years and older, or over 40 kg, get IV inductions. One idea floated was to exclude cases where muscle relaxants are given early, suggesting IV induction. It is harder to differentiate clearly because propofol boluses are common even with inhalational inductions.

v. *Tony Edelman (MPOG Associate QI Director):* The thought is to capture only true inhalational inductions for more accurate performance data?

vi. *Eva Lu-Boettcher (University of Wisconsin)*: Exactly. Otherwise, it overstates high success rates – masking true performance differences among providers

vii. *Meridith Wade (MPOG Pediatric Program Manager)*: I'll check old Peds subcommittee notes. Originally, we just wanted a broad baseline to see overall nitrous use. But now we could refine it. We have phenotypes separating IV vs mask induction, so could use those.

viii. *Tony Edelman (MPOG Associate QI Director):* Even under current definitions, there's huge variability. Tightening definitions would be an improvement.

ix. *Eva Lu-Boettcher (University of Wisconsin)*: Recent literature also discourages nitrous due to oxygenation concerns — especially not preoxygenating 100% FiO_2 in peds. We could update the rationale to reflect that.

x. *Nirav Shah (MPOG QI Director)*: What the feedback/site is saying is that there's still a population of patients they'd like to use nitrous on. And I think that should probably be debated in the Peds subcommittee: is that reasonable, or are we saying — even with the newer literature and climate change data — that we still want to avoid nitrous use broadly? This sounds a little bit like personal preference, but maybe there's more to it.

xi. *Eva Lu-Boettcher (University of Wisconsin)*: The threshold is set at 90%, so it's not like sites can't ever use nitrous. I can think of a few cases where nitrous might be more stable for specific patients, but it really doesn't exceed 10% usage. I think the 90% threshold is very generous. Not sure if that site has a specific number in mind they want us to consider — maybe we can discuss during the Peds subcommittee, but I think our threshold is very reasonable.

xii. *Lucy Everett (Mass Gen)*: I was just going to add: the ASA's recommendation was to eliminate central pipelines for nitrous — but they did note that it's informational. So, I think this measure can be seen that way: if a site wants to eliminate it, great, but they're not forced to.

xiii. *Tony Edelman (MPOG Associate QI Director):* The goal is to make the activation energy higher — make using nitrous more intentional. You have to consciously turn it on rather than having it available by default.

xiv. *Eva Lu-Boettcher (University of Wisconsin)*: 90% of the nitrous waste comes from leaks in central supply systems. So simply removing central supply saves most of the environmental impact. From the pediatric side, newer literature says the safety profile of nitrous isn't as good as once thought. You're not preoxygenating 100% FiO_2 during induction, which increases risks of desaturation and cardiopulmonary arrest. Adults wouldn't be induced without 100% oxygen, so why are we doing that to children? It's a habitual practice — but the true clinical benefit of using nitrous in young, combative patients is questionable. Diane Gordon and Jeff Feldman have written reviews about this. It's worth rethinking the risk-benefit calculation.

xv. *Nick Delasio (Johns Hopkins)*: My biggest nitrous problem is with adult neuro colleagues — not peds. We just gave a talk yesterday. They like nitrous for fast wakeups. Our peds group has moved away from nitrous for inductions. Diane Gordon wrote a nice paper about inhalational induction without nitrous. We did a study on decentralizing nitrous at Hopkins — we're doing slightly better than Washington's numbers. About 13% of our liquid nitrous gets to patients — instead of 10%. We are moving to E-cylinders to make nitrous harder to get. (https://pedsanesthesia.org/wp-content/uploads/2021/08/Low-Flow-Anesthesia-in-Pediatric-Patients.pdf)

xvi. *Tony Edelman (MPOG Associate QI Director):* There's been discussion about whether to move from GWP-100 to GWP-20 for CO_2 equivalent calculations. GWP-20 increases the relative impact of shorter-lived gases — reflecting reality more accurately. Has anyone read much about this? Thoughts?

V) Feedback we've received

a. Should MPOG change kg CO_2 equivalents calculation?

i. MPOG currently uses GWP_{100} for kg CO_2 equivalents calculations

ii. Should we consider using GWP_{20}?

Global Warming Potential (IPCC report)	
GWP_{20}	GWP_{100}
Desflurane = 7020*	Desflurane = 2590 (MPOG uses 2540)
Isoflurane = 1930	Isoflurane = 539 (MPOG uses 565)
Sevoflurane = 702	Sevoflurane = 195 (MPOG uses 144)
Nitrous = 273	Nitrous = 273 (MPOG uses 282)

iii. *1 kg of desflurane has the same effects as 7,020 kg of carbon dioxide over a period of 20 years

b. Discussion:

i. *Nirav Shah (MPOG QI Director)*: GWP-20 is more accurate, and it won't dramatically change relative rankings between gases like sevo, des, or iso – the trends still look the same. Only the absolute CO_2 equivalent numbers would shift. We would need to update the 2.83 kg/hr SUS-02 threshold accordingly, but that's just math. It won't change behaviors or recommendations drastically.

ii. *Lucy Everett (Mass Gen)*: Only concern is that Epic's dashboards were built around GWP-100 because we aligned it with MPOG. People may get frustrated seeing different numbers from different systems. We could update Epic.

iii. *Ben Stam (Corewell West &UM West*): Could we use GWP-100 for nitrous and GWP-20 for the other gases?

iv. *Nirav Shah (MPOG QI Director)*: The numbers stay the same for nitrous either way.

c. GWP Discussion

i. GWP_{100} significantly underestimates the climate effects in the coming decades. The 20-year time horizon values much better reflect the climatological reality for the next 50 years

ii. Our GWP values don't currently use the latest values from IPCC

iii. All-Inclusive Carbon Footprint of Inhalational Anesthesia

iv. GWP_{100} and GWP_{20} values for all volatile anesthetics can be found in the IPCC report (isoflurane = HCFE-235da2; desflurane = HCFE-236ea2; sevoflurane = HFE-34mmz1)

v. Additional background on GWP_{100} and GWP_{20}

vi. The future is now – it's time to rethink the application of the Global Warming Potential to anesthesia

d. Additional information…

i. The science of climate change and the effects of anesthetic gas emissions

ii. "On the basis of GWP, anesthetic gases appear to be very 'damaging'. However, this conclusion is scientifically unsound: their lifetimes are short; their emissions, accumulation and resulting atmospheric concentrations are minute; and their actual radiative forcing is vanishingly small"

iii. And….” A key reason that CO_2e values are misleading is that long- and short-lived gases affect atmospheric concentrations, and thus the planet’s energy budget, in fundamentally different ways.”
iv. …halogenated hydrocarbons such as sevoflurane, desflurane, and other inhaled anesthetic vapors are near term climate forcers and hence shorter GWP numbers (GWP-20) needs to be employed while the GWP-100 numbers are better suited for long term climate forces such as Nitrous Oxide.”

e. Method to calculate kg CO2 equivalents
   i. Gold Standard: agent consumption from the anesthesia machine
   ii. Current MPOG methodology uses Fresh Gas Flow x Inspired Agent
   iii. Cuveele Method: Use FGF, minute ventilation (MV), agent inspired concentration (F_{IN}), agent end-expired concentration (F_{ET})
   iv. MPOG Method will generally underestimate use compared to Cuveele
   v. In a soon to be published analysis, compared to what the machine estimates, Median Absolute Prediction Error (%) was 16% for MPOG and 6% for Cuveele. 90% of the time Cuveele was within 20% of what the machine estimated, this was only 57% of the time for MPOG method
   vi. Not all sites are able to send MPOG F_{ET} and MV
   vii. Discussion:
      1. *Kate Buehler (MPOG Quality Manager)*: If sites have that data, it's usually not mapped. Most just don’t have it coming into their EHRs from the anesthesia machine at all. It would require the same kind of push we did for inspired agents and fresh gas flow — getting anesthetic machine data to flow into EHRs minute-by-minute. We could reassess now — it’s been a year or two — maybe more sites have improved, but originally, hardly anyone had minute ventilation and expired agent mapped, even U of M.
      2. *Ben Stam (Corewell West &UM West)*: Can be information be extracted? Or would it take some work to pull it?
      3. *Nirav Shah (MPOG QI Director)*: I think the latter. It will take work and political effort.
      4. *Ben Stam (Corewell West &UM West)*: The balance is, is tolerating a 10% error rate acceptable? If not, is it worth the time, effort, and ticketing with IT to pull this data?
      5. *Kate Buehler (MPOG Quality Manager)*: We could start by reanalyzing what data gaps exist now and then work over the next year encouraging sites to map it. If we push it too fast, people might get frustrated because we just got everyone on board with the sustainability data they have now.

6. *Tony Edelman (MPOG Associate QI Director):* Minute ventilation can be calculated from tidal volume × respiratory rate, correct?
7. *Nirav Shah (MPOG QI Director)*: Yes, for most sites we get actual tidal volume and respiratory rate (not just set values). But we still need end-tidal anesthetic agent concentrations, and that's less common.
8. *Ben Stam (Corewell West &UM West*): At Corewell West, we have mapped both inspiratory and expiratory agent concentrations. At University of Michigan Health West, only inspiratory is mapped.

f. Cuveele's method to calculate anesthetic agent
   i. If both fresh gas flow (FGF) and vaporizer dial setting (dialed F_{VAP}) are available, anesthetic agent consumption can be calculated as a product of FGF and F_{VAP}
   ii. If F_{VAP} is unknown, theoretical model for calculation F_{VAP}, based on FGF, minute ventilation (MV), agent inspired concentration (F_{IN}), agent end-expired concentration (F_{ET}) and dad space ventilation (V_D)
   iii. FVAP = [FIN - (dead space ventilation * FIN + (1 – dead space fraction) * FET) * (1 – FGF/MV)] / (1 – (1 – FGF/MV))
   iv. Dead space fraction for sevoflurane, desflurane, and isoflurane was therefore determined empirically

$$F_{VAP} = \frac{F_{IN} - (\text{dead space fraction} * F_{IN} + (1 - \text{dead space fraction}) * F_{ET}) * \text{fraction of rebreathing}}{(1 - \text{fraction of rebreathing})}$$

$$\text{Amount of vaporized agent } (L/min) = \frac{FGF * (F_{IN} - (\text{dead space fraction} * F_{IN} + (1 - \text{dead space fraction}) * F_{ET}) * \text{fraction of rebreathing})}{(1 - \text{fraction of rebreathing})}$$

VI) Other changes to consider
   a. SUS-01: Fresh Gas Flow, less than or equal to 3 L/min
   b. SUS-04: Fresh Gas Flow, less than or equal to 2 L/min
   c. SUS-08?: Fresh Gas Flow, less than or equal to 1 L/min
   d. Should we identify short cases with high maintenance flows?
      i. Some of these cases have < 2.83 kg CO2
      ii. Would have to choose a value lower than 2.83 kg CO2 or use some other method to identify these cases
      iii. For example, we could calculate the kg CO2 per minute instead of per hour
   e. Discussion:
      i. *Eva Lu-Boettcher (University of Wisconsin)*: Absolutely. Since 2020, the ASA's "Greening the OR" recommendations have pushed for low flows. Three liters isn't aspirational anymore. Two liters is very safe for Sevoflurane. Flows over two liters should only happen rarely, e.g.,

hypermetabolic or extremely obese patients. And with a 90% success threshold, it's already generous.

ii. *Lucy Everett (Mass Gen)*: There's interest among Epic BPA users too. Some want an even lower flow target (<2 L/min). One complaint, if the measures include flows during wakeup, people feel unfairly "dinged." I tell them if they manage transitions correctly, the impact is small.

iii. *Ben Stam (Corewell West &UM West*): I agree with retiring the three-liter measure too. But — what is our goal with a potential SUS-08 measure at one liter? Is it low-flow anesthesia for its own sake? Or is it environmental stewardship? Because if the goal is stewardship, refining SUS-02 (CO_2 equivalents) is more meaningful than just pushing flows lower.

iv. *Nirav Shah (MPOG QI Director)*: Low flow is a means to an end. If we had an aspirational SUS-02 metric (gold standard CO_2 footprint), flow would be one lever among others (like gas choice).

v. *Tony Edelman (MPOG Associate QI Director):* Low flow measures inform us, but SUS-02 reflects the true sustainability outcome — just like in other QI efforts, intermediate metrics help guide improvements.

vi. *Ben Stam (Corewell West &UM West*): Yes, it homogenizes comparisons across sites with heterogeneous practices.

vii. *Meridith Wade (MPOG Pediatric Program Manager)*: SUS-02 focuses on the maintenance phase. SUS-03 covers induction. Would there be interest in a new measure evaluating sustainability across the entire anesthetic (induction + maintenance)?

viii. *Lucy Everett (Mass Gen)*: I would prefer keeping them separate. The periods are so different, especially for peds cases. Inductions are short and messy, while maintenance is more stable. Also — for induction — training issues could arise around awareness risk if flows are dropped too fast.

ix. *Tony Edelman (MPOG Associate QI Director):* Another question or feedback we received: Should we try to identify shorter cases with high maintenance flows? Is calculating CO_2 equivalents per minute — instead of per hour — a better approach? Is the current 2.83 kg threshold the right number for all case lengths?

x. *Nirav Shah (MPOG QI Director)*: Some shorter cases pass the CO_2 threshold even if they have relatively high flows — just because the maintenance period is short. It makes sense — if your maintenance is short, a brief period of higher flow disproportionately affects the footprint. We could: Set a lower CO_2 threshold for short cases, for example, less than 30 minutes, or calculate CO_2 equivalents per minute, or just leave it alone.

xi. *Ben Stam (Corewell West &UM West*): I prefer more granular data. I'd like to know how short cases compare to long cases in overall anesthetic gas use. If you leave flows at 10 L/min for even five minutes after intubation, you've

already blown through any sustainability gains you'd get later. So yes — I think minute-by-minute CO_2 consumption would give a much more accurate picture.

xii. *Nirav Shah (MPOG QI Director)*: I was with a resident recently who intubated and immediately dropped to low flow — adjusted for gas value, without missing a beat. She had internalized that workflow already. So, it's possible. It is teachable.

xiii. *Tony Edelman (MPOG Associate QI Director):* At Michigan, with end-tidal control turned on immediately after confirming the tube, the machine quickly gets you to your target anesthetic concentrations with minimal flows. Since people are becoming more comfortable with end-tidal control, we've seen decreased anesthetic gas use anecdotally.

xiv. *Ben Stam (Corewell West &UM West*): Yes, I totally agree. I've started using end-tidal control too and it's almost too good. On a standard machine without end-tidal control, my workflow is: intubate → flows to 0.5 → Sevo at 8% → then slowly titrate down as the propofol wears off. With end-tidal control, it achieves maintenance Sevo instantly. I sometimes find it causes hypotension faster. But still — it's an amazing tool if people adapt their workflows. So yes — capturing minute-to-minute flow and consumption variations is important. It nails down how we're utilizing and wasting anesthetic gas.

VII) Next Steps:

a. Schedule the next workgroup meeting to review SUS-03, SUS-07, and SUS-06-Peds
b. Dr. Stam will present SUS-01 and SUS-04, and Lu-Boettcher will present SUS-02 at the Quality Committee on May 19th at 10am EST
c. Peds measures will be reviewed and presented at the Pediatric Subcommittee meeting at the end of June

Meeting Adjourned: 1104