



Waste Anesthetic Gases

The Effects on You and the Environment

Timur Özelsel, MD, DESA



Objectives

1. What are WAG?
2. How much WAG are we exposed to in the OR and in PACU?
3. What do we know about the risks?
4. How can we lower our exposure to WAG?

The Big Picture



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MEDICAL
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Alberta's physicians and the Alberta Medical Association (AMA) are committed to Patients First®.

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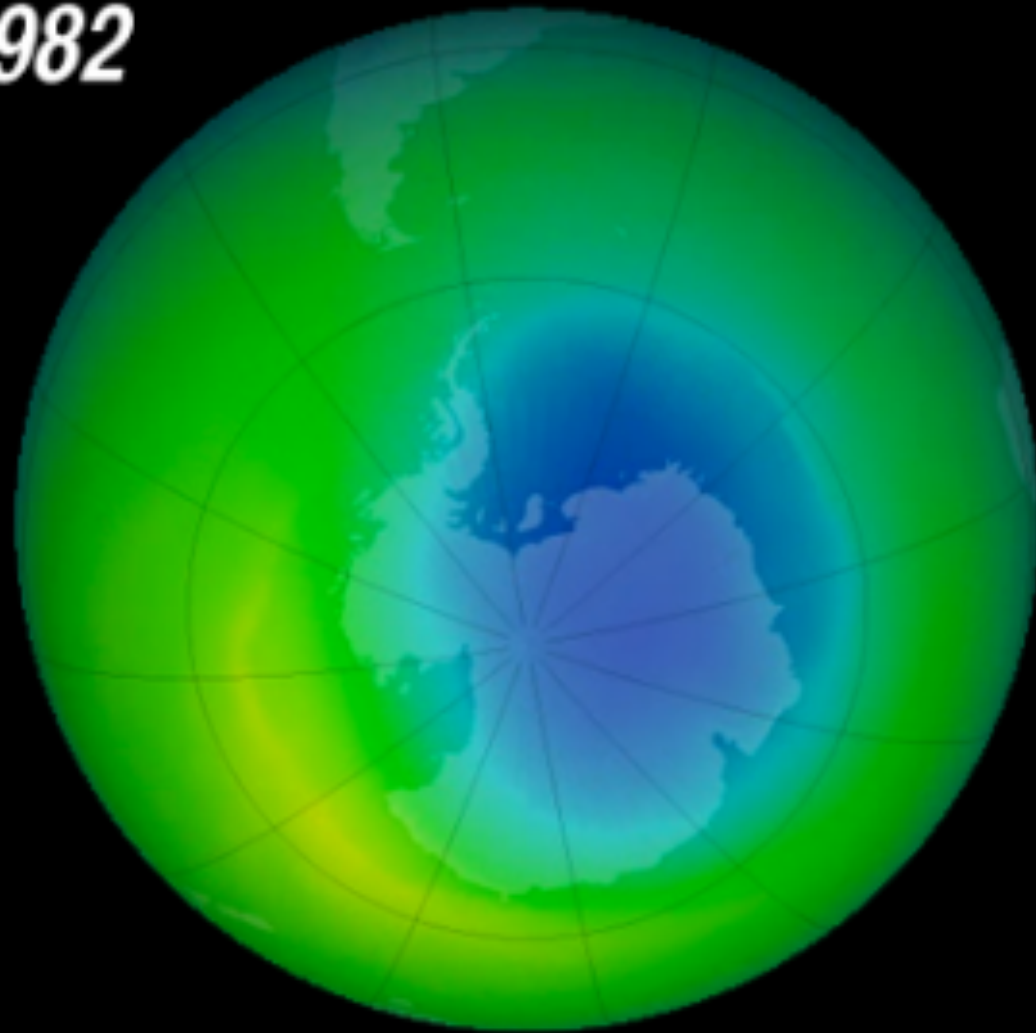
The AMA stands as an advocate for its physician members, providing leadership and support for their role in the provision of quality health care.

Patients first

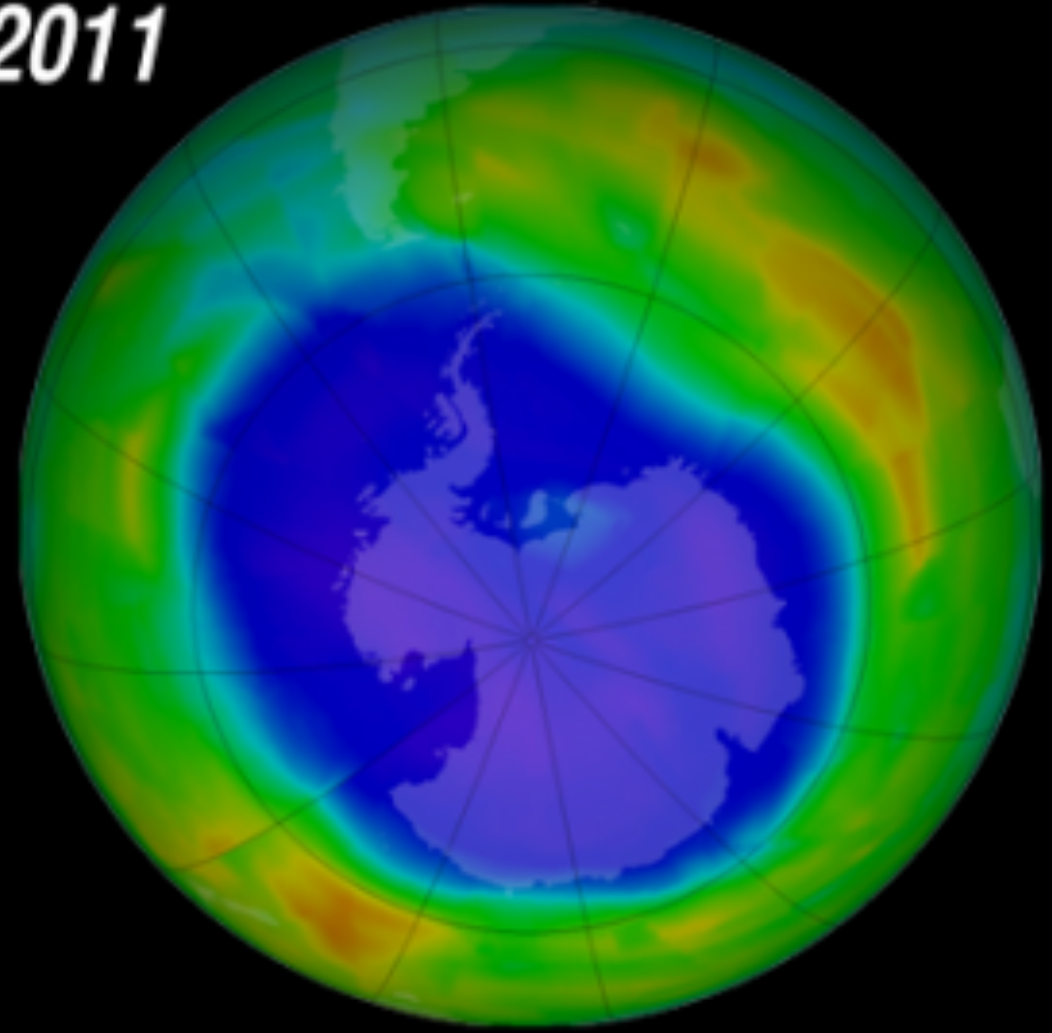


Our Environment

1982



2011



Ozone (Dobson Units)



THE Environment

*Why are we
concerned?*

Occupational exposure to WAG

According to **the National Institute for Occupational Safety and Health** (NIOSH) even short-term exposure to high concentrations of WAG may cause:

- Headache
- Irritability
- Fatigue
- Nausea
- Drowsiness
- Difficulties with judgement and coordination
- Liver and kidney disease

https://www.ccohs.ca/oshanswers/chemicals/waste_anesthetic.html

Occupational exposure to WAG

NIOSH (2007) continues “Although some studies report no adverse health effects from **long-term exposure to low concentrations of waste anesthetic gases**, several studies have linked such exposure to miscarriages, genetic damage, and cancer among operating-room workers. Studies have also reported miscarriages in the spouses of exposed workers and birth defects in their offspring.”

NIOSH (2015) later reports that “Some studies have documented adverse health effects (e.g., headaches, fatigue, irritability, birth defects, miscarriages, liver and kidney disease, cancer) from **excessive exposure** to anesthetic gases. These health effects were mainly noted for **older anesthetics** (e.g., trichloroethylene, methoxyflurane) that are no longer commonly in use...Studies are inconclusive on the potential health effects from occupational exposure to some of the newer anesthetics, such as isoflurane,”





Infrared video of patient exhaling nitrous





What are WAG?





*WAG are anesthetic gases that are released
or leak out during medical procedures.*



Where Do WAG Come From?

PACU:

1.Rebreathing from patients after anesthesia.

OR:

- 1.When filling refillable vapourizers, particularly if bottles do not have an integrated fused filling adaptor.
- 2.During the initial hooking up and checking of the anesthesia system or the scavenging system.

3.From around the patient's endotracheal tube (ETT) or laryngeal mask airway (LMA) if the cuff is not properly inflated or the wrong size is used.

4.Leaks in the anesthesia system.

5.Leaks in the high pressure system between N₂O cylinder and yoke assembly, or between the anesthetic gas column outlets and the N₂O hose.

6.When the system is flushed or purged at the conclusion of a medical procedure.

What Are Permissible Levels?

- There are **no levels which are proven to be safe** and also **no levels which are proven to be harmful**.
- Most data surrounding WAG and potential harmful effects is deduced from **questionnaires** without indisputable scientific validity.
- Most landmark studies and questionnaires are from the **1970s** — Isoflurane, Sevoflurane, and Desflurane were not in clinical use.

What Are Permissible Levels?

- **No country has guidelines** for halogenated volatile anesthetics
- In **Alberta** the only guideline is for **N₂O**
- Most countries have recommendations based on NIOSH data from **1977**



What Are Permissible Levels?

		Combined
N₂O	50 ppm	25 ppm
Isoflurane	2 ppm	0.5 ppm
Desflurane	2 ppm	0.5 ppm
Sevoflurane	2 ppm	0.5 ppm

All of the above values are 8 hour time weighted averages.

International Recommendations

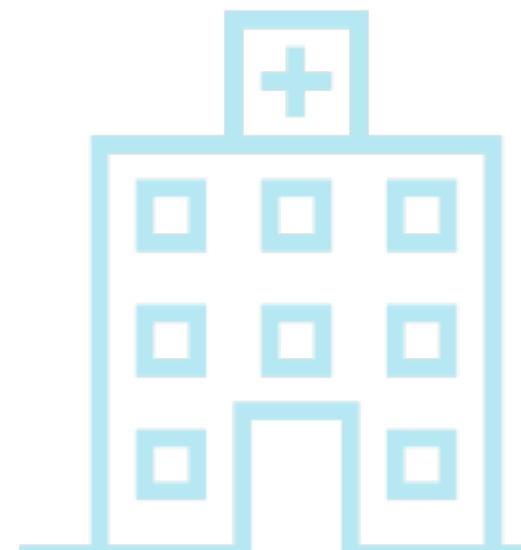
Country	N2O	Halothane	Enflurane	Isoflurane	Sevoflurane	Desflurane
USA (NIOSH)	50 (25)	2 (0.5)	2 (0.5)	2 (0.5)	2 (0.5)	2 (0.5)
Germany	100	5	20	10	-	-
Denmark	100	5	2	-	-	-
France	-	2	-	-	-	-
Italy	100	-	-	-	-	-
Norway	100	5	2	2	-	-
Sweden	100	5	10	10	-	-
Switzerland	-	5	-	-	-	-



At 1200 ppm fluranes may be detected by the human nose.

Research at the UAH

1. Environment in Adult OR
2. Environment in Adult & Pediatric PACU
3. Breath Analysis in 10 PACU nurses in Adult & Pediatric
4. Dosimeter Badge in same 20 nurses
5. Extubation Adult OR vs Adult PACU
6. Retained levels of WAG in the anesthesia machines



*What is our exposure
to WAG?*



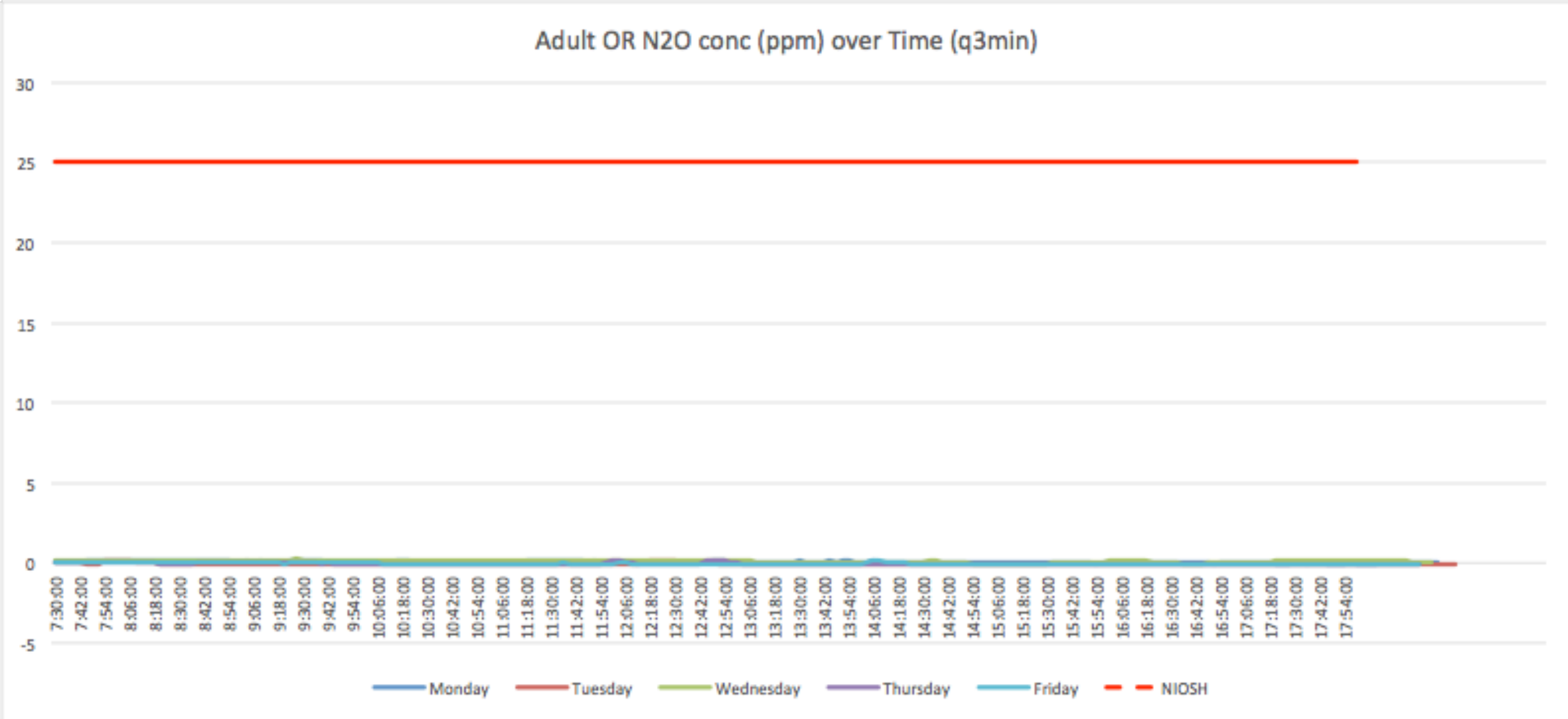
Thermo Miran SapphIRe XL

- Considered the gold standard of ambient air measurement
- Multiple or single gases
- Measurement of **single gas is more accurate**

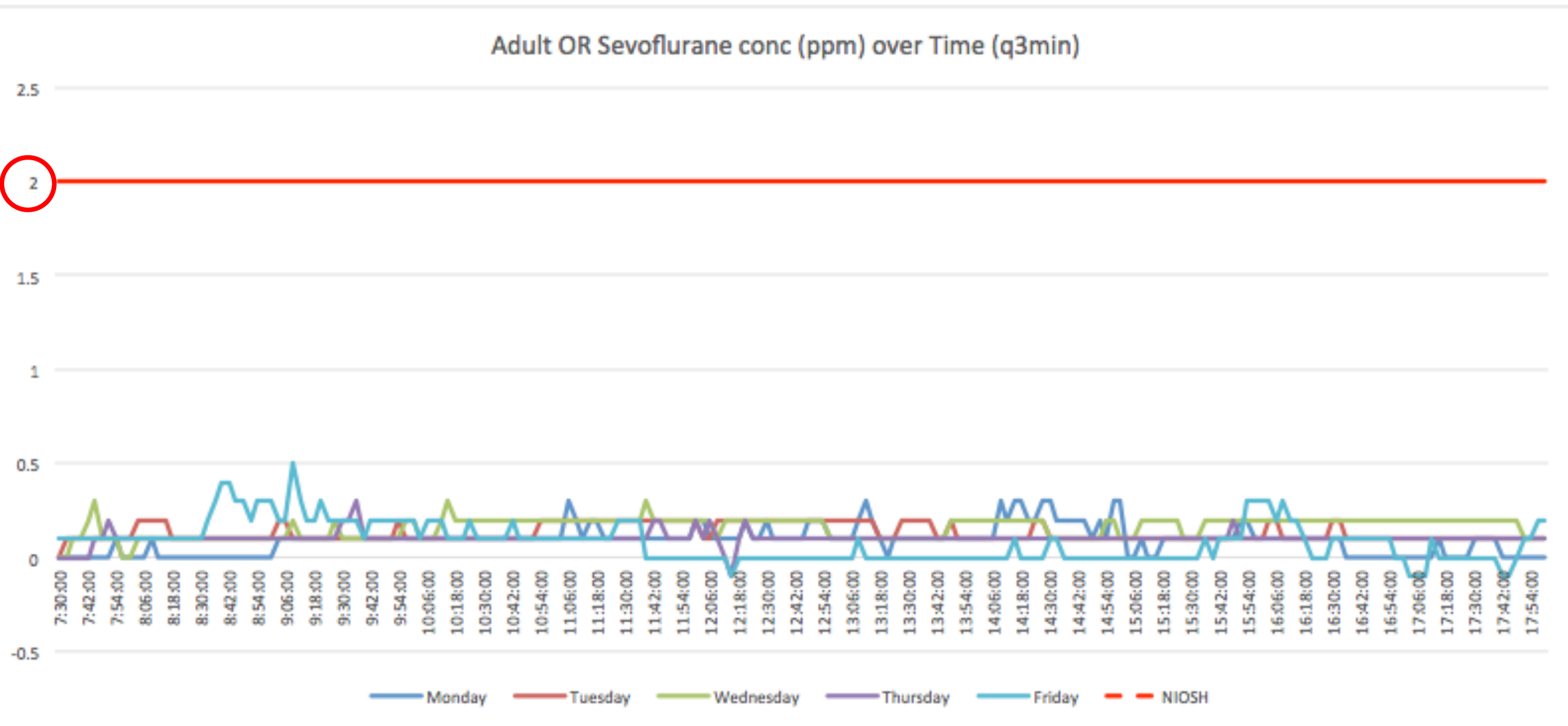


1. Environment in the Adult OR

- Ambient air measured on **5 days** in Ortho Trauma OR
- Measured in direct vicinity of the anesthesia machine
- Every **3 min** for **8 hours** daily
- HVAC: **25-30** air exchanges/hour

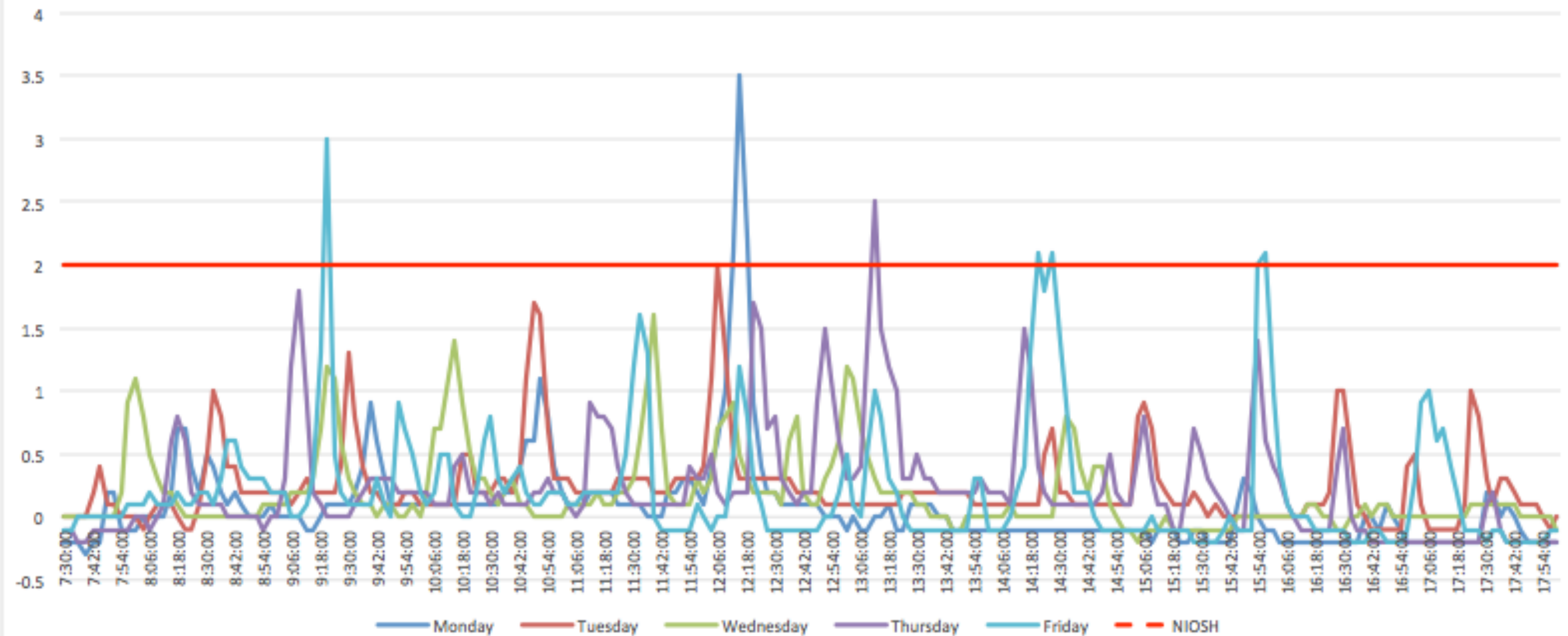


N ₂ O >25 ppm	Mon	Tues	Wed	Thurs	Fri
Total Minutes <i>Between 8am - 4pm (480 min)</i>	0	0	0	0	0



Sevoflurane >2 ppm	Mon	Tues	Wed	Thurs	Fri
Total Minutes <i>Between 8am - 4pm (480 min)</i>	0	0	0	0	0

Adult OR Desflurane conc (ppm) over Time (q3min)



Desflurane >2 ppm	Mon	Tues	Wed	Thurs	Fri
Total Minutes <i>Between 8am - 4pm (480 min)</i>	9	0	0	3	12

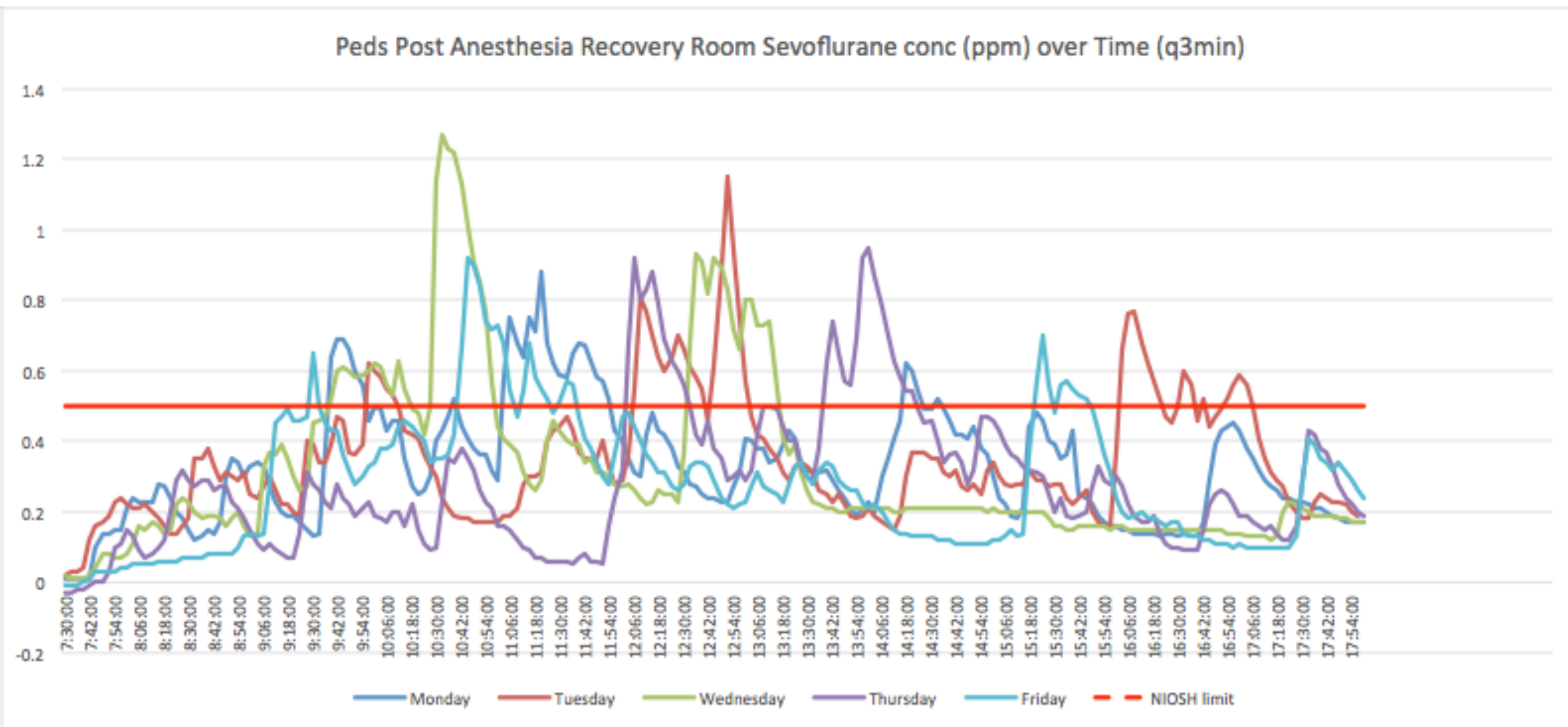
ALL
CLEAN



2a Environment in Pediatric PACU

- Two measurement cycles to represent **low and high patient loads: July 7-11 and October 20-24**
- Samples away from the work area (desk)
- Peds PACU relocated in between measurements
- Sevoflurane was measured as the sole volatile
- The HVAC specs are approximately the same:
 - Air Exchanges **9.1/h** and **8.5/h**
 - At least **50% fresh gas** exchanges

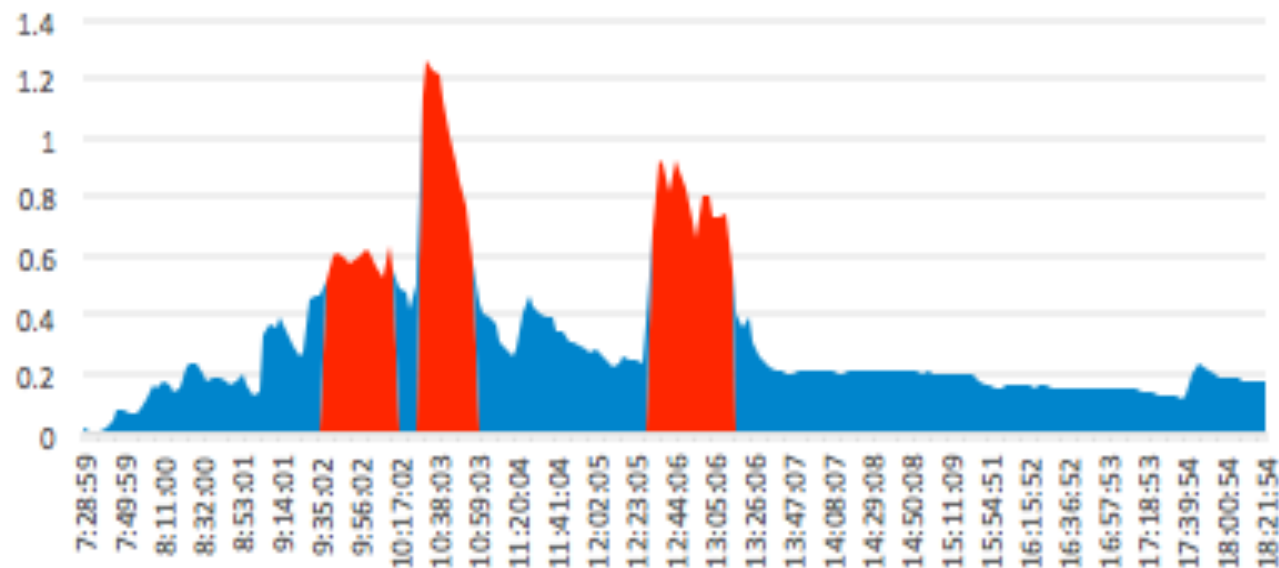
Pediatric PACU Summer



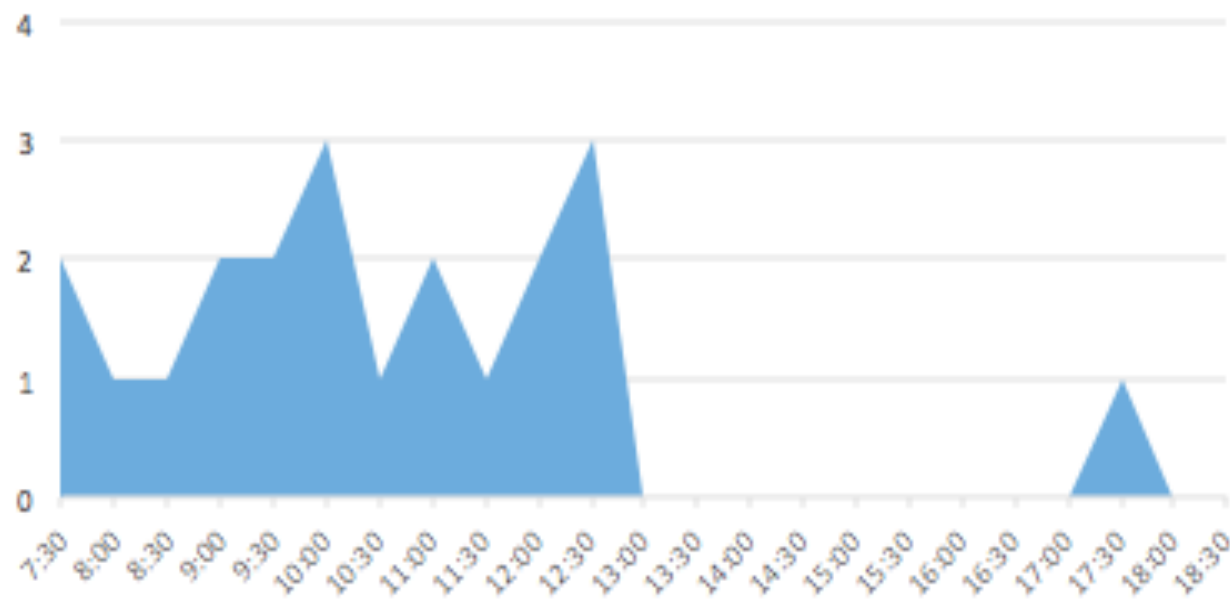
Sevoflurane >0.5 ppm	Mon	Tues	Wed	Thurs	Fri
Total Minutes <i>Between 8am - 4pm (480 min)</i>	87	111	114	75	78

Pediatric PACU July 9, 2014

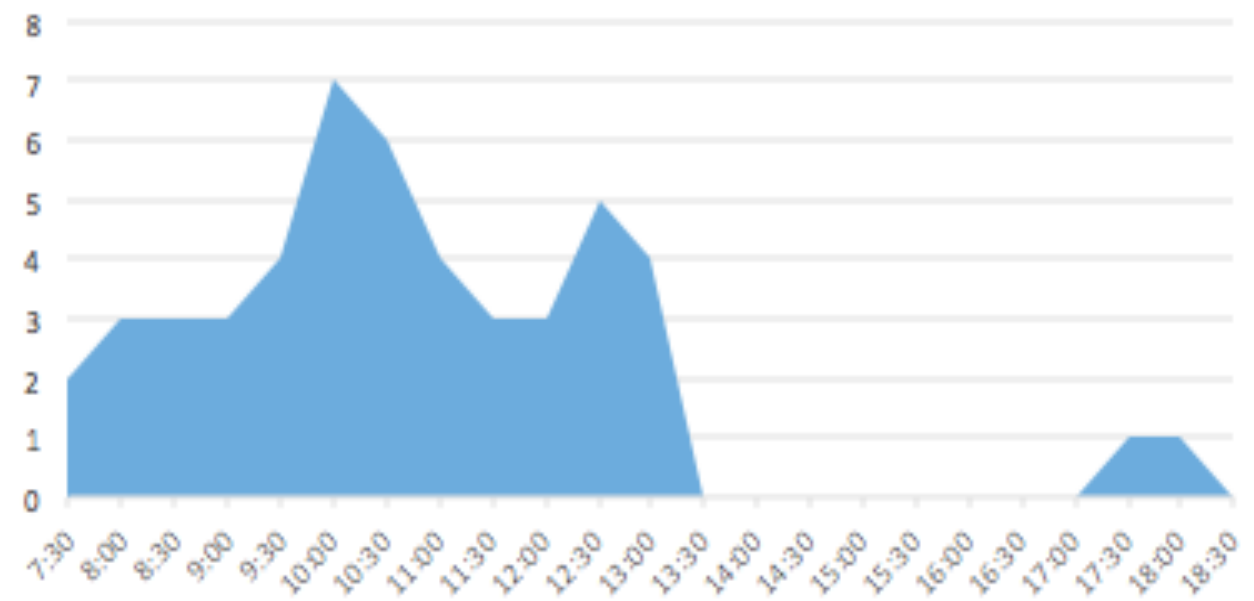
Sevoflurane conc (ppm) over time (q3min)



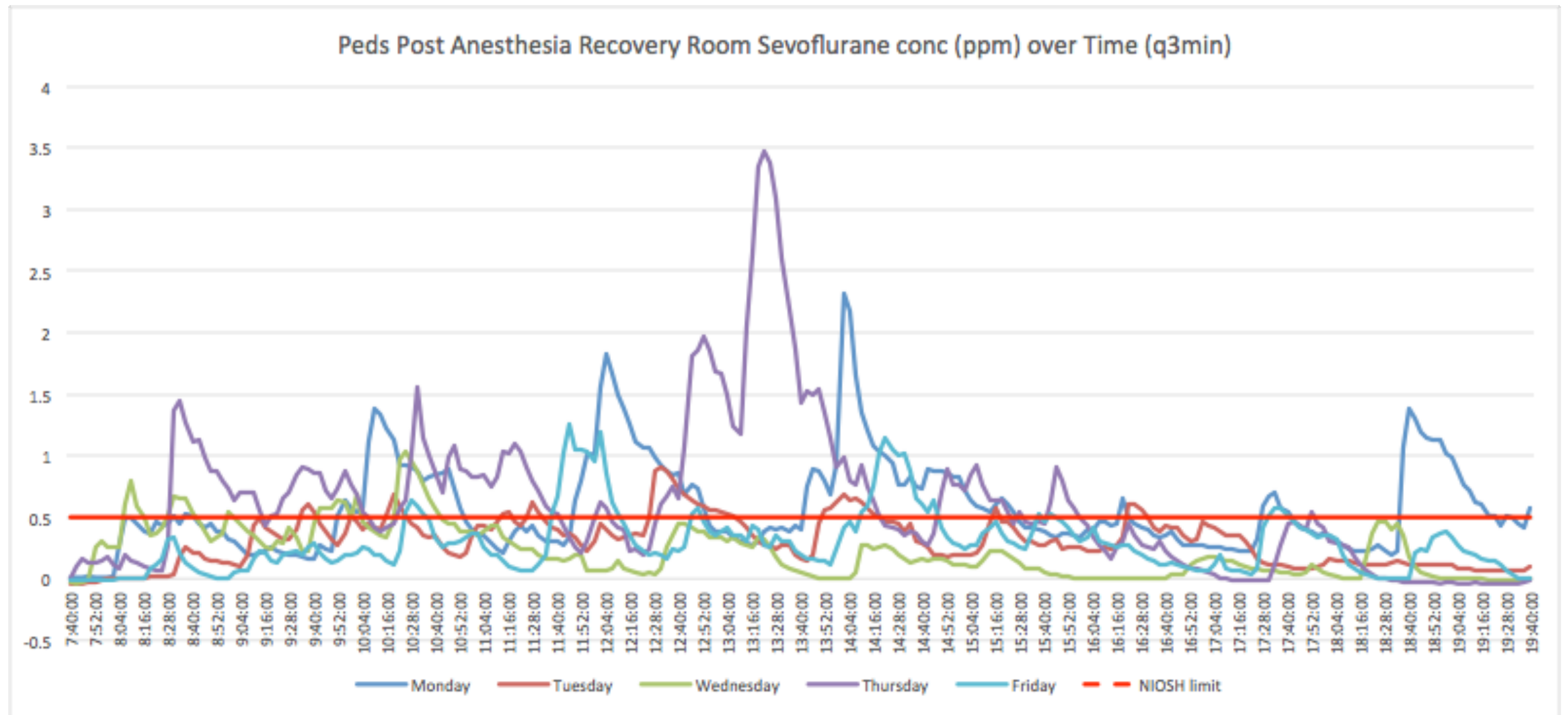
of pts admitted to PARR over time



of pts present in PARR over time

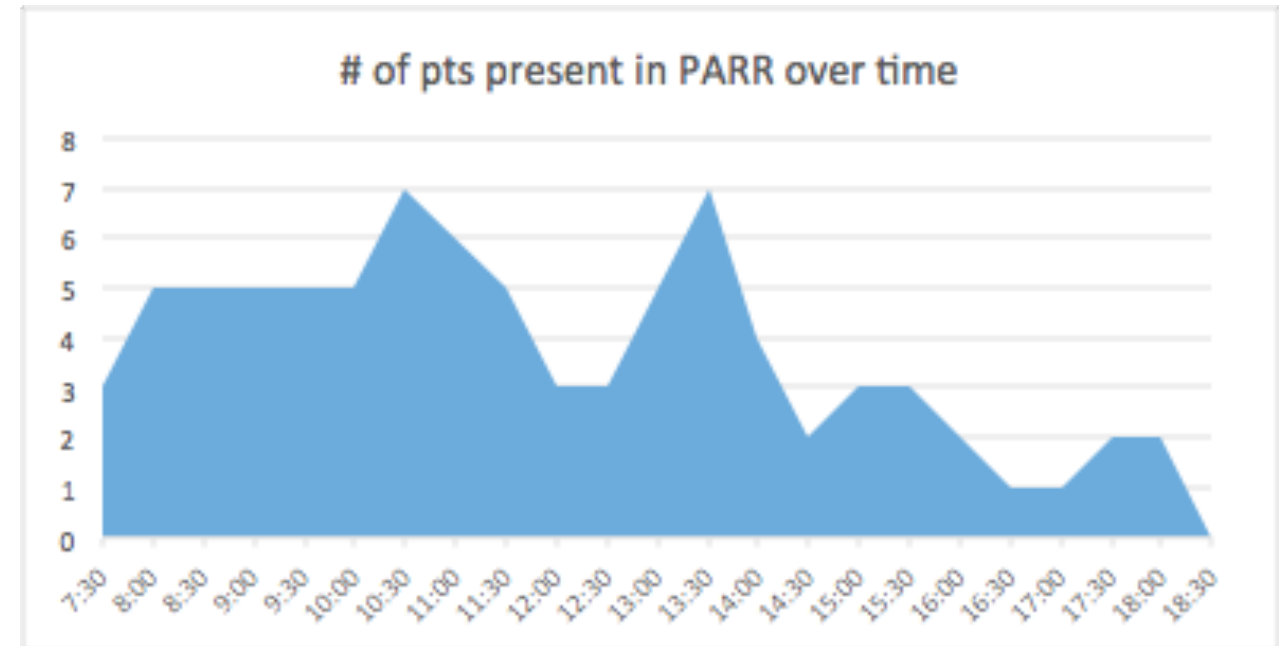
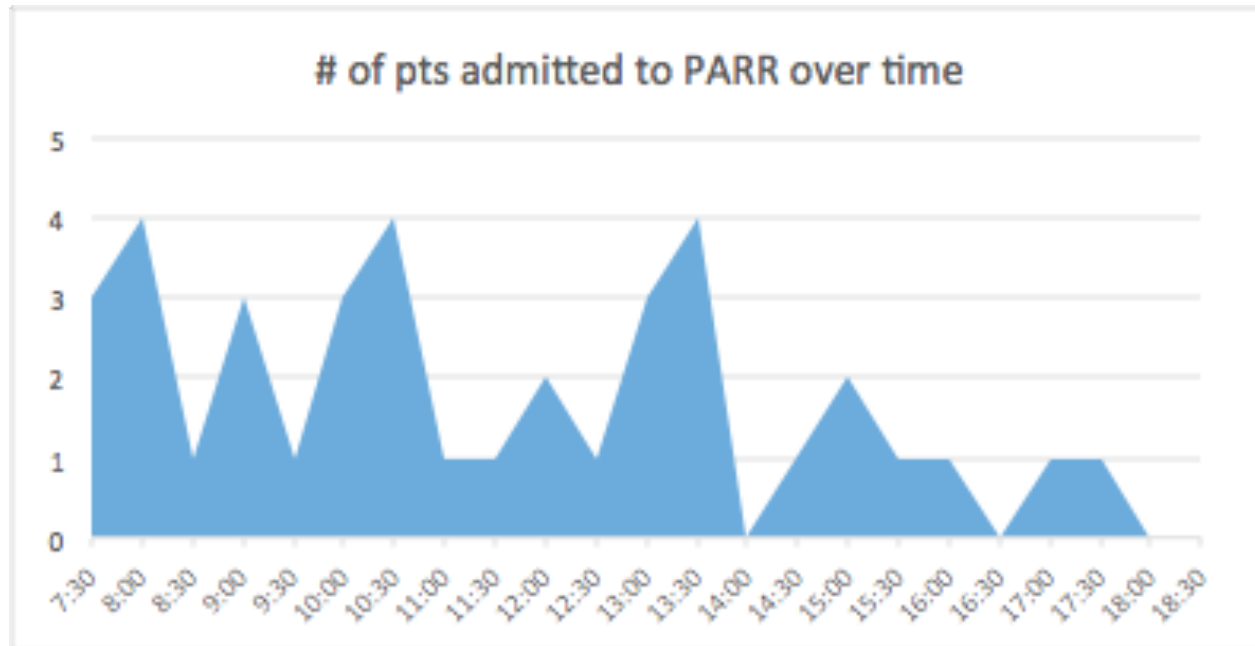
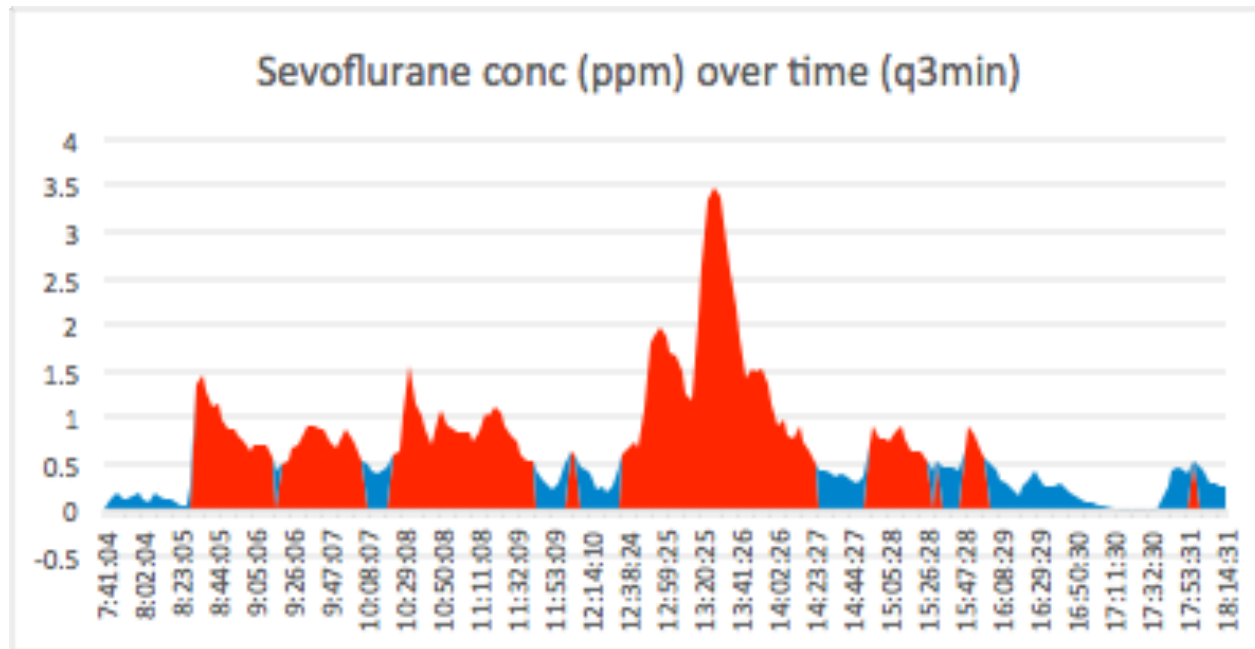


Pediatric PACU Fall



Sevoflurane >0.5 ppm	Mon	Tues	Wed	Thurs	Fri
Total Minutes <i>Between 8am - 4pm (480 min)</i>	315	120	66	348	111

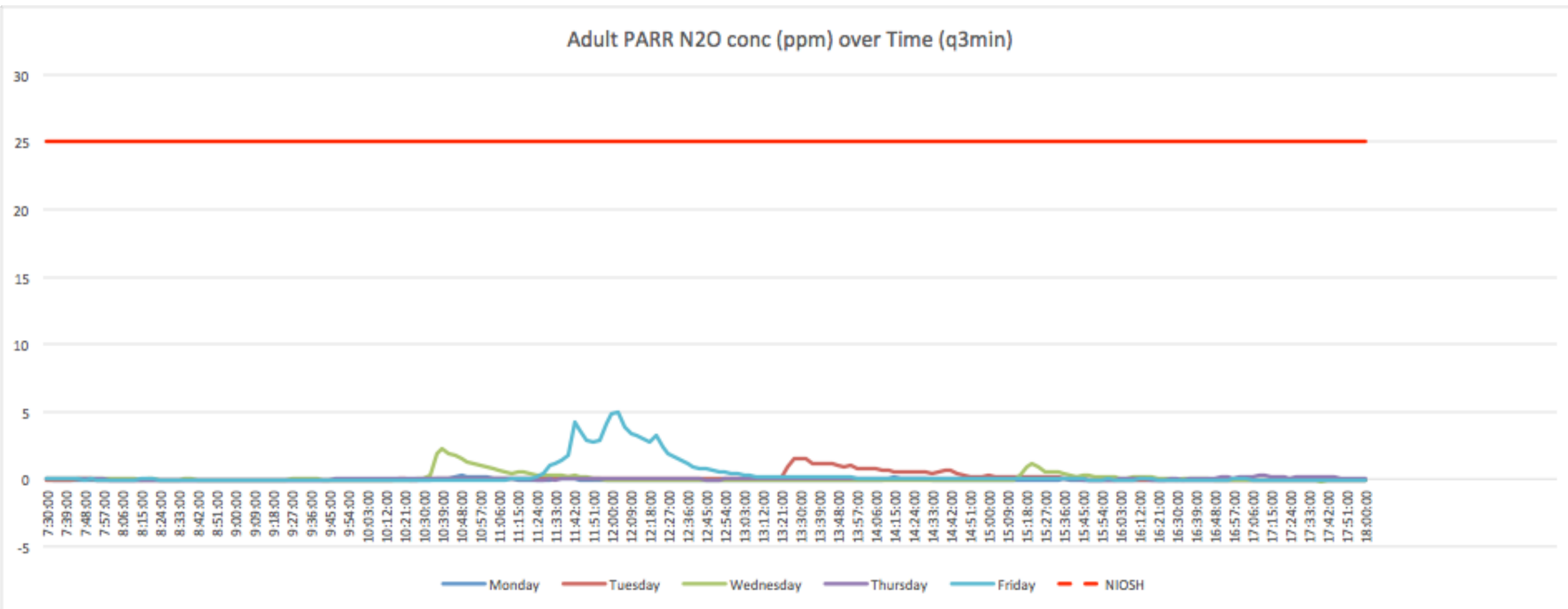
Pediatric PACU October 23, 2014



2b Environment in Adult PACU

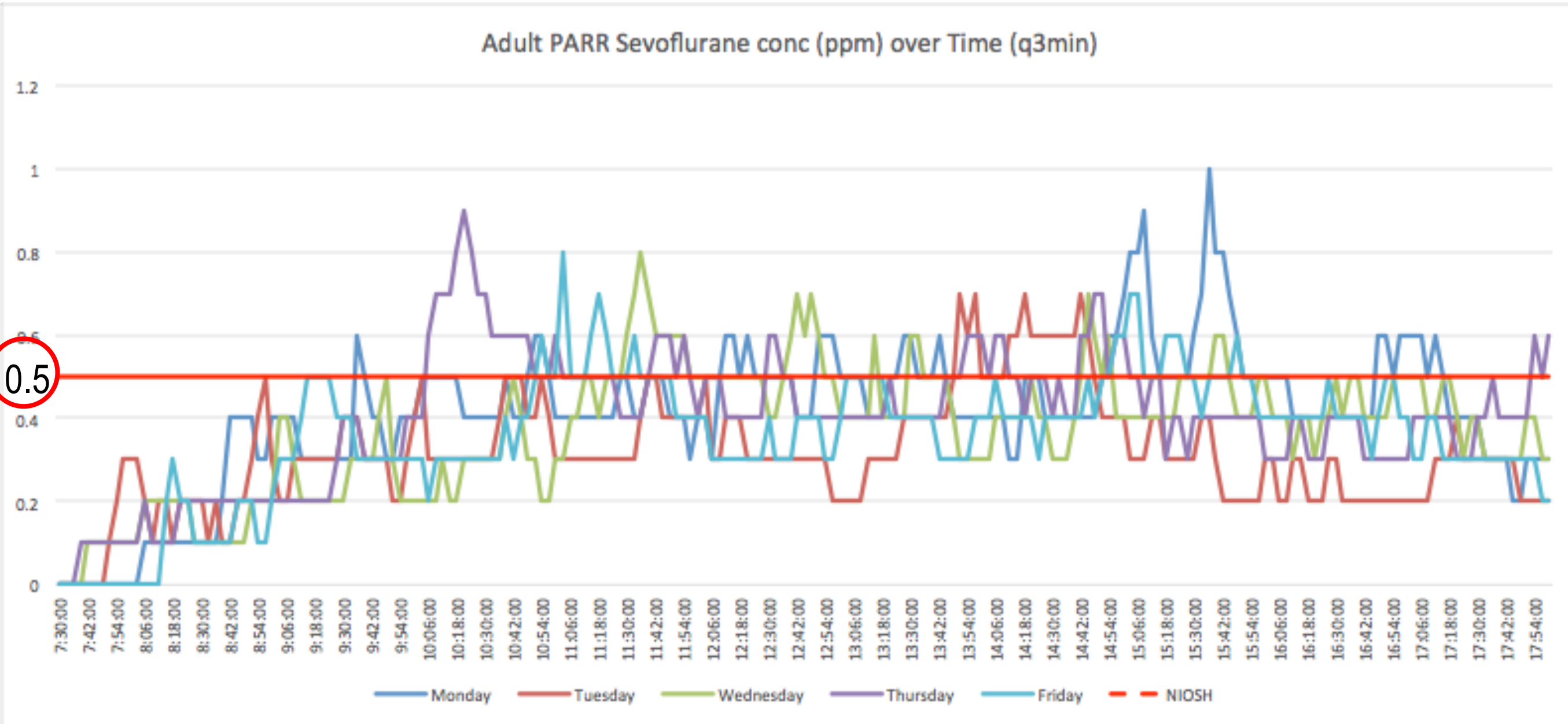
- Two measurement cycles to represent different patient loads - July 21-25 and November 17-21
- Samples were taken away from the work area (desk area)
- Measurements were taken for N₂O, Sevoflurane, and Desflurane
- HVAC Specs for Lvl 3 PACU are 19.5/h (at least 50% of the air exchanges are fresh gas exchanges)

Adult PACU Summer



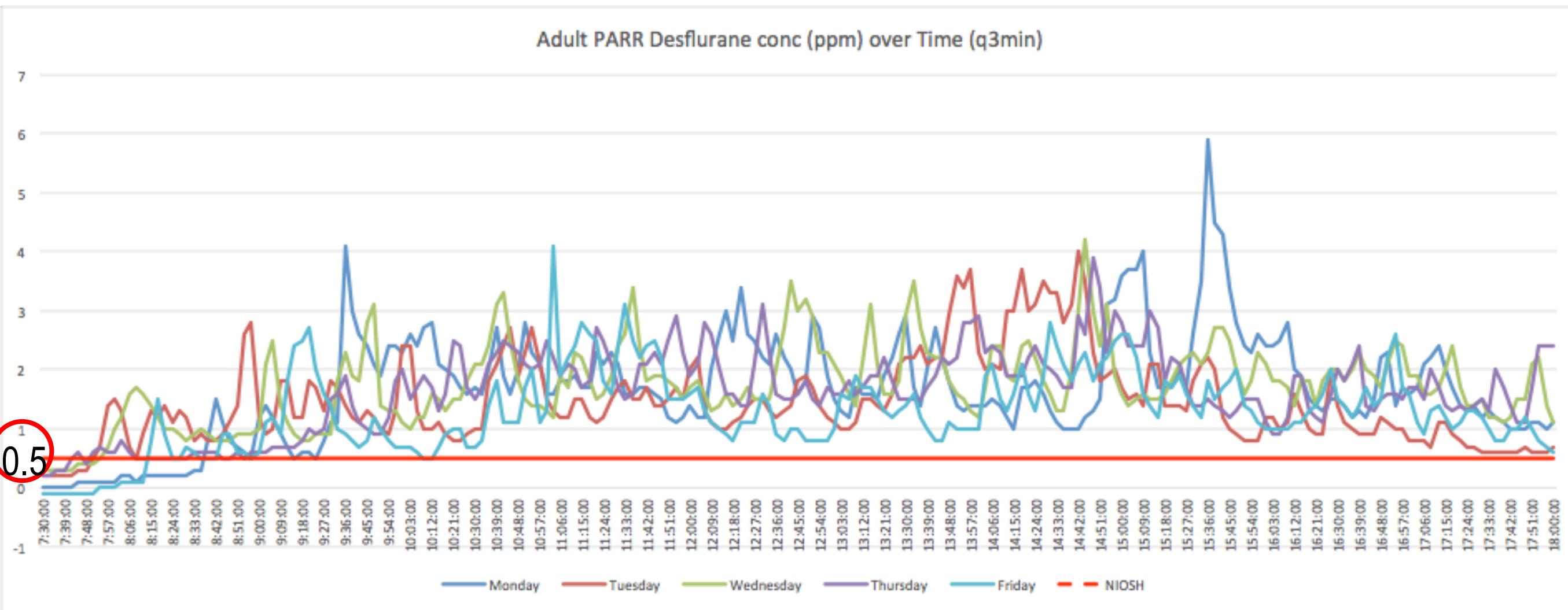
N ₂ O >25 ppm	Mon	Tues	Wed	Thurs	Fri
Total Minutes <i>Between 8am - 4pm (480 min)</i>	0	0	0	0	0

Adult PACU Summer



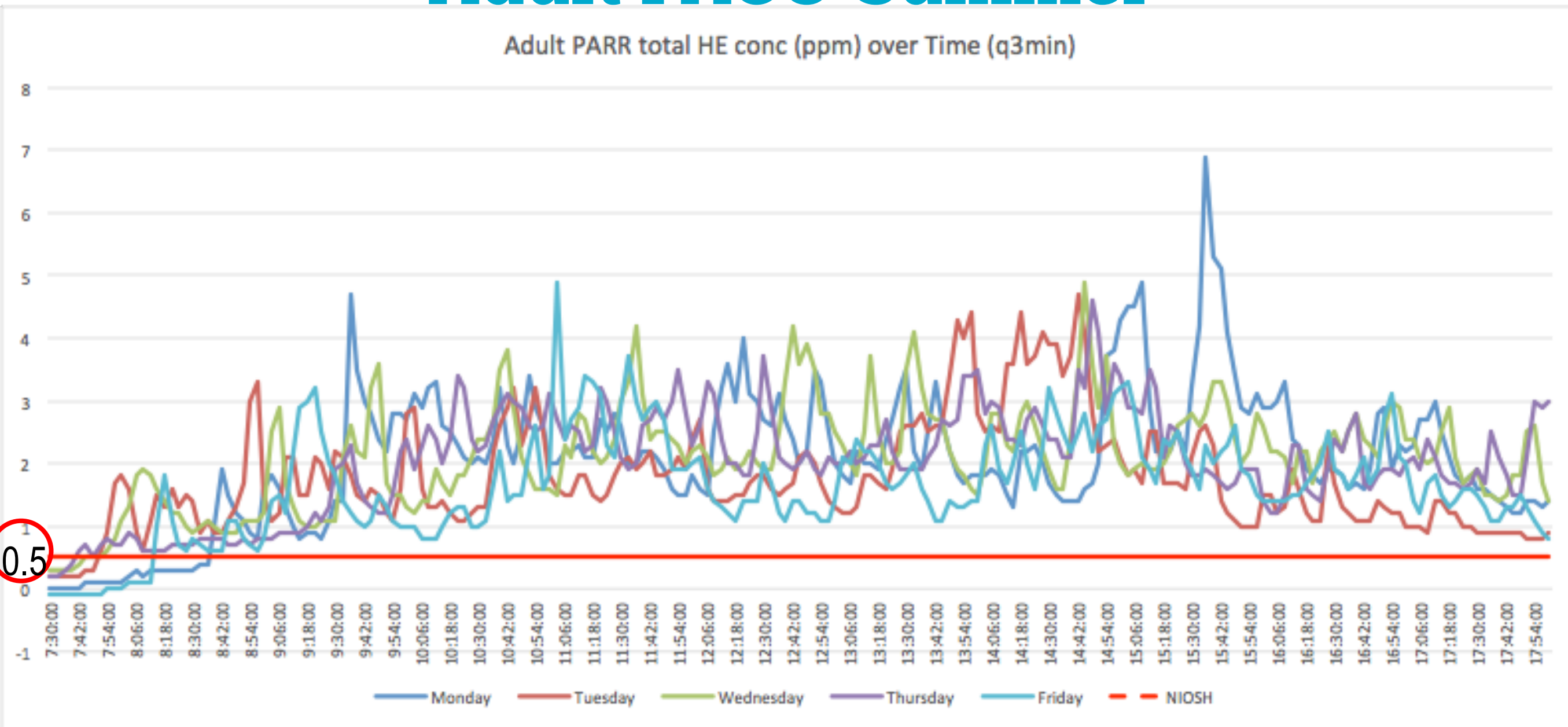
Sevoflurane >0.5 ppm	Mon	Tues	Wed	Thurs	Fri
Total Minutes <i>Between 8am - 4pm (480 min)</i>	78	45	66	99	42

Adult PACU Summer



Desflurane >0.5 ppm	Mon	Tues	Wed	Thurs	Fri
Total Minutes <i>Between 8am - 4pm (480 min)</i>	432	477	480	447	441

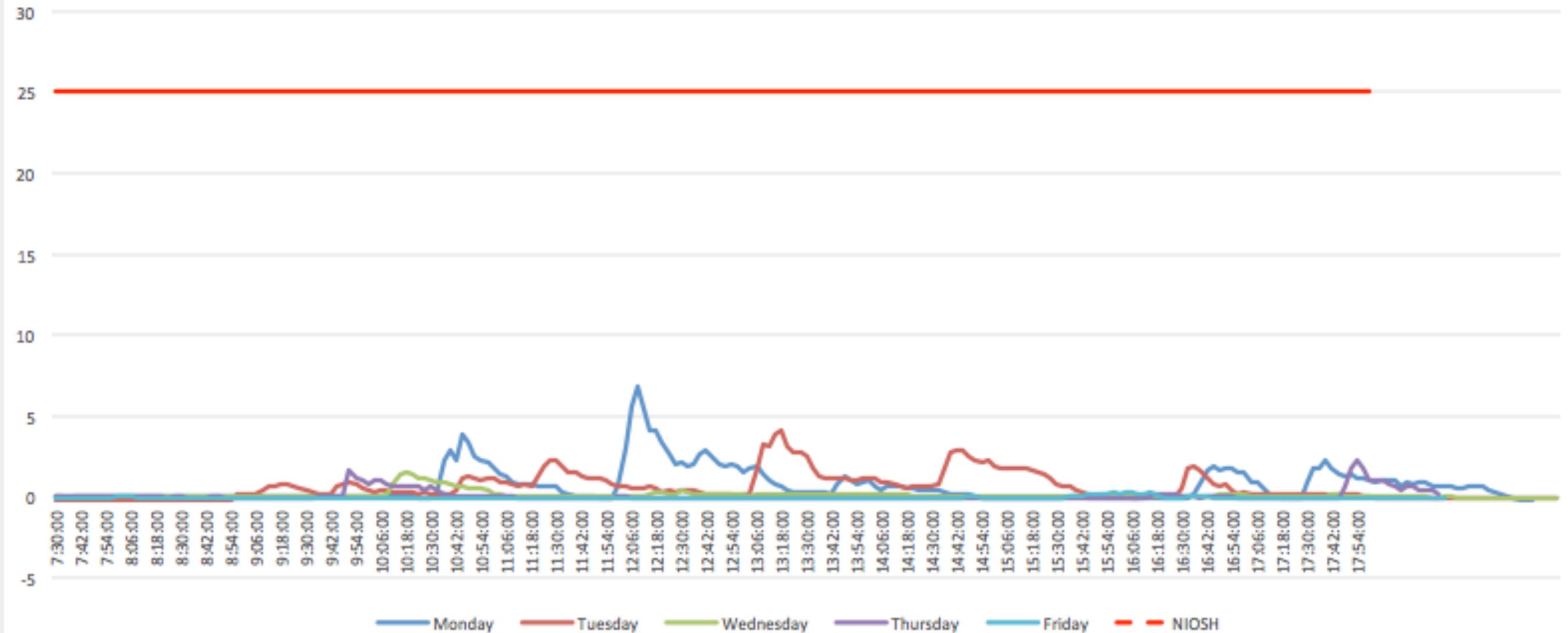
Adult PACU Summer



Total >0.5 ppm	Mon	Tues	Wed	Thurs	Fri
Total Minutes <i>Between 8am - 4pm (480 min)</i>	432	480	480	480	465

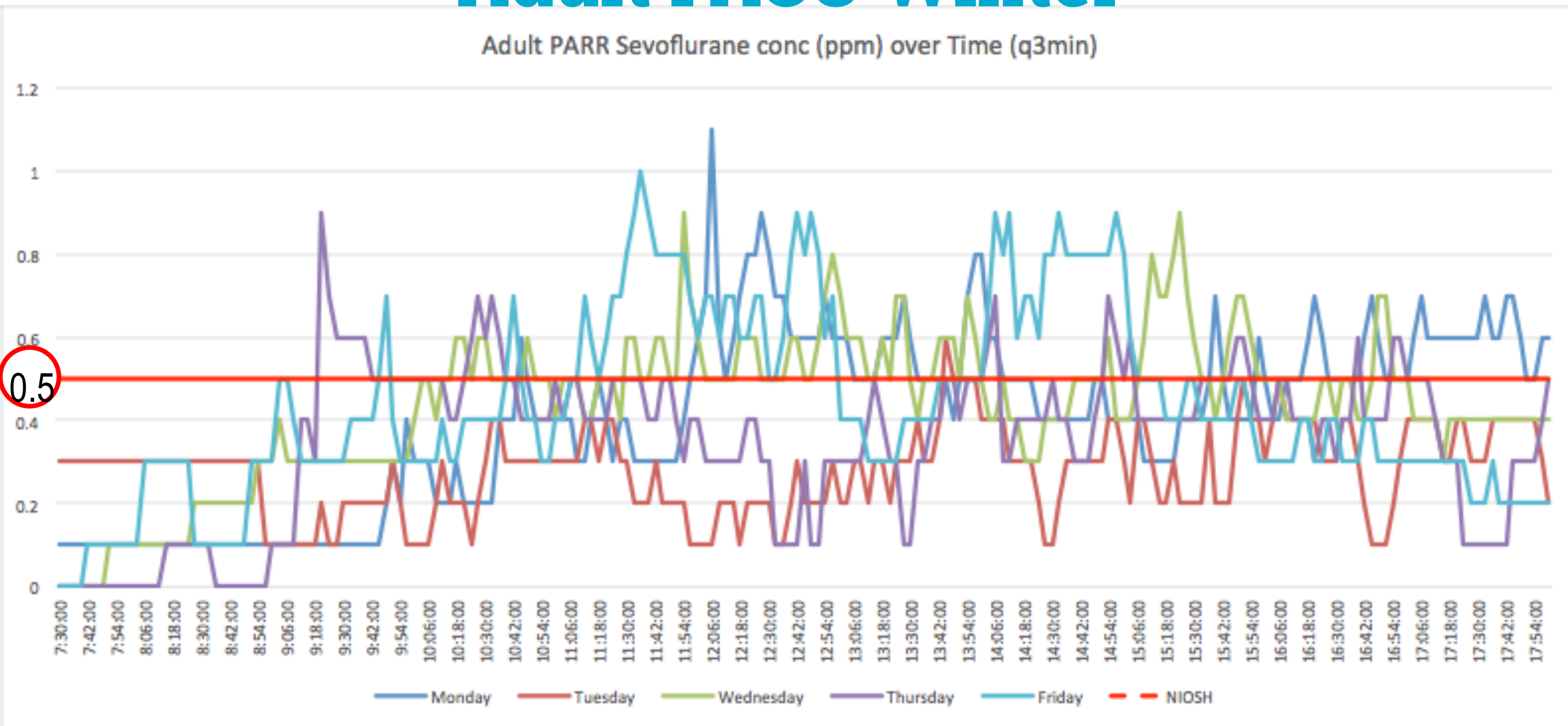
Adult PACU Winter

Adult PARR N₂O conc (ppm) over Time (q3min)



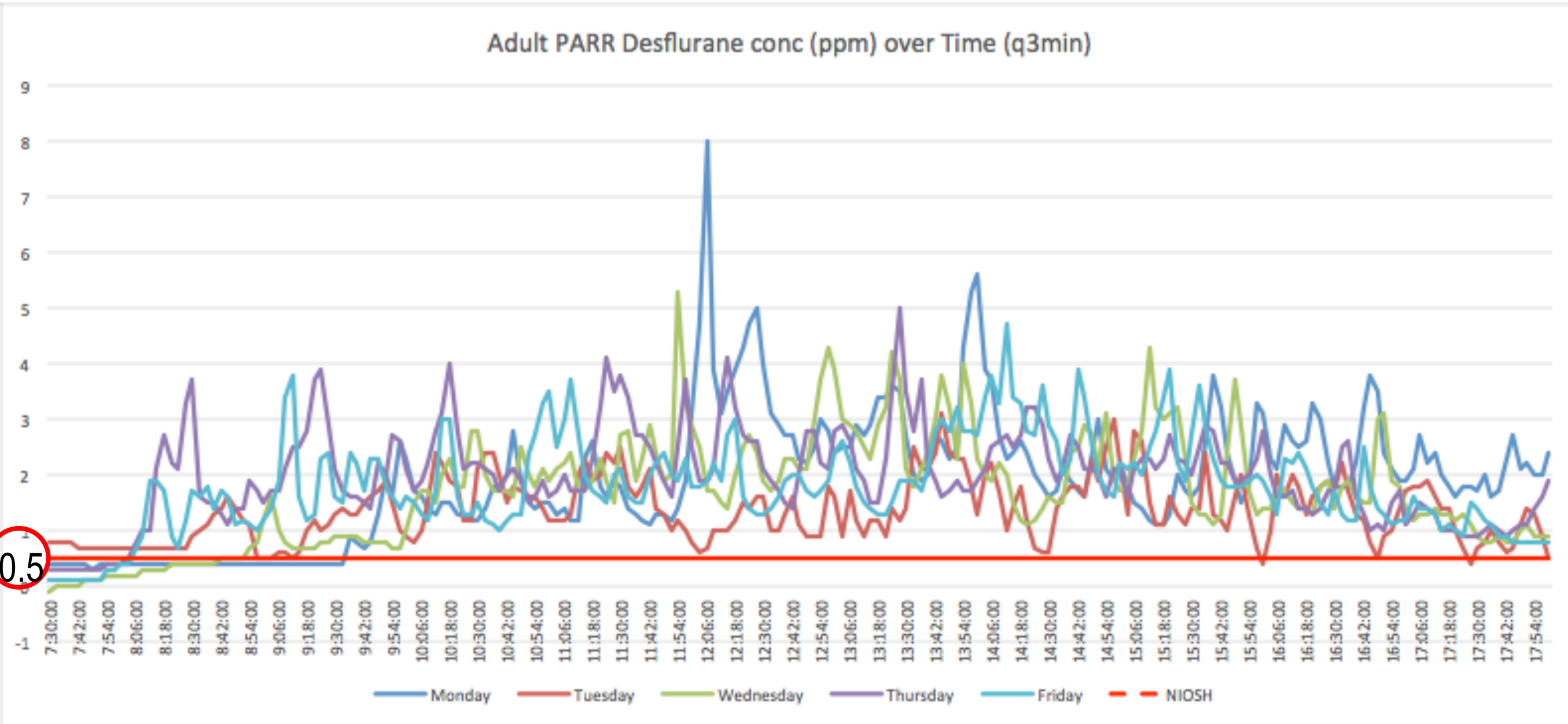
N ₂ O >25 ppm	Mon	Tues	Wed	Thurs	Fri
Total Minutes <i>Between 8am - 4pm (480 min)</i>	0	0	0	0	0

Adult PACU Winter



Sevoflurane >0.5 ppm	Mon	Tues	Wed	Thurs	Fri
Total Minutes <i>Between 8am - 4pm (480 min)</i>	102	3	135	57	168

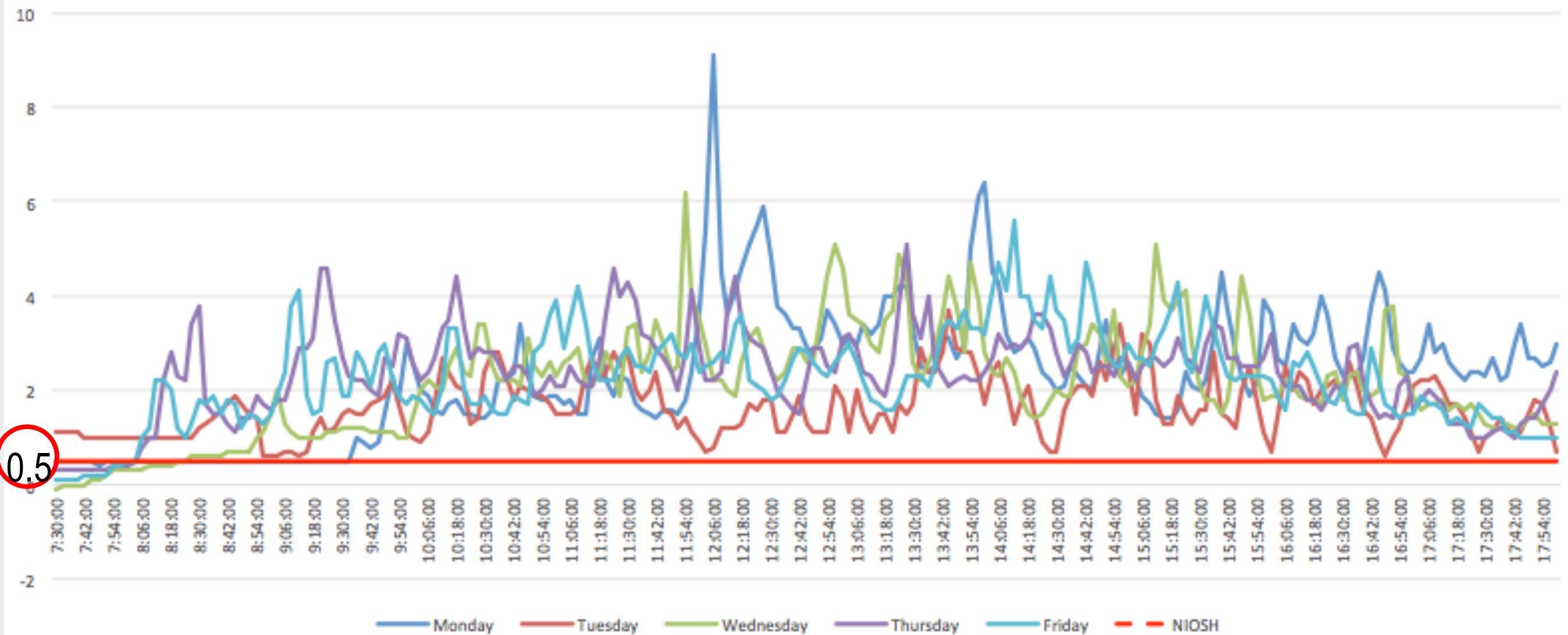
Adult PACU Winter



Desflurane >0.5 ppm	Mon	Tues	Wed	Thurs	Fri
Total Minutes <i>Between 8am - 4pm (480 min)</i>	384	468	426	474	474

Adult PACU Winter

Adult PARR total HE conc (ppm) over Time (q3min)



Total >0.5 ppm	Mon	Tues	Wed	Thurs	Fri
Total Minutes <i>Between 8am - 4pm (480 min)</i>	384	480	453	474	474

All clean?





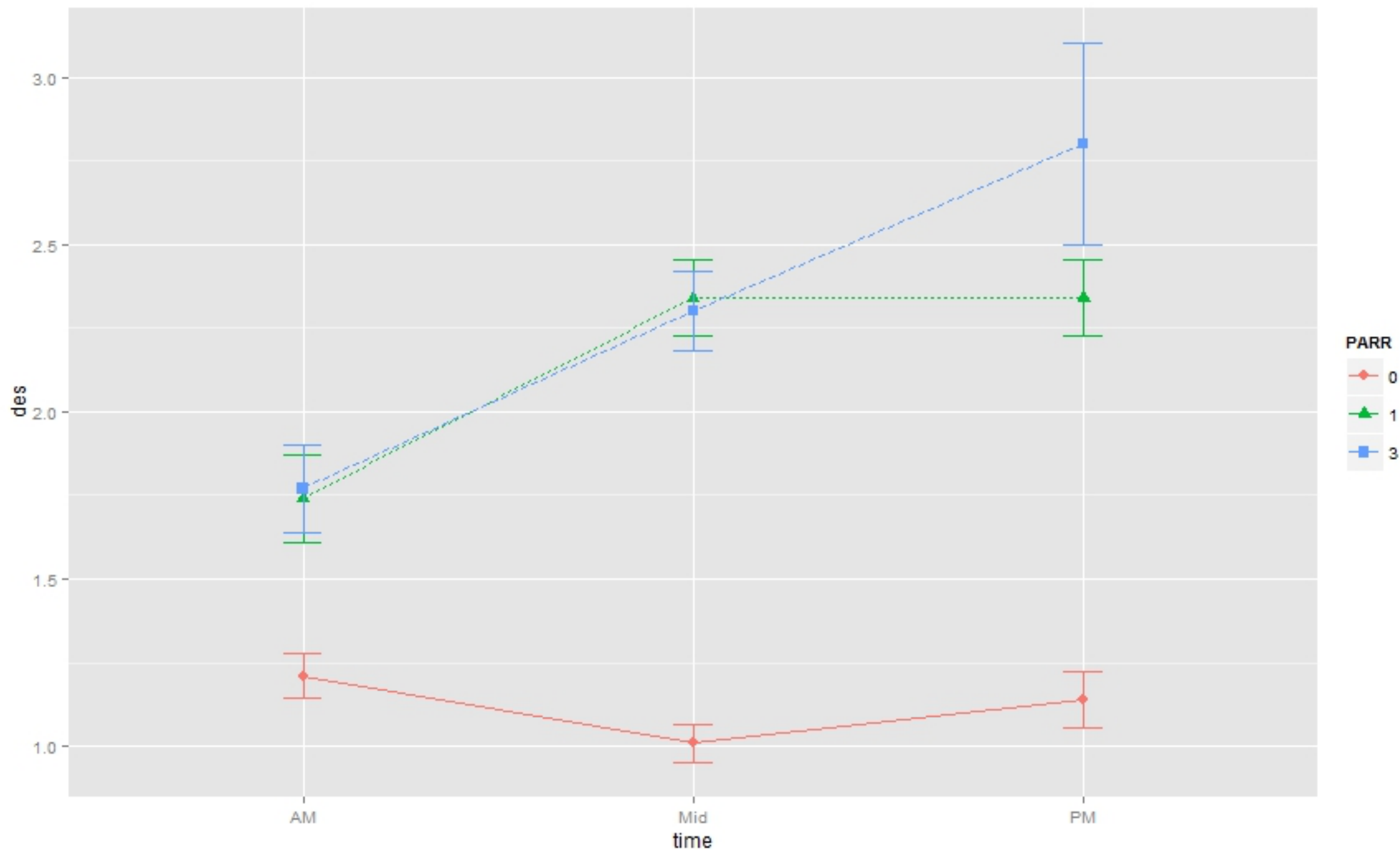
Isoflurane has a half-life of ~ **233** minutes.

It doesn't accumulate in the body throughout the work week.

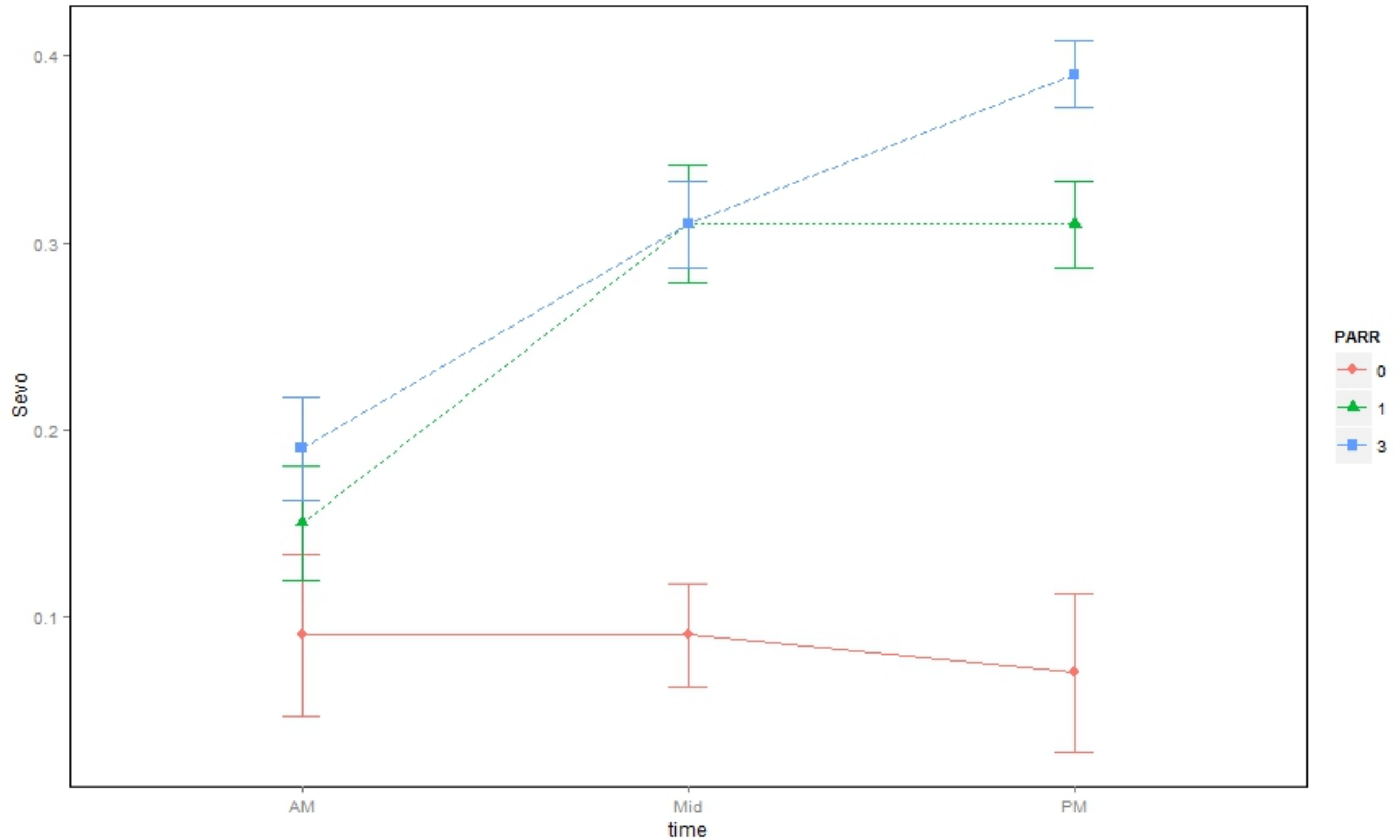
3. Breath Analysis For Anesthetic Gases

- **20 nurses** in Peds (10) and Adult PACU (10), were monitored for 1 day from August 11-15
- Breath analysis: **beginning, middle** and **end** of the shift.
- Samples taken in **uncontaminated** environment.
- All 20 nurses were also given a **dosimeter badge**, analyzed at Galson Laboratories for **sevoflurane** and **desflurane**.

Breath analysis Desflurane



Breath analysis Sevoflurane



4a Dosimeter Peds PACU

Sevo TWA	Des TWA
<0.11	<0.12
<0.11	<0.12
<0.11	<0.12
0.29	<0.12
0.35	<0.13
<0.13	<0.14
<0.11	<0.12
0.25	<0.12
<0.13	<0.14
<0.11	<0.12

4b Dosimeter Adult PACU

[illegible]

Summary

- OR Contamination is **negligible**.
- Both PACU have **measurable levels of WAG**.
- WAG directly **proportional to patient load**.



Summary

- Breath analysis showed **significant accumulation** of WAG **throughout the work day**.
- Dosimeter analysis **did not show** an increased exposure to WAG throughout the work day.



Breath Analysis vs Dosimeter

- Thermo Miran is not designed for breath analysis
- Required air flow is **14 l/min**. Regular minute ventilation is **~ 5l/min** – machine makes up with fresh air intake; potentially leading to a **false low**.
- However, we believe the trends are accurate.
- 2 weeks between dosimeter measurement and analysis.

Breath Analysis vs Dosimeter

- Sampling rates of the 3M 3500 Dosimeter badge
 - Sevoflurane **27.3 cc/min**
 - Desflurane **30.1 cc/min**
- 13.1 - 14.4 litres of air are sampled in 8 hours
- A nurse will breathe around **3000 litres/8 hours**

*Halogenated Ethers Can Cross
The Placenta And Can Also Reach
Breast Milk*



What Does It All Mean?



Literature Evidence

- 1967 by female Russian anesthesiologist Vaisman
- 345 anesthesiologists surveyed
- Found ↑ frequency of headache, fatigue, irritability & nausea and also an **↑ incidence of spontaneous abortions in female anesthesiologists**

Literature Evidence

- **1974** American Society of Anesthesiologists:
US-wide survey with 49,585 exposed OR personnel (from four professional societies) and 23,911 controls (from two professional societies)
- **Higher rates** of spontaneous abortion, congenital abnormalities, cancer, hepatic, and renal disease in the OR group

Limitations

- Surveys had **low participation** and thus **non-representative results**, as well as guided questions
- Healthcare workers **exposed** to many **confounding factors**,
- OR-Scavenging not standard (21% for the ASA survey)
- Only **N₂O** in clinical practice then

Survey UAH

	Adult PACU nurses	Adult OR nurses
No of responses	81.8%	22.8%
No of pregnancies	7	32
Miscarriage	1 (14.3%)	10 (31.3%)
Headache	6 (33.3%)	13 (36.1%)
Fertility problems	0	5 (13.9%)
Emotional disturbances	1 (5.6%)	5 (13.9%)
Chronic fatigue	1 (5.6%)	5 (13.9%)
Diff perception/cog & motor	0	2 (5.6%)
Immunological	0	2 (5.6%)
Lung disease	0	1 (2.8%)

Genotoxicity of WAG



1. Sister Chromatid Exchanges - Cytogenetic Damage
2. Formation of Micronuclei - Cytogenetic Damage
3. Chromosomal Aberrations - Numeric vs Structural
4. AMES Test - Gold Standard of Mutagenicity Tests
5. Oxidative DNA Damage (modified Comet Test)
6. Reactive Oxygen Species in Leukocytes

Genotoxicity of WAG



Test	Sensitivity	Specificity
AMES	Low	High
SCE	High	Low
MN	High	Low

Current Opinion

- *“It’s all Nitrous”*
- Halogenated ethers are considered genotoxically safe

The Role Of N₂O

- Interferes in **DNA synthesis** of cells →
 - megaloblastic anemia, agranulocytosis & bone marrow aplasia
 - potentially teratogenic & harmful to embryos

The Role Of N₂O



Best Practice & Research Clinical Anaesthesiology
Vol. 19, No. 3, pp. 391–397, 2005
doi:10.1016/j.bpa.2005.03.003
available online at <http://www.sciencedirect.com>



6

Nitrous oxide—an outdated anaesthetic

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The Role Of N₂O

Mutation Research 666 (2009) 39–43



Contents lists available at ScienceDirect

Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis

journal homepage: www.elsevier.com/locate/molmut
Community address: www.elsevier.com/locate/mutres



DNA damage induced by nitrous oxide: Study in medical personnel of operating rooms

Teresa Wrońska-Nofer^{a,*}, Jadwiga Palus^a, Wojciech Krajewski^b, Jolanta Jajte^c,
Małgorzata Kucharska^a, Jan Stetkiewicz^a, Wojciech Wąsowicz^a, Konrad Rydzyński^a

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^c Department of Toxicology, Medical University, 1 Muszynskiego St., 90-151 Lodz, Poland

- Comet Test for DNA damage used in OR vs non-OR medical personnel matched for age, gender, height, and weight
- The study found a significantly higher rate of endogenous DNA damage in the OR personnel (p<0.001)

The Role Of N₂O

REVIEW



The perioperative use of nitrous oxide: renaissance of an old gas or funeral of an ancient relict?

Nils Schallner and Ulrich Goebel

Pediatric Anesthesia

Pediatric Anesthesia ISSN 1155-5645

REVIEW ARTICLE

Is nitrous oxide necessary in the future?

Victor C. Baum¹, Harald Willschke² & Bruno Marciniak³

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² Department of Anaesthesia and General Intensive Care, Medical University of Vienna, Vienna, Austria

³ Pôle d'Anesthésie Réanimation, Hôpital Jeanne de Flandre CHRU Lille, France

Genotoxicity of WAG

A Comparison of Sister Chromatid Exchanges in Lymphocytes of Anesthesiologists to Nonanesthesiologists in the Same Hospital

Ahmet Eroglu, MD, Figen Celep, PhD, and Nesrin Erciyes, MD

Departments of Anesthesiology, Medical Biology and Genetics, Karadeniz Technical University, Faculty of Medicine, Trabzon, Turkey

An increased incidence of sister chromatid exchanges (SCEs) in peripheral lymphocytes of operating room personnel exposed to waste anesthetic gases has been reported. We investigated whether the increase of SCEs in anesthesiologists was reversible. Twenty-five anesthesiologists exposed to waste anesthetic gases such as sevoflurane and nitrous oxide were compared with nonexposed internists working in the same hospital. The concentrations of sevoflurane and nitrous oxide in the operating rooms were measured. The incidence of SCE was measured in lymphocytes cultures of anesthesiologists before and after a 2-mo leave from the operating room. These values of SCE were compared with those of nonexposed physicians. Occupational exposure to sevoflurane and nitrous oxide in the operating

rooms were above the threshold values. There was a significant difference in SCE values of the anesthesiologists compared with the nonexposed physicians (11.9 ± 4.4 versus 4.2 ± 1.1 , $P < 0.001$). After a 2-mo leave from the operating room, the SCE values of the anesthesiologists were significantly lower compared with those taken before the leave (4.8 ± 1.8 and 11.9 ± 4.4 , respectively, $P < 0.001$). We conclude that the increase of SCE in anesthesiologists exposed to increased environmental concentrations of waste anesthetic gases, such as sevoflurane and nitrous oxide, are reversible if they work free from exposure for 2 mo.

(Anesth Analg 2006;102:1573-7)

- Studied 25 anesthesiologists exposed to N₂O and sevoflurane for levels of SCE in comparison to 25 internists from the same hospital
- The study found a 300% increase in SCE in anesthesiologists vs internists
- SCE were significantly reduced in the anesthesiologists after a two month leave of the OR

Genotoxicity of WAG



Anaesthesia

Journal of the Association of Anaesthetists of Great Britain and Ireland

Anaesthesia, 2008, **63**, pages 861–864

doi:10.1111/j.1365-2044.2008.05498.x

Increased formation of sister chromatid exchanges, but not of micronuclei, in anaesthetists exposed to low levels of sevoflurane★

G. Wiesner,¹ F. Schiewe-Langgartner,² R. Lindner³ and M. Gruber⁴

- Studied 15 anesthesiologists exposed to sevoflurane (without N₂O) for levels of SCE and MN in comparison to 15 internists from the same hospital
- The study found a 30% increase in SCE in anesthesiologists vs internists, but no increase in MN

Genotoxicity of WAG

**10 – ORIGINAL ARTICLE
CLINICAL INVESTIGATION**

DNA damage and antioxidant status in medical residents occupationally exposed to waste anesthetic gases¹

Ellen Regina da Costa Paes^I, Mariana Gobbo Braz^{II}, Joilson Teixeira de Lima^{III}, Milana Reis Gomes da Silva^{III}, Leilane Bentes de Sousa^{III}, Emerson Silva Lima^{IV}, Marne Carvalho de Vasconcellos^{IV}, José Reinaldo Cerqueira Braz^V

DOI: <http://dx.doi.org/10.1590/S0102-86502014000400010>

- Looked at DNA damage and antioxidant defence in anesthesia and surgery residents compared to non-OR (non-medical?) adults. Matched for age, gender, height, BMI
- Blood samples were drawn and evaluated at 8 months, 16 months, and 22 months
- DNA damage was significantly higher at all evaluation points in the resident group
- Antioxidant defence decreased significantly in the resident group between 8 months and 22 months

The Limits of Dose Limits

- Requires knowledge of harmful concentration
- Requires knowledge of safe concentration
- Still no evidence that long-term exposure to WAG causes harm
- Also no evidence that long-term exposure to WAG is safe

Worldwide Recommendation:

*Reduce Exposure Of Medical Personnel
to Spilled Or WAG*

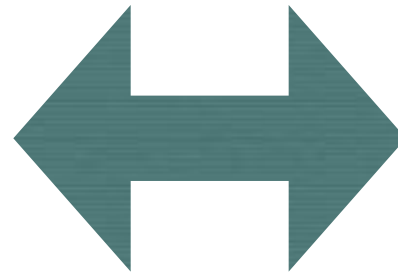
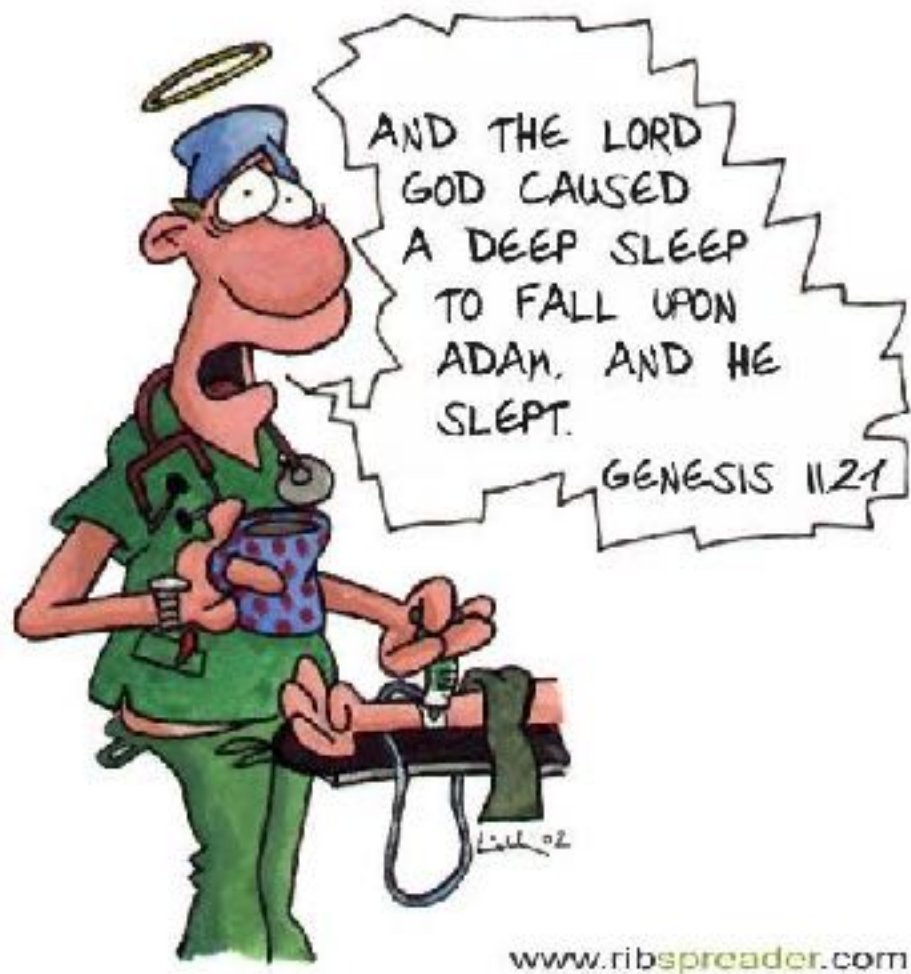
General anesthesia:

Desflurane 60,000 ppm

Sevoflurane 21,000 ppm

Isoflurane 12,000 ppm

How Can We Reduce Exposure To WAG?



Anesthesiology

Facilities
Maintenance
& Engineering

Anesthesia - In The OR

- **Do not disconnect** the patient from the anesthesia machine during operation
- Make sure all connections are **tight**
- **TIVA/TCI** instead of leak

5. Extubation in OR vs PACU

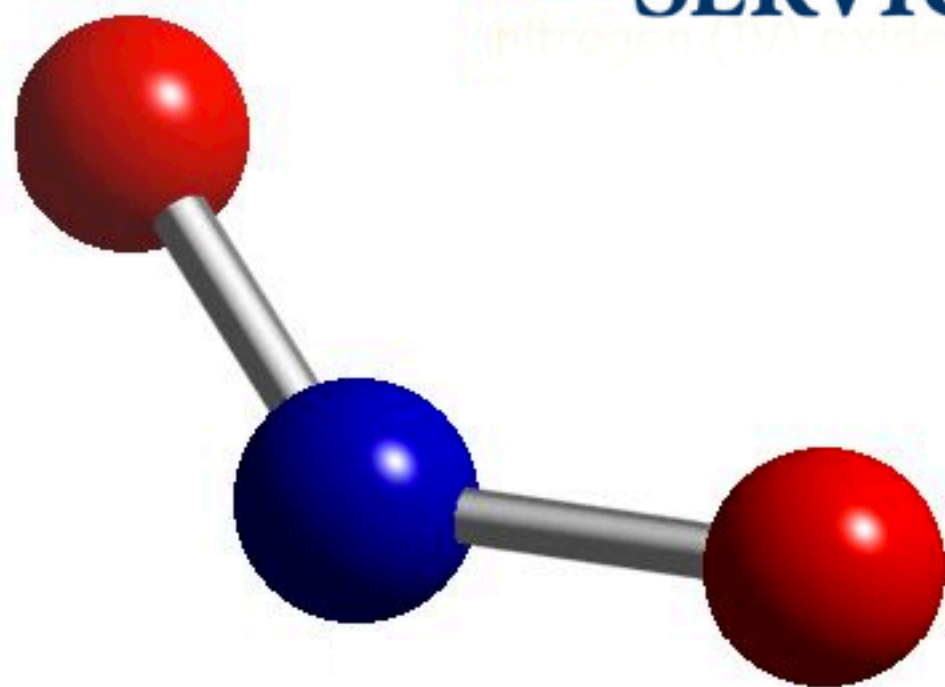
Time	Sevoflurane			Desflurane		
	OR (n=14)	PACU (n=27)	p	OR (n=16)	PACU (n=12)	p
0 (arrival)	0.62 ppm	1.17 ppm	0.02	2.50 ppm	4.00 ppm	0.02
15 minutes	0.45 ppm	0.68 ppm	0.02	2.01 ppm	2.99 ppm	0.02
30 minutes	0.51 ppm	0.58 ppm	0.72	1.75 ppm	2.13 ppm	0.09
45 minutes	0.57 ppm	0.59 ppm	0.73	1.55 ppm	2.12 ppm	0.09
60 minutes	0.64 ppm	0.54 ppm	0.57	1.81 ppm	2.32 ppm	0.33

6. Remaining Levels Of WAG In The Anesthesia Machine

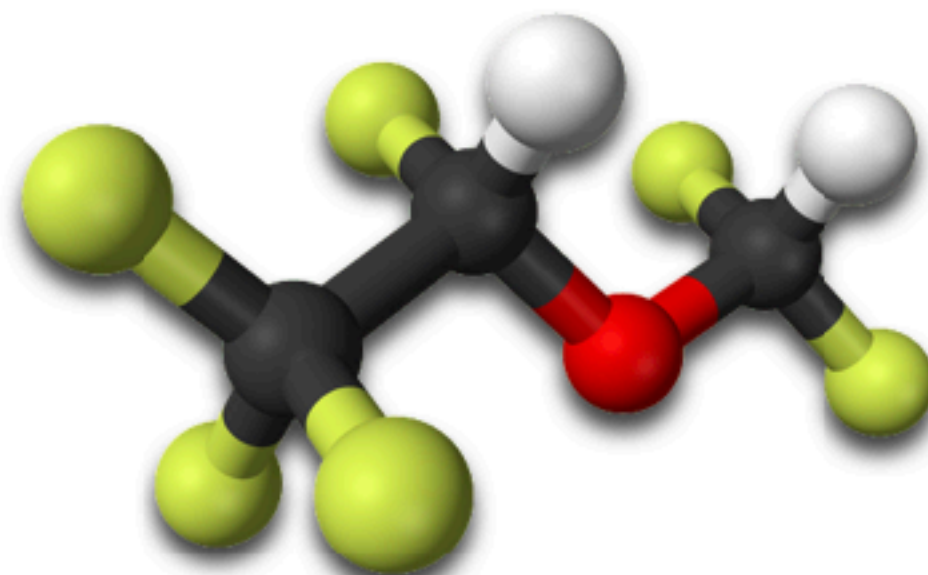
Extubation	Desflurane	Sevoflurane
OR Primus	3216.6 ppm	336.3 ppm
PACU Primus	4843.2 ppm	344.9 ppm
OR Fabius	278.8 ppm	341.2 ppm
PACU Fabius	2586.76 ppm	391.4 ppm



DISTINGUISHED SERVICE AWARD



Nitrous



Desflurane

Building Codes

STANDARD

ANSI/ASHRAE/ASHE Standard 170-2013

(Supersedes ANSI/ASHRAE/ASHE Standard 170-2008)

Includes ANSI/ASHRAE/ASHE addenda listed in Appendix C

Ventilation of Health Care Facilities

Building Codes

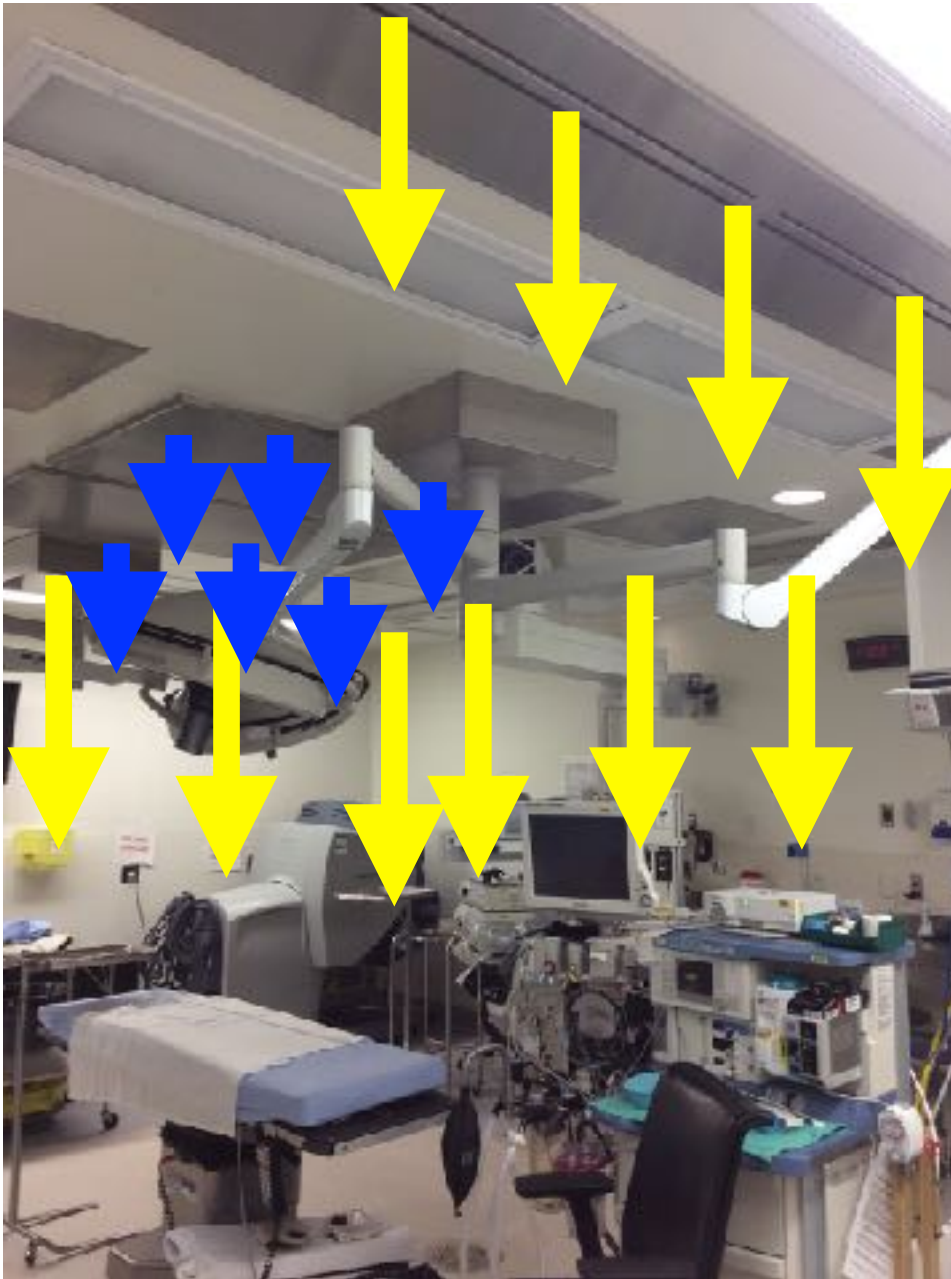
TABLE 7.1 Design Parameters

Function of Space	Pressure Relationship to Adjacent Areas (n)	Minimum Outdoor ach	Minimum Total ach	All Room Air Exhausted Directly to Outdoors (j)	Air Recirculated by Means of Room Units (a)	Design Relative Humidity (k), %	Design Temperature (l), °F/°C
SURGERY AND CRITICAL CARE							
Operating room (Class B and C) (m), (n), (o)	Positive	4	20	NR	No	20–60	68–75/20–24
Operating/surgical cystoscopic rooms, (m), (n) (o)	Positive	4	20	NR	No	20–60	68–75/20–24
Delivery room (Caesarean) (m), (n), (o)	Positive	4	20	NR	No	20–60	68–75/20–24
Substerile service area	NR	2	6	NR	No	NR	NR
Recovery room	NR	2	6	NR	No	20–60	70–75/21–24
Critical and intensive care	NR	2	6	NR	No	30–60	70–75/21–24
Intermediate care (s)	NR	2	6	NR	NR	max 60	70–75/21–24
Wound intensive care (burn unit)	NR	2	6	NR	No	40–60	70–75/21–24
Newborn intensive care	Positive	2	6	NR	No	30–60	72–78/22–26
Treatment room (p)	NR	2	6	NR	NR	20–60	70–75/21–24

HVAC Specs At The UAH

Space	Min. Outdoor ACH	Min. Total ACH	P relative to adj areas	Temp	Relative Humidity
OR	10	22-30	positive	18-26 Celsius	20-60%
Adult PACU	10	17	positive	18-26 Celsius	20-60%

Other Ventilation Differences Between PACU And OR



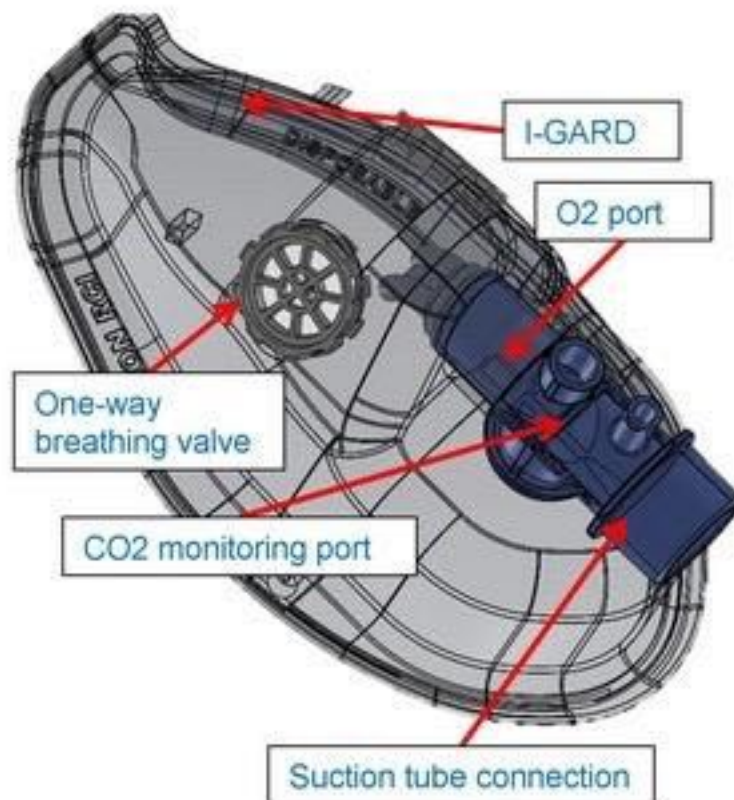
Other Ventilation Differences Between PACU And OR



Source Control Measures

Key New Product & Line Extension Launches

ISO-Gard® Mask with ClearAir™ Technology



PRODUCT DESCRIPTION

- Multi-purpose product that:
 - Reduces hazardous WAG within breathing zone of caregiver
 - Minimizes the cumulative effect of low level exposure of WAG to caregiver
 - Provides unidirectional flow of oxygen through mask to assure maximum FIO2
 - Can handle up to 10 LPM of oxygen flows

LAUNCH DATE

- Full Market Release Q2 2013

Summary - Anesthesia

- No leaks of the breathing circuit
- More use of TIVA/TCI
- Extubate patients in the OR vs in PACU
- Stop using N₂O and Desflurane

Summary - FM&E

- Design PACU units with **true laminar flow**
- Make all air exchanges **fresh gas exchanges**





*Thank You Very Much For Your
Attention*

