To Tube, or Not to Tube?

Comparing Ventilation Techniques in Microlaryngeal Surgery

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Introduction

- Apneic techniques for laryngeal surgery have been advocated since 1959
  - Used frequently since the late 1970's
  - Initially used in pediatrics
- Apneic techniques permit surgeries without an endotracheal tube (fully apneic) or with an endotracheal tube placed intermittently (intermittently apneic/AAIV)
- Benefits
  - Unobstructed view of the larynx
  - Reduction of combustible material in airway
  - "Precludes seeding the larynx and trachea with malignant cells"
  - Even allows for phonation

Sources: Frumin, M. Jack, Epstein, Robert M., Cohen, Gerald, Ph.D.: Apnoeic Oxygenation in Man. Anesthesiology 20:6:789–798 (Nov.-Dec.) 1959
Woodman D. Laryngoscopy under general anesthesia: apneic oxygenation technique. A report of over 100 cases. Annals of Otology, Rhinology and Laryngology 1961; 70: 1113–16.
Weisberger EC, Miner JD. Apneic anesthesia for improved endoscopic removal of laryngeal papillomata. Laryngoscope. 1988 Jul;98(7):693-7.
Weisberger EC, Emhardt JD: Apneic anesthesia with intermittent ventilation for microsurgery of the upper airway. Laryngoscope 1996; 106:1099–102
Mak D, Deligné P, Brault D, Muler H. [Apneic anesthesia in unventilated patients for various operations and explorations in laryngotracheal surgery]. Ann Anesthesiol Fr. 1976;17(8):863-70.
Nelson RA, Miller T. Apneic anesthesia for microlaryngeal surgery. Laryngoscope. 1973 Aug;83(8):1228-33.
Selim J, Maquet C, Djerada Z, Besnier E, Compère V, Crampon F, Clavier T, Marie JP. Anesthetic Management for Awake Tubeless Suspension Microlaryngoscopy. Laryngoscope. 2021 Apr 21.

How do Apneic Techniques Compare?

- ETT
  - Some airways are too small for ETTs
  - Obscures full view of airway
- Jet
  - Risk of pneumothorax
  - Contraindicated in COPD, emphysema
  - Movement of vocal folds due to pressure

Relevant Background

- Weisberger (1996)
  - 250 procedures on larynx and trachea with AAIV
  - Patients intubated when sats <97% or more than 5 mins apnea
  - Proposed Contraindications
    - Disorders of increased metabolic rate (increased CO_2 prod, and O_2 consumption)
      - Fever
      - Hyperthyroidism
      - Age <2
      - Cardiopulmonary disorders

Relevant Background

- Yoo (2018)
  - 66 cases
  - Apnea
  - Average operative time was 72.9 minutes (range, 27-166 minutes).
  - 8 cases required supplemental ventilation

- Studies comparing Apnea with AAIV with control (intubation)?

Study Objective

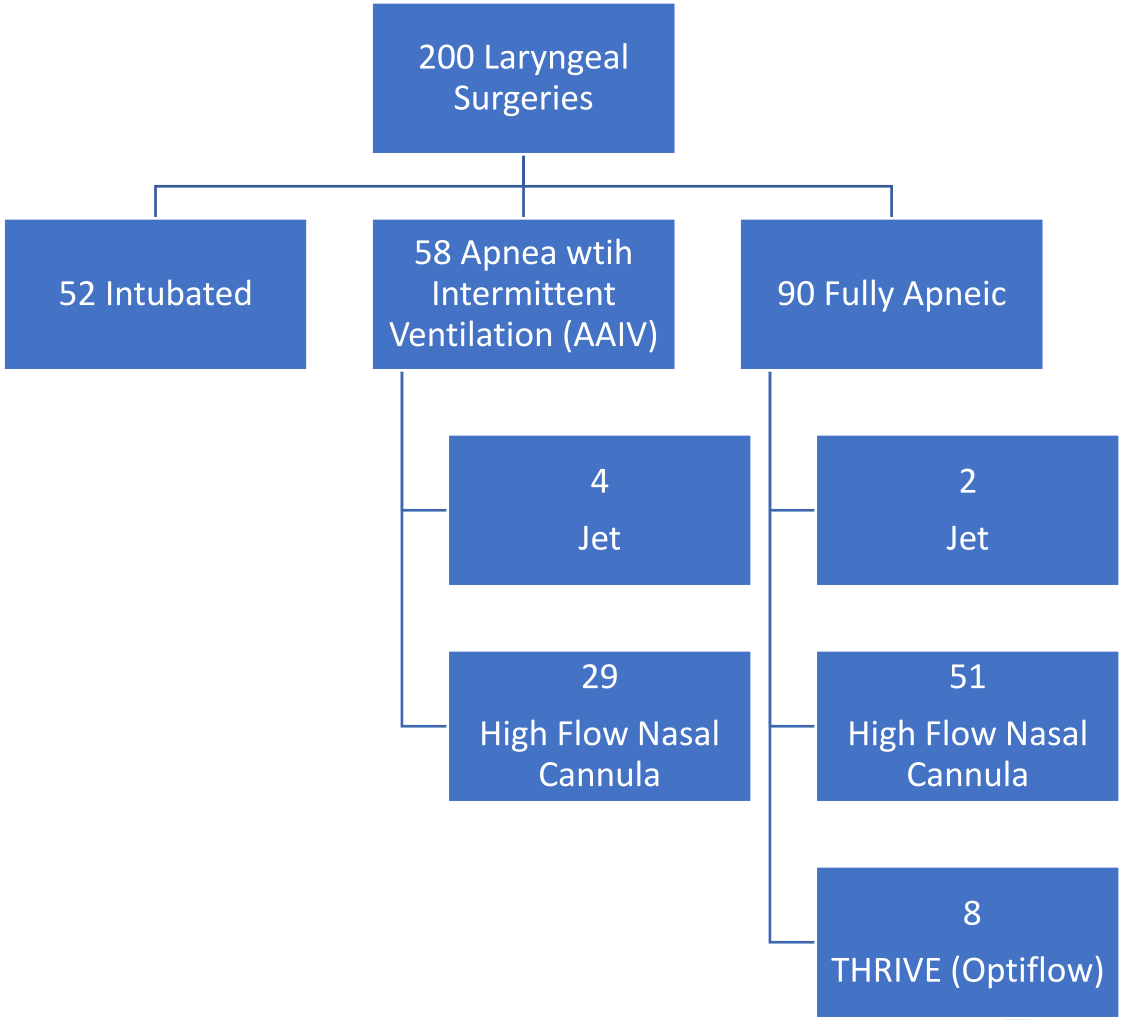
To compare ventilation techniques utilized in microlaryngeal surgery

Study Design & Methods

- Retrospective cohort study
    - 200 microlaryngeal surgeries
    - May 1, 2018 – March 1, 2020
    - Single fellowship-trained laryngeal surgeon

    - Intubated
        - Surgeries where an endotracheal tube was present prior to any surgical intervention
    - Apneic
        - Surgeries performed with no tube in place (ETT, LMA)
    - Intermittently Apneic
        - Surgeries that began apneic and then required intermittent intubation
    - Supplementary oxygenation
        - Jet
        - Nasal canula
        - THRIVE (optiflow)

Study Design



Study Design

- Age
- Sex
- BMI
- Hx of HTN
- Hx of Respiratory Disease
- Smoking status
- ASA class
- Procedure Performed
- Pre-op, Intra-op & Post-op
  - BP
  - HR
- Anesthetic combination
- Intraoperative medication
- Case length
- Longest time to intubation
- Lowest O2 sat
- Highest CO2 reading
- Complaints & Complications
  - 30 days of surgery

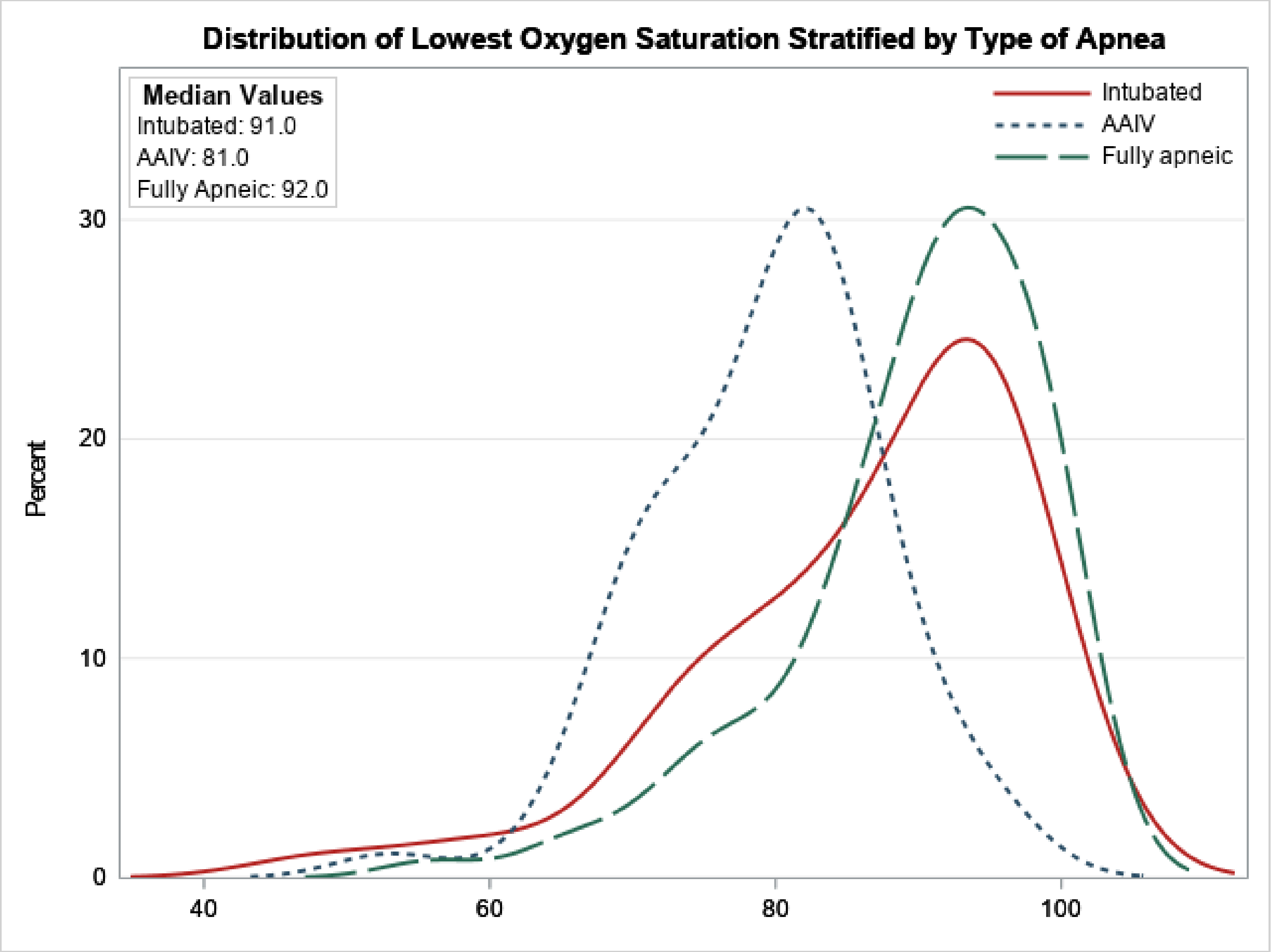
Results: Patient Characteristics

	Total (n=200)	Intubated (n=52)	AAIV (n=58)	Fully Apneic (n=90)	p-value
Age, years *median (IQR)*	56.5 (45.0-69.0)	55.5 (42.5-67.0)	55.5 (43.0-68.0)	59.0 (48.0-71.0)	0.0758
Sex					0.2683
Male	104 (52.0)	32 (61.5)	29 (50.0)	43 (47.8)	
Female	96 (48.0)	20 (38.5)	29 (50.0)	47 (52.2)	
BMI, Kg/m^2 *median (IQR)*	30.1 (26.6-34.5)	29.0 (25.5-33.5)[a]	33.0 (29.0-37.2)[b]	29.6 (26.3-33.9)[a]	0.0117
History of hypertension					0.7677
Yes	112 (56.0)	27 (51.9)	34 (58.6)	51 (56.7)	
No	88 (44.0)	25 (48.1)	24 (41.4)	39 (43.3)	
History of respiratory disease					0.0993
Yes	87 (43.5)	21 (40.4)	32 (55.2)	34 (37.8)	
No	113 (56.5)	31 (59.6)	26 (44.8)	56 (62.2)	
Is the patient currently a smoker?					0.0848
No	83 (41.5)	14 (26.9)	24 (41.4)	45 (50.0)	
Yes	26 (13.0)	11 (21.2)	6 (10.3)	9 (10.0)	
Former	89 (44.5)	27 (51.9)	27 (46.6)	35 (38.9)	
Passive	2 (1.0)	0	1 (1.7)	1 (1.1)	
ASA Class					0.0816
1	0	0	0	0	
2	52 (26.0)	17 (32.7)	8 (13.8)	27 (30.0)	
3	120 (60.0)	26 (50.0)	40 (69.0)	54 (60.0)	
4	28 (14.0)	9 (17.3)	10 (17.2)	9 (10.0)	
Procedure					<0.0001
DML Explorative	5 (2.5)	4 (7.7)	0	1 (1.1)	
DML Microflap/Excision	105 (52.5)	37 (71.2)	32 (55.2)	36 (40.0)	
DML Cordotomy	23 (11.5)	8 (15.4)	9 (15.5)	6 (6.7)	
DML Vocal Cord Injection	51 (25.5)	2 (3.9)	5 (8.6)	44 (48.9)	
DML Subglottic/Tracheal Stenosis	14 (7.0)	1 (1.9)	10 (17.2)	3 (3.3)	
DML Fat Injection	2 (1.0)	0	2 (3.5)	0	
Pre-operative systolic blood pressure, mmHg *median (IQR)*	140.0 (128.0-153.5)	137.5 (124.0-150.5)	143.0 (133.0-154.0)	139.5 (126.0-156.0)	0.2368
Pre-operative diastolic blood pressure, mmHg *median (IQR)*	81.0 (73.0-90.0)	81.0 (74.0-87.5)	81.5 (72.0-93.0)	80.0 (73.0-90.0)	0.9352
Pre-operative heart rate, beats/minute *mean ± SD*	77.6 ± 13.7	78.1 ± 13.0	76.3 ± 13.6	78.2 ± 14.2	0.7665
Does the patient have a history of post-op nausea or vomiting?					0.8878
Yes	18 (9.0)	4 (7.7)	6 (10.3)	8 (8.9)	

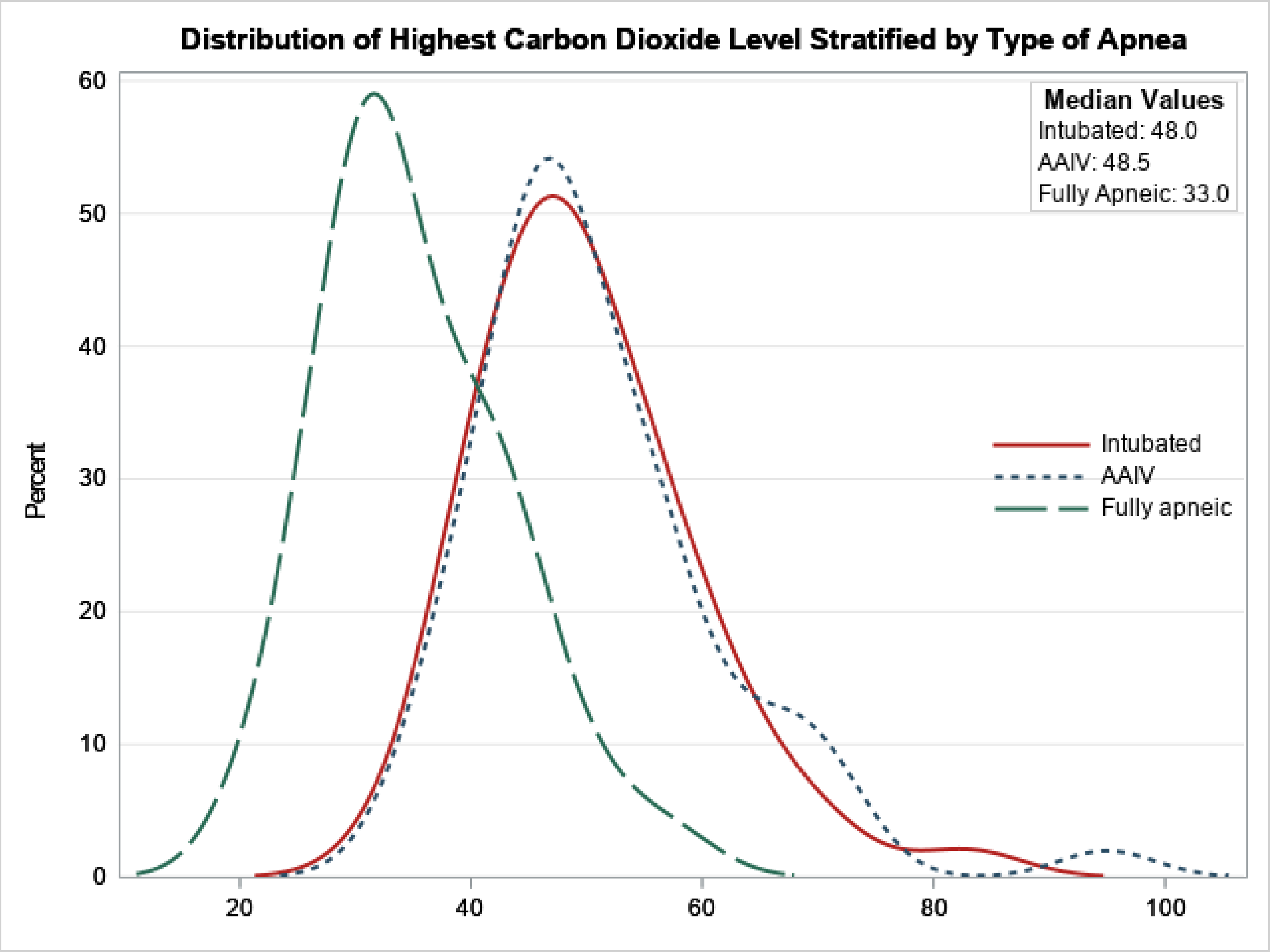
Results: Oxygenation

	Total (n=200)	Intubated (n=52)	AAIV (n=58)	Fully Apneic (n=90)	p-value
Was high flow oxygen delivered?					<0.0001
No	101 (50.5)	47 (90.4)	25 (43.1)	29 (32.2)	
Nasal Cannula	85 (42.5)	5 (9.6)	29 (50.0)	51 (56.7)	
THRIVE/Optiflow	8 (4.0)	0	0	8 (8.9)	
Jet	6 (3.0)	0	4 (6.9)	2 (2.2)	
Longest time without Intubation, minutes *median (IQR)*	3.0 (0.0-7.0)	0.0 (0.0-0.0)[a]	5.0 (3.0-9.0)[b]	4.0 (2.0-8.0)[b]	<0.0001
Highest CO_2 measurement (n=142) *median (IQR)*	47.0 (40.0-53.0)	48.0 (43.0-56.0)[a]	48.5 (44.0-56.0)[a]	33.0 (30.0-41.0)[b]	<0.0001
Lowest oxygen saturation *median (IQR)*	87.0 (79.0-94.0)	91.0 (79.5-94.0)[a]	81.0 (73.0-84.0)[b]	92.0 (86.0-97.0)[a]	<0.0001

Results: Oxygenation



Results: Carbon Dioxide Levels



Results: Supplementary Oxygen

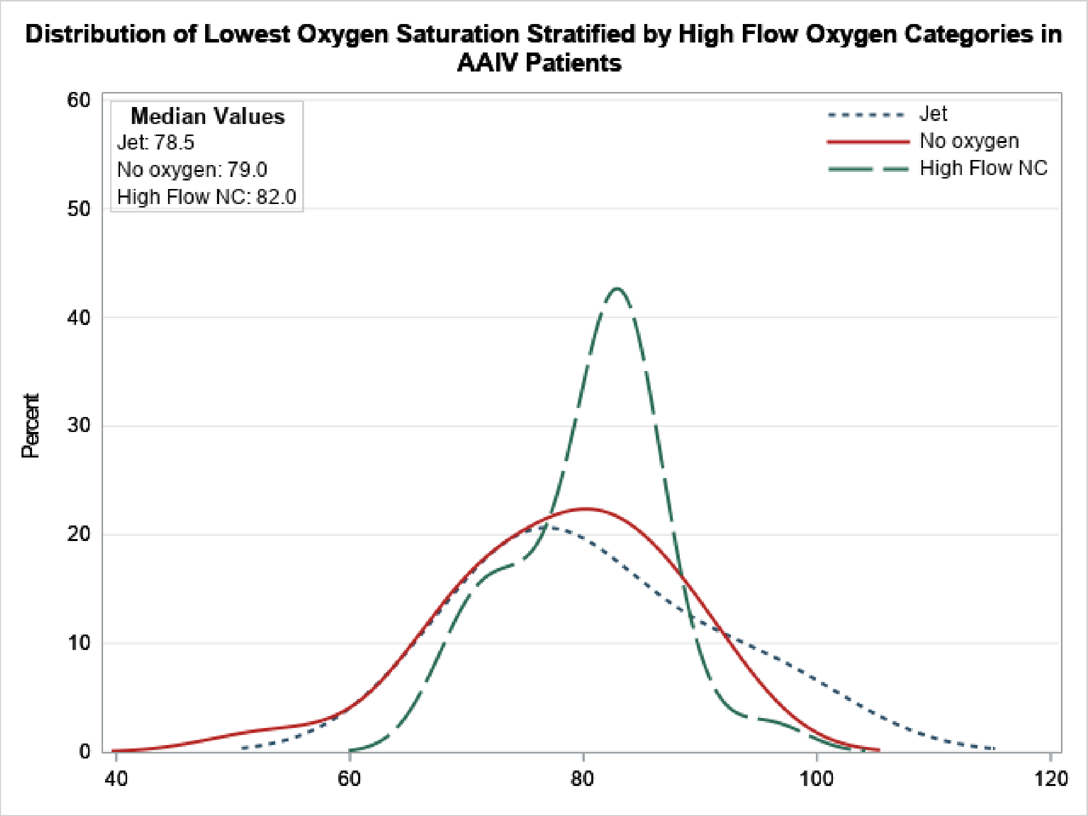
Apneic Oxygenation *(n = 90; Different superscript letters indicate a statistically significant difference between groups)*

	No High Flow Oxygen (n=29)	**Nasal Cannula** (n=51)	**THRIVE (Optiflow)** (n=8)	**Jet** (n=2)	**p-value**
Longest time without Intubation, minutes *median (IQR)*	3.0 (2.0-4.0)[a]	5.0 (3.0-10.0)[b]	7.5 (5.5-9.5)[b]	8.0 (5.0-11.0)[a,b]	0.0013
Highest CO_2 measurement (n=33) *median (IQR)*	32.0 (28.0-40.0)	32.5 (30.5-41.0)	44.0 (44.0-44.0)	43.0 (43.0-43.0)	0.02525
Lowest oxygen saturation *median (IQR)*	92.0 (84.0-96.0)	92.0 (86.0-97.0)	93.5 (89.0-95.5)	83.5 (76.0-91.0)	0.6498

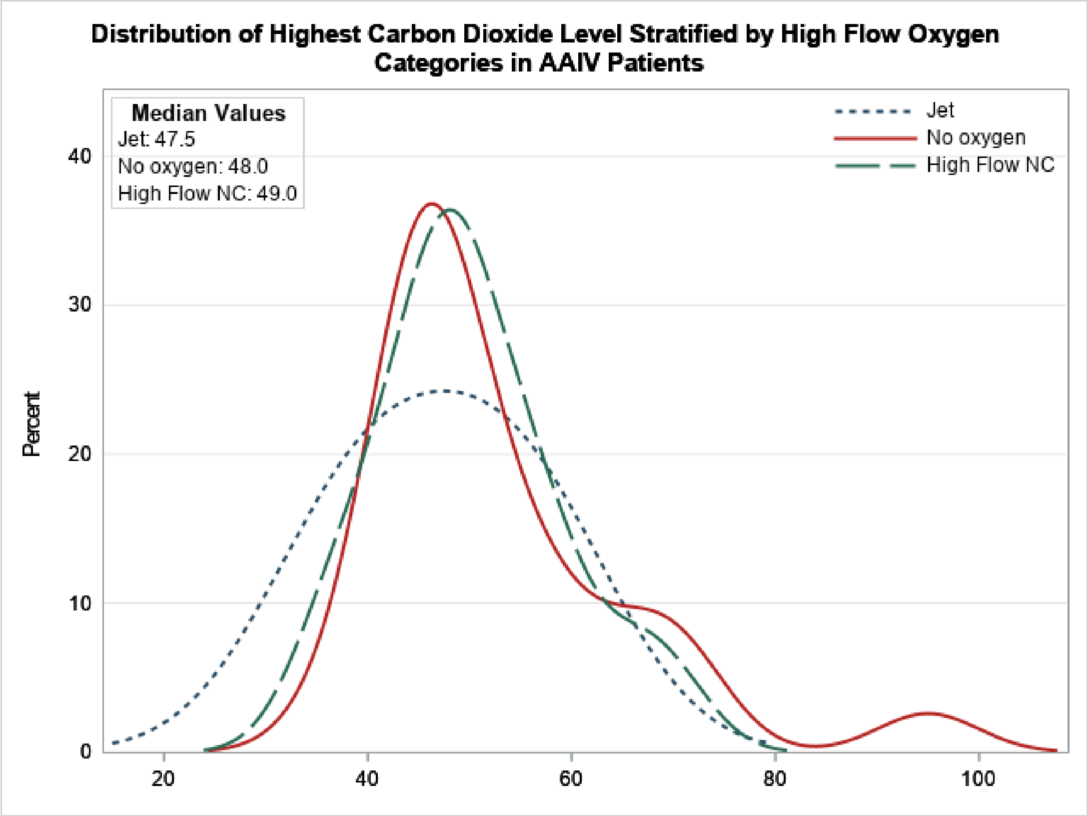
AAIV Oxygenation (n=58)

	No High Flow Oxygen (n=25)	**Nasal Cannula** (n=29)	**Jet** (n=4)	**p-value**
Longest time without Intubation, minutes *median (IQR)*	4.0 (3.0-7.0)	5.0 (3.0-9.0)	7.0 (4.0-10.5)	0.2731
Highest CO_2 measurement *median (IQR)*	48.0 (44.0-56.0)	49.0 (45.0-55.0)	47.5 (39.5-55.0)	0.7739
Lowest oxygen saturation *median (IQR)*	79.0 (71.0-84.0)	82.0 (76.0-84.0)	78.5 (74.0-87.5)	0.5783

AAIV



Distribution of Lowest Oxygen Saturation Stratified by High Flow Oxygen Categories in AAIV Patients
Median Values
Jet: 78.5
No oxygen: 79.0
High Flow NC: 82.0
Jet
No oxygen
High Flow NC
Percent
0
10
20
30
40
50
60
40
60
80
100
120

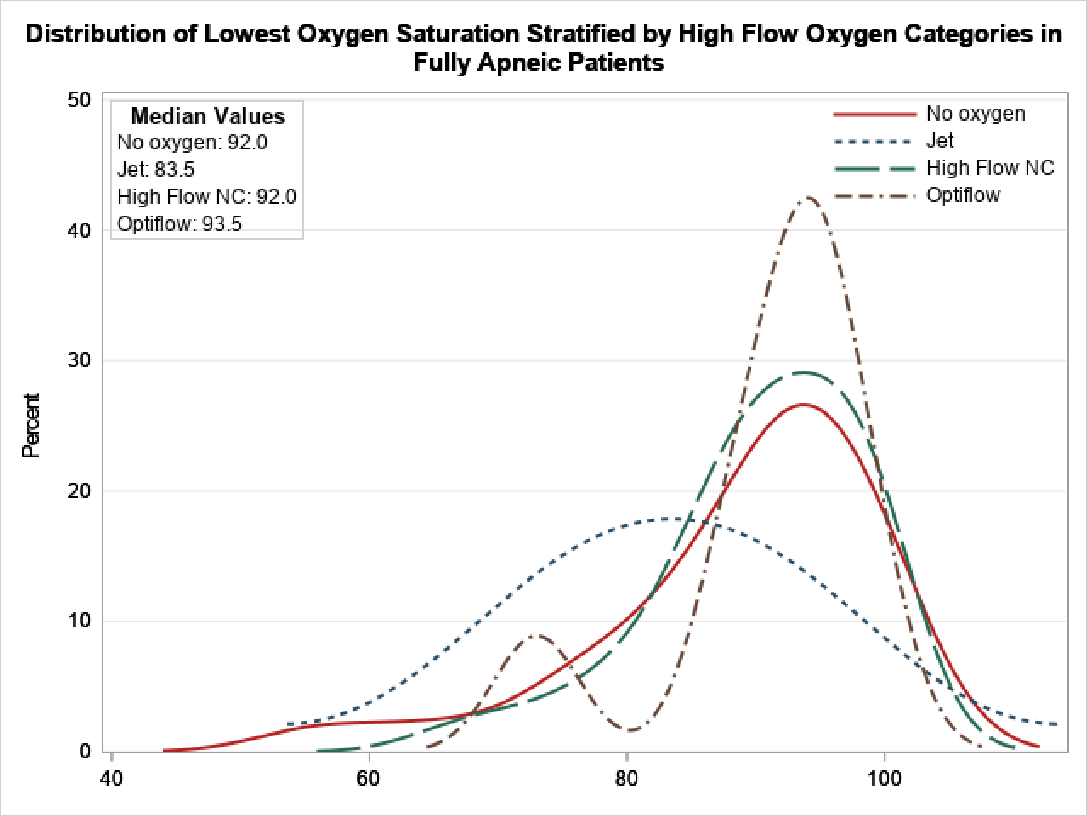


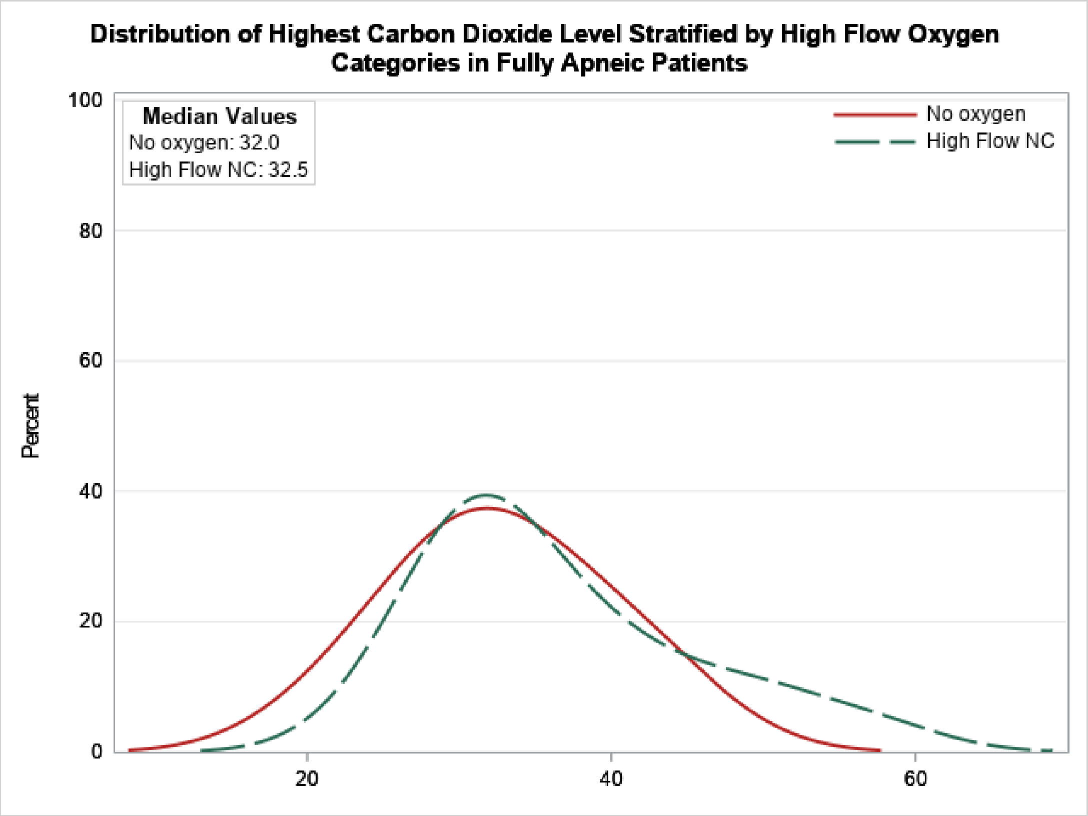
Distribution of Highest Carbon Dioxide Level Stratified by High Flow Oxygen Categories in AAIV Patients
Median Values
Jet: 47.5
No oxygen: 48.0
High Flow NC: 49.0
Jet
No oxygen
High Flow NC
Percent
0
10
20
30
40
20
40
60
80
100

Apneic Oxygenation (n= 90)

	No High Flow Oxygen (n=29)	Nasal Cannula (n=51)	THRIVE (Optiflow) (n=8)	Jet (n=2)	p-value
Longest time without Intubation, minutes *median (IQR)*	3.0 (2.0-4.0)[a]	5.0 (3.0-10.0)[b]	7.5 (5.5-9.5)[b]	8.0 (5.0-11.0)[a,b]	0.0013
Highest CO_2 measurement (n=33) *median (IQR)*	32.0 (28.0-40.0)	32.5 (30.5-41.0)	44.0 (44.0-44.0)	43.0 (43.0-43.0)	0.02525
Lowest oxygen saturation *median (IQR)*	92.0 (84.0-96.0)	92.0 (86.0-97.0)	93.5 (89.0-95.5)	83.5 (76.0-91.0)	0.6498

Fully Apneic





Results: Hemodynamics

	Total (n=200)	Intubated (n=52)	AAIV (n=58)	Fully Apneic (n=90)	p-value
Systolic blood pressure after laryngoscope inserted, mmHg *median (IQR)*	155.0 (134.0-173.0)	145.0 (124.5-168.5)[a]	153.0 (135.0-170.0)[a,b]	159.5 (141.0-178.0)[b]	0.0082
Diastolic blood pressure after laryngoscope inserted, mmHg *median (IQR)*	94.0 (76.0-110.0)	93.0 (74.0-106.0)	95.0 (80.0-112.0)	94.0 (76.0-115.0)	0.6063
Heart rate after laryngoscope inserted, beats/minute *median (IQR)*	91.0 (77.0-102.0)	88.0 (73.5-102.5)	88.0 (75.0-97.0)	94.0 (84.0-104.0)	0.1576
Post-operative systolic blood pressure, mmHg *median (IQR)*	124.0 (111.0-141.5)	127.5 (113.5-137.5)	122.0 (109.0-140.0)	124.0 (111.0-144.0)	0.6418
Post-operative diastolic blood pressure, mmHg *median (IQR)*	71.0 (61.0-82.0)	76.5 (66.0-85.5)[a]	69.5 (60.0-79.0)[a,b]	68.5 (60.0-80.0)[b]	0.0300
Post-operative heart rate, beats/minute *median (IQR)*	84.0 (73.0-94.0)	85.5 (73.5-96.0)	85.0 (73.0-92.0)	83.0 (73.0-93.0)	0.4414

Results: Anesthetics & Medications

	Total (n=200)	Intubated (n=52)	AAIV (n=58)	Fully Apneic (n=90)	p-value
OR procedure time, minutes *median (IQR)*	19.5 (9.0-36.5)	28.5 (20.0-41.0)[a]	20.5 (13.0-42.0)[a]	10.0 (5.0-33.0)[b]	<0.0001
Which anesthetic combination was used?					<0.0001
Prop/Sux	62 (31.0)	5 (9.6)	6 (10.3)	51 (56.7)	
Prop/Sux/Roc	32 (16.0)	8 (15.4)	12 (20.7)	12 (13.3)	
Prop/Sux/Remi	45 (22.5)	8 (15.4)	18 (31.0)	19 (21.1)	
Prop/Remi/Sux/Roc	31 (15.5)	11 (21.2)	16 (27.6)	4 (4.4)	
Prop/Roc	3 (1.5)	2 (3.9)	0	1 (1.1)	
Prop/Remi/Roc	24 (12.0)	16 (30.8)	5 (8.6)	3 (3.3)	
Prop/Remi	1 (0.5)	0	1 (1.7)	0	
Other combination	2 (1.0)	2 (3.9)	0	0	
Was topical lidocaine used? (n=198)					0.0108
Yes	167 (84.3)	36 (72.0)	51 (87.9)	80 (88.9)	
No	31 (15.7)	14 (28.0)	7 (12.1)	10 (11.1)	
Which reversal agent was given? (n=84)					N/A
Sugammadex	84 (100)	33 (100)	31 (100)	20 (100)	
Neostigmine	0	0	0	0	
Was anything given to adjust blood pressure and/or heart rate?					0.2890
No	130 (65.0)	27 (51.9)	39 (67.2)	64 (71.1)	
Esmolol	27 (13.5)	8 (15.4)	5 (8.6)	14 (15.6)	
Phenylephrine	14 (7.0)	6 (11.5)	5 (8.6)	3 (3.3)	
Ephedrine	5 (2.5)	3 (5.8)	1 (1.7)	1 (1.1)	
Glycopyrrolate	12 (6.0)	4 (7.7)	4 (6.9)	4 (4.4)	
Multiple	12 (6.0)	4 (7.7)	4 (6.9)	4 (4.4)	
Was the patient given antiemetics?					0.3953
No	160 (80.0)	40 (76.9)	50 (86.2)	70 (77.8)	
Zofran pre-op	37 (18.5)	11 (21.2)	7 (12.1)	19 (21.1)	
Zofran post-op	2 (1.0)	0	1 (1.7)	1 (1.1)	
Multiple	1 (0.5)	1 (1.9)	0	0	

Results: Complaints & Complications

	Total (n=200)	Intubated (n=52)	AAIV (n=58)	Fully Apneic (n=90)	p-value
Complication within 30 days of surgery?					0.0954
No	155 (77.5)	44 (84.6)	41 (70.7)	70 (77.8)	
Dysphonia	8 (4.0)	2 (3.9)	1 (1.7)	5 (5.6)	
Dysphagia	1 (0.5)	0	1 (1.7)	0	
Dyspnea/SOB	10 (5.0)	0	6 (10.3)	4 (4.4)	
Hemorrhage	4 (2.0)	1 (1.9)	1 (1.7)	2 (2.2)	
Death	1 (0.5)	0	1 (1.7)	0	
Laryngeal Edema	1 (0.5)	0	0	1 (1.1)	
Cardiovascular Event	2 (1.0)	1 (1.9)	0	1 (1.1)	
Pulmonary Event	1 (0.5)	0	1 (1.7)	0	
Tooth/OC Injury	4 (2.0)	2 (3.9)	0	2 (2.2)	
Pain	8 (4.0)	0	4 (6.9)	4 (4.4)	
Anesthesia	2 (1.0)	2 (3.9)	0	0	
Reflux	2 (1.0)	0	1 (1.7)	1 (1.1)	
Conversion to trach intra-op	1 (0.5)	0	1 (1.7)	0	
Did the patient report post-op nausea or vomiting?					N/A
Yes	0	0	0	0	
No	200 (100)	52 (100)	58 (100)	90 (100)	

Complaints: Post-Op Dyspnea (10 cases, 9 pts)

Patient	AGE	Sex	BMI	PROCEDURE	Plan/Notes
H	68	M	19.5	R Cordotomy, GS	Admitted POD#1, Trach POD#2
I	42	M	28.6	B/L Injection (0.2mL R, 0.1 mL L), GS	Temporary "Tightness" (discussed pre-op)
J	40	M	36.9	Incision & Balloon Dilation (2cm SGS)	Improved breathing 2-4 days and worsened
K	53	F	41.8	Incision & Balloon Dilation (A-frame tracheal stenosis, 1.5cm long)	Improved but still some dyspnea when lying flat
J	40	M	37.2	Incision & Balloon Dilation (2cm SGS)	Improved breathing 3 days and then back to baseline
L	56	F	45	R VF Injection (0.8mL R)	1 wk mod-severe dyspnea
M	63	M	34.5	R Cordotomy, GS	Admitted 12 hrs post-op dyspnea, post-op airway still narrow 2wks. Did not follow-up after
N_1	47	F	21.4	B/L Cordotomy, GS	POD#3 ER for steroids
N_2	47	F	22	R Cordotomy , GS	POD#5 ER for steroids
O	56	M	35.1	L Cordotomy, GS	Breathing 40% better than pre-op

All but one patient had varying degrees of airway stenosis where most patients reported an overall improvement in breathing.

Complaints: Dysphonia (8 cases, 7 pts)

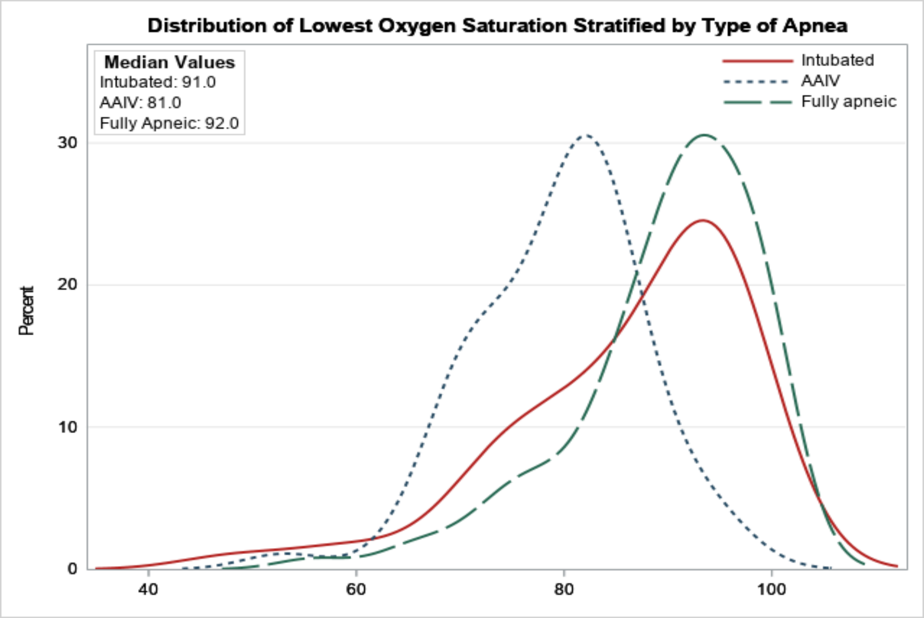
- VHI-10 data were available for 5 patients, all of which reported a net decrease after surgery

Patient	AGE	Sex	BMI	PROCEDURE	Notes
A	30	F	30	Microflap	Chronic Laryngitis
B	83	M	29.1	VF Injection	R VF Paralysis
C	43	F	45.7	Microflap	Chronic MRSA Laryngitis
D_1	57	F	39.5	VF Injection	R VFP, Pre-op VHI-10=36, Post-op VHI-10=33
E	59	F	26.8	VF Injection	L VFP, Pre-op VHI-10=35, Post-op VHI-10=24
F	78	F	26.6	VF Injection	L VFP, Pre-op VHI-10=32, Post-op VHI-10=11
D_2	57	F	39.5	VF Injection	R VFP, Pre-op VHI-10=36, Post-op VHI-10=32
G	83	F	26.8	Microflap	T1NxM0 Stage I SCCa Pre-op VHI-10 = 22, Post-op VHI-10 = 10

Complications: Serious/Readmissions

11 patients (5.5%) sought emergency room evaluation or warranted readmission. There was one mortality within 30 days of apneic vocal fold injection.

NAME	AGE	Sex	BMI	PROCEDURE/Dx	COMPLICATION	Plan/Notes	Mode
X	73	M	32	L Vocal Fold Injection (GS)	Mortality	Inpatient, POD#3 bleeding following NGT insertion	Apnea
H	68	M	19.5	R Cordotomy (GS)	Dyspnea	Admitted POD#1, Trach POD#2	Apnea
M	63	M	34.5	R Cordotomy (GS)	Dyspnea	Admitted 12hrs post-op dyspnea, lost follow-up	Apnea
N_1	47	F	21.4	B/L Cordotomy (GS)	Dyspnea	POD#3 ER for steroids	AAIV
N_2	47	F	22	R Cordotomy (GS)	Dyspnea	POD#5 ER for steroids	AAIV
Y	97	1	28	Microflap (Obstructive Supraglottic Schwannoma)	Bleeding	+Eliquis POD#7 Admitted Bleeding OR control	AAIV
Z	25	0	29	Exploration, granulation removal	Bleeding	+Aspirin POD#1 Admitted for blood crusting in trach tube	Tube
AA	67	0	34.3	Vocal Fold Injection (atrophy) 0.3mL LEFT 0.5mL RIGHT	Laryngeal Edema vs Reaction to Restylane	POD#3 admitted Bilateral fullness & irritation of vocal folds	Apnea
BB	75	1	40.2	Vocal Fold Injection	Cardiac (Atrial Fibrillation)	Admitted from ER POD#1 for AFib w RVR (pre-op hx AFib known)	Apnea
CC	80	1	34.1	Microflap (T3N0M0 SCCa)	Pneumonia	Laryngeal Cancer, POD#5 ER pneumonia, readmitted	AAIV
V	66	F	26	Stenosis (supraglottic)	Pain	Sarcoidosis patient. ER visit and Naproxen	AAIV
DD	47	0	29	Microflap	Reflux	POD#7 ER with heartburn	AAIV



Discussion: Oxygenation

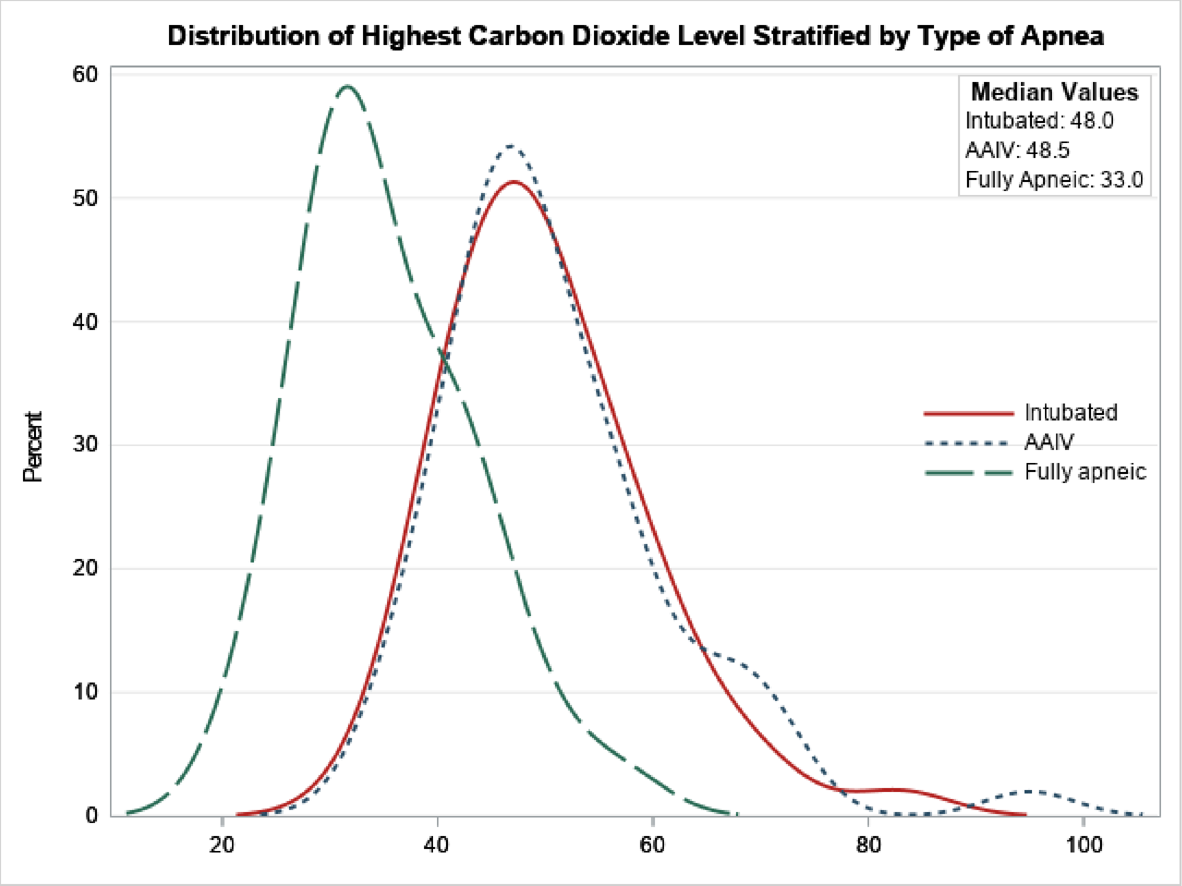
Oxygen nadirs were expectedly lower in AAIV cohort

- BMIs were higher
- Higher BMIs are a limiting factor in the utilization of THRIVE/Optiflow (Benninger et al, 2021)
- BMIs greater than 30 were 5x more likely to require “rescue ventilation” (Huang et al, 2019)
- BMIs greater than 25 also have quicker desaturation (Waters et al, 2019)

Our findings support that regardless of their higher BMIs, AAIV ventilation for these patients did not increase their likelihood of complications

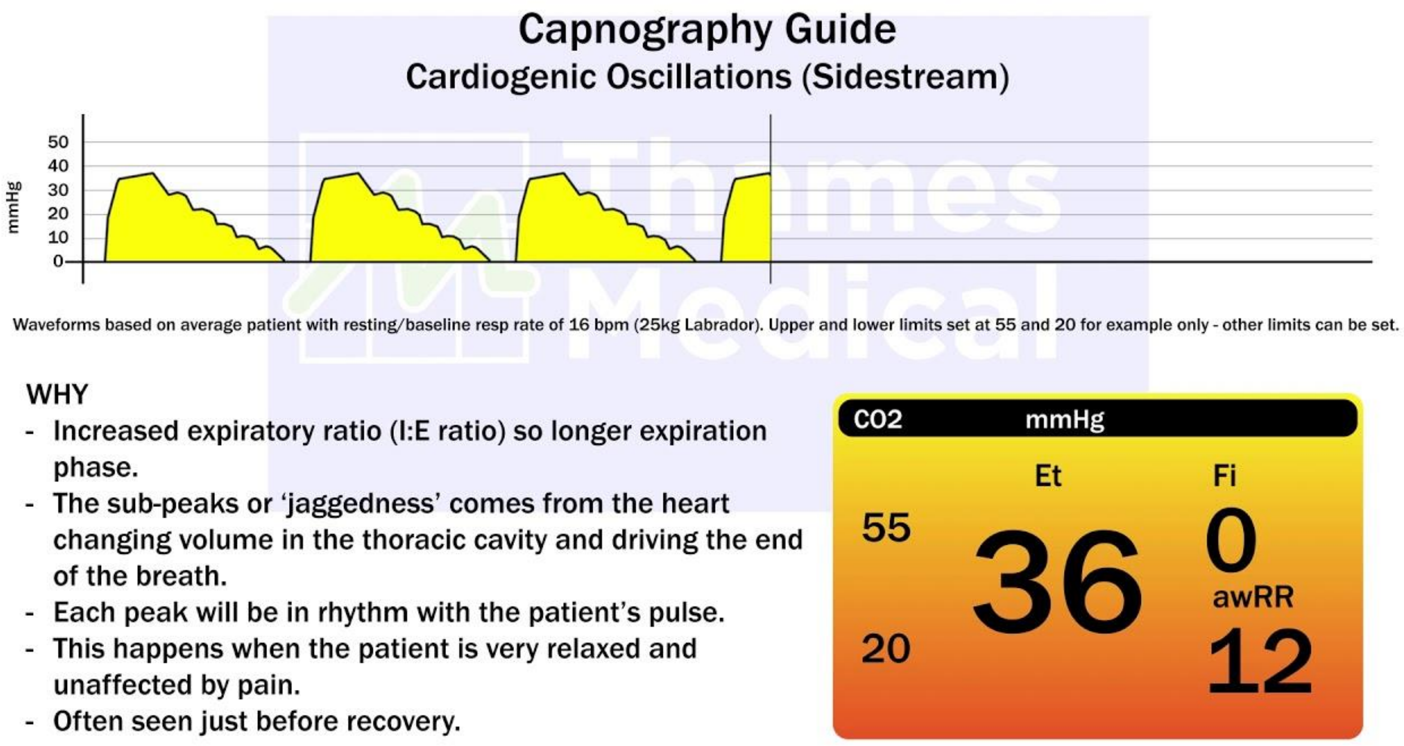
Discussion: Concern for CO_2 Accumulation

- What about CO_2 accumulation?
  - Cardiogenic Oscillations & Gas Mixing naturally occur
  - CO_2 values for 142 out of 200 cases
  - All AAIV cases had values
  - Fully apneic is like the 1st segment of an AAIV
  - Median apnea times in apneic cases were shorter but similar (4 vs 5 minutes) to AAIV cases
  - Therefore, it is reasonable to suspect that the CO_2 measurements would be similar.
- **Our data did not show carbon dioxide accumulation with apneic techniques**



Discussion: Concern for CO_2 Accumulation

- Cardiogenic Oscillations (COS) & Gas Mixing naturally occur
- “heart-synchronous variations” in pulmonary vessels, causing compression and expansion of the small airways.
- COS allow for gas mixing and oxygenation in small airways even in apneic conditions which
- Quantified using Taylor laminar dispersion models.
- Taylor dispersion accounts for gas exchange longitudinally in the trachea.



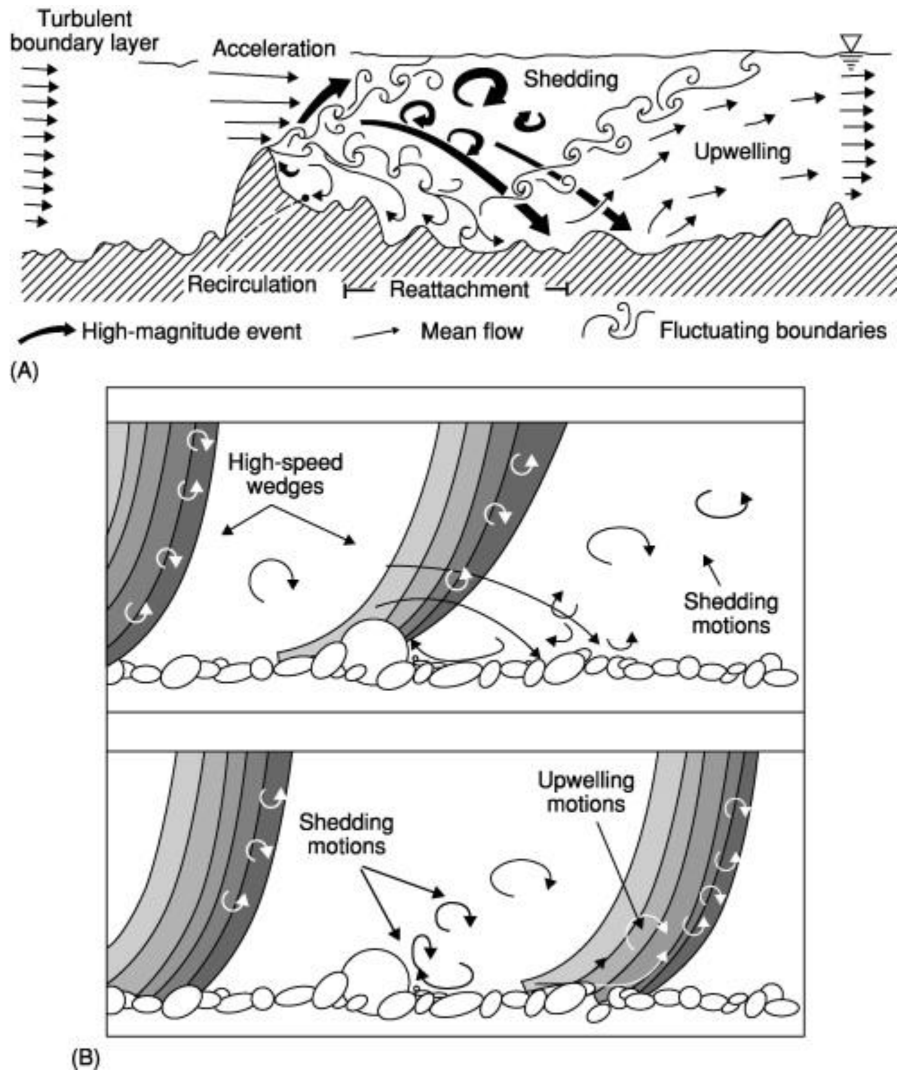
Tusman G, Suarez-Sipmann F, Peces-Barba G, et al. Pulmonary blood flow generates cardiogenic oscillations. Respiratory Physiology and Neurobiology 2009; 167: 247–54.

Slutsky AS. Gas mixing by cardiogenic oscillations: a theoretical quantitative analysis. Journal of Applied Physiology Respiratory Environmental and Exercise Physiology 1981; 51: 1287–93.

Van der Kooij AM, Luijendijk SC. Longitudinal dispersion of gases measured in a model of the bronchial airways. Journal of Applied Physiology 1985; 59: 1343–9.

Discussion: Concern for CO_2 Accumulation

- What about CO_2 accumulation?
  - Turbulent mixing
    - Additional gas exchange due to the creation of turbulence and turbulent eddy (mixing) currents in the oropharynx and pharynx
    - Hermez and colleagues demonstrated that turbulence is present even at flow rates of 1L/min but rises in intensity as flow rate increases particularly in the subglottis.
    - THRIVE (70L/min) provides the ability for greater air flow and therefore results in higher turbulent intensities over high flow nasal cannula (15L/min maximum).



Discussion: Concern for CO_2 Accumulation

- What about CO_2 accumulation?
  - Taylor Laminar Dispersion
    - Dispersion of a solute in a stream of solvent
    - Related to the diffusion coefficient
    - Amount of dispersion is a function BOTH
      - TIME
      - POSITION

2. Taylor Dispersion Analysis

As described above, the amount of dispersion of a solute in a stream of solvent is inversely related to its diffusion coefficient. The amount of dispersion is a function of both the time elapsed as well as the position of the solute within the flow. This relationship is described by Equation 1 which relates the variation of the solute concentration *C* in time *t* to its variation with its axial position *x* along the capillary. Note that *C* is the solute concentration averaged across the capillary diameter in the direction y, perpendicular to the flow axis *x* as illustrated in Figure 3.

$$\frac{dC}{dt} = k\frac{d^2C}{dx^2} \quad \text{Equation 1}$$

Figure 3: The concentration is averaged over the y-direction, perpendicular to the flow axis

The constant *k* is known as the dispersion coefficient and is related to the diffusion coefficient *D* by:

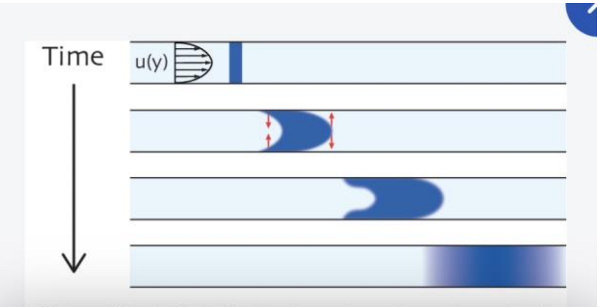


Figure 1: An initial plug of dye in 2D Poiseuille flow, where viscous forces dominate, will experience Taylor Dispersion and spread over time. Collapse

Taylor, Abgail W. “An Accessible Platform for Numerical and Experimental Investigations of Taylor Dispersion.” (2019)

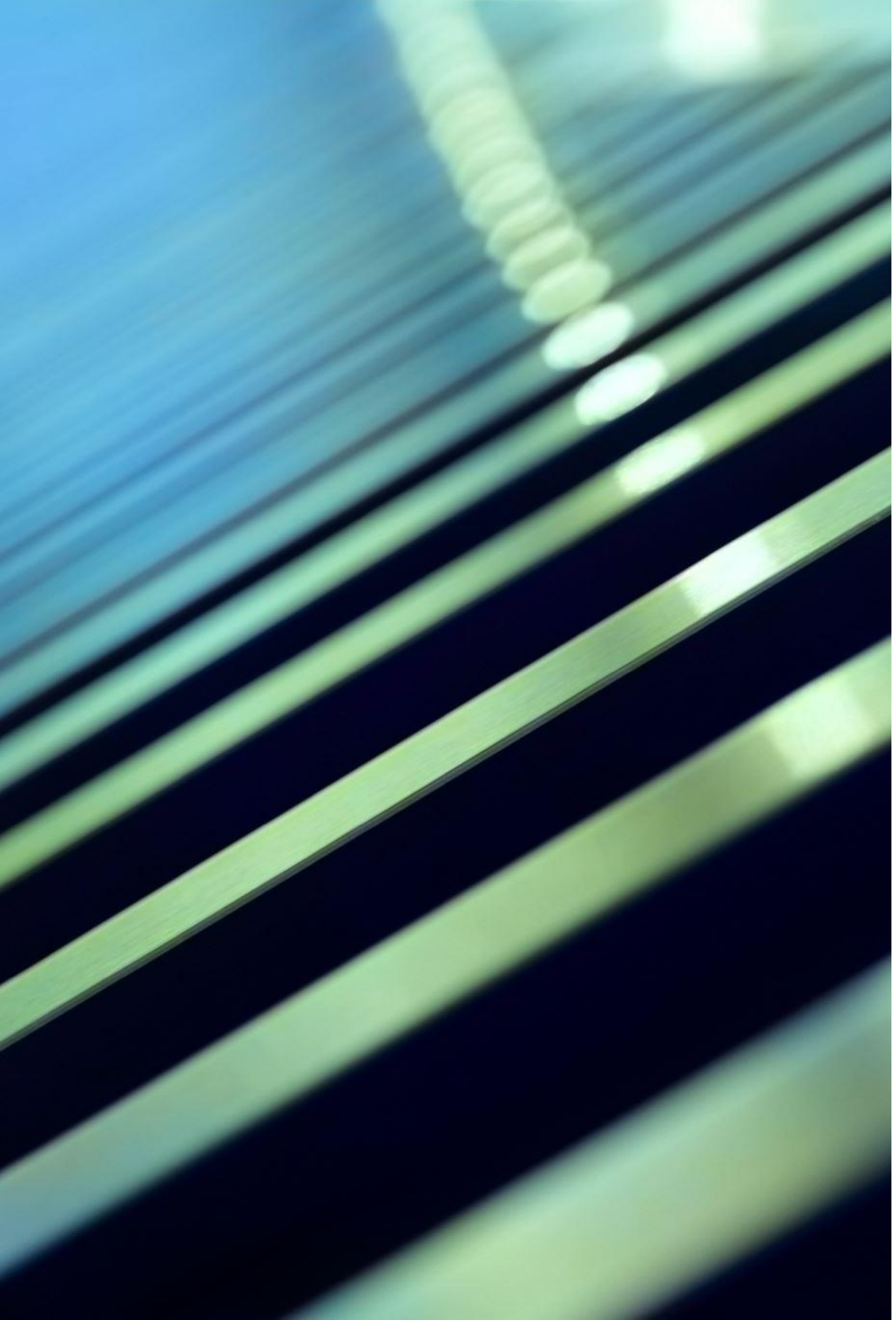
Discussion: Hemodynamics

- Median systolic blood pressure were higher in apnea after laryngoscope insertion
- Median diastolic pressures were lower in apnea
- Why???
  - Laryngoscopy elicits a sympathetic reflex resulting in increases in blood pressure and heart rate due to increasing plasma catecholamines.
- Sympathetic activity is usually balanced by the vagal parasympathetic activation
  - Pressure from laryngoscope on the laryngeal surface of the epiglottis
    - internal branch of the superior laryngeal nerve (the vagus nerve)
  - Vagotropic anesthetic agents such as propofol, remifentanil, and succinylcholine
- In patients where the vagal response is heightened, bradycardia and asystole can occur which is dangerous and potentially life-threatening.
  - This occurred in one patient, was immediately identified, and resolved with releasing the suspension of the laryngoscope.

Discussion: Hemodynamics

- Conversely, if the vagal response is blunted, the opposite can occur.
  - 48.9% of the fully apneic cases were vocal fold injection cases for vocal fold paralysis due to dysfunction or injury to the recurrent laryngeal nerve, a branch of the vagus.
  - These patients may also have some blunting of the normal vagal response to stimulation from the laryngoscope, thereby resulting in a more pronounced sympathetic rise in blood pressure.
  - These patients may be prone to autonomic dysregulation resulting in the systolic and diastolic differences.

- Further studies would be needed to substantiate this as the heart rate was not statically significant



Limitations

- Retrospective study
- Only hypertension and respiratory disease were studied
- Consistent intraoperative CO_2 measurements would lend further power
- Higher numbers in jet and Optiflow cohorts would help as well

Conclusions

- Cohort characteristics were statistically similar aside from BMI
- Adequate oxygenation without concern of carbon dioxide accumulation was achieved for apnea times < 30mins.
- No significant differences existed between events and complications.
- Apneic techniques are as safe and effective as traditional intubation.

RUSH

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Thank you!