

1 **CAPNOGRAPHY 2015**

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2 **DISCLOSURES**

- I have no financial interests in any product or company
- I do not receive honoraria for speaking for commercial entities
- I am a *volunteer/unpaid* Hotline Consultant for the Malignant Hyperthermia Association of the United States
- I am the President-Elect of the Pennsylvania Society of Anesthesiologists and Liaison from the ASA to the ADA, AAOMS, ADSA

3 **AUDIENCE RESPONSE QUESTION TO START THE DAY**

- AAOMS should have instituted capnography as a standard of care years ago (Show of hands)
- Yes
- No

4 **BUT I HAVE PULSE OXIMETRY**

- Do I really need capnography?
- The OAE used to recommend observation, pre-tracheal auscultation, and OPTIONAL capnography for non-intubated patients
- I have never had a problem
- It costs too much

5 **WHY IS CAPNOGRAPHY IMPORTANT?**

- Bailey PL, Pace NL, Ashburn MA, et al. *Frequent hypoxemia and apnea after sedation with Midazolam and Fentanyl*. Anesthesiology 1990; 73: 826-830.
- 80 patients in database DIED
- Replicate data using healthy human volunteers.
- Fentanyl alone depressed the ventilatory response to carbon dioxide

6 **TAKE HOME MESSAGE**

- "Our results demonstrate that midazolam, when combined with an opioid, is likely to place patients at high risk for hypoxemia and apnea."
- "...the availability of persons skilled in airway management are recommended when these or similar type drugs are combined for patient sedation in any clinical setting."
- Capnography "catches" the problem before pulse oximetry does!
-

7 **WHAT IS THE EFFECT OF FENTANYL ON THE PHARMOKINETICS OF MIDAZOLAM?**

- Hase I, Oda Y, Tanaka K et al. I.V. Fentanyl Decrease the Clearance of Midazolam. Br J Anaesth 1997; 79: 740-743.
- Both fentanyl and midazolam are metabolized by the liver enzyme CYP3A in the cytochrome P450 isozymes

- Study using normal, healthy volunteers

8 **STANDARD ASSUMPTIONS USING PULSE OXIMETRY?**

- All hemoglobin: oxygenated or reduced
- No other absorbers between emitter and detector
- All blood that "pulsates" is arterial blood
-
-
- Petterson, Begnoche, Graybeal: The effect of motion on pulse oximetry and its clinical significance. *Anesth Analg* 2007; 105: S78-S84.

9 **HOW DOES IT WORK?**

- It is a light tissue interaction
- Obeys Lambert-Beers Law
- "...light decays as it passes through a nonscattering, light-absorbing substance comprised of one or more components."
- The problem: Heterogeneous tissues
-
- Mannheimer: The Light-Tissue Interaction of Pulse Oximetry. *Anesth Analg* 2007; 105: S10-S17.

10 **LIMITATIONS OF PULSE OXIMETRY**

- Abnormal hemoglobins may not be accurately detected by the usual technology
- Newer technology- may measure 12 light wavelengths
- Methemoglobin, Carboxyhemoglobin, Total hemoglobin
-
-
-
- Barker, Badal: The measurement of dyshemoglobins and total hemoglobin by pulse oximetry. *Curr Opin Anaesth* 2008; 21: 805-810.

11 **IMPORTANT LIMITATIONS OF PULSE OXIMETRY: SAFE LIMITATIONS**

- Motion
- Poor perfusion
- Skin pigmentation
- Nail polish and artificial nails
- Irregular rhythms
- Unusual electromagnetic interference
-
- Fouzas, Priftis, Anthracopoulos: *Pediatrics* 2011; 128: 740-752

12 **PULSE OXIMETRY: POTENTIALLY UNSAFE LIMITATIONS**

¹ PROBLEM

- ² • Calibration

-
- Time lag
-
- Probe positioning

-
- Ambient light interference
-
- Intravenous dyes

3 POSSIBLE SOLUTION

- 4 • Use newest generation device
- Use newest generation device
- Assure sensor and emitter are exactly opposite and age appropriate size
- Cover probe with metallic foil
- Be prepared for lower SpO2 (transiently)

13 BASIS OF NEXT SLIDE

- Benumof et al: Critical hemoglobin desaturation will occur before return to an unparalyzed state following 1mg/kg intravenous succinylcholine. Anesthesiology 1997; 87: 979-982.
- VERY IMPORTANT CONCEPTS

14 WHAT DOES THIS MEAN TO YOU AND YOUR PATIENT?

- The patient is 100% saturated
- They are safe
- However, is everything ok?
- It depends upon where the patient "resides" on the oxygen-hemoglobin desaturation curve

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16 THE REAL OXYGEN-HEMOGLOBIN DESATURATION CURVE

17 REMEMBER THE BASIC SCIENCES?

- Alveolar-Air Equation
-
- $PaO_2 = FiO_2(P_b - P_bH_2O) - PaCO_2/RQ$ (0.8)
-
- At sea level= Room Air or 21%
– 0.21(760-47) → 149-40/0.8 → 149-50 → → → 99
-
- At sea level= 100% oxygen
– 1(760-47) → 1(713)-40/0.8 → 713-50 → → → 663

18 PAO2 OXYGEN SATURATION RELATIONSHIPS

- 1 PaO2
- 2 • 40
- 50
- 60
- 97
-
- 26-28

3 SP02

- 4 • 70
• 80
• 90
• 97
•
• 50

19 **REALITY CHECK**

- At what point of oxygen saturation can the average human eye detect a color change?
- 95%
- 92%
- 87%
- 77%

20 **REALITY CHECK II**

- What is the PaO₂ of the O₂ saturation at which you can detect hypoxemia?
- 92
- 87
- 77
- 59

21 **THE MORE IMPORTANT ANESTHESIOLOGY MONITOR (AT LEAST FOR THIS DISCUSSION)**

BACK TO CAPNOGRAPHY

22 **OBSERVATION OF RESPIRATION**

- Can the chest wall/abdomen move without gas exchange?
- Sure it can...

23 **PRETRACHEAL AUSCULTATION**

- Can auscultation be muffled?
- What happens with ambient noise?
 - Music
 - Pulse oximetry tone
 - Conversation
 - Poorly adherent to skin
 - You have a Bluetooth device? (\$500)
- Have one PLUS capnography not instead

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27 **CAN YOUR ASSISTANT HEAR WHAT YOUR ARE HEARING AND HELP IF THERE IS A PROBLEM?**

28 **HOWEVER....**29 **WHY CAPNOGRAPHY**

- The basics
- Mainstream vs. Sidestream
- What works in the office

30 **EXCELLENT COMPREHENSIVE REFERENCE**

- *CAPNOGRAPHY 2ND EDITION*. EDS. JS GRAVENSTEIN, MICHAEL B. JAFFE, NIKOLAUS GRAVENSTEIN, DAVID A. PAULUS, CAMBRIDGE UNIVERSITY PRESS, 2011

31 **SIDE STREAM CAPNOGRAPHY**32 **SIDESTREAM CAPNOGRAPHY**

- Utilizes gas sampling line
- Connect at elbow or straight connector
- Continuously aspirated at rate of 50-250 ml per minute
-

33 **ADVANTAGES OF SIDESTREAM**

- Airway connection is light
- Widely available for CO₂, O₂, N₂O
- Airway connectors replacements "cheap"
- Easily used on non-intubated patients with sample dilution likely
- Connection by tube not cable

34 **DISADVANTAGES OF SIDESTREAM**

- Multiple components required: airway adapter, sample tube, filters/water trap, water-permeable tubing in certain environments
- Sample to waveform time- < 3 seconds
- Waveform variable depending upon sample rate, mixing, sample cell design, accessories such as airway adapter vs nasal cannula
-

35 **MORE DISADVANTAGES OF SIDESTREAM**

- Water vapor pressure affected due to condensation and drying of sample
- Water traps occasionally clog
- Gas scavenging required
- Pressure fluctuations due to sample rate but compensated with measurement of pressure

36 **CAPNOGRAPHY WAVEFORM**37 38 39

- 40 **EXCELLENT CAPNOGRAPHY REVIEW**
- Kodali BS: Capnography outside the Operating Rooms. Anesthesiology 2013; 118: 1-10
 - Addresses similar concerns for the OMFS
 - GI suite
 - Emergency Room
- 41 **FROM KODALI/ANESTHESIOLOGY 2013**
- 42 **THE NEXT SET OF SLIDES WILL DEMONSTRATE...**
- Capnographic displays in differing clinical situations
 - All from the Kodali article
- 43 **SPONTANEOUS BREATHING
(SIMILAR TO OPEN AIRWAY)**
- 44 **VARYING LEVELS OF SEDATION WITH ROOM AIR OR OXYGEN**
- 45 **NEXT SEVERAL SLIDES**
- Demonstrate problems with intubated or closed airway situations
- 46 **ASTHMA/COPD**
- 47 **PROBABLE CUFF LEAK WITH CARDIAC OSCILLATIONS**
- 48 **MECHANICAL VENTILATION WITH INTERMITTENT SPONTANEOUS BREATHS**
- 49 **MECHANICAL VENTILATION WITH INTERMITTENT SPONTANEOUS BREATHS**
- 50 **EARLY ATTEMPTS AT SPONTANEOUS RESPIRATION AFTER
NEUROMUSCULAR BLOCKADE**
- 51 **THE NEXT SEVERAL SLIDES ARE CRISIS ISSUES**
- It is worthwhile discussing these in depth!
- 52 **ESOPHAGEAL INTUBATION**
- 53 **CARDIOPULMONARY RESUSCITATION**
- 54 **MALIGNANT HYPERTHERMIA**
- 55 **CAPNOGRAPHY WITH EQUIPMENT MALFUNCTION**
- These are not every day occurrences but are noteworthy
- 56 **SUDDEN INCREASE IN BASELINE DUE TO MOISTURE IN/NEAR SENSOR**
- 57 **INSPIRATORY VALVE MALFUNCTION**
- 58 **DOES IT REALLY DECREASE HYPOXIC EVENTS?**
- Deitch et al: Does end tidal CO2 monitoring during emergency department procedural sedation and analgesia with propofol decrease the incidence of hypoxic events: a randomized, controlled trial.
 - Annals of Emergency Medicine 2010; 55: 258-264.
- 59 **THEIR CONCLUSIONS**

- "In adults receiving ED propofol sedation, the addition of capnography to standard monitoring reduced hypoxia and provided advance warning for all hypoxic events"

60 **CAPNOGRAPHY FOR NASAL HOOD**

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67 **CAPNOGRAPHY ADAPTOR FOR NASAL CANNULA**

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69 **PATHOPHYSIOLOGICAL ALTERATIONS**

- Asthma/COPD- upslope to phase III
- No ETCO₂
 - Pulmonary embolism
 - Ineffective CPR
- Small curves=small tidal volumes
- "Camel Hump"=unequal emptying of each lung
- "Hiccup" cleft= singultus or attempted spontaneous diaphragmatic activity

70 **ADVANTAGES OF CAPNOGRAPHY: AIRWAY**

- Confirms intubation
- Obstruction of ETT
- Fiberoptic/blind intubation assistance
- MONITORING DURING SEDATION AND ANALGESIA

71 **ADVANTAGES OF CAPNOGRAPHY: RESPIRATION**

- Detects spontaneous respiration
- Detects existence of neuromuscular block
- Single-lung ventilation
- Distal obstruction/bronchospasm
- Atelectasis

72 **ADVANTAGES OF CAPNOGRAPHY: CIRCULATION**

- Implication of cardiac function
- Cyanotic heart disease/non-peripheral shunting
- PE
- Acid-base changes
- Effectiveness of CPR
- Unconventional forms of ventilation

- 73 **ADVANTAGES OF CAPNOGRAPHY: ANESTHESIA DELIVERY DEVICES**
- Adequacy of fresh gas flow during spontaneous ventilation
 - Circuit leaks/disconnects
 - Soda lime exhaustion
 - Anesthesia machine inspiratory/expiratory valve malfunction
 -
- 74 **ADVANTAGES OF CAPNOGRAPHY: PATIENT PHYSIOLOGY/WELL-BEING**
- Venous thromboembolism
 - Malignant hyperthermia
 - Seizures
 - CO2 retention
- 75 **ADVANTAGES OF CAPNOGRAPHY: NON-OR USES**
- Confirm endotracheal intubation
 - Respiratory failure
 - Apnea or respiratory monitoring
 - Misplacement of NG tube
- 76 **NOT CONVINCED YET?**
- I believe it is a ploy/conspiracy by the ASA, AAOMS, and capnography manufacturers. Show of hands
 - Yes
 -
 - No
- 77 **OPEN AIRWAY EQUIVALENT TO OMFS**
- Procedural sedation in the Emergency Room
 - 9 studies reviewed
 - ALL affirmed that capnography signaled danger prior to hypoxia (pulse oximetry)
 -
 - Burton F: Should capnography be routinely used during procedural sedation in the emergency department? Emerg Med J 2012; 29: 164-166.
 -
 -
- 78 **ANOTHER OPEN AIRWAY EQUIVALENT TO OMFS**
- Friedrich-Rust M, Welte M, Welte C, et al. Capnographic monitoring of propofol-based sedation during colonoscopy. Endoscopy 2014; 46: 236-244.
 - Study: All patients had either colonoscopy or colonoscopy with EGD (Esophagogastroduodenoscopy), all receive 2L O2, all nasal cannula with an oral sampling port
- 79 **OUTCOME MEASURES-DEFINED AS SpO2 DROP OF <90% FOR GREATER THAN 15 SECONDS OR MORE**
- Secondary measures
 - Incidence of severe hypoxia <85%
 - Increase of O2 supplementation

- Episodes of apnea (EtCO₂ at 0 for > 10 sec)
- Time difference between apnea and hypoxemia
- Assisted ventilation
- Incidence of hypotension (sys BP <100) or bradycardia (HR < 50)

80 **EVENTS WITH P VALUE <0.05**

- Hypoxemia for greater than 15 seconds
 - P value 0.00091
- Number of hypoxemic events
 - P value 0.000066
 -

81 **INDEPENDENT RISK FACTORS FOR HYPOXEMIA**

- Age (P 0.00015)
- BMI (P 0.0044)
- History of OSA (P 0.025)
- Total dose of Propofol (P. 0.031)
- Dose of ketamine (when indicated) (P 0.000001)

82 **A REDUCTION OF HYPOXEMIA USING CAPNOGRAPHY VS WITHOUT CAPNOGRAPHY**

- 14%

83 **RISKS OF ANESTHESIA OR SEDATION OUTSIDE THE OPERATING ROOM: THE ROLE OF THE ANESTHESIA CARE PROVIDER:**

- Metzner and Domino: Current Opinion in Anesthesiology 2010: 23: 523-531.
- Conclusions: "...monitoring for respiratory depression is essential. "...pulse oximetry is far from ideal in detecting ventilatory compromise (e.g. hypoventilation, airway obstruction or apnea).

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ANOTHER QUOTE FROM THE SAME ARTICLE...

- "Use of capnography for monitoring the adequacy of ventilation, anesthesia specialists in higher risk patients, and adequate training for non-anesthesia providers can enhance safety of sedation/anesthesia in out-of-operating room settings."

85 **2015 ARTICLE**

- Green SM, Andolfatto G. Managing propofol-induced hypoventilation. Annals of Emergency Medicine 2015; 65: 57-60.
- Patient selection...(where is the surprise here?)
- Avoid opioid co-administration (where is the surprise here?)
- Preoxygenation (no surprise again)
- Titration of medication
- CAPNOGRAPHY!!!!!!!!!!!!!! Capnography detects hypoventilation first (breath/breath quality)
-

86 **IN A RECENT PUBLICATION BY RICH ROBERT....**

- He champions the use of both capnography and Blue Tooth pretracheal or precordial stethoscope
- The use of one does not supplant the need for the other
- They are complimentary and should be used together.
- An example he cites is as follows: "...a faint gurgling sound often heralds the buildup of secretions that may precipitate a laryngospasm, and mild wheezing and other adventitial breath sounds..."

87 **WE SHOULD HAVE BOTH**

- Power failures occur- your stethoscope doesn't unless you fail to use it.
- Mother boards of monitors fail- your stethoscope doesn't unless you fail to use it.

88 **THE NEXT FEW SLIDES...**

- Results of data recently available from dental program directors concerning capnography!

89 **SOME RESPONSES BY POLLS**

- 54% agree or strongly agree with the need for capnography during moderate sedation/open airway
- Only 1/2 of polled pedodontists agree/strongly agree with its need

90 **NEGATIVE COMMENTS**

- "Capnography is expensive, there is a learning curve, and unless the patient is intubated, there can be an error in gas sampling."
- "Safe moderate sedation practice rests on the practitioner and not on capnography monitoring mandate."
- Evidence of the need for capnography is lacking. In moderate sedation used in this group, 3 lead ECG and pre-cordial stethoscope is sufficient
- Not aware of what capnography is but will Google it!

91 **FRIGHTENING COMMENTS**

- Though it is policy, it isn't followed because most anesthesiologists disagree with the policy due to the added cost per case (\$13)
- Where is the evidence in a dental setting
- Belief that capnography during moderate sedation is virtually a worthless tool and adds unnecessary expense to the procedure!

92 **POSITIVE COMMENTS**

- It should be considered standard of care once moderate sedation is initiated
- Initially felt it was going to add complication to care, now it is mandatory for patient safety.
- It should be instituted and mandated for all teaching programs
- This is the most reliable way of sensing whether or not the patient is breathing
- All dental specialties and general practice should use it if ASA, AAOMS, AANA mandate its use.

93 **AFTER THIS DISCUSSION, I...**

- Still think that capnography is overly hyped!
- ...should have started using it long ago!
- Think that observation of the patient, chest wall excursions, pretracheal/precordial

stethoscope alone are as accurate as capnography!

- Will never use capnography...I am the old guy in the practice and too close to retirement!
- Let the new kid in the practice buy it! I am still not convinced!

94  **BIBLIOGRAPHY FOR THE TOPIC**

- Ortega F, Connor C, Kim S, et al. Monitoring ventilation with capnography. *N Engl J Med* 2012; 367: 19: e27 1-5.
- Kodali, BS. Capnography Outside the Operating Rooms. *Anesthesiology* 2013; 118: 192-201.
- Laviv A, Seldin EB, Dodson TB. A simple modification to the nasal hood to facilitate capnographic measurements: a technical note. *J Oral Maxillofacial Surg.* 2013; 71: 854-855.
- Robert RC, Liu S, Patel C, Gonzalez ML. Advancements in office-based anesthesia in oral and maxillofacial surgery. *Atlas Oral Maxillofacial Surg Clin North Am* 2013; 21: 139-165.

95  **MORE ARTICLES**

- Sheahan CG, Mathews DM. Monitoring and delivery of sedation. *Brit J Anaesth* 2014; 113: ii37-ii47
- Waugh et al. Capnography enhances surveillance of respiratory events during procedural sedation: a meta-analysis. *J Clin Anesth* 2011; 23: 189-196
- Manifold CA et al. Capnography for the nonintubated patient in the emergency setting. *J Emerg Med* 2013; 45: 626-632
- Cook TC, Behringer EC, Bengner J. Airway management outside the operating room: hazardous and incompletely studied. *Curr Opin Anesthesiol* 2012; 25: 461-469

96  **THANK YOU**