Advances in Ventilation Monitoring and Airway Management Options in the GI Suite

Sekar S Bhavani MD

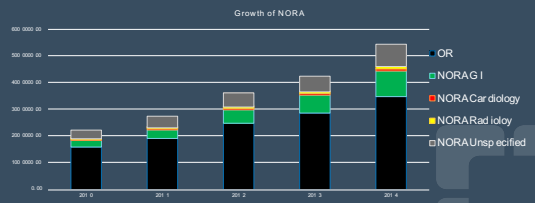
Disclosures

- No conflict on interest

Objectives

- Identify common perioperative risks in the GI suite.
- Consider the options for monitoring
- Consider options for delivering anesthesia
- Identify the need for securing the airway
- Formulate an anesthetic plan based on risk assessment

NORA



Data From: Alexander Nagrebetsky, et al: Growth of Nonoperating Room Anesthesia Care in the United States: A Contemporary Trends Analysis - Anesth Analg 2017;124:1261–7

Reasons for Increased Use

- Increase efficiency
- Shift from diagnostic to therapeutic
- Advanced age
  - Comorbidities – "Too sick for OR"
  - Stop gap measure
- Advances in surgical techniques
- Patient satisfaction
- Economics

Original contribution

A medicolegal analysis of malpractice claims involving anesthesiologists in the gastrointestinal endoscopy suite (2007–2016)

Alexander B. Stone, MD[a], Ethan Y. Brovman, MD[a], Penny Greenberg, RN, MS[b], Richard D. Urman, MD, MBA[a,*]

[a] Brigham and Women's Hospital, Boston, MA, United States
[b] CRICO Strategies, Boston, MA, United States

- CBS database (30% of all cases filed in the US)
- January 1, 2007 and December 31, 2016
- Endoscopy cases where anesthesiology was named the primary responsible service.
- Severity was decided using the National Association of Insurance Commissioners (NAIC) severity score.

Journal of Clinical Anesthesia 48 (2018) 15–20

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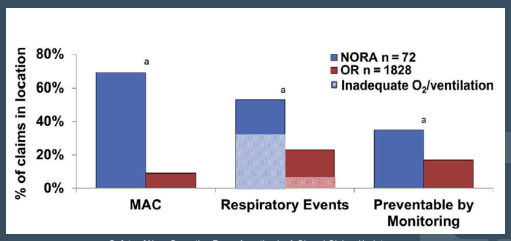
- 2891 closed claims in which anesthesiology was the primary responsible service.
- 58 claims (2.0%) involving anesthesia providers in the gastrointestinal endoscopy suite.

Journal of Clinical Anesthesia 48 (2018) 15–20

Characteristics of malpractice claims in NORA locations compared with OR.



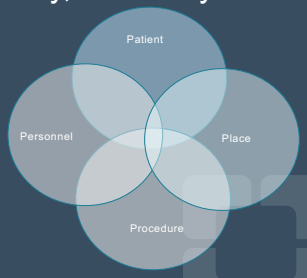
Safety of Non–Operating Room Anesthesia. A Closed Claims Update
Anesthesiology Clin 35 (2017) 569–581

Factors Identified As Leading to Malpractice Payouts

- Technical Skill and clinical judgement
  - Inability to recognize and react to the evolving situation
  - Failure to maintain adequate ventilation and oxygenation
  - Failure to resuscitate
- Oversedation
- Communication
- Documentation

How to Ensure Quality, Efficiency and Safety?

- Right patient
- Right procedure
- Right provider
- Right infrastructure
- Right anesthetic plan
- Right disposition



Modified from: The four Ps: place, procedure, personnel, and patient. Anesthesiology Clin 32 (2014) xvii–xxi

Monitoring

STANDARDS FOR BASIC ANESTHETIC MONITORING

Committee of Origin: Standards and Practice Parameters

(Approved by the ASA House of Delegates on October 21, 1986, last amended on October 20, 2010, and last affirmed on October 28, 2015)

- Apply to all GA, regional and MAC.
  - Qualified anesthesia personnel shall be present in the room throughout the conduct of all general anesthetics, regional anesthetics and monitored anesthesia care.
  - During all anesthetics, the patient's oxygenation, ventilation, circulation and temperature shall be continually evaluated.
- Continual monitoring for the presence of expired carbon dioxide shall be performed unless invalidated by the nature of the patient, procedure or equipment.

Practice Guidelines for Moderate Procedural Sedation and Analgesia 2018

*A Report by the American Society of Anesthesiologists Task Force on Moderate Procedural Sedation and Analgesia, the American Association of Oral and Maxillofacial Surgeons, American College of Radiology, American Dental Association, American Society of Dentist Anesthesiologists, and Society of Interventional Radiology**

- Replace the "Practice Guidelines for Sedation and Analgesia by Non-Anesthesiologists" -2002
- Specifically addresses moderate sedation.
- "Continual monitoring of ventilatory function with capnography to supplement standard monitoring by observation and pulse oximetry."

Anesthesiology, 2018; 128:3 437-479

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Cleveland Clinic

SaO_2 as a Surrogate to Monitor Ventilation

- Decreases in oxygenation are typically not time sensitive measures
  - Existing reserves of lung oxygen
  - Due to the Apneic oxygenation from O_2 supplementation.
- ETCO2 that occurs during apnea, averaging 3–5 mm Hg per min, and the subsequent untoward effects of hypercarbia on sedation and blood pressure.

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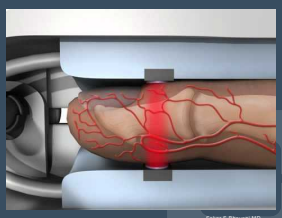
Photoplethysmography

- Was described in 1937 to measure blood volume changes
- Cardiovascular, respiratory, and neural fluctuations in are of different frequencies and can all be characterized according to their sinusoidal components.



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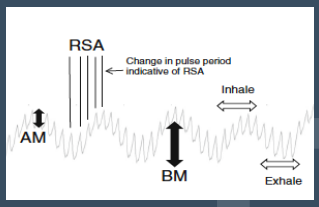
Three Modulations

- Baseline Modulation : Venous Return
- Amplitude modulation : Changes in intrathoracic pressure
- Respiratory Sinus Arrhythmia:

  ? Autonomic system activity. Affected by age, disease states and physical fitness.



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Photoplethysmography

THE PERIPHERAL PULSE WAVE: INFORMATION OVERLOOKED

Willie Bosseau Murray, MB, ChB, MD, FRCA, and Patrick Anthony Foster, MB, ChB, FFARCSI, FRCA

Journal of Clinical Monitoring
12: 365-377. 1996

SPECIAL ARTICLE

Universal Access to Essential Vital Signs Monitoring

J. Mark Ansermino, MBBCh, FRCPC

SPECIAL ARTICLE

Respiration Signals from Photoplethysmography

Lena M. Nilsson, MD, PhD

Respiration Signals from Photo plethysmography Lena M. Nilsson, Anesth Analg 2013;117:859–65

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Cleveland Clinic

Respiration Signals from Photoplethysmography

- Can be used for continuous monitoring
- Error of 8%
- Autonomic nerve activity can interfere with signal activity
- Sensitivity is 75%, Specificity 85%
- Very good at predicting fluid responsiveness in mechanically ventilated patients.

Anesth Analg 2013;117:859–65)

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Photoplethysmography respiratory rate monitoring in patients receiving procedural sedation and analgesia for upper gastrointestinal endoscopy

Hugo R. W. Touw[1] · Milou H. Verheul[1] · Pieter R. Tuinman[2] · Jeroen Smit[1] · Deirdre Thine[1] · Patrick Schober[1] · Christa Boer[1]

- In 81 % of all apnea events, photo plethysmography registered an RRp < 4 brpm.
- A low level of agreement between capnography and the plethysmography respiratory rate during procedural sedation for UGI endoscopy.
- Respiratory rate derived from both the capnogram and photoplethysmogram showed a limited ability to provide warning signs for a hypoxemic event during the sedation procedure.

J Clin Monit Comput (2017) 31:747–754

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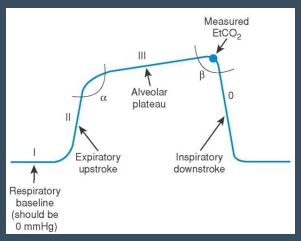
Capnography



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$EtCO_2$ Monitoring in Non-Intubated Patients

- Capnography with an endotracheal tube in place is a reliable method to non-invasively reflect arterial PaCO2.
- Rising ETCO2 indicates hypoventilation and hypoxia is a relatively late finding, especially in a patient receiving supplemental oxygen.

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Limitations of $EtCO_2$ Monitoring in Non-Intubated Patients

- $EtCO_2$ in spontaneously breathing patients can be inaccurate in certain settings during procedural sedation
  - Poor sampling / contamination / Blockage of catheter
  - Changes in respiratory patterns
  - Oxygen supplementation
  - Mouth breathing
- $EtCO_2$ cannot identify and categorize
  - Ventilation/perfusion mismatch
  - Partial airway obstruction
  - Metabolic derangement.

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What can we measure?

- Changes in the photo plethysmograph
- A change in the composition of gas in the airway
- Sounds generated from turbulent flow
- A change in thoracic volume
- A change in arterial carbon dioxide tension

Recent advances in respiratory monitory in nonoperating room anesthesia. Jeff Mandel
Current Opinion in Anaesthesiology. 31(4):448–452, AUG 2018

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Surrogates for Monitoring Ventilation

- Rate Monitors
  - Photo plethysmography
  - Change in composition - Temperature (Dymedix) , Humidity (respiR8™), CO_2 ($eTCO_2$).
  - Sound generated from turbulent flow - (Masimo RRa)
- Volume Monitors
  - A change in thoracic volume (Exspiron)
  - Time to depth sensors
- Systemic Effects
  - $TcCO_2$ monitoring (SenTec).

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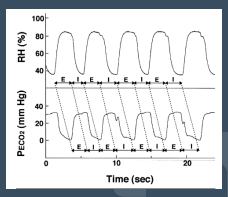
Rapid Response Hygrometer

- Detects the cyclical changes in the relative humidity that occurs with spontaneous respiration using a rapid response hygrometer.
- The sensor is positioned in front of the nose.
- During expiration, the relative humidity rapidly increases to 80%, plateaus and and then falls to 40% on inspiration (ambient)



An Apnea monitor using a rapid response hygrometer.
Tsuneo Tatara et al . Journal of Clinical Monitoring 13: 5-9 1997.

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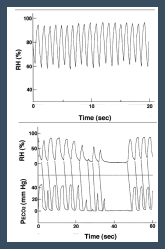
Rapid Response Hygrometer -3



- Respiratory rate can be obtained.
- Early detection of apnea

Limitations:

- Humidity of inspired gas will affect the magnitude of signal.
- Displacement of sensor

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Humidity Sensor

Feasibility of breath monitoring in patients undergoing elective colonoscopy under propofol sedation: A single-center pilot study

Gurpreet W Anand, Ludwig T Heuss

- 76 patients
- Elective Diagnostic Colonoscopy
- Compared with pulse oximetry alone, this new monitoring device detected more respiratory events and may provide earlier warning of impending respiratory abnormalities.

Humidity sensor is marketed in the European Union – the RespiR8 (Anaxsys Technology Ltd., Woking, UK)

World J Gastrointest Endosc 2014 March 16; 6(3): 82-87

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The use of combined thermal/pressure polyvinylidene fluoride film airflow sensor in polysomnography

Meir Kryger · Todd Eiken · Li Qin

From the Sleep Lab

- Simultaneous monitoring of two physical variables: air temperature and air pressure.
- A relatively new combined thermal/pressure sensor using polyvinylidene fluoride (PVDF) film has been developed which has a faster response time than traditional thermal devices and a comparable response time to pressure based airflow devices.
- Respiratory effort belt sensors over the chest and abdomen.

The use of combined thermal/pressure polyvinylidene fluoride film airflow sensor in polysomnography
Meir Kryger & Todd Eiken & Li Qin.. Sleep Breath (2013) 17:1267–1273

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The use of combined thermal/pressure polyvinylidene fluoride film airflow sensor in polysomnography

Meir Kryger · Todd Eiken · Li Qin

- The thermal sensor remains the recommended sensor to detect apneas.
- The nasal pressure remains the recommended sensor to detect hypopneas.
- The combined sensor were equivalent to those obtained by the separate sensors.

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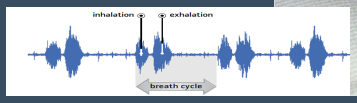
Airway Flow

- The rainbow acoustic monitor (RAM; Masimo Corporation, Irvine, CA) is a technology that continuously monitors RR through the detection of an acoustic signal from airflow



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J Clin Monit Comput (2014) 28:561–566
DOI 10.1007/s10877-014-9556-8

ORIGINAL RESEARCH

Detection of respiratory compromise by acoustic monitoring, capnography, and brain function monitoring during monitored anesthesia care

Pedro P. Tanaka · Maria Tanaka · David R. Drover

- A prospective, single-center study of patients ASA I to III, 18 years of age or older.
- A total of 137,199 paired ETCO2 and RRa respiration rate values were collected.

They concluded

- Acoustic monitoring provided the highest probability of detecting respiratory pause and the lowest probability of missing a respiratory pause
- When compared with clinical observation or capnography, acoustic monitoring of respiration rate may provide the best single method for monitoring ventilation during procedures requiring sedation.

Using the Entropy of Tracheal Sounds to Detect Apnea during Sedation in Healthy Nonobese Volunteers

Lu Yu, M.S.,* Chien-Kun Ting, M.D., Ph.D.,† Bryce E. Hill, Ph.D.,‡ Joseph A. Orr, I
Lara M. Brewer, Ph.D.,|| Ken B. Johnson, M.D.,§ Talmage D. Egan, M.D.,#
Dwayne R. Westenskow, Ph.D.#

- Tracheal sounds originate from the vibrations of the tracheal wall and surrounding soft tissues caused by gas pressure fluctuations in the trachea.
- The signals from a microphone or a piezo-electric film transducer placed over the trachea have been processed
- Sensitivity of 95% and Specificity of 92%

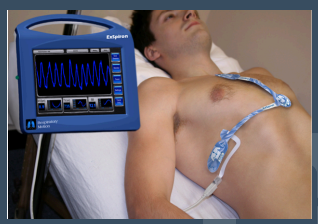
Anesthesiology 2013; 118:1341-9

Entropy of Tracheal Sounds

- Entropy of the tracheal sounds
  - Safe
  - Reliable
  - Easy to accomplish
  - Less apneic events likely to be missed.
- Limitation-
  - Ambient noise
  - ? Ability to detect obstruction

Plethysmography / Impedance

- Impedance-based ventilation monitoring provided a rapid and reliable assessment of decreased ventilation from sedation.



Respiratory Volume Monitoring to Assess the Effect of Airway Maneuvers on Ventilation during Upper Endoscopy
Katherine Holley1,et al Open Journal of Anesthesiology, 2014, 4, 281-290

Plethysmography / Impedance

- The RVM uses a small amount of electrical current across several vectors through the lung.
- The conductivity difference between air and tissue is exploited to calculate the amount of air moving in and out of the lung in real time.
- Displays breath-by-breath waveform as well as 30-second averages for MV, TV, and RR.

A Comparison of Measurements of Change in Respiratory Status in Spontaneously Breathing Volunteers by the ExSpiron Noninvasive Respiratory Volume Monitor Versus the Capnostream Capnometer George W. Williams, II, MD et al Anesth Analg 2017;124:120–6.

Plethysmography / Impedance

- RVM might be helpful in deciding the type of intervention required.

Airway	MV	Respiratory Effort	Intervention
Total Obstruction	0	Present	chin lift or jaw thrust
Total Obstruction	0	Absent	Rescue breathing

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A Comparison of Measurements of Change in Respiratory Status in Spontaneously Breathing Volunteers by the ExSpiron Noninvasive Respiratory Volume Monitor Versus the Capnostream Capnometer

George W. Williams, II, MD,* Christy A. George, MD,* Brian C. Harvey, PhD,† and Jenny E. Freeman, MD†

- Forty-eight healthy volunteer subjects
- RVM measurements (MV and RR) were collected simultaneously with capnography
- RVM measurements of MV change more rapidly and by a greater degree than capnography in response to respiratory changes in nonintubated patients.
- 90% accuracy for MV and TV, and 98% for RR

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Limitations

- Conducted in healthy volunteers.
- Need for calibration – May add delay to flow.
  - Each subject breathed normally for 2.5 minutes through a heated pneumotachometer. The MV measured by is then entered into the RVM to calibrate the MV estimated by the RVM.
- Not been validate in a nonventilated prone patients.

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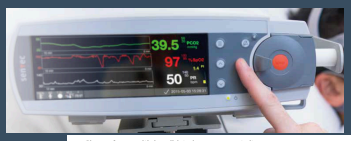
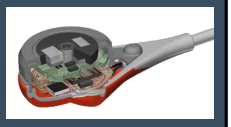
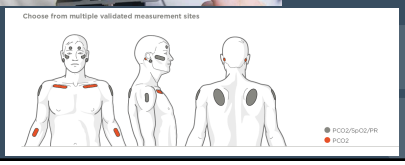
Transcutaneous CO_2 ($tcPCO_2$)







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Transcutaneous CO_2 ($tcPCO_2$)

- First described by Severinghaus et al. in the 1960s.
- Warm sensor placed on the surface of the skin (37-44*C)
- The elevated temperature causes local hyperemia.
- Alters the solubility of CO2 in the blood
- Increases the metabolic rate of the skin by approximately 4–5% for every * Increase

Physiol. Meas. 38 (2017) R204–R252

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Transcutaneous CO_2 ($tcPCO_2$)

- A highly permeable membrane separates the electrochemical cell from the skin, and an Ag/AgCl reference electrode is used to measure the pH.
- Electrochemical cell determines the pH change due to CO_2 concentration.
- Correction factor is often incorporated to determine the arterial PCO_2 from the $tcPCO_2$.
- A good correlation exists between $PaCO_2$ and $tcPCO_2$.

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Limitations

- Lag period for the sensor to stabilize.
- Thermal injury may occur at the sensor site
  - Avoid in patients with poor skin integrity and/or adhesive allergy
- Spurious results:
  - Improper electrode placement
  - Presence of hypervolemia (PaO_2 >100mmHg)
  - increased thickness or edema of the skin and/or subcutaneous tissue

Respir Care 2012; 57(11):1955–1962

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Time of Flight Sensors


Toward Respiratory Assessment Using Depth Measurements from a Time-of-Flight Sensor

- A Microsoft Kinect V2 time-of-flight depth sensor is used to reconstruct 3-dimensional models of the subject's thorax to estimate volume-time and flow-time curves following the introduction of a scaling factor to transform measurements to volume estimates.
- Uses Light Imaging, Detection, And Ranging (LIDAR) technology (works on the principle of radar, but uses light from a laser).

Toward Respiratory Assessment Using Depth Measurements from a Time-of-Flight Sensor.
Sharp C, et al (2017). Front. Physiol. 8:65

frontiers in Physiology

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Toward Respiratory Assessment Using Depth Measurements from a Time-of-Flight Sensor

- 100 Subjects were seated upright with their arms by their sides on a normal chair with no armrests, facing a Kinect v2 positioned 1.5m from the subject, at a height of 0.6 m.
- Patients were provided with figure-hugging t-shirts to improve accuracy of chest motion tracking
- Spirometry was performed using an unmodified spirometer.

Sharp C, Soleimani V, Hannuna S, Camplani M, Damen D, Viner J, Mirmehdi M and Dodd JW (2017) Toward Respiratory Assessment Using Depth Measurements from a Time-of-Flight Sensor. Front. Physiol. 8:65

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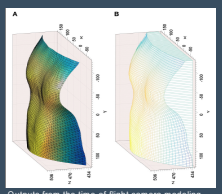
Toward Respiratory Assessment Using Depth Measurements from a Time-of-Flight Sensor



Outputs from the time-of-flight camera modeling—
(A) Reconstructed chest surface
(B) (B) Volume estimation from reference plane, including lateral chest wall.

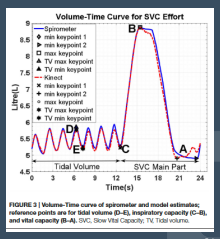


FIGURE 3 | Volume-Time curve of spirometer and model estimates; reference points are for tidal volume (D–E), inspiratory capacity (C–B), and vital capacity (B–A). SVC, Slow Vital Capacity; TV, Tidal volume.

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Toward Respiratory Assessment Using Depth Measurements from a Time-of-Flight Sensor

- Potential of 3D time-of-flight cameras to remotely monitor respiratory rate.
- Benefits include simplicity of set-up, no specialist training, and cost.
- Further algorithms are being developed to allow its independence from spirometry.

Sharp C, Soleimani V, Hannuna S, Camplani M, Damen D, Viner J, Mirmehdi M and Dodd JW (2017) Toward Respiratory Assessment Using Depth Measurements from a Time-of-Flight Sensor. Front. Physiol. 8:65

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Anesthetic Plan

Procedure Related
Complexity
Length
Sepsis
Bleeding
Need for irrigation

Patient Related
ASA PS, Age and Frailty
Obesity and OSA
Pregnancy Status
NPO and split prep
Comorbidities

Place and Personal

PO Issues
Pain
Nausea and Vomiting
Sepsis
Secondary bleeding
Aspiration

Identify Complications
Aspiration, Loss of airway
Hypercapnia
Perforation
Bleeding, Sepsis

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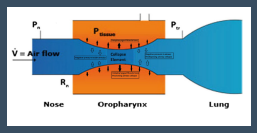
Mechanism of Airway Obstruction



Velopharyngeal mechanism-demonstrating how the negative pressure inside the airway during spontaneous breathing predisposed to airway collapse and the tone of pharyngeal muscles prevents the same.

- Consists of a muscular valve that extends from the posterior surface of the hard palate to the posterior pharyngeal wall and includes
  - soft palate
  - lateral pharyngeal walls
  - the posterior pharyngeal wall
- Obstruction of the oropharynx due to retrolingual collapse

Airway Management During Upper GI Endoscopic Procedures: State of the Art Review
Basavana Goudra, Preet Mohinder Singh. Dig Dis Sci (2017) 62:45–53

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Better Sampling

- Nasal cannulas
- Nasal trumpets
- Bite blocks with integrated sampling ports
- Masks and modifications that allow for better sampling and endoscopy ports.

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Prevention and Management of Hypoxia

- Increasing supplemental oxygen
- Airway Maneuvers - Chin lift , Jaw thrust, Mandibular advancement.
- Insertion of a nasal trumpets
- Positive pressure ventilation
- Laryngeal mask airway,
- Endotracheal intubation

Airway Management During Upper GI Endoscopic Procedures: State of the Art Review
Basavana Goudra, Preet Mohinder Singh. Dig Dis Sci (2017) 62:45–53

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High Flow Nasal Cannula

- Is a new generation of oxygen therapy.
- It provides constant high flow oxygen delivery with heated and humidified air.
- Its high velocity of airflow can create the effect of PEEP and consequently assist in ventilation and work of breathing

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Indications for Intubation

- Patient related
  - Emergency
  - Significant comorbidities
  - Sepsis
  - Obstruction (esophagus, stomach, duodenum or small intestines)
  - Anatomical problems
    - Complex anatomy
    - Short gut syndrome
    - Zenker's diverticulum
    - Short Roux-N-Y loop
    - Large hiatus hernia
  - Morbid obesity
- Procedure related
  - Long duration of procedure (usually > 60 minutes- arbitrary)
  - Complex procedure
  - Drainage of a pancreatic pseudo cyst
  - Use of large volume of fluid irrigant
  - Double balloon
  - Bleeding
- Anesthesia related
  - Known difficult intubation
  - Inadequate NPO status
  - Retained food
  - CO2 use

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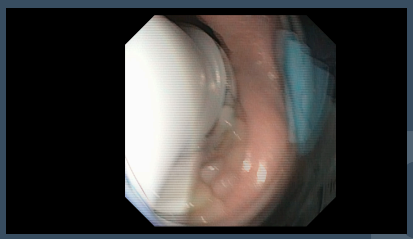
Prone Intubation



Sekar S Bhavani MD
Cleveland Clinic

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Every life deserves world class care.