Clinical Application of High-Flow Nasal Oxygen in the Peri-Anesthesia Environment

Douglas Massey II, DNP, CRNA

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FINANCIAL DISCLOSURES

Douglas Massey II, DNP, CRNA, has received compensation from Fisher & Paykel Healthcare for consulting services related to this presentation.

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OBJECTIVES

- Review the relevant anatomy and physiology of the pulmonary system
- Review the mechanism of action of High-Flow Nasal Oxygen (HFNO)
- Review the current state of literature regarding HFNO
- Discuss the clinical application of HFNO in select patient populations and procedural areas

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IMPLEMENTATION

- ENT (apneic oxygenation)
- ADC (MAC)
- ORs
- ASCs

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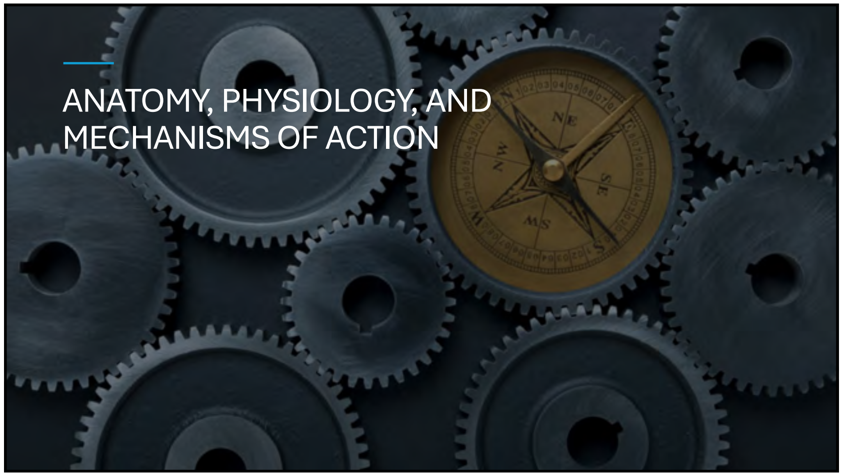
ANATOMY, PHYSIOLOGY, AND MECHANISMS OF ACTION



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H: Heated & Humidified - Provides heated and humidified gas

I: Inspiratory Demands - Can better meet elevated peak inspiratory flow demands

F: Functional Residual Capacity - Increases FRC likely via delivery of PEEP

L: Lighter - More easily tolerable than CPAP or BiPAP

O: Oxygen Dilution - Can minimize oxygen dilution by meeting flow demands

W: Washout of dead space - Provides high flow rates leading to wash out of pharyngeal dead space (CO2 removal)

https://rebelem.com/high-flow-nasal-cannula-hfnc-part-1-how-it-works/

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HUMIDIFICATION AND WARMING

- The nose has three jobs:
  - Filtration – hair, turbulent precipitation
  - Heating – to 37°C
  - Humidification – to nearly 100% relative humidity
- These functions are accomplished by extensive surface area
  - Nasal vestibules, nasal fossae, *nasal conchae*
- These functions are impaired during anesthesia
  - MAC – face masks deliver cold, dry gas
  - GA – bypasses nose; delivers cold, dry gas

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HEATING AND HUMIDIFICATION

- Decreased humidity
  - Airway inflammation
  - Increased airway resistance
  - Impaired mucociliary function
  - Impaired secretion clearance
- Normal humidity
  - Decreased airway inflammation
  - Maintained mucociliary function
  - Decreased energy expenditure

Image Source: Fisher & Paykel Healthcare.

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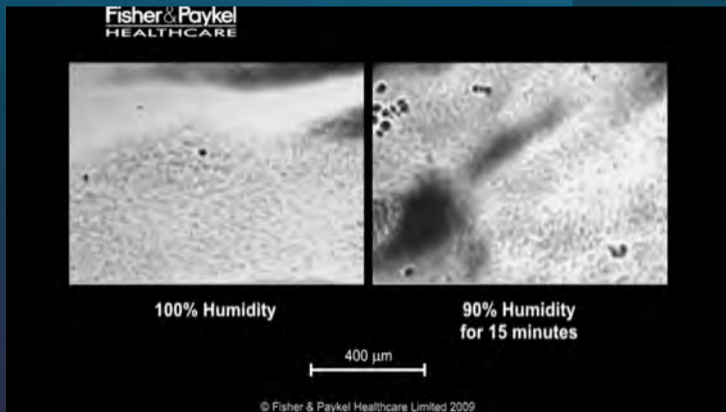

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INSPIRATORY DEMAND

Inspiratory flow rates

- Normal – 25-30 L/min
- Peak – 40-60 L/min

Oxygen flow rates

- Nasal cannula – 6 L/min
- NRB mask – 15 L/min
- HFNO – 70 L/min

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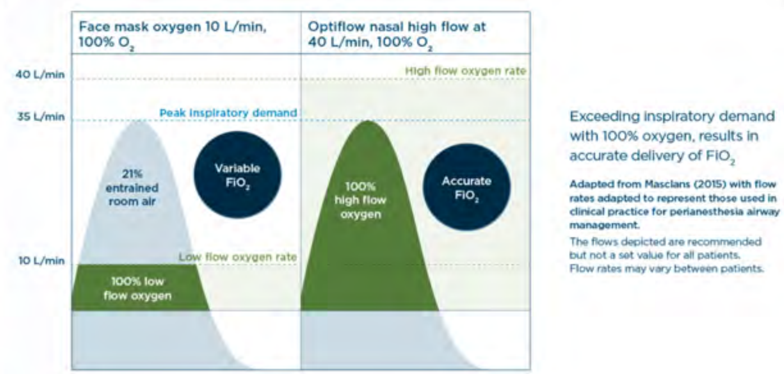
Exceeding peak inspiratory demand with Nasal High Flow…



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FUNCTIONAL RESIDUAL CAPACITY

- Functional Residual Capacity (FRC)
  - Volume of gas remaining in the lungs after normal quiet expiration
    - Represents gas remaining in the alveoli that may participate in gas exchange between breaths or during periods of apnea
- Anesthesia produces atelectasis and decreases FRC
- HFNO generates positive airway pressure (~1-6 cm H_2O) dependent on oxygen flow rate
  - Positive airway pressure prevents atelectasis
    - Prevention of atelectasis maintains or increases FRC
      - Increased FRC provides more gas to participate in gas exchange during periods of apnea

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*Source: Corley et al. BJA (2011) with Prof J Fraser (The Prince Charles Hospital, Brisbane Australia)

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Source: Prof. A. Patel, UCLH, London UK

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Image Source: Fisher & Paykel Healthcare.

LIGHTER

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VENTILATION

- Not all parts of the airway participate in gas exchange
  - Conducting Zone (i.e., anatomic dead space) – oxygenated blood provided by bronchial circulation
    - Larynx, bronchi, terminal bronchioles
  - Respiratory Zone – deoxygenated blood provided by pulmonary circulation
    - Respiratory bronchioles, alveolar ducts, alveoli

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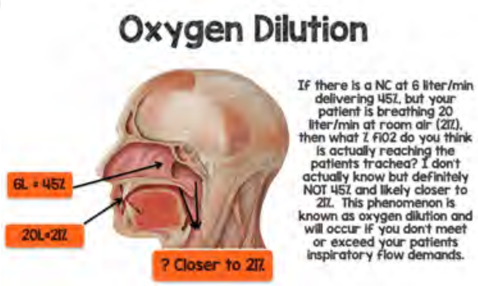
OXYGEN DILUTION

- Oxygen dilution is minimized by meeting peak inspiratory flow
  - HFNO can meet or exceed these needs
- HFNO delivers FiO_2 of 1.0 (100%)



https://rebelem.com/high-flow-nasal-cannula-hfnc-part-1-how-it-works/

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Dead Space

- Ventilated areas that do not receive adequate perfusion to participate in gas exchange
  - Anatomic – volume of conducting airways; approximately 2 mL/kg
  - Alveolar – alveoli that are well-ventilated but poorly perfused
  - Physiologic – sum of anatomic and alveolar dead space (i.e., approximates anatomic dead space under normal conditions)

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WASHOUT OF DEAD SPACE

Spontaneous breathing without HFNO

- Room air (FiO_2 0.21) is mixed with rebreathed air (FiO_2 ~0.15 with higher CO_2 content)
  - Reduces FiO_2 of gas participating in alveolar ventilation

Spontaneous breathing with HFNO

- O_2 is continuously administered at high FiO_2
  - Continuous supply of O_2 and removal of CO_2, even during apnea

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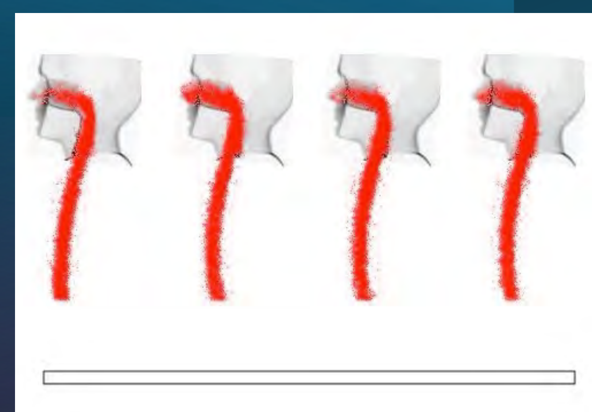

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CURRENT LITERATURE

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Original Article

Transnasal Humidified Rapid-Insufflation Ventilatory Exchange (THRIVE): a physiological method of increasing apnoea time in patients with difficult airways

Summary

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High-Flow Nasal Oxygen Improves Safe Apnea Time in Morbidly Obese Patients Undergoing General Anesthesia: A Randomized Controlled Trial

Original Article

Transnasal humidified rapid-insufflation ventilatory exchange (THRIVE) vs. facemask breathing pre-oxygenation for rapid sequence induction in adults: a prospective randomised non-blinded clinical trial

Summary

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EJA

Eur J Anaesthesiol 2021; 38:1052–1058

ORIGINAL ARTICLE

The efficacy of high flow nasal oxygenation for maintaining maternal oxygenation during rapid sequence induction in pregnancy

A prospective randomised clinical trial

Shuangqong Zhou*, Yao Zhou*, Xiuhong Cao*, Xiu Ni, Weijia Du, Zhendong Xu and Zhiqiang Liu

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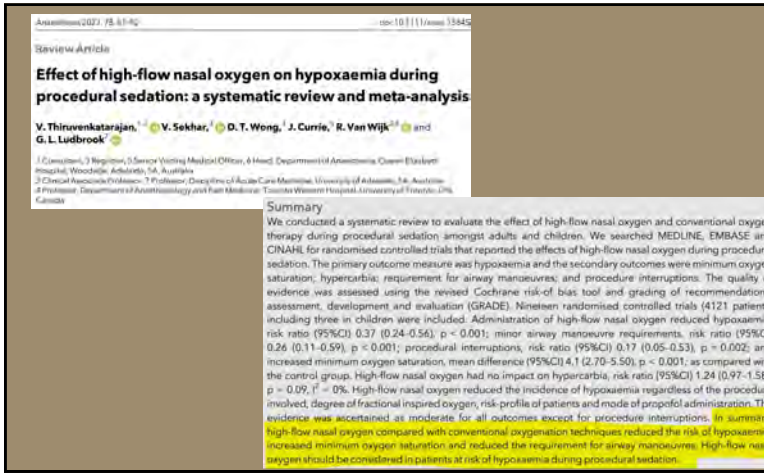
Review Article

Effect of high-flow nasal oxygen on hypoxaemia during procedural sedation: a systematic review and meta-analysis

V. Thiruvenkatarajan, V. Sekhar, D. T. Wong, J. Currie, R. Van Wijk and G. L. Ludbrook

Summary

We conducted a systematic review to evaluate the effect of high-flow nasal oxygen and conventional oxygen therapy during procedural sedation amongst adults and children. We searched MEDLINE, EMBASE and CINAHL for randomised controlled trials that reported the effects of high-flow nasal oxygen during procedural sedation. The primary outcome measure was hypoxaemia and the secondary outcomes were minimum oxygen saturation; hypercarbia; requirement for airway manoeuvres; and procedure interruptions. The quality of evidence was assessed using the revised Cochrane risk-of bias tool and grading of recommendations, assessment, development and evaluation (GRADE). Nineteen randomised controlled trials (4121 patients) including three in children were included. Administration of high-flow nasal oxygen reduced hypoxaemia, risk ratio (95%CI) 0.37 (0.24–0.56), p < 0.001; minor airway manoeuvre requirements, risk ratio (95%CI) 0.26 (0.11–0.59), p < 0.001; procedural interruptions, risk ratio (95%CI) 0.17 (0.05–0.53), p = 0.002; and increased minimum oxygen saturation, mean difference (95%CI) 4.1 (2.70–5.50), p < 0.001; as compared with the control group. High-flow nasal oxygen had no impact on hypercarbia, risk ratio (95%CI) 1.24 (0.97–1.58), p = 0.09, I^2 = 0%. High-flow nasal oxygen reduced the incidence of hypoxaemia regardless of the procedure involved, degree of fractional inspired oxygen, risk-profile of patients and mode of propofol administration. The evidence was ascertained as moderate for all outcomes except for procedure interruptions. In summary, high-flow nasal oxygen compared with conventional oxygenation techniques reduced the risk of hypoxaemia, increased minimum oxygen saturation and reduced the requirement for airway manoeuvres. High-flow nasal oxygen should be considered in patients at risk of hypoxaemia during procedural sedation.

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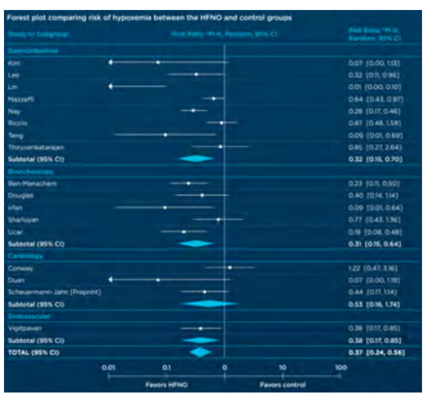
Thiruvenkatarajan et. al., Anaesthesia 2023



A systematic review and meta-analysis of 17 RCTs: GI, bronchoscopy, cardiology, endovascular and dental. (n = 4,212).

Primary end point: Risk of hypoxemia.

Compared to standard oxygen therapy, using HFNO reduced the risk of:

- **Hypoxemia by 63%**
- **Airway maneuvers by 74%**
- **Procedural interruptions by 83%**

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CLINICAL APPLICATION

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CLINICAL APPLICATIONS

- Sedation for procedures/surgeries
- Preoxygenation
- Throughout intubation attempts
- Apneic oxygenation
- Post-extubation

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ANESTHESIOLOGY
Trusted Evidence: Discovery to Practice

2022 American Society of Anesthesiologists Practice Guidelines for Management of the Difficult Airway*
Anesthesiology. 2022;136(1):31-81. doi:10.1097/ALN.0000000000004002

OPTIMIZE OXYGENATION THROUGHOUT[2]

Recommendations for Unanticipated and Emergency Difficult Airway Management
- Call for help.
- Optimize oxygenation…

Examples include low- or high-flow nasal oxygen during efforts securing a tube.

Interventions
- Preparation for difficult airway management
- Unanticipated and emergency (i.e., cannot oxygenate or ventilate) difficult airway management.
  - Call for help
  - Maximize oxygenation
    - Nasal oxygen during efforts securing a tube
    - Expiratory ventilation assistance
    - **High-flow nasal cannula oxygen/transnasal humidified rapid insufflation ventilatory exchange**

[2]Low- or high-flow nasal cannula, head elevated position throughout procedure.

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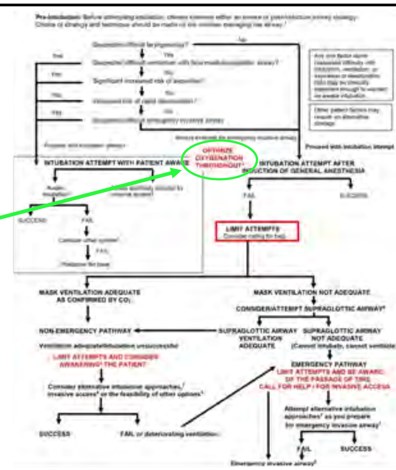
2022 ASA Difficult Airway Management Algorithm:
Adult Patients

Optimize Oxygenation Throughout



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PRONE SEDATION

- 62-year-old male
- PMH: CVA with residual blindness, HTN, HLD, PVD, Type 2 DM
- Procedure: Repair of rupture Achilles tendon
  - Podiatrist requested GETA
    - Decision made to proceed with deep sedation after discussion about planned procedure/operative time, patient positioning, and peripheral neuropathy/residual sensation

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PRONE SEDATION

Preop
- Patient received midazolam 1 mg

Induction
- Patient positioned himself in position of comfort
- Optiflow applied, O_2 administered at 30 L/min
- Administered fentanyl 50 mcg, lidocaine 100 mg, propofol 30 mg
- Initiated propofol infusion at 75 mcg/kg/min

Maintenance
- Ankle block performed by podiatrist
- SpO_2: nadir 95% post-induction, jaw-thrust applied; improved to 97% with appropriate $EtCO_2$ tracing throughout

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LATERAL SEDATION

- 64-year-old female
- PMH: asthma, HTN, cervical cancer
- Procedure: Pleuroscopy
  - Pulmonologist requested avoidance of positive pressure ventilation to the operative lung
    - Sedation with spontaneous ventilation or GETA with lung isolation

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LATERAL SEDATION

Preop
- Patient transported directly to room; no anxiolytics administered

Induction
- Administered fentanyl 50 mcg upon arrival to room
- Patient positioned herself in position of comfort
- Optiflow applied, O_2 administered at 50 L/min
- Administered lidocaine 100 mg and propofol 40 mg
- Initiated propofol infusion at 100 mcg/kg/min

Maintenance
- Lidocaine 1% injected at incision site
- SpO_2: nadir 98% post-induction with appropriate $EtCO_2$ tracing throughout; no airway maneuvers required

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APNEIC OXYGENATION

- 57-year-old male; presenting with stridor
- PMH: history of tracheostomy, subglottic stenosis, HTN, ESRD on hemodialysis, Type 2 DM, cervical osteomyelitis, history of retropharyngeal abscess complicated by empyema and anterior mediastinitis
- Procedure: operative direct laryngoscopy, possible tracheostomy
  - ENT surgeon estimated tracheal diameter to be 4-5 mm

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APNEIC OXYGENATION

Preop
- Patient transported directly to room; no anxiolytics administered

Induction
- Optiflow applied upon arrival, O_2 administered at 70 L/min
- Administered fentanyl 50 mcg, lidocaine 100 mg, propofol 150 mg
- Confirmed ability to mask ventilation after induction; re-applied Optiflow
- Administered rocuronium 50 mg
- Initiated propofol infusion at 150 mcg/kg/min
- Suspension laryngoscope placed by ENT
- MLT placed by ENT after biopsy was complete

Maintenance
- SpO_2: 100%

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CLINICAL APPLICATIONS

If facemask ventilation required...

Don't forget to return the nasal cannula for continued oxygenation!

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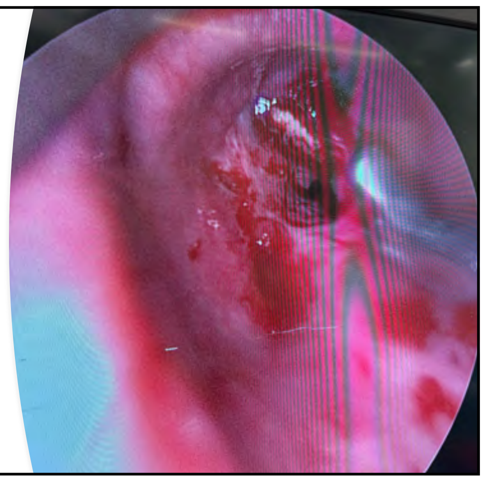
APNEIC OXYGENATION

- 13 minutes
  - Induction → jet ventilation
- 20 minutes
  - Induction → intubation



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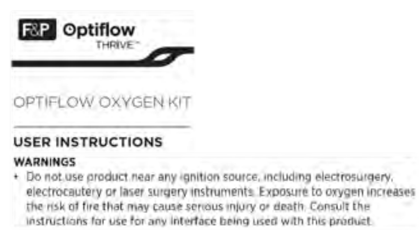
Fire Risk...



F&P Optiflow THRIVE™

OPTIFLOW OXYGEN KIT

USER INSTRUCTIONS

WARNINGS
- Do not use product near any ignition source, including electrosurgery, electrocautery or laser surgery instruments. Exposure to oxygen increases the risk of fire that may cause serious injury or death. Consult the instructions for use for any interface being used with this product.

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FAQs

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"How much O_2 does the system require?"

- E-cylinder (680 L) @ 1900 psi
  - Nasal cannula @ 4 L/min – 133 minutes
  - NRB mask @ 15 L/min – 36 minutes
  - HFNO @ 30 L/min – 17.7 minutes
  - HFNO @ 50 L/min – 10.6 minutes
  - HFNO @ 70 L/min – 7.5 minutes

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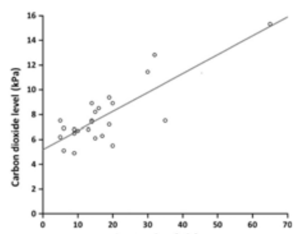
"How does HFNO affect $PaCO_2$?"



Patel, A. & Nouraei, S. A. R. (2015). Transnasal humidified rapid-insufflation ventilatory exchange (THRIVE): A physiological method of increasing apnoea time in patients with difficult airways. *Anaesthesia, 70*(3), 323-329. https://doi.org/10.1111/anae.12923

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"Can I monitor end-tidal CO_2?"

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"Can I monitor end-tidal CO_2?"

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