Role of Mechanical Stresses in Optimising Breathing Therapy Humidification

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Most Common are Nasopharyngeal Complaints:
- Nasal Stuffiness / Rhinorrhea / Nasal Obstruction etc...
- Dry nose & mouth/ Crusted nose.
Why Does Breathing Therapy Require Humidification?

24 hour rest period breathing ambient air at 25°C temperature and 50% RH

- 10,000 litres of air
- 400 ml of water
- 1470 J of heat energy

Nose provides about 90% of respiratory system air-conditioning requirements and recovers 25% of exhaled heat & moisture.
Nasal Air-Conditioning

Isothermic Saturation Boundary (ISB)

Airflow Direction

Distance into Airway

100% RH 37°C

AH
Inhalation

Lower Airway

Nasal Cavity & Bronchi

Nasal Mask

Bias Vent

Pressurised Ambient Air

Heat

Moisture

Nasal Mucosa
Exhalation

Lower Airway → Nasal Cavity & Bronchi → Nasal Mask

- Heat
- Moisture

Bias Vent → Pressurised Ambient Air

Nasal Mucosa
Autonomic Regulation

Sympathetic/Parasympathetic Nervous System

Airflow Regime Regulation

Air Heating Source

Nasal Cycle

~ 40% of population

Widdicombe, J. (1997)
Nasal Morphology And Blood Volume
Epithelial Purinergic Regulation

Current Paradox

Ambient Air
T = 25°C
50% RH
Airway Tissue Mechanical Stress

Pressure (Pa)

\[ \Delta P_{\text{total}} = 10 \text{Pa} \]

(2 m/s)

Kiesselbach’s Triangle

Several arteries anastomose to form vascular plexus

Lateral Wall Shear Stress Distribution

(Bailie, N., Hanna, B., Watterson, J. and Gallagher, G. 2009)
Simulation of variation in septum wall shear stress during inspiration 30mm posterior to nostril at different heights

Simulation of variation in septum wall shear stress during inspiration 30mm posterior to nostril at two specific heights

Epithelial Cell Purinergic Regulation

Airway Surface Liquid Volume and MTV Control – P1 & P2 Channels

Cyclic Breathing Stresses

ADO $\leftrightarrow$ AMP $\leftrightarrow$ ADP $\leftrightarrow$ ATP $\leftrightarrow$ UDP $\leftrightarrow$ UTP

Airway Fluid

P1 $\leftrightarrow$ $\mathbf{P2}$

$\text{Ca}^{2+}_i$, IP$_3$

Role of Mechanical Stress Stimuli

(A) Pressure (cm H₂O) over time (sec).

(B) ATP release rate (fmol/min/cm²) for Control, CCS, and SCS.

(Button, B. & Boucher, R.C. 2008)
Role of Compressive Mechanical Stimuli

(B) ASL height (μm) vs Time (h)

(C) MCT (μm·sec⁻¹) vs Time (h)

=20cmH₂O CCS

● = Control

(Button, B. & Boucher, R.C. 2008)
Epithelial Stresses During Applied Breathing Therapy

![Graph showing applied pressure and flow rate with data points labeled: Weinhold et al. (2004), Kelly et al. (2004), and Simulation.]
Tissue Testing

Purinergic Regulation

Nasal Epithelia
MTV (CBF)
ASL Height (vol)

Stress Induced Stimuli
Mask Pressure
Air Flow Rate

Pressure (cmH\(_2\)O)
Time (sec)

τ

0.06 cmH\(_2\)O

(Wen, J., Tu, I.J. & Wang, S., 2008)
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