Nasal high flow reduces dead space.

AIM:

To test the hypothesis that nasal high flow (NHF) therapy in a dose-dependent manner can clear dead space in the upper airways and decrease CO_2 re-breathing

METHODS:

Patient groups

- Two-part study
  - Part 1 — tracer gas scintigraphy study involving healthy, nonsmoking volunteers
  - Part 2 — nasally-breathing tracheotomized patients admitted to hospital for weaning

Study design

- Randomized cross-over study

Outcome measures

- In healthy volunteers, clearance of ^{81m}Kr tracer gas from the upper airways during NHF therapy was assessed using dynamic gamma camera imaging in five regions of interest (ROI): anterior nasal (Nasal1), posterior nasal (Nasal2), pharynx (space from soft palate to the larynx), trachea, and upper lung
  - Nasal clearance rates were derived from time constants and MRI-measured nasal volumes (VN)
- In tracheotomized patients, reduction of re-breathing during NHF therapy was investigated using volumetric capnography and oximetry by sampling gas from the trachea region
  - The effect of NHF therapy on the volume of inspired O_2 and CO_2 was analyzed for every breath
  - Arterial blood oxygen saturation (SpO_2) and transcutaneous CO_2 were also monitored

Treatment regimens

- NHF therapy was delivered using the AIRVO™ blower-humidifier and the Optiflow™ nasal cannula (Fisher & Paykel Healthcare) at rates of 15, 30, and 45 L/min in a randomized order
  - In the scintigraphy study, NHF was delivered for 30 seconds (during breath holding with closed mouth)
  - In tracheotomized patients, NHF was delivered continuously for 10 minutes, also with closed mouth

RESULTS:

Enrolled patients

- Part 1 — 10 healthy, nonsmoking volunteers, mean age (± SD) 55 ± 14 years
- Part 2 — 3 nasally-breathing tracheotomized male patients not requiring supplemental O_2, admitted to hospital for weaning
  - Two patients (aged 59 and 72 years) had chronic obstructive pulmonary disease (COPD); the third patient (72 years) was recovering from subarachnoid hemorrhage and pneumonia

Outcomes

^{81m}Kr gas clearance in healthy volunteers

- An increase in NHF therapy flow rate from 15 to 45 L/min was associated with an increase in clearance of the ^{81m}Kr gas from the nasal cavities of all participants [Pearson's correlation coefficient (cc) = -0.55, $P < 0.01$] (see Table 1)
  - Nasal1 region cleared significantly faster than Nasal2 ($P < 0.01$); however, there was no apparent correlation between clearance half-times and individual nasal volumes (VN)
- Nasal clearance rates were calculated using the time constants for both ROIs and VN: 40.6 ± 12.3, 52.5 ± 17.7, and 72.9 ± 21.3 ml/s during NHF rates of 15, 30, and 45 L/min, respectively
  - A significant correlation was demonstrated between clearance rate and NHF therapy (cc = 0.61, $P < 0.01$)
- NHF therapy-induced ^{81m}Kr gas clearance was slower in the lower compartments beyond the soft palate (pharynx, cc = 0.41, $P < 0.01$; trachea, cc = -0.51, $P < 0.01$)
  - Pharyngeal and tracheal clearance rates correlated with the nasal clearance rates (cc = 0.4, $P < 0.05$)
  - No ^{81m}Kr gas clearance was observed in the upper lung

Table 1: ^{81m}Kr gas clearance in the anterior and posterior regions of the nasal cavity, pharynx, and trachea regions of interest (ROI) of healthy volunteers during NHF therapy flow rates of 15, 30, and 45 L/min

	HALF-TIME $T_{1/2}$, S		
ROI	**NHF 15 L/min**	**NHF 30 L/min**	**NHF 45 L/min**
Nasal1	0.70 ± 0.26	0.53 ± 0.17	0.39 ± 0.11
Nasal2	0.91 ± 0.34*	0.69 ± 0.24*	0.48 ± 0.11*
Pharynx	7.80 ± 2.96	6.19 ± 3.82	4.43 ± 2.92
Trachea	23.73 ± 6.63	14.30 ± 13.43	10.53 ± 9.85

Values are means ± SD. In all compartments, half-times correlated with NHF (Nasal1, cc = -0.55, P < 0.01; Nasal2, cc = -0.57, P < 0.01; pharynx, cc = -0.41, P < 0.01; trachea, cc = -0.51, P < 0.01). Nasal1 and Nasal2, anterior and posterior parts of nasal cavity, respectively. * P < 0.05 Nasal2 vs. Nasal1, paired t-test.

Re-breathing of expired air during NHF therapy in tracheotomized patients

- In all three patients, NHF therapy resulted in a decrease of inspired CO_2 and an increase of inspired O_2 in a flow-dependent manner
  - NHF-induced decrease of inspired CO_2 correlated with an increase of inspired O_2 (cc = -0.77, P = 0.016)
- The ratio between inspired CO_2 in the first 100 ml of inspired volume and the total inspired CO_2 was significantly higher during NHF therapy relative to baseline ventilation (0.84 ± 0.10 vs. 0.75 ± 0.12; P < 0.01, paired t-test)
- Table 2 shows the change of tidal volume, respiratory rate, minute ventilation, SpO_2, and tissue CO_2 throughout the study

Möller W, Feng S, Domanski U, Franke K, Celik G, Bartenstein P, et al.
J Appl Physiol (1985). 2017; 122(1): 191–197

Table 2: Change of ventilation parameters, peripheral capillary O_2 saturation, and tissue CO_2 in three patients receiving NHF therapy at flow rates of 15, 30, and 45 L/min

	15 L/min		30 L/min		45 L/min	
	BASELINE	NHF	BASELINE	NHF	BASELINE	NHF
PATIENT A						
Tidal volume, ml	332.0	282.6	348.7	300.4	331.5	191.7
Respiratory rate, min^{-1}	10.9	12.2	12.3	10.6	12.3	10.8
Minute ventilation, L/min	3.6	3.4	4.3	3.2	4.1	2.1
SpO_2, %	96.1	96.4	96.8	96.6	96.9	97.1
Tissue CO_2, mmHg	32.0	31.8	31.3	31.2	30.7	30.6
PATIENT B						
Tidal volume, ml	366.7	289.7	438.5	364.3	334.6	332.3
Respiratory rate, min^{-1}	12.9	14.3	12.2	12.4	15.0	14.8
Minute ventilation, L/min	4.7	4.1	5.4	4.5	5.0	4.9
SpO_2, %	92.6	92.2	92.9	92.8	93.5	94.6
Tissue CO_2, mmHg	48.2	49.1	48.0	48.7	48.7	48.3
PATIENT C						
Tidal volume, ml	290.1	264.1	333.0	255.6	391.1	247.6
Respiratory rate, min^{-1}	14.1	13.2	12.2	12.1	14.0	12.3
Minute ventilation, L/min	4.1	3.5	4.1	3.1	5.5	3.0
SpO_2, %	96.6	96.5	97.4	97.6	97.0	97.0
Tissue CO_2, mmHg	39.2	38.5	41.2	40.0	38.3	37.8

CONCLUSIONS:

- NHF therapy reduces dead space by clearing expired air from the upper airways. This leads to reduced re-breathing and improvements in alveolar ventilation and gas exchange
- It is anticipated that an improved gas exchange results in a reduced minute ventilation and/or the normalizing of arterial blood gas (ABG)
- Clearance of the dead space is flow- and time-dependent and may extend below the soft palate

KEY POINTS:

- An increase in the NHF therapy flow rate from 15 to 45 L/min was associated with an increase in clearance of the ^{81m}Kr gas from the nasal cavity
- A significant correlation was demonstrated between nasal clearance and NHF therapy rates and durations
- Gas clearance was slower but still NHF-dependent in the lower compartments beyond the soft palate