Respiratory Physiology & Neurobiology 235 (2017) 27–33

Contents lists available at ScienceDirect

Respiratory Physiology & Neurobiology

journal homepage: www.elsevier.com/locate/resphysiol

High nasal resistance is stable over time but poorly perceived in people with tetraplegia and obstructive sleep apnoea

Nirupama S. Wijesuriya[a,*], Chaminda Lewis[a,b,c], Jane E. Butler[a,b], Bonsan B. Lee[a,c], Amy S. Jordan[d,e], David J. Berlowitz[d,e,f], Danny J. Eckert[a,b]

[a] Neuroscience Research Australia (NeuRA), Sydney, Australia
[b] University of New South Wales, Sydney, Australia
[c] Prince of Wales Hospital, Sydney, Australia
[d] University of Melbourne, Melbourne, Australia
[e] Institute of Breathing and Sleep (IBAS), Melbourne, Australia
[f] Department of Respiratory and Sleep Medicine, Austin Health, Melbourne, Australia

ARTICLE INFO

Article history:
Received 8 July 2016
Received in revised form 6 September 2016
Accepted 30 September 2016
Available online 3 October 2016

Keywords:
Sleep-disordered breathing
Nasal congestion
Spinal cord injury
Autonomic dysfunction
Upper airway

ABSTRACT

Obstructive sleep apnoea (OSA) is highly prevalent in people with tetraplegia. Nasal congestion, a risk factor for OSA, is common in people with tetraplegia. The purpose of this study was to quantify objective and perceived nasal resistance and its stability over four separate days in people with tetraplegia and OSA (n = 8) compared to able-bodied controls (n = 6). Awake nasal resistance was quantified using gold standard choanal pressure recordings (days 1 and 4) and anterior rhinomanometry (all visits). Nasal resistance (choanal pressure) was higher in people with tetraplegia versus controls (5.3[6.5] vs. 2.1[2.4] $cmH_2O/L/s$, p = 0.02) yet perceived nasal congestion (modified Borg score) was similar (0.5[1.8] vs. 0.5[2.0], p = 0.8). Nasal resistance was stable over time in both groups (CV = 0.23 ± 0.09 vs. 0.16 ± 0.08, p = 0.2). These findings are consistent with autonomic dysfunction in tetraplegia and adaptation of perception to high nasal resistance. Nasal resistance may be an important therapeutic target for OSA in this population but self-assessment cannot reliably identify those most at risk.

1. Introduction

Obstructive sleep apnea (OSA) is highly prevalent (>60%) in people with tetraplegia (Berlowitz et al., 2005; Burns et al., 2000; Chiodo et al., 2016; Giannoccaro et al., 2013; Tran et al., 2010). The pathophysiological factors responsible for the high risk of OSA in people with tetraplegia are poorly understood. Increased nasal congestion, a risk factor for sleep-disordered breathing, is common in people with tetraplegia. Injury to the cervical spinal cord disrupts the supraspinal inputs to spinal sympathetic neurons below the level of injury (Weaver et al., 2006), while the parasympathetic drive remains largely unopposed. The result is diminished sympathetic activity overall. This increases vasodilation and mucosal thickening in the nose which may reduce nasal patency and increase nasal resistance (Baraniuk, 2008).

Nasal resistance is estimated to account for 30–50% of total upper airway resistance in non-neurologically impaired, able-bodied populations (Verin et al., 2002). Increased nasal resistance increases upper airway collapsibility (Dawson et al., 1997; Schwartz et al., 1989) and reduces compliance to therapies such as continuous positive airway pressure (CPAP) therapy in able-bodied people with OSA (Sugiura et al., 2007; Zeng et al., 2008) and in people with tetraplegia and OSA (Berlowitz et al., 2005; Burns et al., 2000). While increased nasal congestion is widely recognized clinically following tetraplegia, quantitative assessment of nasal resistance in people with tetraplegia and its potential role in pathogenesis of OSA had not been investigated until recently. The present study aimed to quantify nasal resistance in people with tetraplegia to establish whether strategies to reduce nasal congestion might be warranted as a therapeutic target to reduce OSA in this population. As such, it is important to know if nasal resistance is stable over time and how it compares to able-bodied controls.

Furthermore, there are inconsistencies between current measures of nasal congestion. Both objective and subjective measures have been used. However, it remains unclear whether the different approaches yield similar information (André et al., 2009; Clement et al., 2014; Schumacher, 2002). Therefore, the present study used three common measures of nasal congestion: (i) airway resistance measured via a choanal pressure transducer – laboratory gold stan-

* Corresponding author at: Neuroscience Research Australia, P.O. Box 1165, Randwick, NSW 2031, Australia.
E-mail address: n.wijesuriya@neura.edu.au (N.S. Wijesuriya).

http://dx.doi.org/10.1016/j.resp.2016.09.014
1569-9048/

dard technique to objectively quantify nasal resistance, (ii) anterior rhinomanometry – a routinely used tool to measure nasal obstruction in clinical practice and (iii) self-report nasal congestion to also determine how well the objective and subjective measures of nasal congestion correlate with one another.

2. Materials and methods

2.1. Participants

Participants with tetraplegia were recruited from the Prince of Wales Hospital Spinal Cord Unit and the community. Able-bodied participants were recruited from the local community alone via advertisement. Participants were recruited for the tetraplegia group if they: (i) had an injury to the cervical spinal cord, (ii) had a level of injury completeness according to the ASIA (American Spinal Injury Association) impairment scale (AIS) of either AIS A or AIS B, (Kirshblum et al., 2011), and (iii) were 1 year or more post-injury. Anyone who had experienced a documented recent (within past 6 months) event of autonomic dysreflexia was excluded from participation to avoid any potential lasting effects on autonomic control that may influence nasal resistance (Kalinčík et al., 2010; Krassioukov, 2009). The able-bodied control group was recruited to yield similar age (±5 years) and gender characteristics to the tetraplegia group. People with moderate to severe OSA or known neurological injuries were excluded from participation in the control group. Participants completed overnight polysomnography to determine the apnea/hypopnea index (AHI). People with a history of chronic rhinitis or those who were suffering from current respiratory infections were excluded from participation. The study was approved by the South East Sydney Local Health Service Human Ethics Committee and informed written consent was obtained prior to participation in the study. In the case of participants with impaired hand function, a third party (i.e. a family member or carer) was present to witness verbal consent and provide written confirmation of the participant's verbal consent.

2.2. Experimental protocol and measurements

Participants were studied supine on four separate occasions at the same time of the day with an interval of 1–2 days between each visit. Participants with tetraplegia were assessed in their home shortly after their morning routines. Able-bodied participants were assessed in the laboratory. During each visit, participants were asked to score their perceived level of nasal obstruction using a standardised scale similar to a modified Borg scale (Wilson and Jones, 1989). Specifically, participants were asked to select the score that best described how blocked they perceived their nose to be at that moment. The scale ranged from 0 to 10 and was accompanied by a verbal descriptor. For instance, a score of 0 = completely unblocked, 0.5 = very, very slight (just noticeable) blockage, 1 = slight blockage, 3 = moderate blockage, 5 = severe blockage, and 10 = maximum or completely blocked.

Following nasal perception assessment, nasal resistance was objectively quantified using anterior rhinomanometry (Rhinomanometer 300, ATMOS Medizin Technik, Germany). During anterior rhinomanometry, participants were fitted with a nasal mask while the left nostril was blocked using a nasal plug inserted into the opening of the nostril. Participants were instructed to breathe only through their nose for several minutes during the recording period. A pressure transducer fixed to the mask measured flow through the unblocked (right) side of the nose. The nose plug was then switched to the right nostril and airflow through the left side of the nose was measured. Airflow (cm^3/s) at a transnasal air pressure of 150 Pa was measured in the left and right nostrils separately and resistance through each nostril was calculated according to the following formula: Resistance ($Pa/cm^3/s$) = Pressure/Flow. Anterior rhinomanometry calculates the total nasal resistance as the reciprocal sum of unilateral resistances using following formula: *Resistance in the right nostril x Resistance in the left nostril)/(Resistance in the right nostril + Resistance in the right nostril).*

Table 1
Individual characteristics of the participants with tetraplegia.

Participant Number	Age (years)	Gender	AHI (Events/h sleep)	Injury Level	AIS
T01	65	Male	30	C4	A
T02	54	Male	45	C5-C6	A
T03	33	Male	14	C5-C6	B
T04	44	Male	41	C4	B
T05	45	Male	47	C6	B
T06	52	Male	32	C4-C5	B
T07	54	Female	24	C4	A
T08	52	Male	58	C5	A

AHI = Apnea/Hypopnea Index.
AIS = American Spinal Injury Association Impairment Scale. A = motor and sensory complete, B = motor complete, sensory incomplete.

Following anterior rhinomanometry, during visits one and four, total nasal resistance was measured using the laboratory gold standard in which a pressure transducer (Millar, Houston, TX, USA) was inserted via a nostril to the level of choanae (0.5–1 cm distal to the nasopharyngeal wall). The transducer was inserted via participant's most patent nostril as per participant's report on day 1 and the same nostril was used on day 4 for consistency. Each subject was instrumented with a nasal mask (ResMed, Sydney, Australia). Airflow was measured using a pneumotachograph (Hans Rudolph Inc, 3700, Kansas City, USA) and mask pressure was recorded using an additional differential pressure transducer attached to the nasal mask connected to a pneumotachometer (model RSS100-HR, Hans Rudolph Inc, Kansas City, USA). Nasal resistance was calculated as the pressure difference between mask pressure and choanal pressure at a flow rate of 0.2L/s (Eckert et al., 2009; Eikermann et al., 2010) during a 10 min period of quiet nasal breathing. Data were acquired using a 16-bit analogue to digital converter (CED 1401; Cambridge Electronic Design, Cambridge, UK) and Spike 2 software (version 7.2).

2.3. Statistical approach

Repeated measures ANOVA was performed to test for group differences in nasal resistance and its stability over time. Non-normally distributed data were $\log_{10}$ transformed prior to analysis. The coefficient of variation (CV) of nasal resistance across the study days for each person (within participant daily variability of total nasal resistance) was calculated to quantify the day-to-day variability in nasal resistance in each group and compared using independent sample *t*-tests. Group averages are presented as either mean ± standard deviation (if normally distributed) or median and interquartile range (if non-normally distributed).

3. Results

3.1. Participant characteristics

Eight people with tetraplegia (1 female) (see Table 1 for participant characteristics) and 6 able-bodied controls (1 female) completed the study. Tetraplegia and control groups were well-matched for age (50 ± 9 vs. 48 ± 10, p = 0.8) and body mass indices (26 ± 8 vs. 26 ± 4 kg/m^2, p = 0.9). The tetraplegia group had moderate to severe OSA with a mean apnea/hypopnea index of 36 ± 14 events/h sleep. One of the tetraplegia participants was on contin-