Sustained pharyngeal inflation with oxygen tube effects on upper airway pressure and lumen changes in infants—flexible bronchoscopy measurement

Wen-Jue Soong[1], Chieh-Ho Chen[2], Chien-Heng Lin[3], Chia-Feng Yang[4], and Pei-Chen Tsao[5]

[1]Children's Hospital, China Medical University
[2]China Medical University
[3]China Medical University Hospital
[4]Taipei veterans general hospital
[5]Veteran general hospital, Taipei, Taiwan (ROC)

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Abstract

Sustained pharyngeal inflation (SPI) with pharyngeal oxygen and nose-close (PhO2-NC) can create positive inflation pressure (PIP) inside the pharyngolaryngeal space (PLS). This study measured and compared effects of different SPI durations in the PLS. Method: A one-year prospective study, 20 consequent infants whose age less than 3-year-old and scheduled for elective FB were enrolled. SPI performed in four different durations (0.0, 1.0, 3.0 and 5.0 seconds) consequently. Each infant did two cycles of SPI. Measured the PIP of each SPI in the pharynx, and simultaneously took images at three locations of oropharynx, supra-larynx and larynx. Data of infant's demographics, PIP levels, space expansion scores and images were collected and analyzed. Results: Total 20 studied infants, the mean (SD) age was 11.6 (9.1) month-old, the mean (SD) body weight was 6. 8 (2.4) kg and the mean (SD) study time was 3.8 (1.1) minutes. The measured mean (SD) pharyngeal PIPs were 4.1 (3.3), 21.9 (7.0), 42.2 (12.3) and 65.5 (18.5) cmH2O at SPI duration of 0.0, 1.0, 3.0 and 5.0 seconds, respectively. Which showed positively and significantly ($p<0.001$) correlations. At these assigned locations, the corresponding PLS images also show significant lumen expansion correlated with the PIP. Especially, when there existed pathologic or occult lesions. No any study related complication was noted. Conclusions: SPI with PhO2-NC up to 5 seconds is a simple, safe and feasible clinical ventilation modality. Which could provide enough PIP to expand the PLS and benefit FB performance in infants.

Title pages

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Wen-Jue Soong[1,2,3,4] , Chieh-Ho Chen[1], Chien-Heng Lin[1], Chia-Fang Yang[2,3], Yu-Sheng Lee[2,3], Pei-Jeng Tsao[2,3],

[1]Division of Pediatric Pulmonology, China Medical University Children's Hospital, China Medical University, Taichung, Taiwan

[2]Department of Pediatrics, School of Medicine, National Yang-Ming University;

[3]Department of Pediatrics, Taipei Veterans General Hospital, Taipei, Taiwan;

[4]Department of Pediatrics, Tri-service General Hospital, Taipei, Taiwan

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Corresponding (reprint request) author:

Wen-Jue Soong, MD

Division of Pediatric Pulmonology, China Medical University Children's Hospital, Taichung, Taiwan.

No. 2, Yuh-Der Road, Taichung 40447, Taiwan.

Phone: +886-4-22052121 ext. 4648;

Fax.: +886-4-22032798;

Cell phone: +886-921067989;

E-mail: *wjsoong3@gmail.com*

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Authors	**Highest academic degree**	**E-mail**	**Affiliation**
Wen-Jue Soong[1,2,3]	MD	wjsoong3@gmail.com	Department of Pediatrics, Taipei Veterans General Hospital, Taipei; School of Medicine, National Yang-Ming University, Taipei, Taiwan 3.Department of Pediatrics, Tri-service General Hospital, Taipei, Taiwan
Chia-Feng Yang[1,2]	PhD	pum_-chia@yahoo.com.tw	
Yu-Sheng Lee[1,2]	PhD	leeys@vghtpe.gov.tw	
Pei-Chen Tsao[1,2]	PHD	phinphin.tw@yahoo.com.tw	
Chien-Heng Lin[1]	MD	lch227@ms39.hinet.net	4.China Medical University, Children's Hospital, Taichung, Taiwan
Chieh-Ho Chen[1]	MD	pedlungcmu@gmail.com	

Abbreviated title: *Sustained pharyngeal inflation in upper airway*

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Key words :

Flexible bronchoscopy, noninvasive ventilation, pediatric laryngoscopy, pharyngeal pressure, Soong's ventilation, sustained inflation, upper airway

Introduction

Sustained pharyngeal inflation (SPI) is an assist positive pressure ventilation (PPV) maneuver with prolonged inspiration time while peak inflation pressure (PIP) can be created inside the pharyngolaryngeal space (PLS). In children with a normal patent airway, the pressurized-air flow may actively move from upper into the lower airways and providing the ample time and pressure gradient needed for expand the airway lumens, alveoli and gas exchange across the air-fluid interface. Traditionally, this kind of sustained inflation (SI) is accomplished with a gas flow that delivers via different devices of Ambu-facemask, bi-nasal prongs, laryngeal mask airway (LMA), or endotracheal tube (ETT).[1-8] This SI has gradually become a widespread clinical practice. Theoretically, in a relative close space like the PLS, the levels of created PIP may positively correlate to the durations of SPI.

"Pharyngeal oxygen with optional close-nose and abdomen-compression (PhO_2-NC-AC)" is a novel model of noninvasive ventilation (NIV), without using any artificial device such as mask, LMA or ETT. Which has already demonstrated able to provides adequate oxygenation and ventilation to assist interventional flexible bronchoscopy (FB) in children, even in severe asphyxiated status.[9-15] In the setting of PhO_2, the ventilation effect of the "nose-close (NC)" can also create PIP in the PLS. A prolonged duration of the NC indeed provides a SPI. Closely measuring and monitoring the levels of these created PIPs are clinical imperative. However, to our knowledge, there is no study deal with the SPI durations and associated changes of PIP and image in upper airway of PLS in pediatrics.

In this study, we use the "*PhO_2-NC*" as a SPI technique to evaluate and compare the different durations effect on 1) the created PIP levels in PLS; and 2) the associated changes of airway image measuring by FB.

Methods

This is a one-year prospective study. Total 20 consequent infants who full fill a) age less than 3-year-old, b) a clinical schedule for elective FB, and c) got parents signed-consent were enrolled. Two bronchoscopists (Soong and Chen) carried out these SPI studies. The Institutional Review Board of hospital and IRB approved this study (DMR-109-179, CMUH108-REC3-114). Patient confidentiality was maintained in accordance with Health Insurance Portability and Accountability Act guidelines.

The study child was supine lie on the endoscopy room table, setting with procedural sedation and continuous cardiopulmonary monitoring as usual doing FB. A continuous oxygen flow (1.0 L/Kg/min, maximal 10.0 L/min) delivered via a small nasopharyngeal catheter via (right) nostril as the "PhO_2". This NIV of PhO_2-NC-AC supported the whole FB intervention.

All the SPI studies were performed after completion of their original scheduled FB. Figure 1a shows the configuration of this study. A short (25 cm) working-length FB (OD 3.8mm, HYF-V, Olympus), with an inner channel (1.2 mm), inserted via one side (left) nostril. A small pressure transmitting catheter links the inner channel to a real-time pressure monitor (GB30, Galemed, Taiwan). Therefore, the real-time dynamic intra-pharyngeal pressures could be measured when the FB tip freely located in the PLS.

Modes of SPI

SPI (NC, inspiration) processed in four modes of different durations (0.0, 1.0, 3.0 and 5.0 seconds) consequently, as reveals in Figure 1b. Each SPI followed by an open-nose (deflation) for expiration. A 10-second interval, for spontaneous breathing, set up between each mode of the SPI. Two cycles of these SPI modes were performed in each infant. Measured and recorded levels of these PIP in the PLS. Simultaneously, took image at each plateau of PIP, at three assigned locations of oropharynx, supra-larynx and larynx. Whole these FB videos of SPI studies were recorded.

For objective evaluation of the lumen changes, four captured clear images of four SPI durations were collected and sent for evaluation. From these images, the lumen dimensions were judged independently on a five-point

Likert scale (1 to 5: severe collapsed, collapsed, average, expanded, much expanded) within one week by five qualified pediatric pulmonologists who blinded to their sources. The final scores were averaged and analyzed.

Data of patient demographics, PIP levels, expansion scores and images in the PLS were all collected for further analysis.

Statistic

All analyses were performed using One-way ANOVA of the MedCalc statistical software (version 19.3.1, MedCalc Software Ltd, Acacialaan 22, 8400 Ostend, Belgium). Statistical differences were considered significant at $p < 0.05$.

Results

In these 20 studied infants, as Table 1, the mean (SD) age was 11.6 (9.1) month-old and the mean (SD) body weight was 6. 8 (2.4) kg. The mean (SD) operative time of this SPI study was 5.7 (1.2) minutes.

In the collected 40 sets of study data, the measured mean (SD) PIP in the pharynx were 4.1 (3.3), 21.9 (7.0), 42.2 (12.3) and 65.5 (18.5) cmH2O at SPI duration of 0.0, 1.0, 3.0 and 5.0 seconds, respectively. These PIP levels were all positively and significantly ($p<0.001$) correlated to the durations of the SPI in second.

The corresponding levels of PIP, expansion scores, images of each SPI mode of pharyngeal and laryngeal lesion were illustrated in the Figure 2 and Figure 3, respectively. On the same row, all four images were taken at similar location of same infant but with different PIP levels generated by different SPI modes. Obviously, in these changes of image sequences, there show progressive and significant space expansion, positive correlation, and also greater lumen dimension scores to the associated PIP levels in all locations of the PLS. Especially, when there existed pathologic lesions such as these presented pharyngomalacia, uvular cyst, vallecular cyst, etc. During FB assessment, these created lumen expansions might also help to accurate and comprehensive evaluation of those lesions which were not visible in the low PIP but apparently with the high PIP of long SPI duration.

All these SPI studies were successfully completed. Throughout the whole study, there was no any study-related complication such as upper airway bleeding, subcutaneous emphysema, pneumothorax, desaturation or bradycardia.

Discussion

We here present an elegant and simple NIV of "PhO_2-NC" as a SPI technique to measures changes of the PIP and image in the PLS with FB. To the best of knowledge, this is the first study in the medical literature. Even with the prevalence of NIV worldwide, the types of device and the modes of delivery being used vary among institutes and countries. Clinically, this SPI is unique in waives using other supplementary instruments, except a small oxygen catheter, and capability of operator himself optional and easy controllable skill.

The PLS is a fibromuscular tube-like structure that is semicircular in cross section and relatively closed space. It serves as a continuation of the aerodigestive cavity, providing pathway from the nasal and oral cavities to the trachea, esophagus and the bilateral middle ears. PLS boundaries almost with soft tissues of the mouth and the nasal choanae anteriorly; the soft palate, velum, and portion of the skull base superiorly; the tonsils laterally; the inlets of larynx and esophagus inferiorly; and the pharyngeal constrictors posteriorly. Therefore, the PLS is a potential dynamic space which do expand with increasing inside pressure.

FB examination via nasal track offers real-time visualization and assessment of the whole PLS. FB is useful for detecting dynamic images that better demonstrate the presence, location, degree and extent of lesions. In the PLS, an optional action of SPI by PhO_2-NC can create an enough and controllable positive distending pressure which helps open and appropriate expand the space, increase the cross-sectional area, and therefore allows accurate and precise inspection the anatomic structure with FB. Especially when there exist collapsed space or dynamic lesions such as pharyngomalacia, kissing tonsils, vallecular cyst, laryngomalacia or glottis malacia laryngeal cleft, etc. as showing in the Figure 2 and Figure 3, which may otherwise remain unrecognized when using traditional technique without proper or controllable pressure in the PLS. In addition, the PhO_2-NC itself may provide simultaneous and optional PPV. Which also benefits for the therapeutic intervention of FB such as doing laser partial adenoidectomy and tonsillectomy, check bleeding, marsupialization of vallecular cyst,[11]epiglottoplasty,[16] etc. We have already applied this SPI modality successfully in many pediatric endoscopy interventions of airway[9-16] and esophagus.[17,18]

Physiologically, this PhO_2-NC has combinational effects of "apnea oxygenation" [19-23] and PPV. In the setting of PhO_2, the continuous flow indeed fully fill the PLS with oxygen. For apnea oxygenation, randomized controlled trials have shown that it can extend the period of safe apnea, reduces the unintended hypoxemia when used in patients after sedation or muscle paralyze, even with difficult airways. PhO_2 with addition of optional SPI, positive inflation pressure or PPV can be created for a prolonged period, which allows appropriate and controllable pressures and times to expand the collapsed PLS for FB detail inspection, as well as doing therapy. Furthermore, it may also promote the pressurized oxygen flow into the low airways and lungs.[20-24]

The modality of FB with this SPI offers several clinical advantages. Transnasal approach of FB provides a better dynamic assessment for airway movements. The interface of SPI is inside the PLS which much reduces the ventilation deaspace. This SPI is an easy PPV technique that can be performed with only a continuous oxygen flow and a soft catheter sitting in the pharynx that minimizes impeding airway access during FB procedures. It can optionally control and simultaneously accomplish by FB operator himself. SPI can appropriately open and expand a collapsed PLS, as demonstrated in this study, which facilitates the passage of FB for thoroughly examine the PLS. This allows clear visualization of contains, structures and lesions that helps to yield more accurate diagnosis and subsequent effective management, without interference by artificial airway devices of facemask, nasal prong, LMA or ETT. It is technically simple and readily available, therefore, can be used in resource-limited sceneries. Additionally, it causes less distortion, less invasive, better-tolerated and cost-effective compared to the traditional technique. Controlled and appropriately sustained (3 to 5 seconds) inflations may be more effective than short (1 to 2 seconds) inflations in the prolonged expansion of target airway space for better and detailed measurement which not easily be identified at lower inflation levels. Furthermore, these dynamic pressures of SPI may also transmit and facilitate tracheobronchial lumen expansion and lung ventilation. For patients with risk of compromised airway and oxygen desaturation, it may reduce hypoxia, provide ventilation and, therefore, improve patient safety with little medical resources.

Some limitations may exist in this study. There might have variation of the tightness of the nose (mouth)-closure in the same or between operators. This indeed may affect the levels of measured pressure. A more prolonger duration of SPI, up to 15 seconds or more had been reported,[3,8] but it was not included in this primitive study because worry its adverse effects of high created PIP. In clinical practice, the real effort of SPI may individualize but that is controlled by the operators.

Nonetheless, the findings of the present study are important and suggest the need for further investigations. Such as the opening pressure of a collapse PLS or occult lesions which can be measured and help for determine subsequent pressure of NIV support. The similar SPI effects in the lower airway lumens, ventilation, and lung recruitment.

Conclusion:

In conclusion, we propose that the application of SPI by PhO_2-NC with different durations is a simple, safe and viable modality. This prolonged, up to five seconds, SPI could provide enough PIP to expand the PLS, benefit FB performance and comprehensive inspection in infants. This technique could unmask otherwise difficult-recognize lesions. Further larger controlled trials are needed before widespread clinical application.

End.

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None.

Conflict of Interests

All authors declare that there is no conflict of interests regarding the publication of this paper.

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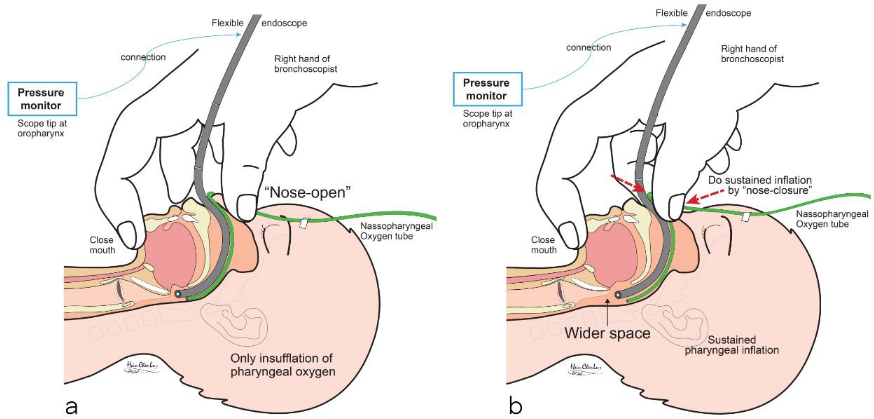

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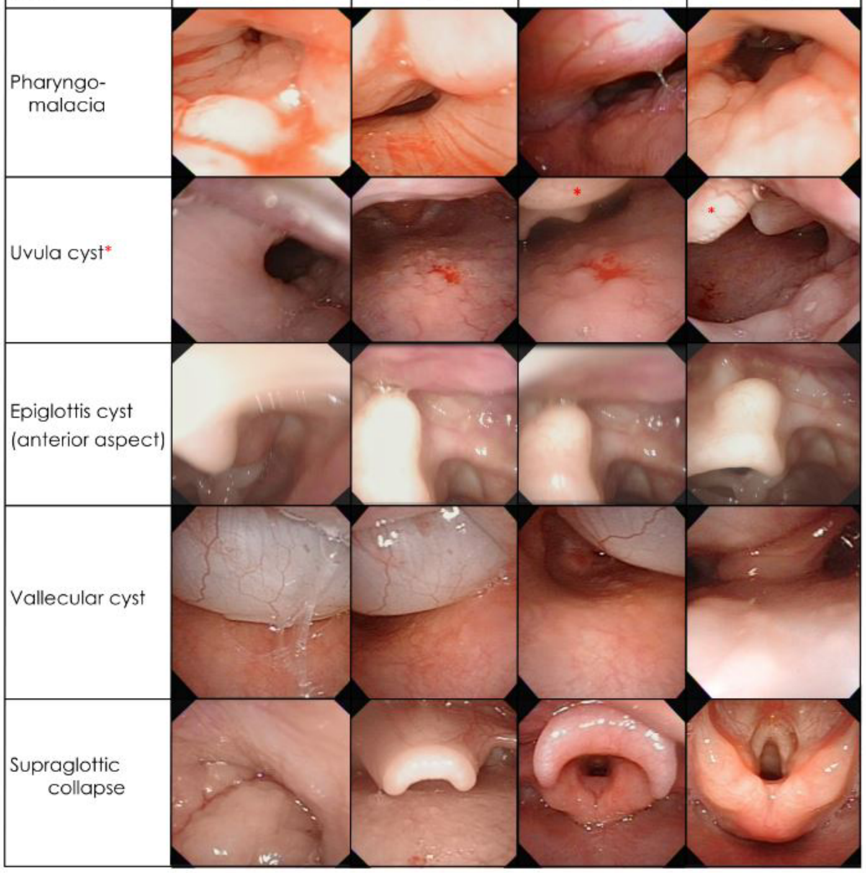
Oxygen flow rate	Pharyngeal oxygen (1.0 L/kg/minute, maximal 10 L/min)			
SPI duration (sec.)	0	1.0	3.0	5.0
IPS PIP (cmH_2O)	4.1 (3.3)*	21.9 (7.0)*	42.2 (12.3)*	65.5 (18.5)*
Lumen expansion score	1.1 (0.2)*	2.5 (0.3)*	3.5 (0.5)*	4.5 (0.2)*



#, images of each row take at same location of same infant. *, p< 0.001.

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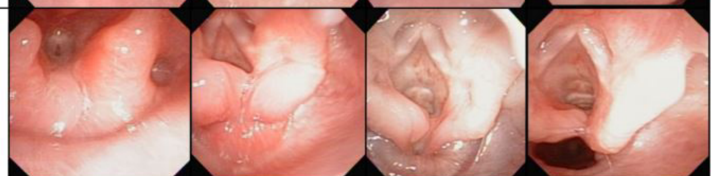
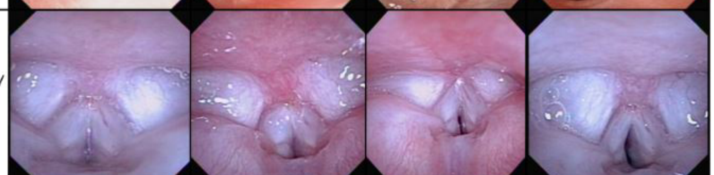
Laryngeal cleft				
Vocal cord palsy and thickness				
Glottis malacia				

#, images of each row take at same location of same infant. *, p< 0.001.