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CASE SERIES AND REPORTS

Physiology and prospects of bimanual tracheoesophageal brass instrument play

Fisiologia e prospettive del suono bimanuale di un ottone in paziente portatore di valvola tracheoesofagea

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SUMMARY

This study investigated whether trachea pressures during brass instrument play of laryngectomised patients are within the range of those measured during tracheoesophageal voicing, and whether application of an automatic speaking valve can 'free' both hands to play a brass instrument. Objective assessment of voicing and music playing parameters was carried out in 2 laryngectomised patients with a low-pressure indwelling voice-prosthesis able to play brass instruments (tenor horn and slide trombone): sound pressure levels in dB, maximum phonation time in seconds and trachea pressures in mmHg; videofluoroscopy, stroboscopy and digital high speed endoscopy to assess neoglottis vibration and opening. The dynamic range of the voice in the patients was 29 and 20 dB, and maximum phonation time was 22 and 19 sec, respectively; intratracheal pressures during voicing varied from 7 mmHg for the softest /a/ to 49 mmHg for the loudest /a/. For brass instrument play, the intratracheal pressures varied from 14 mmHg for the softest tone to 48 mmHg for the loudest tone. Imaging confirmed earlier findings that the neoglottis is closing and vibrating during voicing and remains 'open' without vibrations during music play, indicating good neoglottis control and innervation. From these objective measurements, we can conclude that trachea pressures during brass instrument play are within physiological ranges for tracheoesophageal voicing with a low-pressure indwelling voice-prosthesis. Furthermore, it was shown that application of a stable baseplate for retaining an automatic speaking valve and an additional customisable 'neck brace' makes bimanual play possible again.

KEY WORDS: Total laryngectomy • Videofluoroscopy • Stroboscopy • Trachea pressure • Neck brace

RIASSUNTO

Lo scopo del presente studio è stato quello di valutare se le differenze pressorie misurate durante il suono di un ottone rientrano nel range di quelle ottenute durante la voce parlata tracheoesofagea nei pazienti laringectomizzati, e se l'applicazione di una valvola automatica può permettere di suonare uno strumento musicale senza l'utilizzo delle mani nella gestione della valvola. La valutazione obiettiva della voce e della musica suonata è stata effettuata in due pazienti laringectomizzati portatori di una protesi vocale a bassa pressione, capaci di suonare uno strumento musicale della categoria degli ottoni (corno e trombone) mediante la misurazione di: intensità sonora in dB, tempo massimo di fonazione in secondi, pressione endotracheale; videofluoroscopia, stroboscopia ed endoscopia digitale ad alta velocità sono state utilizzate per valutare l'apertura e la vibrazione della neoglottide. Il range dinamico della voce è stato da 29 e 20 dB, con un tempo di fonazione massimo rispettivamente di 22 e 19 secondi; la pressione intra-tracheale durante la fonazione è variata da 7 mmHg per le tonalità più basse /a/ a 49 per le più alte /a/. Durante l'utilizzo dello strumento musicale la pressione endotracheale è variata da 14 mmHg per le basse tonalità a 48 mmHg per le alte tonalità. L'imaging ha confermato che la neoglottide si chiude e vibra durante la fonazione, mentre rimane aperta senza vibrazioni durante l'utilizzo di uno strumento musicale, indicando che c'è un buon controllo della neoglottide e una buona innervazione. Tramite queste misurazioni obiettive possiamo concludere che le pressioni endotracheali durante l'utilizzo di strumenti musicali rispecchiano i range fisiologici della fonazione tracheoesofagea con ausilio di una protesi fonatoria a bassa pressione. Inoltre, è stato dimostrato che l'applicazione di uno "baseplate" stabile con una valvola fonatoria automatica e un sostegno per il collo personalizzato permette a questi pazienti di suonare tenendo libere entrambe le mani.

PAROLE CHIAVE: Laringectomia totale • Videolaringoscopia • Stroboscopia • Pressione endotracheale • Collare

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Introduction

In 2009, Cavalot and colleagues reported the case of a professional musician and music teacher who regained his ability to play a brass instrument after total laryngectomy and secondary tracheoesophageal puncture

(TEP)¹. The patient had his surgery in 2000 for a pT-3pN0M0 glottic carcinoma and readily developed good oesophageal voice, but obviously was no longer able to play his slide trombone. In 2003, at a workshop on voice rehabilitation with planned live surgery in San Giovanni

di Rotondo in Italy, he asked whether TEP and voice prosthesis (VP) insertion would enable him to regain his ability to play his slide trombone again. The surgical team at the workshop suggested that in any case his voice likely would become stronger and more fluent and that there was a fair chance he also would be able to play his instrument again, based on prior anecdotal observations with patients being able to whistle and softly play a flute. After the TEP and immediate indwelling VP insertion (Provox2, Atos Medical, Hörby, Sweden), he indeed instantly had a better voice, both in loudness and in fluency. After being provided with an automatic speaking valve (ASV; Provox FreeHands HME, Atos Medical, Hörby, Sweden) with the cough relief valve glued shut to prevent its inadvertent opening, at the third or fourth attempt he was able to play his slide trombone again. Indeed, after less than a minute he literally blew the seal of the adhesive (FlexiDerm oval, Atos Medical, Sweden) retaining the ASV, and playing became impossible because of the air leak underneath the adhesive.

As articulately described by Cavalot and colleagues, the patient did not give up and switched to a tenor horn, which he could play with one hand, freeing the other hand for stoma occlusion¹. This enabled him to continue his music career, not only as a teacher, but also as a performing artist. In the publication about his case, the behaviour of the neoglottis during speaking and music play was thoroughly analysed with videofluoroscopy and stroboscopy. As expected, during voicing, there is neoglottis closure and mucosal vibration, while during music play the neoglottis is 'open' and not vibrating, a behaviour similar to that described for the normal glottis and pharynx under both conditions.

Despite this success, the patient still felt the urge to regain his ability to use both hands for music play and to be able to play his slide trombone again. This was the reason he contacted the first author, who he knew from his surgery at the workshop in 2003. Since objective pressure measurements were not available from the otherwise comprehensive study published about his case, the first question to the patient was how much higher the perceived air pressure was during music play than during (loud) voicing. His answer was that it felt to be like "10 times higher". At first, this suggested a pressure that was too high for any ASV adhesive to withstand for a reasonable length of time, but since actual data about intratracheal pressures were not available, it was decided to first assess these pressures before denying the desired 'handsfree' option to the patient.

The goal of the present paper, therefore, is to report on the assessment of the intratracheal pressures exerted during brass musical instrument play and to compare those to the pressures during (loud) voicing, which is the only piece of the puzzle missing. This would also help in determining whether recent developments in adhesives and other support devices would enable to free both hands for bimanual music play. Moreover, the goal was to as-

sess whether this first patient's unique skills are achievable for more patients based on observations in a second laryngectomised patient playing the slide trombone. In other words, can playing a brass instrument be safely recommended to laryngectomised patients without the risk of sanctioning undue high and potentially harmful intratracheal (back) pressures.

Materials and methods

This study investigated 2 laryngectomised patients able to play a brass instrument, i.e. a tenor horn and a slide trombone. The clinical course of patient 1 has been extensively described previously¹. Patient 2, an amateur musician, underwent total laryngectomy in combination with a total thyroidectomy for a deeply invasive papillary thyroid carcinoma (T4aN0) in December 2012. He also received ablative ¹³¹I therapy in the spring of 2013. Recordings and imaging were made in June 2012 (patient 1; 55 years of age at the time) and December 2013 (patient 2; 71 years of age at the time). Both patients were evaluated according to the same protocol, consisting of trachea pressure measurements, voice quality assessment (sound pressure level and maximum phonation time) and imaging of the neoglottis (videofluoroscopy, flexible stroboscopy and high speed digital endoscopy) during voicing and music play. Recordings were made with digital occlusion of the stoma via a HME in a peristomal adhesive.

Trachea pressure measurements

Trachea pressures were recorded with a digital manometer (Druck DPI 705 Digital Pressure Indicator; GE/Druck Incorporated, 4 Dunham Drive, New Fairfield, Connecticut 06812, USA; regular calibration: Amtele AB, Kungens Kurva, Sweden) both during voicing and during tenor horn play. In patient 1, recordings were made both for manual occlusion of the stoma through a HME, and for automatic valve occlusion. Recordings in patient 2 were made with manual occlusion only. A peristomal adhesive (Provox StabiliBase, Atos Medical, Hörby, Sweden) was perforated with a 4 mm dermal punch to allow airtight access for a customised connector tube attached to the manometer (Fig. 1). Since the first patient initially used a Provox2 voice prosthesis, subsequently to be replaced with a Provox Vega (with a lower airflow resistance²), these trachea pressure measurements were also carried out with the latter VP in place. The second patient already had a Provox Vega.

Voice quality parameters

Dynamic range (DR) was measured using a dB meter (Sound Level Meter Chauvin Arnoux CA 834 dB meter, calibrated according to the manufacturer's recommendations). The dB meter was placed at a distance of 30 cm from the patient's mouth. The patient was asked to occlude the stoma and produce a comfortable sustained /a/ (3 times), to



Fig. 1. Trachea pressure measurement during voicing (left), and during brass instrument play (right) using a digital manometer airtight attached into a peristomal adhesive; printed with permission.

phonate as softly as possible on a sustained /a/ (3 times) and lastly to phonate as loudly as possible on a sustained /a/ (3 times). The softest and the loudest of the 3 attempts were taken as the respective sound pressure level, whereas for comfortable loudness the mean was taken. Maximum phonation time (MPT) in sec was assessed in the same set-up by asking the patient to produce the vowel /a/ 3 times at a comfortable loudness level as long as possible. The longest of the 3 attempts was taken as MPT.

Neoglottis imaging

Videofluoroscopy: Videofluoroscopy was done with Omnipaque coating of the mucosa of the neoglottis during soft/loud and low/high pitched voicing and the same during music play with the addition of playing a scale from the lowest to the highest tone and back again. Swallowing proficiency was assessed with thin and thick liquid Omnipaque and coated cake.

Video stills were made with the program 'ImTOO Video to Picture' (version 1.0.35.0825; ImTOO Software Studio, Xilisoft Corporation), which enables batch extraction of video stills for comparison of the neoglottis configuration at similar situations during (soft to loud and low to high pitch/tone) voicing and brass instrument play.

Stroboscopy and high-speed digital flexible endoscopy:

Stroboscopy was done with the Xion flexible video-nasopharyngoscope (with high-resolution CCD sensor at the distal tip) and EndoSTROB System (Xion GmbH, Berlin, Germany). Since stroboscopy of the neoglottis has the drawback that the pitch of TLE voices often is unstable/varying, high-speed digital imaging (HDSI) was carried out to also obtain 'pitch independent' images for verification of the vibrations/behaviour of the neoglottis³. HDSI was carried out with the flexible endoscope of the HreS Endocam 5562 laryngoscopic diagnosis system (Richard Wolf, Knittlingen, Germany).

Bimanual music play enhancement: The peristomal adhesive used for attaching the ASV was the Provox StabiliBase (Atos Medical, Hörby, Sweden) with additional silicon glue⁴. For reinforcing and further stabilising the adhesive seal, the customisable Nijmegen Neck Brace was used (Fig. 2)^{5,6}.

Results

Analysis of videofluoroscopy images showed essentially the same pharyngoesophageal segment configuration and



Fig. 2. Bimanual tenor horn play with an automatic speaking valve (ASV; Provox FreeHands HME) in a peristomal adhesive (Provox StabiliBase) supported with a customisable Nijmegen neck brace; printed with permission.

functional behaviour as published by Cavalot et al.¹ Figure 3 shows the comparative video stills of voicing and brass instrument play for loudness (softest, comfortable, and loudest /a/ and tone) and pitch (lowest and highest /a/ and pitch) for patient 1. Figure 4 shows video stills of

playing a full scale from low to high and back (top left to bottom right) for patient 1. In Figure 3 a, it is clearly visible that the pharynx in all music playing conditions is wider than in the similar voicing conditions. Moreover, the upward bulging of the neoglottic bar in the voicing conditions indicates that there is good neoglottic closure, whereas the 'flat' structure at the neoglottis level during music play is indicating that there is no neoglottis closure, but merely a change in position of a mucosal fold. The images for patient 2 for both conditions were similar, except for the presence of a pseudo-epiglottis, which, however, did not seem to hinder voicing and music play in any of the recordings.

Figure 5 shows the comparison between voicing and brass instrument play. The clear neoglottic closure during a continuous /a/ voicing (frequency here 120 Hz) and the open neoglottic tract (and the mucosal fold indicated in the videofluoroscopy images) during brass instrument play are clearly noticeable. The images for patient 2 for both conditions were similar, again, except for the presence of the pseudo-epiglottis, not hindering voicing and music play.

Both patients had no trouble with oral intake and during swallowing assessment by videofluoroscopy, the pharyngo-oesophageal segment showed a normal postlaryngectomy relaxation/behaviour during passage of the bolus. In patient 2, the pseudo-epiglottis did not seem to affect swallowing.

The objective voice assessment parameters obtained with manual occlusion of the stoma through a HME are shown in Table I. The sound pressure level at loudest voicing was similar in both patients, but patient 1 was able to speak softer, resulting in a wider dynamic range for patient 1 (29 dB) than for patient 2 (20 dB). The maximum pho-

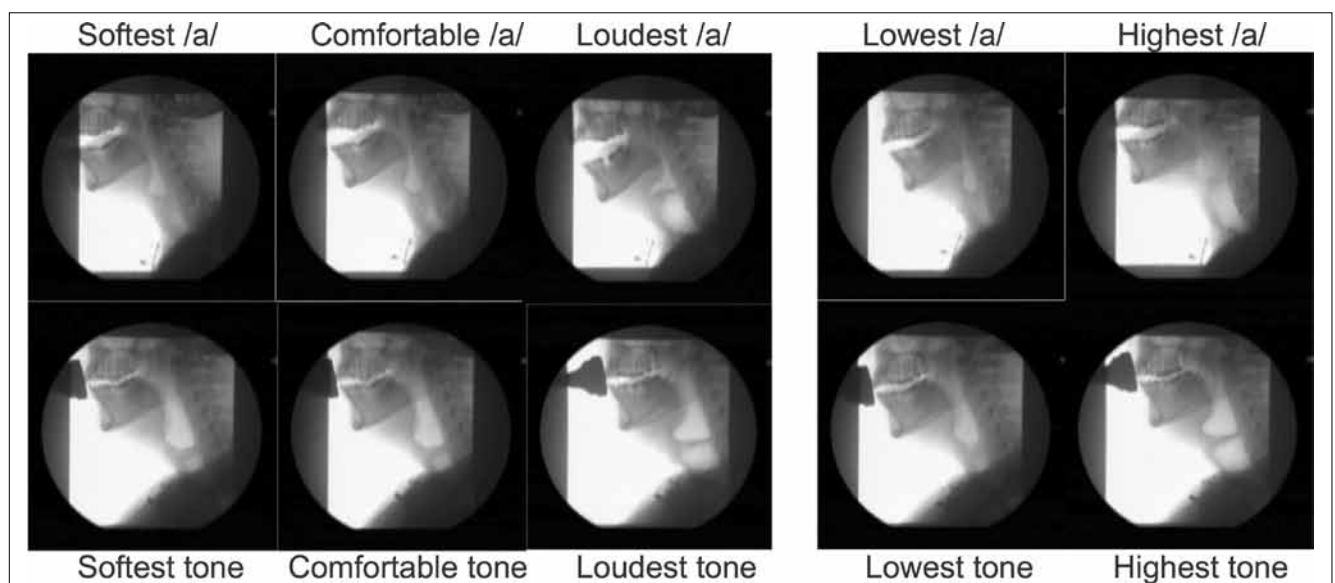


Fig. 3. Comparison of pharyngo-oesophageal segment during voicing and during tenor horn playing.

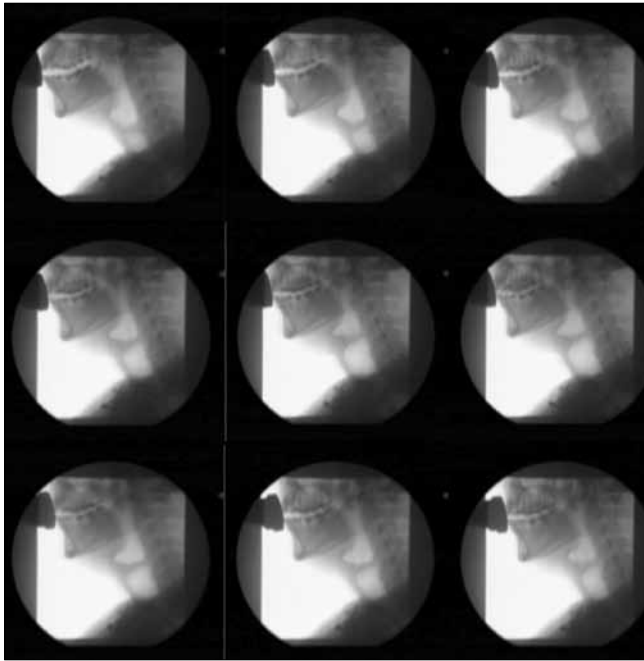


Fig. 4. Comparison of pharyngo-oesophageal segment during playing a scale from low to high and back, starting top left and ending bottom right; highest point in the scale is middle frame.

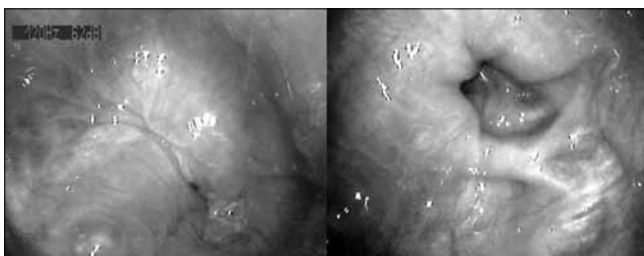


Fig. 5. Laryngoscopy/stroboscopy image of the neoglottis of patient 1 during voicing (sustained /a/; left), and during brass instrument play (right).

nation time for both patients was rather similar (22 and 19 sec). The intratracheal pressures during voicing varied from 7 mmHg for the softest /a/ to 49 mmHg for the loudest /a/. For brass instrument play, this varied from 14 mmHg for the softest tone to 48 mmHg for the loudest tone. Intratracheal pressures recorded with automatic valve occlusion for patient 1 were similar to the values obtained with manual occlusion (data not shown). As shown in Table I, for patient 1 there were slight differences in the pressures during voicing and music play with the Provox2 in situ compared to those with the Provox Vega, the pressures being somewhat lower with the Vega VP.

After application of the StabiliBase Adhesive and the customisable Nijmegen neck brace both patients were able to play their instruments bimanually, which is essential for slide trombone play. For both patients, the airtight seal dur-

Table I. Objective voice parameters, and intratracheal air pressure measurements in patient 1 (P1; professional musician) and patient 2 (P2; amateur musician) while voicing and playing the tenor horn; patient 1 was voicing with his existing Provox2 voice prosthesis first and then with the replacing Provox Vega prosthesis.

		Softest	Comfortable	Loudest
P1	Loudness in dB	57	69	86
	Dynamic range		29	
P2	Loudness in dB	65	67	85
	Dynamic range		20	
P1	Maximum phonation time		22 sec	
P2	Maximum phonation time		19 sec	
Air pressure in mmHg		Softest	Comfortable	Loudest
P1	Provox2/Vega + HME /a/	9.5/9.5	13.5/12.5	32/16
	Provox2/Vega + HME tenor horn	16/14	20/17.5	42/42
P2	Vega + HME /a/	7-11	10-14.7	33-49
	Vega + HME tenor horn	14-16.5	20-22	36-48

ing slide trombone play lasted for at least 2 hours, i.e. the duration of the practise sessions or concerts of his orchestra. An example of patient 1 bimanually playing the tenor horn and slide trombone can be seen and heard through the following link: <http://www.hoofdhalstankker.info/wpav/ wp-content/uploads/SalvatoreBarile-bimanual.mp4>.

Discussion

This study shows that trachea pressures during brass instrument play in these two laryngectomised patients are within physiological ranges for trachea-oesophageal voicing with a low-resistance indwelling voice-prosthesis. Moreover, application of a stable baseplate for the use of an automatic speaking valve⁴ and an additional customisable neck brace⁵ makes bimanual play possible again. Imaging of the neoglottis in this study for patient 1 confirms the earlier findings by Cavalot et al.¹, and adds a second case to the literature showing similar imaging results. Digital high-speed flexible endoscopy, and pitch independent assessment method of the (often irregular) vibrations of the neoglottis³, in both patients confirms the stroboscopy findings earlier obtained in patient 1¹. Voice prostheses have become the gold standard for voice rehabilitation, and over the last decades airflow resistances of indwelling voice prostheses have decreased substantially^{2,7,8}. This has resulted not only in improved and more comfortable voicing⁹, but, as also demonstrated herein, it (still) allows playing a brass instrument.

Knowledge of the trachea pressures during music play, presented here for the first time, can be used during coun-

selling to reassure similar professional and amateur musicians requiring total laryngectomy that there is still a fair chance that, as with the recovery of voicing, they will be able to continue with their work/hobby, despite the loss of their voice box. This certainly will have a positive impact on quality of life, as already mentioned by Cavalot and colleagues, who end their case report with the remark “the insertion of a voice prosthesis in a TE shunt establishes a functional unit useful not only for speech production, but also for fine lung airflow regulation, further improving QOL in patients after TL”. With the trachea pressures exerted during brass instrument play now known, clinicians can advise patients accordingly with even more confidence. Next to the important research on validated voice and speech quality assessments of the substitution voice after total laryngectomy¹⁰, objective assessments of neoglottic function and behaviour as presented here will hopefully trigger more such research on postlaryngectomy recovery prospects. This is especially relevant since the present study only concerns two cases and more series, and more musicians are needed to confirm these promising data.

Conclusions

Trachea pressures during brass instrument play are within physiological ranges for voicing in laryngectomised patients with a low-pressure indwelling voice-prosthesis. Application of a stable baseplate for retaining an automatic speaking valve and an additional customisable neck brace makes bimanual play possible again. Thus, playing a brass instrument safely can be recommended to laryngectomised patients without the risk of sanctioning undue high and potentially harmful intratracheal (back) pressures.

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mances of patient 1, carried out in conjunction with this study. Atos Medical is acknowledged for providing the Druck calibrated digital pressure indicator, and for funding travel expenses for patient 1.

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