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). The patient had his surgery in 2000 for a pT3pN0M0 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 occlusion. 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 assess 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 previously. 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 resistance), 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
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 pho-
nation 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 Omni-
paque coating of the mucosa of the neoglottis during soft/
 loud and low/high pitched voicing and the same during mu-
sic 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 configura-
tion 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-nas-
opharyngoscope (with high-resolution CCD sensor at the
distal tip) and EndoSTROB System (Xion Gmbh, Ber-
lin, 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 verifica-
tion of the vibrations/behaviour of the neoglottis. 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 ad-
hesive used for attaching the ASV was the Provox Sta-
biliBase (Atos Medical, Hörby, Sweden) with additional
silicon glue. For reinforcing and further stabilising the
adhesive seal, the customisable Nijmegen Neck Brace
was used (Fig. 2).

Results
Analysis of videofluoroscopy images showed essentially
the same pharyngoesophageal segment configuration and
Tracheoesophageal brass instrument play

functionality 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 pharyngoesophageal 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 1. 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. 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.

**Fig. 3.** Comparison of pharyngoesophageal segment during voicing and during tenor horn playing.
nation time for both patients was rather similar (22 and
19 sec). The intratracheal pressures during voicing var-
ied 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 loud-
est tone. Intratracheal pressures recorded with automatic
valve occlusion for patient 1 were similar to the values ob-
tained 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 pres-
sures being somewhat lower with the Vega VP.

Table I. Objective voice parameters, and intratracheal air pressure measures-
ments 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.

<table>
<thead>
<tr>
<th></th>
<th>Softest</th>
<th>Comfortable</th>
<th>Loudest</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loudness in dB</td>
<td>57</td>
<td>69</td>
<td>86</td>
</tr>
<tr>
<td>Dynamic range</td>
<td>29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loudness in dB</td>
<td>65</td>
<td>67</td>
<td>85</td>
</tr>
<tr>
<td>Dynamic range</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum phonation time</td>
<td>22 sec</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum phonation time</td>
<td>19 sec</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Air pressure in mmHg</th>
<th>Softest</th>
<th>Comfortable</th>
<th>Loudest</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provox2/Vega + HME /a/</td>
<td>9.5/9.5</td>
<td>13.5/12.5</td>
<td>32/16</td>
</tr>
<tr>
<td>Provox2/Vega + HME tenor horn</td>
<td>16/14</td>
<td>20/17.5</td>
<td>42/42</td>
</tr>
<tr>
<td>P2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vega + HME /a/</td>
<td>7-11</td>
<td>10-14.7</td>
<td>33-49</td>
</tr>
<tr>
<td>Vega + HME tenor horn</td>
<td>14-16.5</td>
<td>20-22</td>
<td>36-48</td>
</tr>
</tbody>
</table>

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).

After application of the StabiliBase Adhesive and the cus-
tomisable 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-
ing slide trombone play lasted for at least 2 hours, i.e. the
duration of the practise sessions or concerts of his orches-
tra. An example of patient 1 bimanually playing the tenor horn and slide trombone can be seen and heard through the
following link: http://www.hoofdhalskanker.info/wpavl/

Discussion

This study shows that trachea pressures during brass in-
strument play in these two laryngectomised patients are
within physiological ranges for trachea-oesophageal voic-
ing with a low-resistance indwelling voice-prosthesis.
Moreover, application of a stable baseplate for the use of
an automatic speaking valve and an additional custom-
isable neck brace makes bimanual play possible again.

Digital high-speed flexible endoscopy, and pitch inde-
dependent assessment method of the (often irregular)
vibrations of the neoglottis, in both patients confirms the
stroboscopy findings earlier obtained in patient 1.

Voice prostheses have become the gold standard for voice
rehabilitation, and over the last decades airflow resistanc-
es of indwelling voice prostheses have decreased substan-
tially. This has resulted not only in improved and more
comfortable voicing, 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-
Tracheoesophageal brass instrument play

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 laryngectomy 10, 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.

Acknowledgements

We are very grateful for the support of Anne Kornman SLP, Merel Laterstein SLP, and Lisette van der Molen PhD SLP with videofluoroscopy. Liset Lansaat is greatly acknowledged for taking care of the logistics of the assessment programs. Lot Zuur, MD PhD, head and neck surgeon at the Netherlands Cancer Institute is acknowledged for musical support during the professional performances 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.

References

9 Hilgers FJ, Ackerstaff AH, Jacobi I, et al. Prospective clinical phase II study of two new indwelling voice prostheses (Provox Vega 22.5 and 20 Fr) and a novel anterograde insertion device (Provox Smart Inserter). Laryngoscope 2010;120:1135-43.

Address for correspondence: Frans J.M. Hilgers, Department of Head and Neck Oncology and Surgery, The Netherlands Cancer Institute-Antoni van Leeuwenhoek, Plesmanlaan 121, 1066CX, Amsterdam, The Netherlands. Tel. +31 20512550. Fax +31 205122554. E-mail: f.hilgers@nki.nl.