Transtracheal jet ventilation in 50 patients with severe airway compromise and stridor

D. J. Ross-Anderson*, C. Ferguson and A. Patel
Department of Anaesthesia, Royal National Throat, Nose and Ear Hospital and University College London Hospital, London, UK
*Corresponding author. E-mail: davinarossanderson@googlemail.com

Key points
- Airway management is difficult in patients with stridor and critical airway stenosis undergoing laryngopharyngeal surgery.
- Transtracheal high-frequency jet ventilation (TTHFJV) has potential advantages in this scenario but data are sparse.
- In this case series of 50 procedures TTHFJV was used successfully and morbidity was low.
- Important factors include experience of the anaesthetist, and the use of an automated jet ventilator with limitation of airway pressure.

Background. Management of the airway is difficult in patients with pharyngeal or laryngeal pathology caused by malignancy, extensive surgery, or radiotherapy scarring, particularly when undergoing pharyngolaryngeal surgery. Tracheal intubation, with or without fibreoptic guidance, is often impractical because of the severe glottic stenosis and primary tracheostomy under local anaesthesia has been the preferred technique. However, complication rates as high as 30% have been reported after primary tracheostomy and there is the potential for long-term morbidity. High-frequency jet ventilation (HFJV) has several advantages over other techniques in the management of the difficult airway and can be delivered by supraglottic and infraglottic routes. To date, no large series has described the use of transtracheal HFJV (TTHFJV) in adult patients with stridor and critical airway obstruction.

Methods. We report a prospective, descriptive audit of the safe use of TTHFJV in patients with severe airway compromise and stridor undergoing pharyngolaryngeal surgery (50 consecutive procedures in 44 patients).

Results. TTHFJV was successful in all 50 cases. There were no major complications and the incidence of minor complications was 20% with no subsequent morbidity.

Conclusions. We attribute this low incidence to the use of an automated jet ventilator with airway pressure monitoring and control, and the alteration of ventilator parameters by an experienced anaesthetist.

Keywords: airway obstruction; high-frequency jet ventilation/methods; laryngeal stenosis, complications; otorhinolaryngological surgical procedures; tracheostomy, methods

Accepted for publication: 30 June 2010

Pathological pharyngeal or laryngeal anatomical abnormalities caused by malignancy, extensive surgery, or radiotherapy scarring can present significant airway management challenges to the anaesthetist. When these patients require pharyngolaryngeal surgery, they present additional problems of optimal and safe surgical access. Tracheal intubation, with or without fibreoptic guidance, is often impractical because of the severity of glottic narrowing. Historically, primary tracheostomy under local anaesthesia has been considered the optimum airway management technique in patients with severe airway compromise requiring airway surgery, but complication rates as high as 30% have been reported and long-term morbidity can cause patient dissatisfaction.

High-frequency jet ventilation (HFJV) is an alternative to tracheal intubation or tracheostomy. Transtracheal oxygenation via a needle puncture was introduced in the 1950s as a resuscitation measure using oxygen insufflation and progressed to ventilation using intermittent oxygen supplied at 4 bar. It has since been described as suitable for use in elective surgery including oral surgery, endolaryngeal surgery, anticipated difficult airway, and as a rescue technique in the ‘Can’t intubate, can’t ventilate’ scenario. It has more recently been described as the technique of choice for laryngeal surgery, especially laryngeal endoscopy, and transtracheal HFJV (TTHFJV) has been reported in the 2% of the patients who require elective airway control.

Transtracheal jet ventilation has several advantages in the management of the difficult airway. These include: securing the airway before induction of general anaesthesia; reducing the need for tracheostomy under local anaesthesia; eliminating the need for laryngoscopy to secure the airway; providing an unobstructed view of the larynx; and the potential to leave the catheter in place in the event that the patient needs further respiratory support.

The choice of route for HFJV will be governed by the intended surgery and the degree of abnormality or obstruction of the airway. Supraglottic techniques require the
airway to be established by the surgeon with an interruption in airway maintenance while responsibility is handed over to the anaesthetist. The quality of ventilation is dependent on the ability of the surgeon to align the jet with the airway, which may be affected by surgical priorities and anatomical abnormalities. The lack of a direct line of sight to the glottis may lead to poor alignment and ineffective ventilation. Subglottic techniques may be impeded by difficult direct laryngoscopy and cause an obscured surgical field. TTHFJV can overcome these difficulties in patients undergoing pharyngolaryngeal surgery.

Methods

A prospective audit database of patients has been kept since 1999 at our institution, and these data represent our first intended analysis after 50 procedures. Patients were included if they had severe airway obstruction (>75% reduction in the lumen) secondary to tumour, previous radiotherapy, oedema, or fibrosis, in whom TTHFJV was considered to be the most appropriate route of airway management for anaesthetic, surgical reasons, or both. Individual case reports have described successful TTHFJV as an emergency technique before definitive airway management in patients with stridor, and case series have included patients with stridor within their groups. In our knowledge, this is the first series concentrating solely on the use of TTHFJV as the principle ventilatory strategy for elective surgical procedures in adult patients with stridor and critical airway obstruction.

We present a case series of 50 procedures in patients who had stridor and severe airway compromise (>75% reduction in the lumen) secondary to tumour, previous radiotherapy, oedema, or fibrosis, in whom TTHFJV was considered to be the most appropriate route of airway management for anaesthetic, surgical reasons, or both. Individual case reports have described successful TTHFJV as an emergency technique before definitive airway management in patients with stridor, and case series have included patients with stridor within their groups. Previous case series of TTHFJV have not specifically described its use in adult patients with stridor and critical airway obstruction.

Results

Fifty procedures were performed on 44 patients [mean age 60 (range 21–88) years]. Twenty-six procedures were undertaken in subjects with stridor on exertion and 24 in patients with stridor at rest. Their characteristics are listed in Table 1. All patients were of ASA grade III or above.

Airway maintenance for emergence was achieved using either a face mask with or without oropharyngeal airway, laryngeal mask airway (LMA), or tracheostomy. If the TTC had not been removed due to tracheostomy formation, removal immediately after emergence, in recovery, or 24 h later on the ward was at the anaesthetist’s discretion. Complications were recorded.

Face-mask ventilation was easy in 54% (27/50), difficult in 40% (20/50), and impossible in 6% (3/50) (Fig. 1). Of the 50 procedures, 44 were carried out electively in awake patients under local anaesthesia and six after induction of anaesthesia because of difficulty with face-mask ventilation. The site of insertion was evenly distributed between the cricothyroid membrane (28%), below first tracheal ring (38%), and below second tracheal ring (34%). Insertion was successful at the first attempt in 84%, second attempt in 10%, and third attempt in 6%.

Adequate ventilation was obtained in 96% of the patients using DP <2 bar, and no case required a DP >3 bar.
In 14 patients, the ventilation rate had to be reduced from 100 min\(^{-1}\) to allow adequate expiratory time. This was necessary in 22% of those who were easy to mask ventilate, but 35% of the difficult/impossible mask ventilations needed rate reduction (Table 2). Similar figures were seen regarding stridor, with a 21% of exertional stridor patients needing rate reduction compared with 35% of those with stridor at rest (Table 3).

Patients were maintained on TTHFJV for the duration of the surgery in 90% of the cases, avoiding tracheal intubation entirely. The remaining 10% were changed to other airway devices (4% nasal tracheal tube, 4% microlaryngoscopy tube, and 2% LMA) after tumour debulking. Twelve patients had tracheostomy formation either as a primary procedure or for laryngectomy. Of the remainder, emergence was managed with an LMA in 71% (27/38) and a face mask in 29% (11/38). Removal of the TTC was done for the tracheostomy in 12 cases, in theatre post-procedure in 19, in recovery in two, and on the ward after 24 h in 17 cases. Twelve % (2/17) of the TTCs left in for 24 h were used for insufflation of oxygen on the ward.

Ten complications occurred (Table 4); all were minor and resolved without sequelae. There were no episodes of desaturation below 95%, no pneumothoraces, no cardiovascular instability, and no postoperative complications. In the two patients who bled, TTC insertion was successful at the first attempt, bleeding was minor (<5 ml) and caused no airway compromise. The case of surgical emphysema, which was confined to the neck, occurred in a patient who had successful TTC insertion at the first attempt but needed high DP (2.1–3 bar) and in whom face-mask ventilation was impossible. In four cases, catheters became kinked and needed replacing, and in three cases, kinked catheters could be used effectively after manipulation to allow an adequate gas flow. Complications were not increased by a low anatomical approach, previous radiotherapy history, stridor severity, severity of airway obstruction, or the procedure being performed by a less senior anaesthetist.

### Table 1 Patient characteristics showing underlying diagnosis and elective surgical procedure undertaken

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Number of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laryngeal malignancy</td>
<td>34</td>
</tr>
<tr>
<td>Oropharyngeal malignancy</td>
<td>12</td>
</tr>
<tr>
<td>Rheumatoid disease of the larynx</td>
<td>1</td>
</tr>
<tr>
<td>Bilateral vocal cord palsy</td>
<td>1</td>
</tr>
<tr>
<td>Glottic haematoma</td>
<td>1</td>
</tr>
<tr>
<td>Laryngeal oedema</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Surgery</th>
<th>Number of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transoral laser</td>
<td>27</td>
</tr>
<tr>
<td>Microlaryngoscopy + biopsy</td>
<td>8</td>
</tr>
<tr>
<td>Panendoscopy</td>
<td>6</td>
</tr>
<tr>
<td>Tracheostomy</td>
<td>6</td>
</tr>
<tr>
<td>Laryngectomy</td>
<td>3</td>
</tr>
</tbody>
</table>

### Table 2 HFJV rate and DP compared by difficulty of face-mask ventilation. The standard ventilatory rate was set at 100 min\(^{-1}\). This was reduced incrementally if the PP exceeded 10 mbar. The DP was set at 1 bar and increased to maintain \(\text{So}_{2} > 95\%\) to a maximum of 3 bar. No significant difference (\(\chi^2\)) was found between the ease of face-mask ventilation groups for changes in ventilatory rate or for DP

<table>
<thead>
<tr>
<th>Ease of face-mask ventilation</th>
<th>Easy (n=27)</th>
<th>Difficult (n=20)</th>
<th>Impossible (n=3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilatory rate, standard/reduced</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driving pressure (bar),</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–1.0/1.1–2.0/2.1–3.0</td>
<td>13:13:1</td>
<td>7:13:0</td>
<td>1:1:1</td>
</tr>
</tbody>
</table>

### Table 3 HFJV rate and DP compared by the severity of stridor. No significant difference (\(\chi^2\)) was found between the severity of stridor groups for changes in ventilatory rate or for DP

<table>
<thead>
<tr>
<th>Stridor on exertion (n=24)</th>
<th>Stridor at rest (n=26)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilatory rate, standard/reduced</td>
<td></td>
</tr>
<tr>
<td>Driving pressure (bar), 0–1.0/1.1–2.0/2.1–3.0</td>
<td>11:11:2</td>
</tr>
</tbody>
</table>

### Table 4 Observed complications of TTHFJV in this series

<table>
<thead>
<tr>
<th>Complication</th>
<th>Incidence [n (%)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinking of catheter</td>
<td>7 (14)</td>
</tr>
<tr>
<td>Bleeding</td>
<td>2 (4)</td>
</tr>
<tr>
<td>Surgical emphysema</td>
<td>1 (2)</td>
</tr>
<tr>
<td>None</td>
<td>40 (80)</td>
</tr>
</tbody>
</table>

Fig 1 Assessment of ease of ventilation after induction of anaesthesia and neuromuscular blockade. The three patients with impossible face mask ventilation all had stridor at rest, but stridor at rest did not predict difficult face mask ventilation overall (\(\chi^2\) no significant difference).
Discussion

In this series of patients with stridor and severe airway compromise undergoing pharyngolaryngeal surgery, we found TTHFJV at the cricothyroid or first or second tracheal space to be safe with no serious complications, and 80% of the cases were uneventful. Previously documented minor complications of TTHFJV, including kinking of the catheter, soft tissue emphysema, and bleeding, occurred. There were no instances of other major pressure-related complications (pneumomediastinum, or cardiovascular instability), which contrast with reports of TTHFJV as the major independent risk factor for complications during laryngeal surgery compared with other methods of ventilation. Some authors have cautioned against the use of TTHFJV when ventilation from supraglottic or subglottic catheters is possible, as the risk of iatrogenic injury with TTHFJV is too high. The risk of complications and benefit of an expected surgical outcome must be carefully considered when choosing transtracheal over supraglottic or subglottic HFJV.

Safe TTHFJV requires a free passage of inspiratory and expiratory gases since pulmonary barotrauma or cardiovascular instability is more likely to occur if there is a reduced or intermittent expiratory pathway. This is a particular risk in oropharyngeal and laryngeal tumours and post-radiotherapy, although our series includes these pathologies. A higher risk of serious pressure-related complications might be expected when there is a greater degree of airway obstruction, although this has not been shown as significant in the small number of severe airway obstruction cases included in the larger TTHFJV series or in the current report.

A recent survey into jet ventilation practice in the UK noted that transtracheal jet ventilation is performed by only a third of centres conducting airway surgery, compared with rates of 50% and 86% for subglottic and supraglottic jetting, respectively. Despite this, transtracheal high-pressure ventilation was involved in an equal proportion of the complications, implying a higher complication rate with this technique, although denominator data were not fully available. It is notable that most serious complications, and all deaths, reported in that survey occurred during the use of manual ventilation techniques. Automatic ventilators featuring a pressure monitor/alarm and automatic cut off when a peak or pause airway pressure is raised may protect against some instances of pressure-related complications. We use an automated ventilator with this facility and are able to adjust the ventilator parameters by reduction in rate and DP. The presence of a second anaesthetist to monitor and ensure maintenance of an unobstructed upper airway is also an important factor in preventing increased airway pressures.

Other case series report an increase in complications when multiple attempts or anatomically low approaches are made and in patients who have cancer, have had radiotherapy, and when inexperienced operators perform the procedure. The majority of our cases fit at least one of these categories but our incidence of major pressure-related complications was zero. Our total complication rate of 20%, with only minor complications, compares favourably with rates of 5–15.4% in case series with low risk patients.

It has been shown that the rate of complications is directly related to the number of jet ventilation episodes performed and that in the UK, centres performing more than 100 jet ventilation cases per year have complication rates of around 1%. Our centre performs over 700 HFJV cases annually, of which the minority are transtracheal and our practice is to use subglottic HFJV for benign vocal cord work and supraglottic HFJV for smaller supraglottic lesions and subglottic stenoses, including a majority with stridor and severe airway compromise. We perform ~50 TTHFJV cases annually in selected patients with bulky supraglottic lesions, and 1/10th of these patients have stridor and severe airway compromise. We reserve the transtracheal route for cases where it is the only option anaesthetically or surgically, since it may be a higher risk strategy than supraglottic or subglottic HFJV.

As a consequence of this, the patients receiving TTHFJV in our unit are high-risk patients, but the expected surgical benefit using this technique outweighs those risks.

In summary, we report the safe use of TTHFJV in a series of patients with severe airway compromise and stridor. With the careful use of an automated jet ventilator with airway pressure monitoring and control, and the alteration of ventilator parameters by an experienced anaesthetist familiar with the technique, complication rates can be as low as when TTHFJV is used in patients with no airway compromise. Case series and surveys may overstate the dangers of TTHFJV when assessed retrospectively. Despite this, we believe that the safety, efficacy, and non-invasive nature of other HFJV techniques should keep TTHFJV as a technique for only the most complicated anaesthetic or surgical problems.

Conflict of interest

A.P. has received an honorarium from The Laryngeal Mask Company.

Funding

Support was solely from departmental resources.

References