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REVIEW

Advances in laryngeal and airway surgery: what has changed?

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Abstract

Laryngeal and airway surgery continues to see innovation and advances, similar to other specialties of modern medicine. Research in this field has led to a greater understanding of conditions resulting in new terminology, diagnoses and change in management. This article looks at advances in laryngeal and upper airway surgery and discusses their ongoing impact on clinical practice.

Key words: Airway stenosis; Airway surgery; Endoscopic surgery; Laryngeal injury; Robotic surgery

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Introduction

Laryngeal and airway surgery continues to see innovation and advances in prevention, diagnosis and management. Research has led to a greater understanding of conditions resulting in new terminology, diagnoses and changes in clinical practice.

Prevention

Despite advances in the treatment of laryngeal and airway conditions, prevention remains better than cure. Iatrogenic causes remain one of the most common causes of injury to this part of the body. These include patients requiring intubation, those with a prolonged stay on intensive care units and those undergoing treatment for head and neck cancer. All of these can result in long-term injury to the larynx and trachea which can have a significant impact on a patient's quality of life. The key functions of the larynx – breathing, voice and a safe swallow – are inextricably linked and loss of these can have life-changing effects for the patient (Brodsky et al, 2018).

The polio pandemic in the 1950s led to an increased incidence of intubation- and ventilation-related problems. Greater understanding of these has led to the development of methods to decrease the incidence of injury to the larynx and trachea. For example, an inflated cuff in the airway reduces blood flow to the trachea and can cause ulceration, erosion and scarring, so high-volume, low-pressure cuffs are now used and the pressure is measured regularly with a manometer to prevent long-term injury to the trachea (Haas et al, 2014).

Most tracheostomies are now performed percutaneously. This is a safe technique often performed on the intensive care unit, and a systematic review has shown that this has reduced infection rates and levels of tracheal stenosis compared to an open tracheostomy. This is partly a result of the smaller defect created in the trachea and wound compared to an open tracheostomy, but there is also an element of selective bias as patients that require an open tracheostomy often have multiple comorbidities (Brass et al, 2016).

The TracMan trial revealed there was no difference in mortality between an early or late tracheostomy in patients requiring long-term ventilator support (Young et al, 2013). The benefit of an early tracheostomy is that it helps to prevent damage to the larynx. Using an endotracheal tube for prolonged intubation can cause scarring in the posterior glottis and result in injury to the delicate cricoarytenoid joints. This can lead to patients living with a reduced airway and possibly requiring a lifelong tracheostomy or airway reconstruction (Lornz, 2003).

Developments in intensive care nursing have also helped to prevent the sequelae of long-term ventilation. Airway humidification, manometer checks, suctioning and turning

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patients all help to reduce the risk of airway injury. Early rehabilitation with physiotherapy and speech and language therapy to start vocalising and swallowing early will help clear secretions in the larynx, speed up recovery and move towards being able to decannulate the patient earlier (Wallace and McGrath, 2021).

Advances in the treatment of head and neck cancer that aim for functional preservation without compromising oncological outcomes include endoscopic laser resection and transoral robotic surgery for oropharyngeal and laryngeal tumours as well as intensity modulated radiotherapy. Although adverse effects can still occur in the larynx and airway following cancer treatment, there is a greater understanding of the impact on the patient's quality of life and the multidisciplinary team makes efforts to reduce this.

Assessment

Since the human larynx was first viewed with a mirror over 150 years ago, laryngoscopy has continually developed. Today distal chip scopes are widely available and enable high-definition visualisation of the larynx and airway. The nasendoscope is now lighter, offers a higher resolution and recorded images can be easily viewed for assessment and treatment (Hantzakos and Khan, 2021). Patients can view the images to help them understand their condition and biofeedback techniques can be used to help with breathing techniques. This is particularly useful in patients with inducible laryngeal obstruction, who can be given speech and language therapy strategies to help them control and overcome breathing issues.

Continuous laryngoscopy during exercise allows observation of the dynamic movement of the larynx and upper airway. This is used in combination with pulmonary exercise testing and helps diagnose and treat patients with exercise-induced laryngeal obstruction (Koh et al, 2023) (Figure 1).

Computational fluid dynamics is a method of understanding airflow through the airway. It uses traditional imaging such as computed tomography to create three-dimensional models of the airway. It can help understand the extent of the airway pathology and to decide which intervention is necessary to improve airflow (Faizal et al, 2020) (Figure 2).

Images created on the latest endoscopes and scans can easily be shared with the multidisciplinary team. Many centres now run a joint upper airway clinic, with a

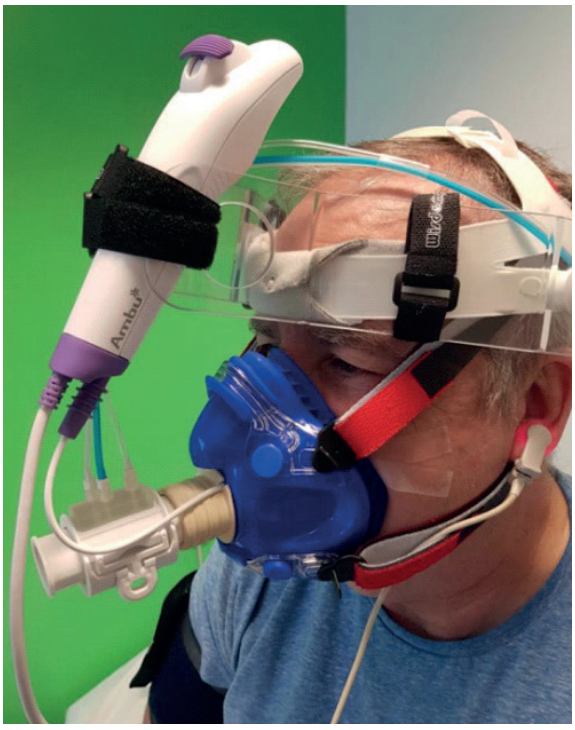

Figure 1. Flexible nasoendoscope anchored to a face mask and head band, allowing continuous visualisation of the larynx during exercise.

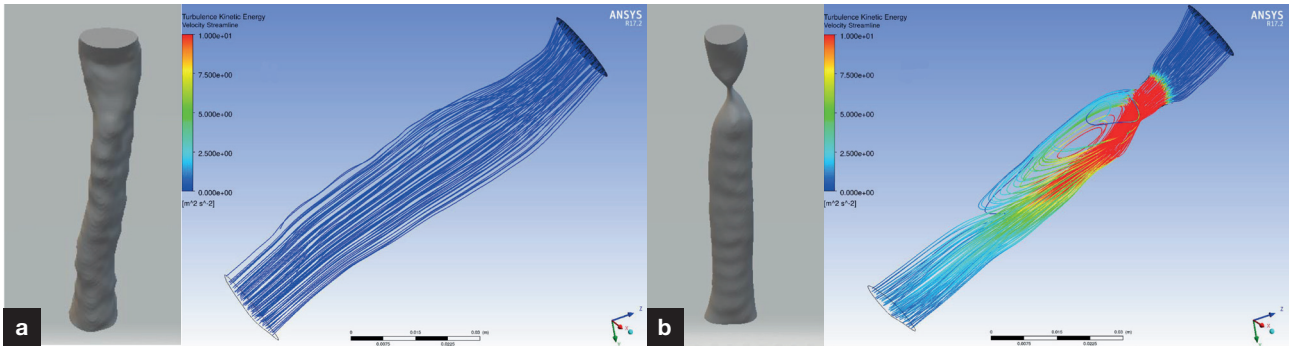

Figure 2. Tracheal geometries and velocity streamlines of (a) a normal trachea and (b) a stenotic trachea.

multidisciplinary team approach involving otolaryngology, respiratory, cardiothoracic surgeons, physiotherapists, speech and language therapists and psychologists. The multidisciplinary team is vital for managing complex cases in a holistic manner.

Treatment

Medical

Vasculitis, specifically granulomatosis with polyangiitis, can affect the airway and cause inflammation and fibrosis in the tracheobronchial tree. Immunosuppression helps control inflammation and reduce re-stenosis in the airway, although frequent dilatations might still be required. Use of monoclonal antibodies, such as rituximab, has led to better disease control and higher remission rates. Monoclonal antibodies can reduce airway inflammation in people with vasculitis and potentially prevent re-stenosis even in patients with idiopathic subglottic stenosis (Zammit et al, 2022).

Anaesthesia

Advances in airway surgery would not be possible without developments in anaesthesia. There are challenges of shared airway surgery for both the surgical and the anaesthetic teams. In some cases, traditional endotracheal intubation is not possible as a result of airway stenosis and in other cases intubation prevents access to the operative area. Rigid ventilation bronchoscopes are still used but limit the procedures that can be performed. Flexible bronchoscopy has continued to advance, with the equipment becoming smaller and an increasing number of flexible instruments including forceps, lasers and diathermy that can be passed down the working channel (Pearson and McGuire, 2017).

Many ear, nose and throat surgeons prefer to perform airway procedures using suspension laryngoscopy, which has not changed in many years. This allows the surgeon to have both hands free to use instruments and mobilise the larynx. Doing this without an endotracheal tube has typically required high frequency jet ventilation that could be supraglottic, transglottic or infraglottic (with a jetting a catheter placed in the trachea, such as a Hunsaker tube). Transnasal humidified rapid-insufflation ventilator exchange enables a prolonged apnoeic time and reduces the level of end-tidal carbon dioxide. This uses high flow oxygen to enter the nose at 70–90 litres/min and can be used alongside other techniques to prevent desaturation at induction. However, care must be taken when using laser or diathermy with high flow oxygen because of the risk of airway fires (Patel and Nouraei, 2015).

Surgical techniques

Advances in surgical equipment have led to a rise in office-based ear, nose and throat procedures. This prevents the need for general anaesthesia, is cheaper and frees up theatre space (Hantzakos and Khan, 2021). Transnasal oesophagoscopy with dilatation, biopsy and laser can all be performed safely under local anaesthesia and are normally well tolerated. Fibreoptic laser fibres have been used to treat papillomas and other lesions in the upper airway under local anaesthesia in the clinic. The latest is the ‘blue laser’ which combines the properties of different lasers to aid with both cutting and treating subepithelial lesions. Botulinum toxin under local anaesthesia has been used for decades to selectively denervate

laryngeal muscles and treat conditions such as spasmodic dysphonia and dystonias. This is typically performed under laryngeal electromyography guidance and advances in equipment have improved the accuracy of this procedure. Laryngeal electromyography is more widely used to diagnose vocal cord paresis and aid patient selection for laryngeal reinnervation surgery.

Endoscopic laryngotracheal surgery has been developed to treat subglottic stenosis in children. The cricoid is split endoscopically and a posterior cartilage graft inserted to expand the airway. This is possible in children because they have softer cartilage which has not yet ossified and is effective in cases of posterior glottic stenosis, cricoarytenoid joint fixation or bilateral vocal cord paralysis (Blanchard et al, 2014).

Autologous rib cartilage grafts have traditionally been used to expand the cricoid in patients with subglottic stenosis. Use of homologous cartilage grafts such as Tutoplast (an irradiated homologous costal cartilage; Corza Medical, New Jersey) can speed up the operation and have shown reduced morbidity (Kherani et al, 2020).

Laryngeal reinnervation

Laryngeal reinnervation techniques have been used to treat vocal cord paralysis for almost a century. Non-selective reinnervation is when an anastomosis is created between the main stem of the recurrent laryngeal nerve and the donor nerve (vagus nerve, phrenic nerve or ansa cervicalis). Although this does not create movement, it keeps the tension in the vocal cord and prevents muscular atrophy. This has good voice outcomes for the patients compared to traditional medialisation techniques (Gibbins, 2014).

Selective reinnervation is a procedure for patients with bilateral vocal cord palsy who have mobile cricoarytenoid joints. A nerve conduit is harvested and attached to a branch of the phrenic nerve (C3); this is then used to innervate the posterior cricoarytenoid muscles. This procedure aims to create movement of the vocal cords and has been helpful in children to enable removal of a tracheostomy (Lee et al, 2020).

Future

Vaccination

Vaccinations against human papillomavirus infection have been available for almost two decades. Following 10-year surveillance in Australia, the vaccination has led to reduction in the prevalence of both resurrect respiratory papillomatosis and oropharyngeal cancer. Considering the long latency period between human papillomavirus infection and progression to cancer and the introduction of more worldwide vaccination programmes, the full impact of the vaccine is yet to be seen (Patel et al, 2018).

Robotic surgery

Robotic surgery is increasingly commonly used to treat head and neck cancers. The robot allows better visualisation with a magnified three-dimensional view and greater freedom of movement to the surgeon. Endoscopic surgery can take place in narrow and deep sites, without the morbidity associated with open surgery. Despite advances in technology, current systems are bulky, and access may still be limited in the airway. Flexible single-port robotic systems are being developed, and more streamlined devices could enable robotic surgery to become a viable option in laryngeal and airway surgery (Hockstein et al, 2005).

Laryngeal pacing

Treating permanent bilateral vocal fold paralysis is challenging. Bilateral laryngeal reinnervation is not suitable for every patient and requires extensive surgery. The more common surgical techniques involve widening the space between the vocal cords, either open or endoscopically. This static modification of vocal cords improves respiratory function but can result in loss of voice quality and risk of aspiration on swallowing. Dynamic restoration would improve respiratory function without compromising the voice or swallow. In animal models, stimulation of the paralysed posterior cricoarytenoid muscle restored ventilation and exercise tolerance. Pioneering clinical trials demonstrated that using an external pacemaker, fixed on the chest wall and connected to minimally invasive electrodes

into the posterior cricoarytenoid muscle (the key muscle for vocal cord abduction), could significantly improve ventilation with no negative effect on voice quality. There are ongoing studies in this area, both in human and animal models, and this could be life changing for these patients in future (Mueller et al, 2017; Leonhard et al, 2023).

Airway stents

Intratracheal stents have been used to treat a variety of conditions causing airway stenosis. However, their use can lead to complications, including granulation formation, migration and perforation, so they are mostly used temporarily or in a palliative situation. Traditional stents were made of a variety of materials. Nitinol-covered stents, like AERO stent by Merit Medical, are an attractive option for difficult cases. Nitinol is a metal alloy of nickel and titanium, which has increased elasticity and shape memory. This allows the stents to be deployed endoscopically using a pre-loaded delivery system and maintain their transformed structure once in situ. A radio-opaque tip allows accurate placement and verification of placement as needed (Mehta, 2008).

Biodegradable stents are being studied. Most are made of synthetic polymers and disintegrate within 12–15 weeks. They are intended to maintain airway patency for a predetermined time, without endoscopic removal being required. This could be especially relevant for use in the developing airway in children. Drug-eluting stents could deliver medications, such as steroids or mitomycin C, locally to prevent airway granulation and fibrosis (Dutau et al, 2015).

Laryngeal electrical stimulation

Electrical stimulation is a potential therapeutic measure following peripheral nerve injury, which could not only promote regeneration and reinnervation of denervated muscles, but also promote specificity of reinnervation. The applicability of selective electrical surface stimulation for treating unilateral vocal cord paralysis has shown promising results in trials, but not yet integrated into clinical practice (Kurz et al, 2021). As for bilateral vocal cord palsy, selective stimulation of denervated posterior cricoarytenoid muscle in a canine model improved functional recovery and minimised paradoxical closure of the glottis during inspiration. These results should promote further investigation of functional electric stimulation of the posterior cricoarytenoid muscle during the critical period of regeneration following recurrent laryngeal nerve injury (Mueller, 2011).

Human laryngeal and tracheal transplantation

Laryngeal transplantation has been performed in isolated cases in humans. Unlike other organ transplants, the trachea and to some extent the larynx do not have isolated vessels for arterial and venous drainage. The other limitation is the need for immune suppression to prevent rejection in an organ that is constantly exposed to inhaled pathogens. In vitro studies used larynxes that had been irradiated pre-transplantation, which improved immune tolerance. Another limitation in creating a functional larynx is reinnervation of abductor and adductor motor nerves as well as the sensory nerve (Bewley and Farwall, 2020). Successful tracheal transplantation has been performed in a staged procedure using an autologous free flap from the forearm muscles while the irradiated donor tracheal cartilage gains a blood supply. Advances in this area were hindered by the tracheal transplant scandal where stem cells were used with a synthetic tracheal scaffold. This had catastrophic effects for patients and any future research in this field will be carefully scrutinised.

Conclusions

Laryngeal and airway surgery is a constantly developing field, with great changes in practice in recent years. With ongoing research and evolution of knowledge and experience, further innovations are expected, providing better options for treating patients.

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Key points

- Laryngeal and airway surgery continues to see innovation and advances.
- Prevention of iatrogenic airway injuries, by improving ventilation and airway management techniques, reduces the frequency and severity of laryngotracheal stenosis.
- Introduction of new endoscopic and imaging technologies allow a vivid view and better understanding of airway physiology and pathologies.
- Treatment modalities continue to evolve. New technologies have revolutionised surgical techniques with incorporation of endoscopic and robotic technologies. With ongoing research and development more is yet to come.

Conflicts of interest
The authors declare that there are no conflicts of interest.

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