Review Article

Anaesthesia for transoral robotic surgery in oral cancer: a review

Clementina M. Calabria^, Patrick A. Ward^

Department of Anaesthesia, St John's Hospital, Livingston, NHS Lothian, Scotland, UK

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Correspondence to: Dr. Patrick A. Ward. Consultant Anaesthetist, Department of Anaesthesia, St John's Hospital, Howden West Road, Livingston, EH54 6PP, Scotland, UK. Email: patrickward81@hotmail.com.

Abstract: Oral cancer is the sixth most common cancer worldwide, of which 90% is squamous cell carcinoma (SCC), with habitual smoking and alcohol consumption remaining the significant risk factors. Current treatment modalities include chemotherapy, radiotherapy and surgery, alone or in combination. Transoral robotic surgery (TORS) is the most recently introduced surgical technique, that permits minimally invasive surgery to be performed in patients that would previously have undergone major open oromaxillofacial procedures associated with significant patient morbidity. While TORS appears to offer numerous advantages over open surgery, it brings with it a different set of challenges to the anaesthetist, particularly with respect to restricted intraoperative access to the airway, the necessity for meticulous planning and preparation of perioperative management, the unique operating theatre ergonomics, and the distinct procedure-specific postoperative requirements and complications. Since TORS' introduction, the associated surgical, functional and oncological outcomes have been relatively well studied; however, there is limited anaesthetic-specific guidance currently available. Supported by the most up-to-date scientific evidence, this review aims to provide a detailed summary of the pertinent anaesthetic considerations and recommended perioperative strategies for TORS, in order to aid clinicians in their decision-making and conduct of anaesthesia, so that surgical access and operating conditions can be optimized, complications may be mitigated and patient outcomes enhanced.

Keywords: Anaesthesia for oral cancer; transoral robotic surgery (TORS); minimally invasive surgery

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Introduction

Transoral robotic surgery (TORS) is the most recent development in surgical techniques in the treatment of oral cancer (1). It allows surgeons unprecedented access to the oropharynx, whilst also offering potential benefits over traditional non-surgical treatments, where curative chemoradiotherapy (or neo-adjuvant therapy) may result in delayed and significant patient morbidity.

Background

Tumours of the oropharynx, of which 90% are squamous cell carcinoma (SCC), include those originating from the tonsillar region, base of tongue, soft palate and posterolateral oropharyngeal walls (2,3). Oropharyngeal SCC is associated with habitual smoking and alcohol consumption, as well as more recently identified human papilloma virus (HPV) infection (4). The rise in HPV-

^ ORCID: Clementina M. Calabria, 0000-0002-5336-0750; Patrick A. Ward, 0000-0003-1925-9744.

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associated malignancy has led to younger patients presenting with reduced premorbid disease burden, shifting the focus of management towards morbidity-free survival (5-7). Treatments for oropharyngeal cancer include chemotherapy, radiotherapy and surgery, alone or in combination. Radiotherapy and surgery are most commonly used in the treatment of head and neck cancer, with similar survival rates, but different side-effect profiles (8). Long-term toxicity caused by chemoradiotherapy includes severe mucositis and dysphagia requiring percutaneous endoscopic gastrostomy (PEG) or radiologically-inserted gastrostomy (RIG) feeding (9). In assessing the most appropriate treatment pathway, the multidisciplinary team (MDT) must take an individualised approach to each patient, tailoring treatments based upon tumour response and patient's tolerance to side-effects.

The primary open surgical approach to oropharyngeal malignancy involves gaining direct access to the tumour through mandibulotomy or pharyngotomy procedures (6), associated with a high risk of aesthetic deformity, malocclusion and dysphagia (2). Consequently, this surgical approach has now become less common, with randomized controlled trials having demonstrated comparable outcomes with radical chemoradiotherapy (2). However, more recently, the extensive reporting of delayed toxicity from chemoradiotherapy treatments has turned the focus back towards surgical management. Over the last four decades, minimally invasive techniques such as transoral laser microsurgery (TLM), transoral videolaryngoscopic surgery (TOVS) and endoscopic laryngopharyngeal surgery (ELPS) have gained popularity, due to their potential for lower morbidity (10).

TLM is a well-studied, effective treatment option, with good functional outcomes, however its utility is limited by the restricted access to the base of tongue, the difficulty in teaching the technique, and the requirement for margin review of resected tissue (which if not tumour-free, may necessitate adjuvant chemoradiotherapy) (11,12). TORS is superior in its ability to visualise the aerodigestive tract, with improved precision and optics (13,14), such that its use has expanded to include surgery on the larynx, hypopharynx and skull base (15). For oropharyngeal cancer specifically, its use is associated with reduced bleeding and infection intraoperatively and immediately postoperatively compared with open surgical approaches, as well as improved wound healing (16). There is a decreased requirement for PEG/RIG and tracheostomy placement, though a recent randomized controlled trial showed this conferred no significant impact upon long-term quality of life scores or patient outcomes (17).

The original surgical robot models were designed in the late 1980s, and have since become widely adopted in urological, general and gynaecological laparoscopic surgery. In the field of head and neck surgery, TORS was first described for laryngectomy in a canine subject, using the da Vinci® Surgical Robot (Intuitive Surgical, Sunnyvale, CA, USA) (18)—still the most commonly used system in current practice. The surgeon uses a master-control console together with a three-dimensional (3-D) vision system to guide three arms (two for surgical instruments and one for the endoscopic cameras) which originate from a robotic side-cart positioned next to the patient (15). The endoscopic cameras and vision system combine to provide excellent high quality 3-D views, and the robotic arms have the advantage of tremor abolition, motion scaling, and wristed instrumentation (ideal for surgical sites with limited accessibility, like the oropharynx).

For now, TORS remains limited to specialist institutions where the higher case numbers permit the necessary MDT training as well as justifying the financial costs associated with the robotic equipment. Logistical and practical aspects, including the requirement for a spacious operating theatre and storage facilities (given the large footprint of the robot platform) must also be considered. Patient selection is key to success, and must be guided by MDT assessment, taking into account a number of accepted contraindications to TORS (discussed later).

Rationale and knowledge gap

TORS is a relatively new surgical technique in the treatment of oral cancer, when compared with more established primary open techniques; however, it is becoming more widely adopted in tertiary head and neck surgical centres. Consequently, anaesthetists specializing in head and neck anaesthesia at these institutions must be aware of the main perioperative requirements of TORS, so that they can tailor their preoperative evaluation, intraoperative management, and postoperative care accordingly. While the surgical, functional and oncological outcomes of TORS have been studied increasingly in recent years, there is a paucity of studies relating specifically to the anaesthetic techniques, and relatively limited existing clinical guidance for anaesthetists.

Objective

This review aims to provide anaesthetists with greater

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awareness and knowledge of the anaesthetic considerations for patients undergoing TORS for oral cancer, largely dictated by the unique surgical requirements of this treatment approach. Based upon the best available scientific evidence, it provides guidance to anaesthetists on factors determining patients' suitability for TORS, important aspects of preoperative evaluation, factors to consider in formulating and executing safe airway management, the elements of intraoperative care that can be tailored to facilitate robotic surgery, as well as the principles of postoperative care, in order to optimize patient outcomes.

TORS has more recently expanded to the treatment of patients with benign disease [e.g., obstructive sleep apnoea syndrome (OSAS)], but this review focuses upon its application specifically in patients with oropharyngeal malignancy.

Preoperative considerations

Patient selection

The utility of the robot is limited by certain patient anatomical and physiological factors, as well as tumour-related factors. Patients must have sufficient mouth opening and hyoid-mental distance to permit instrument access, with cadaveric studies demonstrating that retrognathia, class II dental malocclusion and prominent maxillary dentition all impair access (19), such that they should be considered relative contraindications. Similarly, limited neck extension and large neck circumference have been shown to negatively impact upon patient positioning and accessibility. Screening for these anatomical restrictions is an essential part of the preoperative airway examination.

Patient comorbidities may also affect their appropriateness for the technique—in TORS, wound healing is dependent upon secondary intention, such that any patients that may be at risk of delayed mucosal healing (immunosuppressed, previous radiotherapy, diabetes, connective tissue disease) may be deemed unsuitable. Likewise, given the risk of bleeding associated with the technique, patients on long-term anticoagulation may present an unacceptably high risk of intraoperative bleeding or postoperative haematoma to be considered.

The aim of TORS is to achieve complete tumour resection, as well as resection of involved lymph nodes, such that only certain tumour sites are amenable to this technique—specific anatomical regions that have been reported successfully are the oropharynx, skull base, parapharyngeal space, larynx, hypopharynx and supraglottis. The tumour stage is also important: TORS appears to have worse functional outcomes in T3 and T4 tumours (16); outcomes appear to be equivalent to primary radiotherapy or chemoradiotherapy in T1 and T2 tumours (up to 4 cm) (20); involvement of neighbouring structures, including mandibular invasion, carotid artery involvement or fixation to the prevertebral fascia, are considered contraindications; and, TORS is not considered suitable if tumour resection requires removal of more than 50% of the tongue base or posterior pharyngeal wall.

Preoperative assessment and optimisation

Most patients undergoing TORS for oropharyngeal SCC, have already undergone panendoscopy and tissue biopsy under general anaesthesia earlier in their diagnostic/treatment pathway, and many will also require a limited neck dissection and lymph node resection prior to TORS, typically undertaken a few weeks in advance (subject to institutional variation), though it can be undertaken synchronously. If undertaken separately, there is some evidence to support the prophylactic ligation of branches of the external carotid artery in order to minimise the risk of severe haemorrhage during subsequent TORS (1). If the procedures are undertaken concomitantly, there is a risk of a communicating defect being established between the oropharynx and the neck, which may require free flap closure (21) to prevent abscess formation.

Preoperative assessment should include a focussed history (with emphasis placed upon conditions associated with smoking and alcohol consumption), a directed physical examination, and a full set of baseline blood tests (including blood crossmatching, given the potential for significant bleeding). Cardiovascular disease is common in those with non-HPV related pathology, and its presence should prompt evaluation with electrocardiography, echocardiography (and other cardiac investigations, as indicated), as well as evaluation of patients' functional status. A physical activity score less than 4 metabolic equivalents (METs) (unable to climb a flight of stairs) is indicative of poor physiological reserve, and suggestive of a high-risk candidate for anaesthesia and surgery (22). Patients identified as high risk, such as those with known ischaemic heart disease or valvular disease, should be discussed with cardiology to optimise their perioperative management. Concomitant respiratory disease, such as chronic obstructive pulmonary disease, is common, such that pulmonary function tests may be helpful in assessing disease severity (though patients with

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airway stenoses may not produce reliable results). Anaemia is also a frequent finding, and should be optimised prior to surgery as it is associated with an increased risk of morbidity and mortality (23), as outlined in the head and neck cancer pre-treatment clinical assessment guidelines (24). Various perioperative scoring systems can be used to quantify the predicted risk of patient morbidity and mortality. Unfortunately, well-established risk prediction models, such as the Portsmouth-Physiological and Operative Severity Score for the enumeration of Mortality and morbidity (P-POSSUM), are of limited value since they are not validated for head and neck cancer patients; however, the Head and Neck Surgery Risk Index (HNSRI) is a recently validated disease-specific model that has shown promise as a predictor of major adverse events or death in these patients (25), and may be used to help guide assessment, as well as discussions with patients and their families.

Nutritional assessment and planning

Nutrition planning for the postoperative period is especially important in TORS patients and should be undertaken in conjunction with specialist dieticians and speech and language therapists (SLTs). As TORS aims to reduce requirement for PEG/RIG feeding, no prophylactic procedures are required, and there is often limited time for nutritional optimisation prior to the procedure due to the nature of the pathology being treated. Nevertheless, dysphagia, dysgeusia and nasopharyngeal reflux are common post-TORS and a plan for safe (supervised) reintroduction of oral intake must be in place.

Airway assessment and strategy planning

Patients with oropharyngeal malignancy undergoing TORS may pose potential difficulties with all facets of airway management—facemask ventilation, laryngoscopy and tracheal intubation, supraglottic airway insertion/seal and front of neck airway may all be more challenging/impaired. A combination of history taking, bedside examination and imaging review may aid in identification of specific predictors of difficulty and assist in formulating an airway management strategy-which should be undertaken as part of an MDT process.

Tumour burden may present with a variety of symptoms in these patients, including sore throat, hoarseness, dysphagia, dyspnoea, stridor, and/or a neck lump (26), and patients may also report symptoms of intermittent airway obstruction such as snoring, orthopnoea and paroxysmal nocturnal dyspnoea (which may become apparent, or more prominent when lying supine).

Bedside airway physical examination tests have been shown to have poor predictive value as screening tests for airway management difficulty (27); nevertheless, their practice ensures proper consideration of the airway, and facilitates the planning of a comprehensive airway management strategy (28). In the context of TORS, dentition and cervical spine movements/circumference should afford special attention, given the previously described difficulties with robotic instrument access and positioning for surgery that may arise. A history of previous radiotherapy or evidence of scarring/fibrosis should also be specifically sought, and if the cricothyroid membrane is difficult to locate on palpation, identification using front of neck ultrasound should be considered (29).

Earlier in these patients' diagnostic/treatment pathway, they have often undergone a number of imaging investigations (to aid in diagnosis and cancer staging) that may be helpful in airway management planning. Previous computed tomography or positron emission tomography imaging can assist in delineating airway anatomy and the degree and location of any anatomical distortion. Whilst these imaging modalities do not provide a dynamic assessment of the airway and are usually undertaken in the supine position, they still provide valuable information. Magnetic resonance imaging can also be helpful, e.g., in assessment of patients with tumours that may extend through the laryngeal cartilage. Flexible nasendoscopy is an under-utilized tool, and can be performed easily and quickly just prior to anaesthesia to provide real-time dynamic information about the airway during respiration. However, an important limitation to this technique is its inability to accurately predict whether the larynx will be visible under direct or indirect laryngoscopy once the patient is anaesthetized. In some head and neck surgical centres, these two techniques have been combined together in the form of virtual fibreoptic endoscopy, which along with 3-D printed modelling, may also be of benefit in the planning and rehearsal of airway management (30).

Prior to TORS, most patients have undergone previous panendoscopy and neck dissection procedures under general anaesthesia, and whilst the relative ease/difficulty of previous airway management may change over time with disease progression, these previous encounters may help inform decision-making. It is also worth noting that in patients that have undergone recent (within weeks) selective

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neck dissection, some airway manoeuvres may be painful.

Patients with head and neck disease represented a significant proportion of cases reported in the UK Fourth National Audit Project (NAP4) examining airway complications (31), therefore, advanced airway techniques (including awake techniques) should be considered. Crucially, in the presence of predictors of airway management difficulty, a standard induction of anaesthesia with direct laryngoscopy is associated with a greater risk of complications (32). Whichever the chosen technique, there must be contingency plans and equipment in place ("planning for failure") and the airway strategy must be communicated clearly to the rest of the MDT (33). On the day of surgery, a detailed preoperative MDT brief is recommended to discuss the specific requirements of the surgical, anaesthetic and nursing teams. Post anaesthesia care unit (PACU) nursing staff should be included to discuss any anticipated postoperative issues. For the more surgically complex cases, patients with significant comorbidities, and in those where tracheostomy is planned, elective admission to the intensive care unit (ICU) should be arranged in advance.

Intraoperative anaesthetic considerations

Operating theatre ergonomics

The operating theatre setup must be carefully planned in advance (following locally adapted protocols) to ensure optimal positioning of equipment, allowing sufficient space for the patient, robot side-cart, surgeon's console, vision system, instrument trolley, anaesthetic machine and staff. The anaesthetic team should have immediate, unobstructed access to the difficult airway trolley and other ancillary equipment/medications. The patient should be orientated on the operating table with their head away from the anaesthetic machine and ventilator, for maximum accessibility. The robot side-cart (with instrument and endoscope arms) is generally located on the opposite side of the patient to the anaesthetic machine, maximizing access to the patient's head.

The surgeon's console is usually located in a corner of the operating theatre—once sitting at the console, the surgeon's field of vision is focussed solely on the 3-D viewer, as their direct view of the operating field and their assistants is often obscured by the robot side-cart and instruments. Clear communication via the in-built audio system is key to overcoming the physical distance, noise from the vision system, and loss of visual cues between team members.

During the procedure, the surgeon and the rest of the MDT must communicate clearly with each other, particularly during the docking and undocking of the robotic instruments. Poor communication has been associated with worse surgical outcomes (increased operative time and increased bleeding) in gynaecological robotic procedures, with extraneous noise in the operating theatre and the challenge of achieving effective console-to-bedside communication specifically highlighted (34). Procedural and MDT familiarity plays a crucial role in overcoming some of these issues, such that in-situ team simulation is recommended to practice the equipment setup, critical stages of the surgical procedure, and management of perioperative emergencies. In particular, it is recommended that the emergency undocking procedure is rehearsed (35), which may be necessary in the event of significant haemorrhage, airway compromise, airway fire, conversion to an open procedure or cardiac arrest. In practice, the emergency undocking process is relatively straight forward but it should be rehearsed regularly so that staff are familiar with the procedure and their roles, along with quick release of the mouth gag. There are a number of significant challenges posed by TORS procedures, both in terms of physical obstruction to patient accessibility (in particular, access to the airway) as well as barriers to effective communication, such that any perioperative emergency may be more difficult to manage. Meticulous planning and preparation of the patient, equipment and operating theatre environment is key to prevention, combined with a high degree of vigilance to identify any issues early.

Airway management

As discussed earlier, airway management in these patients may be potentially challenging, so a clear individualised airway management strategy must be in place. It is recommended that airway management (whether conducted awake or following induction of anaesthesia) takes place in the operating theatre, with the patient positioned on the operating table. This permits the surgical team to be present and on standby for emergency front of neck access (in the event of primary airway plan failure and unsuccessful rescue oxygenation). More commonly, it also reduces the requirement for additional patient transfer, minimizing the risk of dislodgement of the carefully positioned airway device, monitoring and vascular access. Both oro- and nasotracheal tubes can be used for TORS, though this should be discussed at the pre-surgical brief as there may be individual surgeon/institutional preferences. For orotracheal

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intubation, a size 6.0 mm internal diameter reinforced tube (to prevent kinking) may be used, secured firmly at the corner of the mouth (contralateral to the tumour site). For nasotracheal tubes, a similar sized reinforced or North-facing Ring-Adair-Elwyn (RAE) tracheal tube is recommended, passed via the contralateral nostril (pre-prepared with co-phenylcaine spray, or a similar alternative). The smaller diameter tracheal tube facilitates surgical access, though care must be taken to ensure sufficient tube placement depth (narrower tubes are also often shorter) to avoid accidental dislodgement on head extension during patient positioning. For patients with anticipated difficult airway management, such that awake tracheal intubation and postoperative tracheostomy are planned, an awake nasotracheal intubation may be preferred, followed by immediate tracheostomy formation, prior to proceeding to the TORS procedure.

The intraoperative use of electrocautery is associated with a potential airway fire risk if there is oxygen leakage from around an inadequately inflated tracheal tube cuff. Cuff manometry should be a standard requirement post-tracheal intubation to optimise cuff pressure and seal adequacy—also necessary to reduce pulmonary aspiration of blood and surgical debris. Other measures to reduce airway fire during diathermy usage include utilising the lowest fractional oxygen concentration to maintain adequate patient oxygenation, avoidance of nitrous oxide, utilising the lowest effective diathermy voltage, minimizing time in cutting mode (cutting mode generates higher temperatures than coagulation mode), and ensuring properly configured surgical drapes to prevent oxygen pooling (36).

A mouth gag (there are a number of different options available, e.g., Crow-Davis or Feyh-Kastenbauer-Weinstein-O'Malley, FKWO) is used intraoperatively, to keep the mouth open and to retract the tissues, especially the tongue, allowing the instruments access to the intended operative site. The mouth gag blade is large, and the frame is opened wide, therefore maximal muscle relaxation is required during insertion and positioning. During this process, the mouth gag can also compress or dislodge the tracheal tube and the anaesthetic team should be watchful for this particular issue.

Most patients undergoing TORS are suitable for tracheal extubation at the end of surgery, which should be undertaken in the operating theatre, and just like tracheal intubation, this should be performed with the surgical team present. In preparation for tracheal extubation, the anaesthetist should inspect the airway, assess the degree of oedema present (crucial in determining suitability for extubation) and perform suctioning under vision to remove secretions, blood, and surgical debris. Suction manoeuvres must not be undertaken blindly, and should be undertaken carefully to minimize traumatic bleeding. This can be achieved by direct or videolaryngoscopy, though the latter confers particular advantages in these patients; in particular, videolaryngoscopy performed with a hyperangulated blade, permits an "incremental exposure" technique minimizing trauma on blade advancement, and provides a superior wider-angle view (37), requires less force during laryngoscopy (38), and does not require the blade tip to be advanced into the vallecula (which may be part of the surgical resection bed) to achieve a view of the glottis.

The use of oropharyngeal airways should be avoided, given the attendant risk of iatrogenic trauma and bleeding on insertion. If there are particular concerns regarding airway oedema, the MDT may decide that delayed tracheal extubation (to allow oedema to subside) or tracheostomy placement may be indicated. Tracheostomy may be undertaken as a planned procedure in patients with anticipated difficult airway management (as described above), in patients expected to require prolonged postoperative invasive ventilation, or in patients undergoing extensive resection or salvage surgery. If deemed suitable for tracheal extubation, this should be undertaken in the awake, spontaneously breathing patient. Tracheal extubation in a deep plane of anaesthesia is contraindicated, given the significant risk of airway obstruction from laryngopharyngeal/tongue oedema and the risk of pulmonary aspiration from ongoing "surgical ooze" from the resection bed. Given the necessity for deep neuromuscular blockade during certain phases of TORS, it is essential that quantitative neuromuscular monitoring is utilised to guide reversal agent administration and to confirm full return of neuromuscular function prior to emergence and tracheal extubation.

Patient positioning and monitoring

Extra special care must be taken with this particular aspect of perioperative management. Once the robot has docked, movement of the operating table and/or patient may cause serious tissue injury (shearing) from the robotic instruments. Consequently, every aspect of patient positioning, pressure area protection, configuration of breathing circuits, monitoring and vascular access lines, securing of connections, application of pneumatic compression

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devices and diathermy pad placement must be done before skin preparation and draping. The patient's head should be placed in a neutral position (no head ring or pillow; a shoulder bolster may be required). The eyes and face must be protected to avoid iatrogenic injury from the robotic instruments—eyes should be taped and padded fastidiously (eye goggles may also be used), and additional padding should be placed between the tracheal tube and the face to avoid pressure injuries. The patient's arms should be placed by their side, padded and wrapped. Peripheral venous access is usually sufficient in most patients, though central venous access (femoral) and/or invasive arterial blood pressure monitoring may occasionally be required, depending upon patient comorbidities and expected duration of surgery. All vascular access lines should have extensions, and must be clearly labelled. Breathing circuits (and capnography sampling lines) also require extensions, and should be carefully secured, supported, and positioned away from the operating field. All vascular access lines, monitoring cables and breathing circuits are ideally placed on the contralateral side of the patient to the robot side-cart.

Maintenance of anaesthesia

Both total intravenous anaesthesia (TIVA) and volatile anaesthesia techniques may be used. Currently, there is no robust evidence to support one particular technique over another for TORS, though the cough suppression and reduced haemodynamic response at emergence (39), and reduced postoperative nausea and vomiting (40) associated with propofol-based TIVA may be of particular benefit in these patients. Whichever the chosen technique, a continuous infusion of a potent opioid (usually remifentanil, but alfentanil is a suitable alternative) is advocated to attenuate patients' sympathetic response to what can be particularly stimulating surgery (including mouth gag insertion). Often remifentanil alone, titrated to peaks of surgical stimulus, is sufficient to avoid significant haemodynamic effects, though beta adrenergic blockers, dexmedetomidine, clonidine, and magnesium may provide alternatives/second-line agents. Neuromuscular blockade is generally recommended throughout the procedure, to facilitate surgical access and to abolish the risk of patient movement or coughing whilst the robot is docked (which may have potentially catastrophic consequences). This can be readily achieved with repeated boluses of a neuromuscular blocking agent or via a continuous infusion (guided by quantitative neuromuscular monitoring). In practice, once the mouth gag has been placed, there is less requirement for profound muscle relaxation, with the remifentanil contributing to attenuation of cough/airway reflexes. The UK fifth National Audit Project (NAP5), which reported on accidental awareness during general anaesthesia (AAGA), suggested that patients undergoing TIVA were at a higher risk of AAGA when neuromuscular blocking agents were used (41). Thus, in addition to standard Association of Anaesthetists anaesthetic monitoring (42), quantitative neuromuscular monitoring and processed electroencephalography (pEEG) is recommended during TORS conducted with a TIVA technique. Forehead placement of pEEG monitoring electrodes is not precluded, though meticulous skin preparation prior to placement (to ensure good electrode contact, with low electrical impedance) and careful arrangement of the monitoring cable (to avoid interference with the robotic arms) is required.

The combination of rocuronium-induced neuromuscular blockade and reversal with sugammadex is often preferred to traditional antagonism by neostigmine (combined with glycopyrrolate) in these patients, largely due to a perceived reduction in postoperative airway and/or pulmonary complications (PPCs) that may result from residual neuromuscular blockade. One third of all adverse airway events reported in NAP4 occurred during emergence or recovery from anaesthesia (31), and the airway oedema associated with TORS undoubtedly poses additional risk during this phase of anaesthesia. Sugammadex has been shown in meta-analyses and systematic review (of studies that have included patients undergoing head and neck surgical procedures, though not specifically TORS) to reduce PPCs (43,44) and postoperative nausea and vomiting (45); however, in other studies neostigmine was found to be non-inferior (46). A small study whose findings may be generalizable to TORS [involving patients undergoing airway surgery for benign disease (OSAS)], found sugammadex to be superior to neostigmine in reducing PPCs and associated treatment costs (47).

Analgesia and antiemesis

Whilst remifentanil is the mainstay of intraoperative analgesia, a multimodal approach is advocated, with intravenous paracetamol and administration of a longer-acting strong opioid towards the end of surgery (usually fentanyl). Antiemesis prophylaxis should be routinely administered, with ondansetron and dexamethasone often given in combination. Clearly, it is desirable to minimize

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postoperative nausea and vomiting in all patients, but it is especially important in TORS, since retching and vomiting are associated with increased venous pressure and possible disruption of delicate surgical sutures/haemostasis—causing bleeding/haematoma formation.

In addition to its antiemetic properties, dexamethasone is especially beneficial in reducing oedema, and if given prior to skin incision and continued regularly into the postoperative period (short course, 2–3 days), has also been shown to decrease length of hospital stay and reduce time to resumption of solid diet (48).

Nutrition

Following TORS, the pharyngeal reflexes may be impaired in the short-term, during which time patients are at risk of pulmonary aspiration, such that nasogastric feeding may be required for the first two or three days (depending upon regular SLT assessment and progress with swallowing rehabilitation). Therefore, once the surgery is complete, and before tracheal extubation, a nasogastric tube should be inserted (under direct or videolaryngoscopy) and carefully secured to prevent accidental removal—as re-insertion may be particularly challenging.

Fluid therapy

A relatively restrictive intraoperative fluid regimen is advocated to reduce airway oedema at emergence and in the immediate postoperative period; however, dehydration is also a recognized postoperative complication in TORS patients (49)—reinforcing the importance of nasogastric tube insertion at the end of surgery to permit temporary feeding in those with significant odynophagia or dysphagia.

Haemostasis

Towards the end of surgery, the patient's systemic blood pressure must be returned to baseline (if this has not been done already) to identify any bleeding points, and the surgeon may also request a Valsalva manoeuvre to confirm haemostasis.

General measures

General principles of good perioperative management should be followed, such as prevention of venous thromboembolism (using graduated compression stockings and pneumatic compression devices), prevention of infection (local policies guiding prophylactic antimicrobials should be followed), and maintenance of normothermia (with active warming measures and continuous temperature monitoring). Nasally inserted temperature probes are not generally recommended given the potential for interference with the operative field; the free (non-intubated) nasal passage may also be required to pass a flexible aspiration tube to aid in smoke evacuation. Instead, a rectal temperature probe or urinary catheter with integrated temperature sensor are practical choices for procedures anticipated to be more complex/prolonged.

Postoperative considerations

An MDT approach to the postoperative care of TORS patients is advocated, with crucial involvement of pain specialists to optimise analgesia, SLT to ensure safe reintroduction of oral intake, dieticians to optimise nutritional support, and physiotherapists to promote early mobilisation. TORS procedures are well suited to Enhanced Recovery After Surgery (ERAS) programmes, which can incorporate all these aspects in a multimodal care pathway to promote patient recovery (50).

Though less severe than with open procedures, postoperative pain may still be significant, particularly relating to intraoperative tongue retraction. There is significant variation between institutions in terms of postoperative analgesic preferences, but a multimodal approach is universal. Patient controlled analgesia (usually fentanyl; bolus-only regimes, with no continuous background infusion are recommended) may be required for the first postoperative day, in combination with regular intravenous paracetamol and non-steroidal anti-inflammatory drugs, after which these medications can be converted to liquid formulations (for oral or nasogastric administration). Since postoperative dysphagia is common, tablet formulations are generally not suitable. Gabapentinoids (liquid formulations) and transdermal fentanyl patches have also been used postoperatively, though adverse side-effects, especially dizziness, and the risk of respiratory depression respectively may limit their use.

Airway oedema can be minimised by nursing patients in a head up position, regular dexamethasone (for 2–3 days), judicious intravenous fluids (which should be discontinued once nasogastric feeds or oral intake are initiated) and early mobilisation.

The requirement for temporary nasogastric feeding is

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largely based upon the specific oropharyngeal pathology. Patients undergoing TORS for T1 or T2 tumours, or well-lateralized base of tongue lesions are more likely to resume oral intake immediately postoperatively, or only require a brief period of nasogastric feeding; whereas, patients with pre-existing dysphagia, or those undergoing TORS for T3 or T4 tumours, with pathology that crosses the midline, involves the hypopharynx, or requires more extensive tongue base resection, are more likely to require nasogastric feeding for a more prolonged period, as well as swallow rehabilitation (51,52). Oral intake should not be resumed until clinical assessment by SLT, and in patients deemed especially high risk, oral intake should not be resumed until after instrumental assessment (using videofluoroscopy or fibreoptic evaluation of swallow, FEES).

Though less relevant to most patients undergoing TORS for malignancy (and more pertinent to patients undergoing TORS for OSAS), continuous positive airway pressure (CPAP) is relatively contraindicated in the immediate postoperative period, due to the potential risk of pneumomediastinum in the presence of a pharyngo-cervical fistula (more common if synchronous neck dissection has been performed).

The complication rate following TORS has been reported to be as high as 12% (53), and can be classified as immediate or delayed (16). Important immediate complications include bleeding, pulmonary aspiration and airway oedema secondary to venous congestion (often seen in prolonged cases). Serious delayed complications include bleeding, infection, as well as abscess and fistula formation. The risk of postoperative bleeding is reported to be between 3–8%, and most commonly occurs around postoperative day 10 (54). Minor bleeding may be self-limiting, but more major bleeding may require local external pressure to the neck on the side of the defect (as a temporizing measure), electrocautery or full surgical re-exploration. In the event of a return to theatre, these patients can present significant challenges, including difficult airway management (relating to oedema, anatomical distortion, bleeding and aspiration risk) as well as potential haemodynamic instability in the case of major haemorrhage, such that senior experienced personnel and advanced airway techniques and equipment is recommended.

The future

Despite its relatively recent introduction into the field of oral cancer surgery, TORS offers a number of potential advantages over open major surgery, with reduced patient morbidity, whilst also remaining relatively cost effective (53). TORS is currently still limited to specialist head and neck surgical centres, though its utility (and availability) is likely to continue to increase, having also demonstrated efficacy as a salvage approach to treatment of residual or recurrent malignancy (55).

Review strengths and limitations

The main strength of this review is its inclusion of the most up-to-date studies relevant to this field, providing evidence-based clinical guidance to anaesthetists delivering perioperative care to patients undergoing TORS for oral cancer—specifically addressing the need for greater awareness and knowledge in an expanding area of practice.

Whilst studies relating to the surgical, functional and oncological outcomes following TORS have certainly increased in recent years as this surgical approach has become more widespread, the main limitation of this review is that there remains a relative paucity of studies relating specifically to the anaesthetic techniques for TORS (distinct from anaesthesia for other robotic surgery). Consequently, in the absence of large randomized controlled trials, the guidance on anaesthetic techniques is largely based upon smaller studies, expert and consensus opinion.

Conclusions

TORS has become more widely adopted in recent years as a surgical approach in oral cancer treatment, due to the reduced patient morbidity it offers over open major surgery and non-surgical therapies. However, it poses a number of unique challenges, necessitating careful case selection, thorough perioperative planning, scrupulous preparation and a high degree of anaesthetic vigilance throughout the perioperative course.

Meticulous airway assessment is crucial to identify patients that have adequate mouth opening and neck mobility to permit robotic instrument access, and those with potentially difficult airways that may require advanced (awake) airway management techniques. Nasotracheal intubation is often preferred, to provide unobstructed operative access. Fastidious positioning of the patient, eye protection, placement of monitoring equipment/cables, and secure fixation of the airway device and peripheral venous catheters is essential, since access to all of these is severely restricted once the surgical robot is engaged. Neuromuscular blockade is advocated, especially for mouth

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gag insertion, surgical retraction and robotic instrument insertion. Physical barriers to co-operative working must be overcome by close, effective communication between the surgical and anaesthetic teams. The MDT must also be familiar with emergency robot undocking procedures and fire safety precautions. Intra- and postoperative multimodal analgesia and antiemetic prophylaxis are crucial aspects of perioperative care since postoperative pain from tongue retraction can be significant and vomiting may disrupt surgical haemostasis. Most patients are suitable for tracheal extubation at the end of surgery, though some may require delayed tracheal extubation in ICU (having allowed airway oedema to subside) or surgical tracheostomy formation. Assessment of readiness, and preparation for, tracheal extubation must include inspection of the airway under direct or videolaryngoscopy, enabling the degree of airway oedema to be determined and to allow directed suctioning of blood, secretions and surgical debris to be performed. Tracheal extubation should be performed in the awake, spontaneously breathing patient in whom full restoration of neuromuscular function has been confirmed using quantitative neuromuscular monitoring. A short course of regular intravenous dexamethasone is recommended to reduce residual airway oedema, whether tracheal extubation is performed immediately or delayed. Patients must be managed in an appropriately monitored and equipped clinical environment, by staff that are familiar with the postoperative care of head and neck surgical patients. Temporary postoperative dysfunction of pharyngeal reflexes should be anticipated, with a nasogastric tube inserted prophylactically in all patients, with the safe resumption of oral intake directed by SLT specialists. The care of these patients depends upon the teamwork of a vast number of specialists, such that many institutions have developed comprehensive TORS clinical pathways that incorporate all of these aspects, in order to optimize patients' medical, surgical, functional and oncological outcomes.

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