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Robotic Surgical Systems in Maxillofacial Surgery-A Review

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ABSTRACT

In the twenty-first century, robotic surgery is used in maxillofacial surgical procedures for the treatment of tumors, maxillofacial regions and non-malignant diseases. With the use of robotic surgical systems, maxillofacial surgery is done with minimal blood loss, lesser complications, minimal hospitalisation and more cosmetic standard open surgery. Till now, the application of robotic surgery techniques in the treatment of head and neck diseases remains in an experimental stage. Maxillofacial surgeries are being performed with large incisions, either via a Trans mandibular or a trans pharyngeal approach, because of anatomical complications and minimal surgical space. These procedures typically result in significant surgical morbidity, speech dysfunction and dyspepsia from the dissection of large amounts of normal tissue.

Key words Non-malignant, Robotic surgery, Maxillofacial surgery, Head and neck diseases

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INTRODUCTION

The surgeries performed in the cranial area includes surgeries of fronto-zygomatico-maxillary complex, nasal cavity, Para nasal sinuses, ear, and the skull base that have close proximity to highly critical structures like nerves, vessels, the eye, cochlear and labyrinth organ, or the brain [12]. Such operations often require re-establishing functional and aesthetic anatomy by repositioning displaced skeletal elements, or by grafting and contouring abnormal bony contours and transplants [14]. There is a need for accurate preoperative determination of the proposed surgical procedure and excellent intra-operative orientation and manual skills are required for surgical precision and reliable protection of vital anatomic structures [11]. The development of image-guided surgery provides new revolutionary opportunities by integration of pre-surgical 3D imaging, obtained by computed tomography (CT) or magnetic resonance imaging (MRI), and intra-operative manipulation through three fundamental issues:

- Localisation - determination of a target's locus for as, tumour, foreign body.
- Orientation - information on current location on the patient's anatomy that defines where the surgeon is for operating surgical instruments.
- Navigation - the process of guidance to reach a desired target from the current location (for like biopsy, tumour resection, bone segment manipulation.

To overcome these limitations, robotic surgical systems were innovated and introduced into surgical practice. Transoral robotic surgery (TORS) was proposed and first applied clinically in maxillofacial surgery by McLeod and Melder to excise a vallecular cyst. This procedure was approved by the US Food and Drug Administration (FDA) in 2009 for use in stage T1 and T2 oropharyngeal cancer. Since that time, robot-assisted maxillofacial surgery has been growing steadily [6]. Taking inspiration from its use in other surgical fields, the benefits to surgeons include a three-dimensional magnified view, precise movements, bimanual operation with articulated arms and suppression of tremor, which enhances the surgeon's physical capabilities. Thus, procedures with robotic assistance can be performed with less blood loss, fewer complications, shorter hospital stays and better cosmetic results than standard open techniques [13]. Hence, robotic surgery may hold promise in the treatment of craniofacial conditions, such as head and neck neoplasms, cleft palate and craniofacial asymmetry, among others. In this review, we summarise the current applications of robot-assisted maxillofacial surgery.

History of robotic surgical systems

During the late 1980s and early 1990s, endoscopic techniques were booming, and limitations were being reached as well. Subsequently, the potential capability of tele robotics in MIS was well recognised [10]. Robotic surgical system was manufactured to overcome the limitations of laparoscopic surgery, including tremor, fatigue, 2D imaging and a limited range of freedom. Additionally, robotic surgery can also be described as an ability to enable surgical interventions via the application of telecommunications and robotic systems, where the patient and surgeon are separated. Since Puma 560,6 the first robotic surgical system was introduced in the mid-1980s to orient a needle for brain biopsy, three generations of systems have followed:

- Generation I: CMI's Automated Endoscopic System for Optimal Positioning (AESOP). AESOP, a voice-controlled robot, was developed to serve as a stable camera platform and not multi-arm units.
- Generation II: Tele robot Zeus. Zeus was a kind of master-slave teleoperator between the surgeon and the patient-side manipulator.
- Generation III: da Vinci surgical system. The da Vinci system aims at recreating the feeling of open surgery and was preferred by the open surgeon, while the Zeus system was primarily adopted by the laparoscopic surgeon.

Apart from those mentioned above, there are several other robotic surgical systems, including, Computer-Assisted Surgical Planning and Robotics (CAS- PAR), Robotic Arm Interactive Orthopaedic System (MAKO Surgical Corp RIO) and so forth, that have been generally applied in orthopaedic surgery, such as arthroplasty. Overall, the da Vinci surgical system is currently considered the most successful robotic surgery system and it was approved by the FDA in 2009. Currently, the da Vinci robot is used for almost all surgical procedures performed in the head and neck region.

Clinical applications of robotic surgery in the head and neck and maxillofacial surgeries

Search methods

Online, they were also searched. Manual searches were also conducted in relevant Chinese journals, and reference lists of relevant articles were reviewed. To find ongoing clinical trials, the World Health Organization International Clinical Trials Registry Platform was searched. They included "Robotics," "Operation, Remote," "Oral Surgical Procedures," "Oral Surgery" and "Head and Neck Neoplasms." Language was restricted to Chinese and English. As a result, a total of 503 studies were identified; of these, 119 that were associated with the application of robotic surgery in the head and neck region.

Clinical applications

The development of a robotic surgical system for maxillofacial surgery has been relatively delayed because of the limited surgical field and complex surgical anatomy. The first application of a robotic surgical system in maxillofacial tumors was reported the chief indications for robotic surgery in the head and neck region are (1) removal of head and neck neoplasms or cysts that can be sufficiently exposed via a robotic approach; (2) therapeutic and selective neck dissection; and (3) obstructive sleep apnea syndrome (OSAS) [1]. Meanwhile, tumors with jaw or internal carotid artery invasion are not currently suitable for robot-assisted resection.

HPV is one of the most important known risk factors for oropharynx cancer. The first use of a robotic surgical system for mediastinal parathyroid resection via a transaxillary incision in 2004 and showed that transaxillary robotic surgery is a minimally invasive, effective and safe procedure. Later, Lewis et al. demonstrated the feasibility of trans axillary robotic thyroidectomy [5]. No significant bleeding or edema occurred intraoperative or postoperatively. Recently, Byeon et al. performed robotic retro auricular thyroidectomy for clinically suspicious papillary thyroid carcinoma [2].

Cleft lip and palate

Currently, the use of robotic surgical systems in the treatment of cleft lip and palate is still in an early stage of development.

Maxillofacial fracture

The development of robotics for the treatment of fractures is much more difficult than in other regions for two main reasons. First, the position of fracture segments changes before and after reduction, making it difficult to provide precise navigation. Second, it is impossible to provide appropriate resistance during the fixation period because of the lack of tactile and haptic feedback.

Craniofacial asymmetry

The theoretical feasibility of the clinical application of robotic orthognathic surgery has not been reported, and the robotic surgical system mentioned above remains in an experimental stage.

Obstructive sleep apnea syndrome (OSAS)

OSAS is the most common type of sleep apnea, resulting from complete or partial obstruction of the upper airway [4]. It can be due to decreased muscle tone, thickened soft tissue around the airway, such as nasal polyps or adenoid hypertrophy, and structural features, such as nasal septum deviation, which result in a narrowed airway. Continuous positive airway pressure (CPAP) was often used as a standard treatment for OSAS.OSAS sufferers unwilling or unable to comply with CPAP, a properly selected surgical treatment would be an alternative option, based on the patient's-specific anatomy [8]. Treatments include tonsillectomy uvulopalatopharyngoplasty (UPPP), reduction of the tongue base, maxillomandibular advancement and hyoid suspension [16].

Neurosurgical robotic surgery

Robotics has been introduced in the field of neurosurgery for robotic image guided stereotactic biopsy197 and intracranial surgical procedures [7].

Cost-benefit ratio

Image-guided surgery is considered to be more accurate than standard surgery. Comparative studies in oral implant surgery indicate significantly more accuracy compared to the manual freehand procedure even if performed by experienced surgeons .Image -guidance in other procedures, such as percutaneous interventions, removal of foreign bodies, access to deep seated locations.

DISCUSSION

Superiority and limitations

Robot-assisted surgery has been increasingly applied in the head and neck region. Compared with conventional or endoscopic surgery, robotic surgery has several distinctive advantages and limitations.

Superiority of robotic surgery

The surgical space can be stereoscopic and 10–15 times magnified via two or more integrated cameras that are used in the system, which can enhance the surgeon's capability to distinguish normal tissues from tumors and to preserve normal tissues to the highest extent. Thus, the tumor can be removed en bloc, with minimal morbidity and accelerated functional recovery. Breaking the limit of human hands [15].

Robotic surgery could remove tumors via a minimally invasive approach, such as a transoral and a retro auricular approach, to decrease surgical complications and functional damage to a large extent. The average blood loss was minimal, and no patient required blood transfusions intra- or postoperatively [17]. Remote operation and real-time shared surgery can be available via Internet and satellite technology. Economizing medical staff. The robotic surgical system is highly automated; thus, only one surgeon, one anaesthesiologist and one or two nurses are required, even for a difficult surgical operation [9]. This could overcome the restrictions of operating room capacity and the shortage of medical resources.

Limitations of robotic surgery

Lack of tactile perception and proprioception. It is impossible, through a robotic surgical system, to feel the strength and resiliency of tissues or the radial pulse. Therefore, it is difficult to control bleeding in a timely fashion once exsanguinating haemorrhage occurs. Lack of haptic feedback. For some fine motions, such as tying, suture breakage can occur as a result of excess tension. Additionally, several studies found that the postoperative rate of lingual edema is significantly higher with robotic surgery than with the conventional approach.

Prospective of robotics in the head and neck; oral and maxillofacial region

The robotic surgical system is a novel, minimally invasive procedure with promising impact, and the development of robotic surgery is still in an early stage.

The available research indicated excellent outcomes in terms of surgical morbidity, oncologic control and functional recovery for head and neck tumor patients treated by robotic surgical systems. The incidence of capsule breakage or neoplasm fracture during robotic surgery is relatively high. Robotic surgery typically requires a long surgical duration or large storage of drainage, especially via a retro auricular approach or a modified face-lift approach, because of the extended flap [3]. It remains unclear whether robotic surgery would improve the prognosis of HPV-negative patients. The regional or distant metastasis rate for robot-assisted resection of recurrent tumors is quite variable.

CONCLUSION

Due to the anatomic situations with high- risk structures and the high demands for functional and aesthetic results, surgery in the oral and maxillofacial region and cranial region is complex. The primary outcomes of robotic surgery in the head and neck region demonstrate good disease control, quick postoperative functional recovery and low surgical morbidity. A definitive recommendation for the application of robotic surgical systems in the treatment of head and neck tumors, cleft lip and palate, OSAS and other conditions will require more well-designed studies and technical modifications in current surgical robots and in the future.

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