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Robot-Assisted Maxillofacial Surgery, Real Scientific Dream: Current Status and Future Perspectives

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Abstract:
Advances in the basic scientific research within the field of computer assisted oral and maxillofacial surgery have enabled us to introduce features of these techniques into routine clinical practice. One of the most significant developments in medical technology in the past decade is the advent of Robot-assisted maxillofacial surgery. Robotic surgery has distinct advantages over conventional open surgery, and most surgical procedures can now be performed by the robots. However, the popularity and acceptance of computer assisted surgery is far from universal, mainly due to the technical difficulties in the procedure. Robot assisted surgery requires training and skill, and has a long learning curve. Robot-assisted surgery may help overcome some of these problems. The techniques of virtual reality and computer assisted surgery are increasingly important in their medical applications. Many applications are still being developed or are still in the form of a prototype. It is already clear, however, that developments in this area will have a considerable effect on a surgeon's routine work. Robot Assisted Neck Dissection followed by Transoral Robot Surgery in some cancers of the head and neck are feasible and showed a clear cosmetic benefit, although the longer operating time is a drawback. Studies of more patients with longer follow-up are required to evaluate long-term oncological and functional outcomes in more detail.

Keywords: *Robot-assisted surgery, maxillofacial procedures, Robot Assisted Neck Dissection, Transoral Robot Surgery.*

1. Introduction

Robot-assisted surgery (RAS) using the da Vinci surgical system (dVSS; Intuitive Surgical, Sunnyvale, CA, USA) has led to a revolution in minimally invasive urological surgery. As of 30 June 2011, there have been 1933 dVSSs sold worldwide, 1411 in the USA, 342 in Europe and 180 in the rest of the world [1]. The popularity of RAS has been partly due to the three main advantages it offers over conventional laparoscopy; magnified three-dimensional (3D) vision for precise vision, Endowrist instrument technology allowing exact excision and reconstruction, and a superior ergonomic environment for the operating surgeon.

Computerized enhanced robotic surgery using the da Vinci Robotic Surgical System has been applied successfully in urology, cardiac, general, orthopedic surgery, ophthalmology, neurosurgery, craniofacial, maxillofacial and gynecology. The use of robotic assistance (RA) in laparoscopy has been proposed to overcome the disadvantages of traditional laparoscopy while still benefiting from the advantages of the minimally invasive technique. The RA laparoscopic surgery has the potential to facilitate surgical procedures by allowing the surgeon to seat comfortably while visualizing the abdominopelvic cavity in three dimensions with magnification. The dexterity and precision of the surgeon is increased by using articulated instruments allowing more range of motion and filtration of natural tremor [2].

The most invasive surgeries involving wide dissections in craniofacial or maxillofacial surgeries are surgical treatment of head and neck cancers, so emphasis should focus over these surgeries. Traditionally, surgical treatment of cancers of the head and neck has involved various external approaches to remove the primary tumour followed by open neck dissection. These techniques provided the surgeon with optimal surgical view and access, and fairly satisfactory oncological outcomes. However, they resulted in considerable postoperative morbidity, functional deterioration, and disfigurement. Many surgeons have therefore investigated other options for preservation of organs with comparable oncological outcomes. The Department of Veterans Affairs laryngeal trial and the 91-11 Radiation Therapy Oncology Group trial showed comparable survival after primary chemotherapy and radiotherapy and conventional surgery and adjuvant radiotherapy with preservation of the larynx [3]. However, long-term follow-up studies of functional outcomes after chemotherapy reported worsening outcomes as a result of increased dependence on tracheostomy and gastrostomy tubes together with other poor outcomes.

Consequently, to achieve equivalent rates of organ preservation and oncological safety while minimising morbidity, minimally invasive surgical techniques have been investigated such as transoral laser microsurgery together with less toxic doses of radiotherapy or concurrent chemoradiotherapy. Since the advent of surgical robotics a few years ago, transoral robotic surgery (TORS) is currently being used worldwide for the treatment of cancers of the head and neck. Since 2010, we have reported the feasibility of robot-assisted neck dissection (RAND) for patients with necks classified as cN+ and cN0.

1.1. Advantages of the Da Vinci Robotic System

- At the console, the surgeon has a binocular three-dimensional view of the pelvis in High Definition. This gives a perception of depth.
- The camera remains still, and is controlled by the surgeon's foot pedal when necessary.
- The console has armrests and, adjustable height and eyepieces. These reduce surgeon fatigue.
- Motion scaling converts very large movements of the surgeon's hand to very fine movements of the instruments.
- At the console, the surgeon controls the robotic arms and the EndoWrist instruments with natural hand and wrist motions that mimic movements performed in open surgery.
- The EndoWrist instruments are designed with seven degrees of motion, one more than the human hand.
- The three operating arms are controlled by the surgeon who can switch between instruments using the control pedal. On disengaging one arm to use another, the disengaged arm remains stationary but maintains tension on the grasped tissue.
- Changing operating instruments can be done quickly, as the new instrument returns to the same place as the removed one.
- The energy sources are controlled by the surgeon through foot pedals.
- Additional ports can be introduced to use alternative energy sources or for morcellation.
- Uterine manipulator inserted vaginally adds to the ease of operating.

1.2. Disadvantages of the Da Vinci Robotic System

- Cost is the biggest disadvantage. This includes the initial cost, the cost of instruments and the cost of maintenance.
- Setting up and docking takes time, but gets quicker with use.
- There is a loss of tactile sensation; hence the amount of force to be used comes with experience.
- There is a learning curve, although it is shorter than laparoscopic surgery.
- Staff needs to be trained in set up of the system and cleaning of instruments.

2. Robotic Surgery in Oral and Maxillofacial, Craniofacial and Head and Neck Surgery

2.1. Clinical Application in Craniofacial Surgery

There are several ways to classify the use of robots in medicine. One scheme, as developed by Taylor et al. in 1997, is to classify robots by the role they play in medical applications. Taylor stresses the role of robots as tools that can work cooperatively with physicians to carry out surgical interventions, and identifies five classes of systems: (1) intern replacements, (2) telesurgical systems, (3) navigational aids, (4) precise positioning systems, and (5) precise path systems. Although this classification is technology oriented. Clinical applications are more interesting to the end-user, and a list of seven clinical areas where robotics has been applied these including: neurosurgery, orthopedic, urology, maxillofacial, radiosurgery, ophthalmology, and cardiac surgery [4].

2.2. Maxillofacial Surgery

Maxillofacial surgery is a branch of surgery that is concerned primarily with operations on the jaws, face and surrounding soft tissues. In many maxillofacial surgery cases, it is necessary to manipulate the skull bone by drilling, cutting, shaping, and repositioning operations. Accuracy is at a premium, because the shape of the bone and the aesthetic appearance of the skull and face are extremely important to patients. The current procedures are done manually using tools such as pliers, chisels, electric saws, and drills. As primarily bony structures are involved and accuracy is so important, maxillofacial surgery may be a good application area for robotics [5].

Experimental operating room for developing an interactive robot system for maxillofacial surgery, an experimental operating room has been set up at the Charite´ Hospital of Humboldt University in Berlin, Germany, in 1998. This operating room includes a unique robotic system, the SurgiScope. While most robotic systems described are based on a serial kinematic structure in which the links are attached one after the other as in the human arm, at least one company has developed a medical robot based on a parallel kinematic structure. The SurgiScope is a general-purpose 6DOF robotic device consisting of a fixed base, three parallel links, and a movable end-effector. The system is designed to be fixed on the ceiling, and provides a large workspace while not cluttering the operating room floor. The parallel kinematic structure also provides a very stable structure for precision operations. The robot was originally sold by Elekta, but is now being marketed by Jojumarie Intelligente Instrumente in Berlin. The use of this system for placement of the radiation source in brachytherapy in animal studies is described by Heissler et al. in 1998 [6].

2.3. Craniofacial Osteotomy

Another system for maxillofacial surgery has been developed at the Institute of Process Control and Robotics in Karlsruhe, Germany, in cooperation with the Clinic of Craniofacial Surgery at the University of Heidelberg. Animal studies were carried out to perform osteotomies where an RX 90 surgical robot (ortoMaquet, Staubli) was used to guide a surgical cutting saw; Burghart et al. in 1999, in his studies were carried out as follows. Twelve titanium screws were implanted into the head of a pig to be used as landmarks. A CT scan with 1.5 mm slice spacing was done, and the resulting images were used to create a surface model for surgical planning. A haptic interface was used to trace the cutting lines on the surface of the skull. Once the planning was completed, the robot was registered with the pig in the operating room, and the surgeon manually guided the Robot Arm along the trajectory where his movements perpendicular to the cutting line were restricted. This system has also been evaluated; using sheep, for the autonomous milling of a cavity in the skull needed for customized titanium implant [7].

2.4. Neurosurgery

Neurosurgical stereotactic applications require spatial accuracy and precision targeting to reach the anatomy of interest while minimizing collateral damage. This section presents three neurosurgical robotic systems: (1) Minerva from the University of Lausanne in Switzerland, (2) NeuroMate from Integrated Surgical Systems in the United States, and (3) An MRI-compatible robot developed by Dohi et al. in Japan. Minerva One of the earliest robotic systems developed for precise needle placement was the neurosurgical robot Minerva (Burckart, 1995) designed for stereotactic brain biopsy.

The mechanical design of this system was presented by Glauser et al. (1993); the system consists of a five-degree-of-freedom structure with two linear axes. NeuroMate is a six-axis robot for neurosurgical applications that evolved from work done by Benabid (1987) and Lavalle´e (1996) in University Hospital in France. The images can be in digital form (DSA, CT, or MRI images) or can be digitized (radiographs, for example) using a digitizing table or scanner. MRI-Compatible Robot in Japan, in the Mechatronics Laboratory at the University of Tokyo, Dohi et al. (1995) developed an MRI-compatible needle insertion manipulator intended for use in stereotactic neurosurgery. The manipulator frame was manufactured using polyethylene terephthalate (PET), and ultrasonic motors were used for the actuators Researchers in Germany (Kaiser et al., 2000) have developed an MRI compatible robotic biopsy system, focusing on breast cancer as an initial application [8].

2.5. Oncosurgery

The use of the robotic surgical system for treatment of cancers of the head and neck is currently upcoming in many countries, and the number of patients operated on is steadily rising over time. Initially, Robot-assisted neck dissection **(**RAND) was done through a transaxillary retroauricular approach to remove the necknodes confidently and comfortably. However, as surgeons gained in experience they realised that the operation can successfully be done through a retroauricular or modified facelift approach alone. RAND should not be used in every case in which neck dissection is indicated though, because the oncological safety could be violated in cases of nodal metastases in the neck with overt extranodal extension including encasement of the carotid artery. Its use should be limited to necks that are cN0 or cN+ with no obvious extranodal extension on preoperative examination. Likewise, Transoral robotic surgery (TORS) should not be used in patients with poor oral exposure or tumours with extensive local invasion. TORS, which is a minimally invasive technique for organ preservation with equally acceptable oncological outcomes, is now emerging as a standard of surgical care in cancers of the head and neck where it is indicated

3. The Future: Robotic Surgery Training

With the expansion of Robot Assisted Surgery (RAS) in Craniofacial surgery the focus in this coming decade will shift towards training the next generation of craniofacial or maxillofacial surgeons. In a worldwide survey of both practising and trainees, most of respondents feel it is required or beneficial to have training in RAS [9]. However, training in RAS poses unique challenges when compared with conventional surgery. For example, the absence of tactile feedback during RAS requires the development of visual cues with 3D depth perception. Although RAS is now included in the Core Curriculum for residencies, guidelines for robotic surgery training have not yet been produced.

Recently, Lee et al. [10] published a best-practices model for training and credentialing in RAS. This consists of a structured curriculum incorporating preclinical and clinical components in a competency-based format. Requirements of the preclinical stage include familiarity with the workings of the various dVSS models. This can be achieved through didactic sessions from clinical staff and industry representatives, as well as informal hands-on tutorials outside the operative setting.

An online tutorial on the fundamentals of the dVSS has now been released by Intuitive Surgical and should prove helpful [11]. Completion of this module can help trainees be conversant in the docking of the patient-side cart, instrument insertion and exchange, as well as control of the various aspects of the robotic interface through the surgeon's console.

4. Conclusion

In conclusion, robotic surgery, and particularly the dVSS, have expanded surgical skills, thanks to increased surgical accuracy and precision, movements beyond the manipulation that can be achieved by the human hand, tremor reduction, 3D magnification of the operative field, motion scaling, ergonomic advantages and remote operations. Phantom, cadaver as well as clinical studies showed the increasing surgical accuracy and precision of different robotic devices. So for best results, those exposed to RAS training in their residency or fellowship must provide evidence of experience with a minimum of 20 robotic cases. However, two important principles must be followed if RAS is to be successfully practised and taught [12]. First, care must be provided in the context of a close-knit surgical team. Second, there is no substitute for practice.

'Learning by doing' is simply not good enough and puts the patient at risk. Robot-assisted surgery has revolutionized many surgical subspecialties. While a number of obstacles exist for surgical robots, interest appears to be growing, as highlighted by a number of recent presentations and publications. Robotic assistance for craniofacial surgery has the potential to expand our treatment armamentarium, reduce complication rates, and treat conditions that remain incurable today.

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Regarding clinical feasibility this study revealed the following main indications for robotic surgery in the field of OMF, craniofacial and head and neck surgery: TORS for upper digestive and respiratory tract lesions; TORS for skull base surgery; and TORS for transaxillary thyroid and endocrine surgery. In paediatric surgery, adjustments to the instruments are still needed. As far as functional outcome is concerned, this study revealed a promising reduction of morbidity in patients with head and neck cancer.

5. References

1. Intuitive Surgical. How many units have we sold? http://investor. intuitivesurgical.com/phoenix.zhtml?c=122359&p.=irol-faq #22324; 2011 [last accessed 18.09.11].
2. Nezhat C, Lavie O, Lemyre M, Unal E, Nezhat CH, Nezhat F, Robot-assisted laparoscopic surgery in gynecology: scientific dream or reality?, Fertility and Sterility 91, 2009, 6.
3. Forastiere AA, Goepfert H, Maor M, et al. Concurrent chemotherapy and radiotherapy for organ preservation in advanced laryngeal cancer. N Engl J Med., 349, 2003, 2091–8.
4. Hemal AK, Menon M, Robotics in urology. Curr. Opin. Urol. 14, 2004.89–93.
5. Hassfeld S, Muhling J, Computer assisted oral and maxillofacial surgery – a review and an assessment of technology. Int. J. Oral Maxillofac. Surg. 30, 2001, 2–13.
6. Korb W, Marmulla R, Raczkowsky J, Muhling J, Hassfeld S, Robots in the operating theatre – chances and challenges. Int. J. Oral Maxillofac. Surg. 33, 2004, 721–732.
7. McBeth PB, Louw DF, Rizun PR, Sutherland GR, Robotics in neurosurgery. Am. J. Surg. 188, 2004, 68S–75S.
8. Byeona HK, Holsingerb FC, Kima DH, Kimc JW, Parkd JH, Koha YW, Feasibility of robot-assisted neck dissection followed by transoral robotic surgery British Journal of Oral and Maxillofacial Surgery xxx (2014) xxx–xxx
9. Guru KA, Hussain A, Chandrasekhar R, Piacente P, Hussain A, Chandrasekhar R, et al Current status of robot-assisted surgery in urology: a multi-national survey of 297 urologic surgeons. Can J Urol 2009; 16:4736–41.
10. Lee JY, Mucksavage P, Sundaram CP, McDougall EM. Best practices for robotic surgery training and credentialing. J Urol 2011; 185:1191–7.
11. Intuitive Surgical. Training resources and support tools. http:// www.intuitivesurgical.com/training/training_resources.html [last accessed 18.09.11]
12. Zorn KC, Gautam G, Shalhav AL, Clayman RV, Ahlering TE, Albala DM, et al Training, credentialing, proctoring and medicolegal risks of robotic urological surgery: recommendations of the society of urologic robotic surgeons. J Urol 182, 2009, 1126–32.