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REVIEW

Robotic endoscopic sinus and skull base surgery: Review of the literature and future prospects

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Robotics;
Skull base;
Paranasal sinuses;
Surgery

Summary
Objective: There has been a considerable growth in the indications of endonasal surgery that now include malignant tumours of the nasal fossae and anterior and middle cranial fossa. However, new limitations have also been identified, such as bleeding and cerebrospinal fluid leak, as well as the need to use several instruments simultaneously. Can robotics provide solutions to these problems?
Method: Review of the literature based on the three main databases: Medline, Pubmed and Cochrane.
Results: Ten publications were identified. Some authors have developed surgical approaches to the skull base using the da Vinci® robot, while others have designed specific robots.
Conclusion: None of the currently available solutions appears to be completely suitable. The da Vinci® robot is very cumbersome and can only be used in the middle cranial fossa via complex and relatively invasive routes. The other robots are laboratory prototypes. We are currently developing an innovative, compact, ergonomic and safe dedicated endoscope holder.

Introduction

The robots used in head and neck surgery are either commercial robots (exclusively the Intuitive Surgical da Vinci® robot), or laboratory prototypes. Several teams have published promising results with the use of the da Vinci® robot in head and neck surgery [1], but no results have been published for prototype robots. In contrast, the da Vinci® robot is not used in otological surgery, while several prototypes have been tested over recent years in France, particularly by Prof. Sterkers, and in the rest of the world [2—6].

Endonasal surgery was developed in the 1970s by the Austrian surgeons Stammberger and Messerklinger [7] for the treatment of chronic sinusitis refractory to medical treatment. In 1985, Dr David Kennedy (trained by these two surgeons) was the first author to describe Functional Endoscopic Sinus Surgery (FESS). This new technique constituted a revolution in this field, by transforming extensive non-functional surgery into minimally invasive surgery designed to restore functional and physiological ventilation of the sinuses. Improvement in operative techniques,

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reconstruction techniques and equipment subsequently allowed extensions of the operative indications, first to benign tumours and now to malignant tumours invading the skull base. However, these extensive resections are limited by new complications (bleeding and cerebrospinal fluid leak) requiring the use of several tools simultaneously (endoscope, suction, grasping forceps, coagulation). Castelnuovo et al. [8] (otorhinolaryngologist in Varese, Italy) and Nicolaï (Neurosurgeon in Varese, Italy) consequently published several papers describing a technique called ''Four-hand surgery'' allowing extensive skull base resections by a team of two surgeons using several instruments introduced via the two nostrils. This technique demonstrates the possibility of working with more than two instruments in the nose, but it is poorly reproducible, not very ergonomic and requires two experienced senior surgeons.

We believe that robotics can provide the surgeon with an ''additional hand'' and we therefore conducted a review of the literature to see whether other teams are working on this subject, the problems encountered and the solutions provided.

Method

The review of the literature was performed on the Pubmed, Medline and Cochrane databases and robotic and otorhinolaryngology specialist journals using the following key words: ''skull base robotics'', ''sinonasal robotics'', ''functional endoscopic sinonasal surgery and robotics'' and ''ENT [and] robotics'' at Montpellier university hospital and in the Laboratoire d'Informatique, de Robotique et de Micro-électronique de Montpellier (LIRMM) (Montpellier Computers, Robotics and Micro-electronics laboratory). No selection criteria were used and all articles concerning this subject were therefore reviewed. However, as navigation, simulation and augmented reality are not considered to be robotic techniques, articles concerning these aspects were not included in this analysis.

Results

Endonasal surgery and the da Vinci® robot

In 2007, Hanna et al. [9] described a surgical approach to the anterior cranial fossa using the da Vinci® robot on four frozen cadavres via bilateral superior vestibular incisions. Osteotomies of the anterior wall of the maxillary sinuses in canine fossae were then performed. Two bilateral middle meatotomies were performed from the interior of the sinus to the nasal fossa to allow introduction of two instruments. After resection of the posterior part of the septum, the 5 mm diameter 3D camera was introduced via one of the nostrils:

- advantages: this approach provides access to the posterior ethmoid, sphenoid, sella turcica, suprasellar and parasellar regions and the cribriform plate. Skull base reconstruction can be performed with the robot. The two-hand approach, the absence of tremor and the magnified vision facilitate surgery;

Figure 1 C-TORS technique: surgical incision posterior to the submaxillary glands.

- disadvantages: this approach remains extremely invasive and does not provide access to the anterior ethmoid or middle meatus.

O'Malley and Weinstein [10], in 2007, described a skull base approach using the da Vinci® robot: cervical transoral robotic surgery (C-TORS) on one cadavre and one dog: incision along the posterior margin of the 2 submaxillary glands and ''blind'' placement of blunt trocars directed superiorly, medially and along the anterior border of the cervical spine. Instruments were then introduced with their extremities in the oropharynx. The 3D camera was introduced transorally:

- advantages: according to the authors, this technique allows resections in the sellar, suprasellar and parasellar regions with good visualization of the anterior skull base (Fig. 1);
- disadvantages: this technique is extremely invasive and requires blind introduction of trocars.

Lee et al. [11], in 2010, described an entirely transoral approach on seven cadavres: the camera and instruments were introduced transorally. Two red rubber catheters were then introduced via the nostrils and brought out through the mouth to retract the soft palate (Fig. 2):

Figure 2 Transoral approach.