Potential of Robot-Based Surgery for Otosclerosis Surgery

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KEYWORDS

• Stapes • Otology • Robotics • Planning • Stapedotomy • Minimally invasive

KEY POINTS

- Robot-based devices have the potential to improve accuracy of the surgical gesture.
- Prototypes have proved the feasibility of achieving some of the key steps of stapedotomy with success on temporal bones models.
- The functional outcomes, potential improvements, and medicoeconomic efficiency of robot-based devices remain to be demonstrated.

Video content accompanies this article at http://www.oto.theclinics.com.

INTRODUCTION

Otosclerosis surgery requires complex procedures and surgical gestures to be carried out in a confined surgical workspace. When it comes to planning surgical treatment for otosclerosis, one should always propose a hearing aid fitting as an alternative for hearing rehabilitation. Otosclerosis surgery is very demanding, because a high percentage of success with no complications is expected by the patient. Consequently, when the procedure is performed by experienced surgeons, excellent outcomes are expected, with a hearing improvement and a postoperative air–bone gap of less than 10 dB in more than 90% of cases. Immediate postoperative complications of the surgery

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include invalidating vertigo or worsening of the auditory threshold. Worsening of the auditory threshold can result from an abnormal positioning of the prosthesis, a dry labyrinth, an intralabyrinthine hemorrhage, or a perilymph fistula. In the worst cases, this can lead to sensorineural hearing loss that can be partial or total and irreversible. Even though these complications are rare, their rates may vary with the experience of the surgeon.[1,2]

Some technical refinements have been proposed and progressively adopted by the otological community to lower the complication rate and achieve a minimal postoperative air–bone gap. Subsequently, stapedotomy instead of stapedectomy was proposed to lower sensorineural hearing loss. The mechanical stapedotomy using a drill or a trephine was further secured with the use of a laser alone[3] or in combination with a microdrill[4] to improve reproducibility from one procedure to another. Development has also focused on piston prostheses to obtain thinner devices so as to allow a good exposure of the footplate during placement and easy crimping of the incus with a clipping system or nitinol prostheses that only requires heating and no crimping to achieve contact with the incus.[5] Moreover, it has been shown in some stapes fixation training models that more experienced surgeons would apply less mechanical constraints on the ossicular chain during prosthesis manipulation.[6]

In this context, it seems that one of the limitations to further improving the safety and results of otosclerosis surgery is the surgeon's dexterity and experience. Thus, it has been proposed to use robot-based devices to enhance the quality of the surgical gesture. This article discusses the main contributions in the field of robot-based devices for otosclerosis surgery.

A ROBOT-BASED DEVICE FOR OTOSCLEROSIS SURGERY: RATIONALE

Otosclerosis surgery is conventionally performed through a small endaural incision or more frequently through a transcanal approach guided by the view from an operating microscope. Such an approach raises constraints that are commonly encountered in middle ear surgery. First, the surgery is performed in a deep workspace through a narrow approach restricted by the diameter of the external auditory canal and speculum. Under these conditions, even a small amount of bleeding can affect field exposure. Second, the surgeon holds the tools oriented along an axis collinear with exposure of the surgical field; thus, she or he may interfere with his visual field. Even though he is not working blindly, he may lose the stereoscopic view if one of the oculars of the microscope is hidden and, thus, she or he may lose depth perception. Third, the procedure is performed on millimetric structures, and low forces of less than 1 N are used to achieve the surgical tasks.

In addition, otosclerosis can also be considered to be a simpler procedure compared with other middle ear surgeries. First, the approach is repeated from 1 patient to another. Second, the lesions are mostly located in the oval window region and the extent of disease does not change the surgical strategy apart from in the case of well-advanced otosclerosis. Third, the anatomy is not often modified by the disease from 1 patient to another. Fourth, even though their order can be modified according to each surgeon's technique, the steps performed during the procedure are always the same: raising the tympanomeatal flap, lowering the scutum, sectioning the posterior tendon and crura, stapedotomy, piston placement and crimping, and folding the tympanomeatal flap down. For these reasons, a high level of success is expected when the surgical procedure is performed.

However, the current technique has 2 limitations to guaranteeing a reproducible quality of surgical gesture. First, the conventional technique with a tool holder relies