Robotic Approaches to Palatoplasty and the Treatment of Velopharyngeal Dysfunction

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Abstract

The operative techniques used to address palatoplasty and velopharyngeal dysfunction rely on traditional methods of surgical exposure and tissue handling. As the role of robotic surgical systems has expanded, emphasis has shifted from extirpative to reconstructive applications. We discuss the possible role of surgical telemanipulation systems in the treatment of these diagnoses. Furthermore, we present a feasibility study that addresses a commonly performed treatment of velopharyngeal dysfunction—posterior pharyngeal flap (PPF). In brief, PPFs were successfully performed on a small series of cadaveric human specimens. The technical aspects of the procedure, including telemanipulator set-up, positioning, surgical instrumentation, and timing are described in detail. All cadavers underwent successful performance of PPFs. Operative times were within an acceptable range and use of the robotic system demonstrated a steep learning curve. Many of the potential advantages and costs associated with robotic surgical systems are discussed.

Keywords

- ▶ robotic surgery
- ▶ palatoplasty
- ▶ velopharyngeal dysfunction

Cleft palate is a common diagnosis among pediatric patients and occurs with a range between 0.1 to 1.1 per 1,000 live births.¹ Children affected with the condition commonly undergo palatoplasty within the first 18 months of life. Although the techniques used to perform palatoplasty vary among centers, all have the same functional goals: to create a stable barrier between the oral and nasal cavities, and to reposition the levator veli palatini muscle in such a way as to provide for appropriate closure of the velopharyngeal mechanism to produce normal speech. Within the group of patients that undergo palatoplasty, a subgroup exists that does not attain appropriate speech. These patients sometimes develop hypernasality during speech—also referred to as velopharyngeal dysfunction (VPD). The mainstay of treatment for VPD is speech therapy. When this modality fails to produce intelligible speech, surgery to improve the competence of the valve is performed.

The surgical methods used to treat VPD rely on alteration of the velopharynx to create a more competent sphincter mechanism. By “tightening” the velopharyngeal port in some way,

less nasal air escape occurs during speech. The surgical management of velopharyngeal dysfunction has essentially three options: palatal lengthening procedures (such as the Furlow palatoplasty), sphincter pharyngoplasty, and posterior pharyngeal flaps (PPF). All of these procedures rely on traditional methods of surgical exposure and tissue handling. This often includes use of a mouth gag, a headlight worn by the operative surgeon, and elongated surgical instruments. Although the outcomes associated with palatoplasty using conventional instrumentation continue to be good or excellent, the procedure is often accompanied by muscular discomfort and fatigue on the part of the surgeon due to excessive neck flexion.

There now exists a growing literature addressing the use of robotic-assisted systems in plastic surgery procedures.^{2–7} This growing literature emphasizes reconstructive applications that are different in focus from the extirpative procedures for which robotic systems have been frequently used in the head and neck. Nonetheless, few reports have documented the use of robotic systems for reconstructive applications related to either palatoplasty or the treatment of VPD.⁸

Fig. 1 Photographs of the surgical procedure. (A) The margins of a superiorly based posterior pharyngeal flap after being incised using monopolar cautery. (B) The flap is fully mobilized. (C) The superiorly based flap is inset into the palatal defect. (D) View of the velopharyngeal ports following the procedure.

Feasibility Study

The purpose of the study was to perform an evaluation of a robotic telemanipulator in the performance of (PPFs).⁹ We hypothesized that use of this surgical platform would have benefits including improved exposure and more favorable ergonomics for the surgeon.

Method

A pilot study was performed using three fresh cadaveric human heads. PPFs were performed using the da Vinci S Surgical System (Intuitive Surgical Inc., Sunnyvale, CA). All procedures were performed in accordance with the Institutional Animal Care and Use Committee (IACUC) and the University of Pennsylvania Institutional Review Board.

Set-Up of Robotic Telemanipulator

The procedure was performed with the human model in the supine position. A 30-degree three-dimensional (3D) camera was used with the camera mounted in the most inferior position in the operating field. Two robotic surgical instruments were used (one Maryland forceps, one spatula/monopolar cautery) to perform incisions in the soft palate, raise nasal mucosal lining flaps, and raise a Hogan-style PPF. Once the flaps were raised, the PPF was sewn into position with a Maryland forceps and needle driver. A surgical assistant positioned near the head of the model provided suctioning of the oropharynx and cut sutures when necessary.

Posterior Pharyngeal Flap Procedure

The soft palate was split along its midline with monopolar cautery, and nasal lining flaps were elevated in the standard

fashion. A superiorly based PPF was marked along the posterior wall of the oropharynx. The flap was based slightly cephalad to the level of the velum. The flap was raised with monopolar cautery in the avascular plane anterior to the prevertebral fascia. The PPF was then inset into the nasal aspect of the soft palate. It was sewn into position with interrupted 4–0 Vicryl sutures (►Fig. 1). The PPF was lined with nasal mucosal flaps, and the cleft palate was closed in layers.

Results

The da Vinci surgical system was able to perform PPFs successfully in these human specimens. Operative times were 122, 113, and 105 minutes (mean = 113 min). ►Fig. 1 and ►Video 1 (supplemental digital video content) depict the operative field at various portions of the operation. The velopharyngeal “ports” were clearly visible via the 3D camera, and ports would have been easily modified under the exposure provided by the robotic system had the surgeon deemed it necessary. The 30-degree scope allowed for improved surgical exposure and all surgeons reported minimal fatigue following the surgery.

Video 1

Supplemental digital video content viewable at: www.thieme-connect.com/ejournals/html/10.1055/s-0034-1368165. Excerpts from placement of the posterior pharyngeal flap in a cadaveric human head.

Discussion

The surgical exposure provided by traditional instrumentation used in palatal surgery has changed little over the previous century. Access to the posterior pharynx is provided using some form of intraoral retractor (i.e., Dingman retractor), operating loupes, and surgical headlamps. Substantial neck extension by the patient and flexion by the surgeon are required to visualize the pertinent anatomy. Although the surgical outcomes following velopharyngeal surgery are generally good, surgical exposure and surgeon comfort are both areas in which improvements in technique might be found.

With the advent of transoral robotic surgery (TORS) for ablative procedures,^{10–12} there has been a corresponding increase in the need for novel reconstructive approaches to these intraoral defects. Previous reports of the use of surgical robots in plastic surgery have focused on microsurgical anastomoses,¹³ and the robotic harvest of traditional muscle flaps.^{13,14} In recent years, however, reconstruction of oropharyngeal defects has received increasing attention in applications such as free-tissue transfer and local myomucosal flaps.¹⁵ Most recently, Bonawitz et al described the use of the da Vinci surgery system to perform a facial artery myomucosal (FAMM) flap for reconstruction of a soft palatal defect.⁸

This was a feasibility study designed to emulate a procedure that has been performed by traditional means with good to excellent results for a long period. As such, the robotic platform would have to provide a significant number of benefits over traditional equipment. In our opinion, the two most powerful benefits of the robotic platform are improved exposure (especially of the velopharyngeal ports) and improved surgeon ergonomics. It was the opinion of the authors that the robotic platform provided improved exposure of most structures involved in the operative dissection. Of note, we all believed that the velopharyngeal “ports” were well visualized during the placement of the PPF and at the completion of the procedure.

Furthermore, the ergonomic benefits of the robotic platform are most likely its greatest comparative advantage. Recent studies on occupational injuries in plastic surgeons have documented an alarmingly high rate of muscular strain and cervical spine pain.¹⁶ We have little doubt that this data accurately reflects the occupational status of cleft surgeons—the group most commonly performing procedures that require prolonged neck flexion. The console of the robotic platform is ergonomically designed and eliminates completely the need for awkward and prolonged neck flexion.

Despite our guarded optimism regarding the future role of robotics in surgery of the palate and velopharynx, there are several barriers to widespread adoption of this technology in the treatment of cleft palate and its associated speech disorders. Currently, the da Vinci robot is FDA-approved for TORS in adults only. The system is only FDA approved for pediatric use in laparoscopic and urologic

procedures. The robotic system is expensive and the instruments required to perform the procedure are only semi-reusable (they have a manufacturer determined expiration after a small number of procedures). Furthermore, the instrumentation is geared toward laparoscopic applications and is somewhat bulky. Few of the instruments available replicate the instruments used in cleft or plastic surgery. In this respect, cleft surgeons are not unlike other reconstructive microsurgeons in that the current instrumentation does not truly address their needs.

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