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Transoral Thyroidectomy Using A Flexible Robotic System: A Preclinical Cadaver Feasibility Study

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**Objectives/Hypothesis:** Traditionally, most thyroid surgery utilizes a curvilinear cervical incision with a resulting permanent scar. Minimally invasive and remote access thyroid surgery techniques continue to evolve. Transoral approaches through a vestibular incision have been developed at several centers throughout the world, obviating the need for a cutaneous incision and optimizing aesthetics. To date this technique has been performed using rigid endoscopes or a linear robotic platform. The goal of this study was to test the feasibility of a novel flexible robotic system to perform a transvestibular thyroidectomy in a preclinical cadaver model.

**Study Design:** Preclinical feasibility study.

**Methods:** Right and left thyroid lobectomies were successfully performed via a transvestibular approach in four cadavers.

**Results:** A single vestibular incision between bilateral mental nerves allowed entrance of the flexible robot in a subplatysmal plane in both male and female cadavers. The recurrent laryngeal nerves and parathyroids were identified and preserved. The flexible three-dimensional camera allowed excellent visualization and could be easily repositioned for optimal visualization of right and left structures. The flexible and wristed instruments enabled an atraumatic approach and allowed for precise surgical technique.

**Conclusions:** The transoral vestibular approach to the central neck is a promising technique for thyroidectomy with optimal cosmesis and can be successfully accomplished using this novel flexible robotic system. Improvements in visualization and access offered by this system may improve application of this technique.

**Key Words:** Transoral thyroidectomy, robotic thyroidectomy, minimally invasive thyroidectomy.

**Level of Evidence:** NA

INTRODUCTION

In the late 1880s, Theodore Kocher described the cervical incision by which the vast majority of thyroidectomies are performed today.1 This open approach involves a low transverse cervical incision, at least 4 cm long, providing excellent visualization and access, but resulting in a scar. There is an increasing societal emphasis on avoiding visible scars in locations such as the neck.2,3

Concurrently, the incidence of thyroid cancer has increased over the past 30 years.4–6 These factors, together with ever-evolving technology, has created a drive to develop more aesthetically favorable alternatives to the traditional cervical approach without sacrificing surgical outcomes.4–6

**MATERIALS AND METHODS**

Using a fresh-frozen cadaver model, we investigated the feasibility of the Flex Robotic System (Medrobotics, Raynham, MA) for the transoral vestibular approach for thyroidectomy. This study was deemed exempt by our institutional review board. Four Caucasian adult cadavers (two male, two female, age at death 57–71 years) were used in a simulated surgical setting in accordance with institutional protocols. Each specimen consisted of a cephalus extending to the fourth thoracic vertebra, with all structures intact, including dentition, and without obvious cervicofacial anomalies or prior neck surgery.

The specimens were placed supine, with the neck in extension and immobilized. An approximately 4-cm vestibular mucosal incision was made, from the mandibular first premolar to contralateral first premolar (no. 21–no. 28), using monopolar cautery, and blunt dissection was undertaken to expose the bilateral mental nerves and ensure clearance of the nerves bilaterally when advancing the robot through the vestibular incision (Fig. 1). Blunt dissection was then carried out in a subplatysmal plane to the level of the clavicles and sternal notch, creating a tunnel approximately 4 cm wide.
After skin and platysma elevation, a laryngeal blade (Medrobotics) was inserted to retract the skin flap and suspended from a bed-mounted retraction arm, allowing excellent subplatysmal visualization from the pogonion to the clavicles (Fig. 2). The robot could be docked on either side of the patient, with the endoscope unit placed over the patient in the midline and secured to the rail at the head of the bed, allowing an approach to the oral cavity caudally. The endoscope (28 mm × 15 mm) was driven through the vestibular incision while stabilizing the mandible (Figs. 2 and 3). With the robotic endoscope in position, the flexible instruments were inserted through the external accessory channels to perform the procedure (Fig. 3). A 3.5-mm grasper (Flex Fenestrated Grasper or Flex Monopolar Maryland Dissector; Medrobotics) and 3.5-mm cauterizing instrument (Flex Monopolar Spatula; Medrobotics) were used for tissue retraction, manipulation, and cutting. Smoke evacuation was achieved via both the suction port on the laryngeal blade as well as the suction port built into the robotic endoscope.

The instruments could be switched from the right to left port as needed throughout the procedure without moving or repositioning the flexible robotic scope. When the flexible robotic scope needed to be moved to a new position to optimize visualization, the instruments were retracted into the accessory ports to ensure no inadvertent damage. No torque or stretch was placed on tissues along the insertion paths of the instruments.

With the robot in position, right and left thyroid lobectomies were performed in each cadaver using surgical techniques previously described for a transoral endoscopic thyroidectomy vestibular approach (TOETVA). In brief, the strap muscles were identified, and the midline raphe was incised from the thyroid notch to the clavicles (Fig. 4). Gentle blunt dissection and monopolar cautery allowed the strap muscles to be dissected free of the anterior and lateral aspect of the thyroid lobe (Fig. 4). A Vicryl suture was passed through the cervical skin, through
strap muscle, and back through the skin to allow lateral retraction of the sternohyoid and sternothyroid muscles from the midline. These could be dynamically retracted by an assistant, or statically retracted and secured to the bed-mounted retraction arm and adjusted to achieve adequate visualization without causing trauma. The thyroid isthmus was identified and transected in the midline. The superior pole was identified and retracted laterally and inferiorly to allow identification and dissection of Joll’s space and isolation of the superior pole vessels that were ligated. The lobe was retracted medially, and the tubercle of Zuckerkanzl identified (Fig. 5). The middle thyroid vein was ligated, allowing medial rotation of the lobe, and the superior parathyroid gland was identified and bluntly dissected off of the thyroid capsule (Figs. 6 and 7). The recurrent laryngeal nerve (RLN) was identified at its entry into the larynx at the cri- cocothyroid joint (Fig. 8). The RLN was traced inferiorly in the tracheoesophageal groove, and a capsular dissection freed the thyroid lobe from the parathyroid glands and Berry’s ligament using a combination of gentle blunt dissection and cautery as needed. The inferior vascular pedicle was ligated, and ligamentous attachments to the trachea were incised. The specimen was removed through the vestibular incision. The thyroidectomy bed was inspected, and the RLN and both parathyroids were found to be intact. All procedures were recorded with continuous video and still photography. Contralateral lobectomy was accomplished in similar fashion. After bilateral lobectomies were completed, all robotic instruments were removed, and a 4-cm Kocher incision was made to inspect all anatomy in the standard view.

RESULTS

Eight thyroid lobectomies were successfully performed in four cadaver specimens. For the purposes of this study, we focused on feasibility of the approach rather than timing and expediency; therefore, exact time spent for each step of the setup process was not calculated. However, we found that time for total setup, including robot start-up, placement, draping, and retractor placement in the cadaver, was approximately 10 to 15 minutes per cadaver. In our experience, the learning curve for the optimal positioning of the robot as well as the suspension blade was short and improved quickly. Again, due to our focus on feasibility of the approach, the total operative time was not calculated; however, the average time for creating the vestibular incision and developing the subplatysmal plane was approximately 5 to 10 minutes per cadaver. The small size of the robotic endoscope permitted entry through the vestibular incision in all specimens regardless of sex. Driving the robotic endoscope from the vestibular incision to the obtainment of adequate view of the central neck and with insertion of the instrument arms was less than 5 minutes. The robot was docked in place once the desired view was reached.

Fig. 5. View during left thyroid lobectomy after the superior pole has been taken and the thyroid gland (TG) is retracted anteriorly and medially. The sternothyroid muscle (ST) is retracted laterally by a suture, and the internal jugular vein (IJ) is in view. The thyroid cartilage (TC) and Berry’s ligament (BL) are seen here, and the superior parathyroid can be seen just lateral to Berry’s ligament. Blunt dissection to free the parathyroid down and away from the gland will continue to allow the gland to rotate further medial and off of the trachea. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

Fig. 6. The left lobe has been lifted anteriorly and rotated medially to reveal more clearly the superior parathyroid. Further blunt dissection will allow the parathyroid to be swept down off the lobe and the lobe to be further retracted medially, allowing more exposure of the tracheo-esophageal (TE) groove. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

Fig. 7. View of the superior parathyroid (*) with feeding vessel. The recurrent laryngeal nerve (arrow) can be faintly seen beneath the fascia, traveling within the left tracheoesophageal groove. The left thyroid lobe has been rotated medially on top of the trachea and is being gently retracted by the fenestrated grasper. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]
Advancement and fine adjustments of the flexible endoscope could be performed as the procedure proceeded and did not require movement of the base of the robot to maximize visibility for lateral, inferior, and deep dissections. We did find that driving the scope just lateral to the midline after entry through the vestibule, and then angling the scope slightly medially, allowed optimal visualization.

The coaxial nature of the robotic arms in relation to the camera ensured that the instrumentation remained within the field of view. Haptic feedback from the endoscopic instruments proved useful and allowed assessment of tissue firmness. The built-in evacuation ports of the Flex retractor aided in smoke evacuation from the surgical field without the need for a separate instrument to be inserted. However, if a separate suction were desired, a 14-French flexible suction catheter can be placed through the instrument port to reach the more distal field without the need for a separate instrument to be inserted. Gross and fine motor control of the flexible robotic endoscope using the joystick facilitated driving of the endoscope to the desired site. A one-surgeon, two-handed approach was sufficient for our dissections. However, we found that the addition of a second surgeon was feasible and theoretically could aid in suctioning, counter traction, or retraction of either of the specimen or of the straps and carotid sheath structures. In these cases, small incisions lateral to the mental nerve can be used as previously described.7–9

In each procedure, flexible instruments were introduced into the accessory channels without difficulty. There were no collisions or crossover of instruments during the procedure or with instrument exchange. The flexible instruments allowed for coordinated and adequate range of motion. However, as with other endoscopic instruments, the lack of memory and rigidity at times resulted in unpredictable rebound movement after incision through a tissue plane. Incisions using the spatula or needle tip were clean and precise, and although there was a learning curve, judgment of depth was aided by three-dimensional visualization and haptic feedback. The grip strength of both the Flex Fenestrated Grasper and Flex Monopolar Maryland Grasper was adequate for retraction of thyroid tissue and strap muscle, and was delicate enough on the thyroid gland that we did not observe shearing.

Inspection via the Kocher incision after bilateral lobectomies had been completed in the first cadaver revealed small remnants of thyroid tissue left behind measuring approximately 1 cm, similar to historical near-total thyroidectomies. It was notable that in the cadavers there was considerable homogeneity of color between the strap muscles and thyroid tissue, which would not be problematic in live patients with vascularized thyroid glands. These remnants were successfully removed using the Flex robot, and heightened awareness allowed the subsequent thyroidectomies to be completed without leaving remnant tissue.

**DISCUSSION**

Various minimally invasive and remote access approaches have been proposed including the minimally invasive transoral endoscopic approach,10–12 transcervical minimally invasive transaxillary endoscopic or robotic-assisted thyroidectomy approaches,13–16 and transareolar breast approach.17 Benhidjeb et al. defined the ideal minimally invasive approach as one that respects surgical planes while minimizing trauma, avoids distant surgical access with the need for excessive tissue dissection, and minimizes or altogether avoids a scar.18 Yet, whereas many of these innovative approaches do respect surgical planes, minimize surgical trauma, and minimize or hide visible scarring, these approaches all represent some degree of compromise between surgical exposure and aesthetics, either necessitating a small but visible scar or requiring extensive tissue dissection from a remote but hidden incision.6–8,17–22 Furthermore, some approaches are associated with increased postoperative pain and longer hospital stays given the additional tissue dissection and retraction necessary to gain access to the central neck from a distant cutaneous entrance site.4,23

In response to these concerns, in 2007, Witzel et al. published a proof of concept study for performing transoral endoscopic thyroid surgery in human cadavers, which they called the natural orifice transluminal endoscopic surgical approach.19 In this approach, the thyroid is accessed in the subplatysmal plane through a concealed incision made in the floor of the mouth, posterior to the mandible, allowing access to the central neck and bilateral thyroid lobes with minimal additional dissection as compared to prior remote-access approaches. Since the publication of this feasibility study 10 years ago, there have been numerous reports in the literature on the use of transoral endoscopic thyroid surgery.7,8,17–22,24,25 The evolution of this technique has led to several modifications, including abandoning the floor of mouth incision in favor of a vestibular incision in the gingival-buccal sulcus, and has included both robotic and endoscopic approaches.22,24,25 The transoral endoscopic vestibular approach has gained favor particularly in Asia, where it continues to evolve with refinement of incision placement.7,8 When contrasted with other

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**Fig. 8.** The needle tip monopolar cautery points to the recurrent laryngeal nerve (arrow), which has been dissected for better visualization. A grasper is gently lifting the parathyroid (†). [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]
remote-access approaches, the transoral vestibular approach offers the potential for limited dissection and a completely hidden incision. Several authors have reported excellent outcomes using the transoral vestibular approach (both robotic and endoscopic), including Anuwong et al. in a series of 425 patients in Thailand, Yang et al. and Fu et al. in a series of 41 and 81 patients in China, respectively, Kim et al. in a series of 24 patients in Korea, and Russel et al. in a series of 14 patients in the United States.

In addition to a completely concealed incision and the minimal dissection required to gain access to the central neck, the transoral vestibular approach is the only remote approach with a midline point of view and equal access to both sides of the neck, a considerable advantage over the transaxillary and facelift approaches, which have limited capacity to address the contralateral neck. The vestibular incision spares the tongue, floor of mouth, and salivary papillae; however, as with any transoral approach, there is a risk of contamination of the neck with oral flora. Although this has not been seen, authors advocate irrigation and prophylactic perioperative antibiotics. It should also be noted that there is a considerable amount of time needed for both setup and approach, especially with use of the da Vinci robotic system, which prolongs surgical times significantly beyond that of the standard open approach.

Those who advocate the robotic technique note that the da Vinci system provides a magnified, high-definition, three-dimensional view of the surgical field and wristed instruments with tremor filtration, which aid dexterity and mobility. Those who prefer an endoscopic approach note the robot's lack of tactile feedback, prolonged setup time, and higher cost. Although the endoscopic approach is less costly and has quicker setup, instrumentation is nonwristed and lacks the elegant dexterity of the da Vinci. Both robotic and endoscopic approaches lack flexible instrumentation as well as single port–technology and require insufflation within the confined space of the neck.

The Flex Robotic System was developed for head and neck surgery and combines a flexible endoscope, robotic system, and flexible-wristed 3.5-mm instruments. It received Food and Drug Administration clearance for head and neck surgery in 2015. Its use has been well documented for transoral robotic surgery both in the United States and abroad. The system has been described in detail elsewhere but summarily, it consists of a surgeon-controlled console with a touchscreen monitor and three-axis joystick that controls the flexible endoscope that advances via a follow-the-leader mechanism and has two built-in ports for flexible endoscopic tools and a built-in suction port. The endoscope used in the lab is equipped with a three-dimensional, high-definition digital camera and six light-emitting diode lights. The overall platform is considerably smaller and more mobile than other systems.

The camera is able to move in all directions and can rotate on its axis. Upon reaching the anatomy of interest, the robotic scope becomes rigid, serving as a stable platform to deploy the instruments. This also means that in retracting and manipulating tissues, the structures along the course of the robotic scope are protected from rubbing and torque with no damage, stretch, or tearing. In our study, this prevented unnecessary torsion or stretch of the mental nerves. To date, this robotic platform has been successful in cadaveric applications to base of tongue resection, tonsillectomy, epiglotectomy, posterior corpectomy, vocal cord resection, complete nasopharyngectomy, and laryngectomy.

Adequate visualization and access using the Flex Robotic System was obtained in each cadaver. The flexible endoscope allowed for visualization of the lateral, inferior, and superior portions within the surgical field without the need to use angled endoscopes. The size of the endoscope permitted entry through the vestibular incision without stretch on the mental nerves in all specimens regardless of sex or dentition status. Although a 4-cm vestibular incision was used for the purposes of dissecting the mental nerves to confirm safe passage of the flex robot, a smaller incision of 3 cm could be used to allow admittance of the 2.8 × 1.5-cm robotic endoscope. Although the most common location of the mental foramina in the average Caucasian adult male is along the longitudinal axis of the second premolar, variations exist among patients with ethnicity, sex, age, and dental status playing a role in the exact location. Additionally, the mental nerve has a mesial trajectory after exiting the foramen and can be encountered during the mucosal dissection in an axis consistent with the canine. In 2016, Laher and Wells published a report on the ability to localize the mental foramina with excellent accuracy with ultrasound using an 8-MHz transducer. In theory, if there was doubt about the location of the mental foramina, these could be visualized with ultrasound and marked preoperatively.

Familiarity was quickly achieved, and setup and time to exposure improved significantly after the initial procedure. The controlled flexibility of the robot allowed the operator to maneuver the endoscope to provide direct views and adequate working space in all areas during the resections. There were no collisions of the endoscope or instruments with surrounding tissues, and at the conclusion of each hemithyroidectomy, mental nerves were intact. There is no need for a scope-holder or to manually hold the scope, nor is there need for insufflation. Currently, the Flex Robotic System offers only monopolar cautery devices including a needle tip, spatula tip, Maryland dissector, and scissors. For ligation of thyroid vessels, we feel that the endoscopic clip applicators or other endoscopic cautery, such as the harmonic, will be necessary. These can be introduced into the field via lateral ports, which have been described previously for TOETVA. High-definition, three-dimensional imaging required specialized three-dimensional glasses when looking at the screen. Although this did result in some reduction of brightness, it significantly improved depth perception.

As with any new technology, a learning curve is inherent to successful application. Proficiency in surgical technique is required, as the experience of a surgeon may be reflected in the number of complications that occur.
Additionally, with future iterations of the equipment of the Flex System, improvements in durability and grip strength are expected, which when combined with increased experience may further facilitate its successful use in this surgical application. A major consideration in the application of minimally invasive thyroidectomy approaches continues to be the cost. Current studies evaluating cost efficacy in transoral vestibular approach thyroidectomy are limited and differ between robotic and endoscopic techniques. Additional studies are required that include evaluation of additional parameters such as costs of the postoperative hospital stay, complications, and rehabilitation.

Appropriate patient selection and meticulous port placement and dissection will be critical as this technique is explored on live human patients. Its role in the growing field of minimally invasive thyroidectomy is yet to be defined. Future studies in clinical settings will help to elaborate the effectiveness of this technique. Additionally, there are several barriers to the adoption and evolution of robotic thyroid surgery in the United States, particularly with changes in reimbursement and a move toward preferential referral to high-volume centers. At this time, further investigation and development are needed to ensure excellent outcomes, cost effectiveness, and safety.

CONCLUSION

The purpose of this study was to demonstrate the feasibility of using the Medrobotics Flex Robotic System for thyroidectomy using a transoral vestibular approach. In our experience with eight lobectomies in four cadavers, there were no major limitations to its use. However, at this time, lateral ports would still be necessary for the introduction of endoscopic bipolar, ultrasonic, or clip-applicator instruments. The technique embodies minimally invasive principles, including limited tissue dissection and retraction, close access to the thyroid gland, natural orifice surgery, and no cutaneous scar or deformity. The size and flexibility of this robotic platform provide access to and maneuverability within the small surgical field, three-dimensional visualization, and flexible, wristed instruments that also allow haptic feedback. These improvements address many of the limitations of current robotic and endoscopic technology.

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