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Robotic Surgery for Thyroid Disease

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Key Words
Robot · Thyroid · Thyroidectomy · Robotic thyroidectomy · Neck dissection · Robotic neck dissection

Abstract
Robotic surgery is an innovation in thyroid surgery that may compensate for the drawbacks of conventional endoscopic surgery. A surgical robot provides strong advantages, including three-dimensional imaging, motion scaling, tremor elimination, and additional degrees of freedom. We review here recent adaptations, experience and applications of robotics in thyroid surgery. Robotic thyroid surgeries include thyroid lobectomy, total thyroidectomy, central compartment neck dissection, and radical neck dissection for benign and malignant thyroid diseases. Most of the current literature consists of case series of robotic thyroidectomies. Recent retrospective and prospective analyses have evaluated the safety and oncologic efficacy of robotic surgery for thyroid cancer. Although robotic thyroid surgery is often associated with longer operation times than conventional open surgery, robotic techniques have shown similar or superior levels of surgical completeness and safety compared with conventional open or endoscopic surgery. Compared to open thyroidectomy, robotic thyroidectomy has been associated with several quality-of-life benefits, including excellent cosmetic results, reduced neck pain and sensory changes, and decreased voice and swallowing discomfort after surgery. For surgeons, robotic surgery has improved ergonomics and has a shorter learning curve than open or endoscopic surgery. The advantages of robotic thyroid surgery over conventional surgery suggest that robotic thyroidectomy with or without neck dissection may become the preferred surgical option for thyroid diseases. Robotic thyroid surgery will likely continue to develop as more endocrine and head-and-neck surgeons are trained and more patients seek this newly developed surgical option.

Introduction

The advantages of endoscopic over open surgery for thyroid diseases include reduced rates of hyperesthesia and paresthesia of the neck and highly improved cosmetic outcomes. The learning curve for endoscopic thyroidectomy with neck dissection, however, is long, and this method has technical limitations due to the two-dimensional view and reduced dexterity of movement, particularly when operating on thyroid tumors and adjacent

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lymph nodes (LNs). A robotic approach has been developed to overcome these limitations, facilitating manipulations and reducing the learning curve. This system has enabled surgeons to control a three-dimensional high-definition camera, reduced physiological tremor and enabled free dexterity of movement using articulated instruments. This technique offers an especially easy approach when working in deep and narrow spaces such as the neck area [1, 2].

Endocrine and head-and-neck surgeons are aware of the advantages of robotic thyroidectomy, with more than 6,000 robotic thyroidectomies with or without neck dissection performed in Korea between 2007 and 2011. Pioneers in thyroid surgery continue to refine surgical techniques in robotic thyroidectomy and neck dissection, building on the principles and framework described for the indication, as well as on surgical tips [1–4]. The first step taken to improve robotic thyroid surgery was characterized by the rapid evolution of robotic surgical techniques and training programs [1–8]. The second step should be directed toward better perioperative assessment of oncologic outcomes and safety [1, 5–11]. The third step would be a determination of the impact of this procedure on functional outcomes including patient satisfaction [1, 9, 12–15]. The ultimate goals of robotic thyroid surgery are to achieve the best possible oncologic outcomes and to enhance patient quality of life after surgery.

At present, robotic thyroidectomy compares favorably with open thyroidectomy in surgical completeness, safety, and quality-of-life outcomes, including cosmetic results. The safety and oncologic efficacy of robotic surgery for thyroid diseases have been established [1, 5–11]. Moreover, several innovations at large-volume centers have enhanced quality-of-life outcomes in patients who have undergone robotic compared with conventional open thyroidectomy [9, 12–15]. Among the quality-of-life benefits of robotic surgery are excellent cosmetic results, and reductions in neck sensory changes, voice, and swallowing discomfort after surgery. For surgeons, robotic surgery has improved ergonomics and has a shorter learning curve than open or endoscopic surgery [16–18].

Robotic surgery for thyroid diseases has been successfully extended to complete total thyroidectomy with radical neck dissection (RND) for patients with thyroid cancer, indicating that robot technology can overcome the limitations of conventional endoscopic and open surgery and make sophisticated thyroid and neck node surgical procedures easier to complete. Few prospective studies, however, have assessed outcomes of robotic surgery in patients with thyroid diseases, indicating the need for additional prospective randomized studies with longer follow-up to evaluate the benefits of robotic surgery for both patients and surgeons. This review describes the indications of and surgical techniques used in robotic thyroidectomy with RND, and summarizes the operative outcomes.

Indications and Contraindications

Prior to full awareness of the oncologic effects and safety of robotic thyroidectomy with neck dissection, candidates for this surgery were limited to patients with small-sized thyroid tumors. Indications for robotic thyroidectomy with neck dissection widened as surgeons became more familiar with the robotic procedure, with many studies describing the technical aspects of robotic thyroidectomy with neck dissection and comparing robotic with conventional open or endoscopic methods. Recently, robotic thyroidectomy with neck dissection was perceived to be as good as open surgery in the management of thyroid cancers [1, 5–11, 16, 19–22].

Patient selection is of the utmost importance when considering the use of robotic surgery. In patients with thyroid cancer, accurate preoperative evaluation of tumor aggressiveness is required to choose an optimal surgical method. Preoperative patient workups include a physical examination and imaging methods, such as high-resolution ultrasonography (US) and neck computed tomography. Thyroid nodules have been diagnosed preoperatively based on the results of US-guided fine-needle aspiration cytology (FNAC). Among the tumor characteristics assessed by these methods were size, site, presence of extrathyroidal invasion, multiplicity, bilaterality, and presence of cervical LN metastasis [1, 2].

Patients considered eligible for robotic thyroidectomy include those with (a) follicular proliferation and tumor size ≤5 cm and (b) differentiated thyroid cancer without contraindications to robotic surgery. Exclusion criteria included (a) a history of previous head-and-neck surgery or irradiation; (b) uncontrolled thyrotoxicosis; (c) lesions located in the dorsal thyroid area, especially in the region adjacent to the tracheoesophageal groove, because of possible injury during surgery to the trachea, esophagus, or recurrent laryngeal nerve; (d) suspected perinodal infiltration to adjacent structures such as the internal jugular vein (IJV) or major nerves at the lateral metastatic LN, and (e) distant metastasis.

The extent of thyroidectomy and RND was determined based on American Thyroid Association (ATA) guidelines [23]. All patients with thyroid cancers also underwent prophylactic central compartment node dissection. Patients with clinically palpable lateral neck LNs or lateral LNs with a suspicious appearance on preoperative staging US and who underwent FNAC also underwent TT with modified RND (mRND). The preoperative presence of lateral LN metastasis was determined by US-guided FNAC, with metastasis based on thyroglobulin concentrations in FNAC washout fluid from lateral LNs. In these patients with N1b tumors, we followed the prescribed extent of mRND for papillary thyroid carcinoma (PTC) (levels IIA, III, IV, and Vb), whereas LNs in levels IIB and VA were not routinely dissected. However, if palpation or preoperative imaging showed evidence of an enlarged or suspicious LN at level I, IIB or VA LN, these compartments were included in en bloc dissection [24, 25].

Robotic Thyroidectomy Procedure

We have previously described our robotic technique, and arm placement design, for thyroidectomy and neck dissection in detail. We also formulated a standard template for robotic thyroidectomy [1, 2, 19, 20, 26]. In robotic thyroidectomy, the port (cannula) placement is of major concern to avoid collisions among robotic instruments but also to provide free access to the thyroid bed. As camera location is important to prevent collision of the robotic arms, special care must be taken during robotic docking procedures. We shortly describe the main highlights of this technique.

Patient Positioning

Patient Preparation. Briefly, under general anesthesia, the patient is placed in a supine position on a small shoulder roll with the neck slightly extended. The arm is extended and a 5- and 6-cm vertical incision is marked in the anterior aspect of the ipsilateral axilla. The arm is then replaced into its natural position to ensure that the incision will be hidden after the procedure is completed. The arm of the lesion side is raised naturally, within the range of shoulder motion, to avoid brachial plexus paralysis. The arm is fixed to afford the shortest distance between the axilla and the anterior neck. This setup rotates the clavicle, lowering its medial aspect and providing excellent access to the thyroid. Modified patient positioning has been developed in the United States, especially for patients with obstacles due to a large body habitus [3, 4].

Creation of Working Space. A 5- to 6-cm vertical skin incision was then made in the axilla and a subcutaneous skin flap was prepared toward the anterior neck over the anterior surface of the pectoralis major muscle by electrical cautery under direct vision. After crossing the clavicle, a subplatysmal skin flap was made until the bifurcation of the sternocleidomastoid (SCM) muscles was exposed. The dissection is approached through the avascular space of the two heads of SCM muscles and beneath the strap muscles. After exposing the contralateral thyroid gland, an external retractor (Chung's thyroid retractor) with a table mount lift is placed under the strap muscles to maintain a working space.

Robot Positioning and Docking

Docking Stage (Two-Incision Technique). The novel method of robotic thyroidectomy using a gasless transaxillary approach requires two skin incisions: an axillary incision for camera, first and second robotic arm access, and an anterior chest incision for the third robotic arm [1, 2, 19, 20]. In two-incision robotic thyroidectomy, a 0.6- to 0.8-cm second skin incision is made on the tumor side of the anterior chest wall to permit insertion of the fourth robotic arm. A dual-channel telescope is placed on the central arm, and Harmonic curved shears, together with a Maryland dissector, are placed on both lateral sides of the scope. A ProGrasp forceps is inserted through the anterior chest wall incision [26]. Our initial robotic thyroidectomy procedures (about 700 cases) were performed using this novel method using the two-incision approach.

Docking Stage (Single-Incision Technique). After performing more than 700 robotic thyroidectomies via a two-incision technique, we found that we were able to perform robotic thyroidectomy without the second incision (fig. 1) [26]. According to the single-incision technique, all robotic arms with camera are inserted through an axillary single incision. To prevent collision between robotic arms, we realize several tips and rules about where to place the ProGrasp forceps, and how to introduce the robotic arms at appropriate angles and inter-arm distances. The edge of the camera cannula is inserted in an upward direction and centered at the bottom of the incision. The tip of the ProGrasp forceps is then positioned parallel and just to the lesion side of the retractor blade at the top of the incision just above the thyroid. The 5-mm cannula for the Harmonic curved shears at the lesion side of the camera and the 5-mm cannula of a Maryland dissector are then positioned on the opposite edge of the incision. Instruments should be as far apart as possible. If the setup is performed correctly, the Maryland dissector arm,

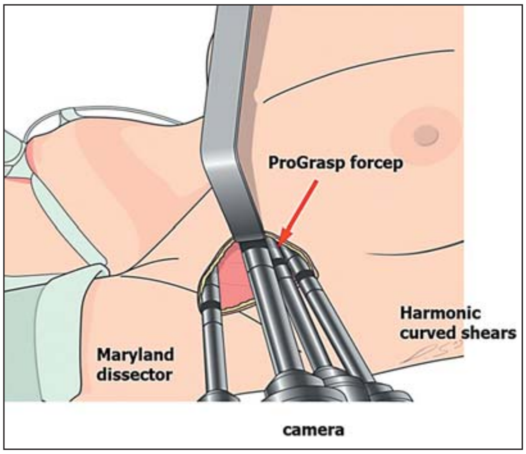

Fig. 1. Single-incision robotic thyroidectomy. All four robotic instruments and the camera were placed through the axillary incision [source: 26].

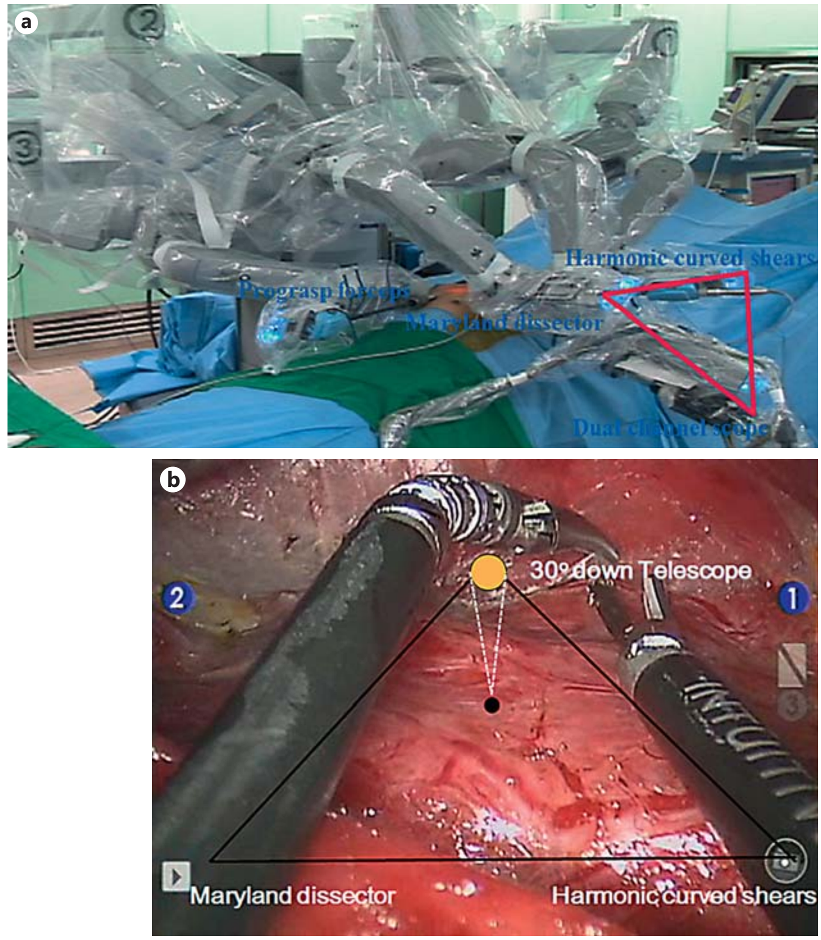

Fig. 2. Positions following a correct final external setup of the robot. **a** A Maryland dissection, the camera arm and ProGrasp arm should form an inverted triangle external to the insertion axis. **b** The instrument and camera tips should form a normal triangle internally to the site of operation.

Fig. 3. Immediate postoperative scar after robotic thyroidectomy.

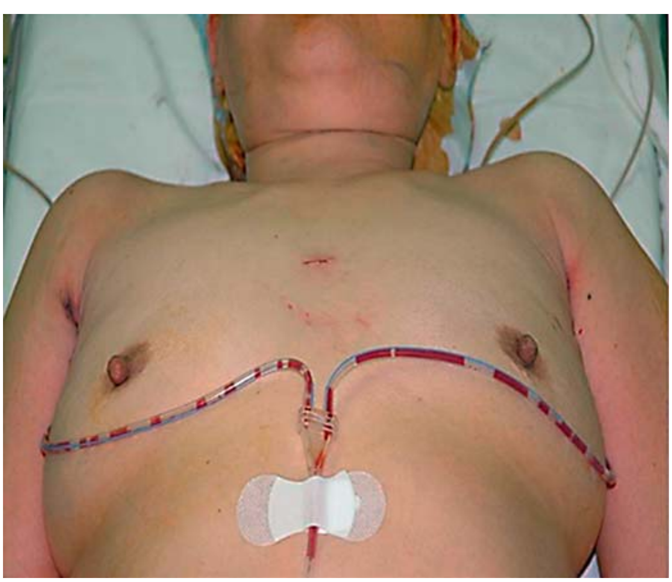

Fig. 4. Postoperative scar immediately after bilateral robotic mRND in a PTC patient showing bilateral lateral neck node metastasis.

the camera arm, and the ProGrasp forceps arm will form an inverted triangle externally with the insertion axis, and make a triangle internally with the instrument tips. The arms must be spaced and positioned in a manner minimizing collisions between the instruments and the camera. (fig. 2a, b) [26].

Actual Operation Steps

Console Stage. The general principle of operation proceeding for robotic thyroidectomy was in the same manner as a conventional open thyroidectomy. Due to its visual perspective of surgical anatomy, the gasless transaxillary approach has demonstrated many merits. First, the operative view is the same as that in open surgery. Therefore, the upper and lower poles of thyroid gland, major vessels and neck LNs can be easily revealed and manipulated. Second, parathyroid glands and recurrent laryngeal nerve can be straightly exposed in the lateral view. So, the dissection near this organ and neck LN dissection can be safely and completely performed without injuries of important organs. Third, the working place by stable and safely established without gas can be maintained by continuous negative pressure suction of the air and blood. Apart from docking of the robotic arms, during the console stage the two-incision and single-incision robotic thyroidectomy procedures are the same. The thyroid gland is retracted using ProGrasp forceps on the fourth robotic arm and dissection is performed employing a Harmonic curved shears and a Maryland dissector. The thyroid gland is retracted using ProGrasp forceps on the fourth robotic arm and the dissection is performed using a Harmonic curved shears and a Maryland dissector. This procedure allows the surgeon to use three robotic arms during thyroidectomy. A 3-mm closed suction drain is inserted through a separate skin incision under the axillary skin incision (fig. 3). Wounds are closed cosmetically. The incision scar in the axilla is completely covered when the arm is in its neutral position.

Robotic Radical Neck Dissection Procedure

The operative procedure for robotic mRND using the gasless transaxillary approach has been described in detail previously [24, 25]. Briefly, with the patient in the supine position and under general anesthesia, the neck is extended slightly by inserting a soft pillow under the shoulder. The lesion side arm is abducted by 80° from the body to expose the axilla and lateral neck, and the head is tilted and rotated to face the non-lesion side.

A 7- to 8-cm vertical skin incision is made in the axilla along the anterior axillary fold and the lateral border of the pectoralis major muscle. The flap is dissected medially over the SCM muscles toward the midline of the anterior neck. Laterally, the trapezius muscle is identified and dissected upward along its anterior border. During the flap dissection in the posterior neck area, the spinal accessory nerve is identified and exposed along its course. After subplatysmal flap dissection, the clavicular head of the SCM muscles is divided at the level of its attachment to the clavicle to expose the junction area between the IJV and the subclavian vein, and the dissection proceeds upwards along with the posterior surface of the SCM muscles to expose the submandibular gland and the posterior belly of the digastric muscle. A wide-size external retractor (Chung's retractor) is then used to raise and tent the skin flap at the anterior chest wall, the SCM muscles, and the strap muscles to create a working space. The entire neck levels (level IIa, III, IV, Vb, and VI areas) are fully exposed by elevating the SCM and strap muscles. A second skin incision (0.6–0.8 cm) is then made on the medial side of the anterior chest wall to allow the fourth robotic arm to be inserted (2 cm superiorly and 6–8 cm medially from the nipple). The docking procedure for the robot is similar to that described previously for robotic thyroidectomy. Actually, the robotic mRND procedure is similar to the conventional open technique. Lateral neck dissection is initiated from the level III and IV area around the IJV. The IJV is handled medially using ProGrasp forceps, and soft tissues and LNs are pulled laterally using a Maryland dissector. Careful dissection is needed during the detachment of the LNs from the posterior aspect of the IJV to avoid injury to the common carotid artery and the vagus nerve. After performing the level III, IV and VB node dissection, re-docking is needed for a better operating view to dissect the level II LN. The external retractor is reinserted through the axillary incision toward the submandibular gland, and level IIA dissection proceeds to the posterior belly of the digastric muscle and to the submandibular gland superiorly. The incision scar in the axilla is completely covered when the arm is in its neutral position (fig. 4).

Oncologic Outcomes and Safety after Robotic Surgery

Robotic thyroidectomy and RND is a complex and sophisticated surgical procedure. Its complexity may explain the rapidly growing body of literature on this meth-

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od [1–11, 19–22]. Robotic thyroidectomy was first performed in 2007, with the results of the first 100 patients to undergo robotic thyroidectomy by a single surgeon reported in 2009 [19]. The operative safety and feasibility of robotic thyroidectomy were demonstrated in studies of 200, 338, and 1,000 patients, all of whom underwent successful procedures [20–22]. The first multi-institutional study of 1,043 patients with low-risk differentiated thyroid carcinoma who underwent robotic thyroidectomy at four academic centers was published in 2011 [5]. Major complication rates of 0.8% [22] and 1.0% [5] have been reported, comparable to the rates reported after open thyroidectomies performed in experienced centers of excellence. Studies comparing robotic thyroidectomy with endoscopy or conventional open surgery have shown similar postoperative complication rates for the former, suggesting that robotic thyroidectomy is feasible and safe, and can overcome some of the technical limitations associated with endoscopic methods.

The largest multicenter trial of robotic thyroidectomy to date, which included 2,014 patients with thyroid cancers, showed that robotic thyroidectomy yielded excellent postoperative outcomes, including minimal complication rates, a high degree of oncologic safety, and superior ergonomic benefits for surgeons [6]. That study was distinguished from previous studies in that it evaluated the surgeon's perspective on this technique. Surgeons completed a survey on neck, shoulder, and back muscle discomfort after open, endoscopic, and robotic thyroidectomies, three approaches involving different physical tasks and varying types and magnitude of musculoskeletal stress. Survey results showed that musculoskeletal discomfort was lower during robotic than during open or endoscopic thyroidectomy.

Oncologic outcomes of cancer-related surgery are important for patient prognosis. The short-term oncologic effectiveness of thyroid cancer surgery can be assessed by measuring serum thyroglobulin concentration via iodine-131 (^{131}RI) scanning, whereas the long-term effectiveness can be evaluated by lack of tumor recurrence [7–9, 16, 17, 20, 21, 24, 25]. The number of retrieved neck LNs is also significant in determining surgical radicality. The number of LNs retrieved during robotic thyroidectomy was higher than or similar to the number retrieved during endoscopic or conventional open surgery. The larger number of LNs retrieved during robotic thyroidectomy may be due to the ability of the three-dimensional, magnified view to allow an accurate dissection plane, as well as the careful manipulation resulting from the use of multi-articulated robotic arms. During robotic surgery, the LNs may be optimally dissected by a traction/countertraction technique. Indeed, large case series and comparative analyses have shown greater surgical completeness and radicality using robotic than using conventional open or endoscopic methods [16, 17, 21, 22, 24–27].

Although robotic thyroidectomy with RND is a feasible procedure with reasonable surgical completeness and radicality rates as well as low morbidity rates, to date no randomized trials have assessed robotic surgery for thyroid diseases, likely due to differences in surgical costs. In addition, the follow-up period of these studies was not sufficient to determine the long-term effects of robotic surgery on oncologic outcomes. Therefore, prospective randomized clinical trials with long-term follow-up are necessary to compare the surgical outcomes of robotic with open and endoscopic methods.

Robotic mRND was first described using a gasless transaxillary approach for PTC with lateral LN metastases (N1b) [24]. Our initial evaluation of outcomes after robotic mRND in 33 patients with PTC and lateral neck node metastasis (N1b) showed that robotic mRND was satisfactory, with no serious postoperative complications, and that axillary incisions reduced the cosmetic effects of this method. A comparison of early postoperative outcomes in 56 patients who underwent robotic and 165 who underwent open mRND found that, although the mean operation time was significantly longer in robotic than in open mRND, the complication rates were similar [25]. Robotic total thyroidectomy with mRND using these methods may have similar benefits for length of hospital stay and length of convalescence. Moreover, compared with the open procedure, robotic total thyroidectomy with mRND did not significantly alter oncologic outcomes, including postoperative ^{131}RI scans and serum thyroglobulin concentrations, or the number of cervical LNs retrieved. These findings indicate that the oncologic outcomes and safety of robotic and conventional open mRND were similar, whereas robotic mRND provided significantly more satisfactory cosmetic outcomes compared with the long neck scar resulting from open mRND. However, the long-term oncologic outcomes after robotic mRND require further evaluation.

Functional Outcomes and Patient Satisfaction after Robotic Surgery

Most studies investigating robotic thyroidectomy with or without neck dissection for the management of thyroid disease have been case series that did not assess functional outcomes. More recent studies, however, have presented comparative analyses of functional outcomes and patient satisfaction after robotic and conventional open procedures [9, 12–15]. Patients undergoing open surgery experienced higher levels of dissatisfaction and regret than those undergoing robotic surgery, with the most obvious difference being satisfaction with the postoperative scar. Other prospective trials comparing robotic with open (or endoscopic) endoscopy found that functional measurements, including pain, neck discomfort, and sensory changes in the neck, as well as cosmetic measurements, favored robotic thyroidectomy [9, 12, 13]. This may be due to the lower rates of dissection of the strap muscle and anterior neck area in the robotic than in the open group.

Studies comparing objective and subjective changes in voice and swallowing after robotic and open surgery have yielded contradictory results. Early postoperative voice and swallowing changes, measured with a subjective questionnaire, found that patients undergoing robotic thyroidectomy had improved short-term swallowing outcomes than those undergoing conventional open thyroidectomy [9, 12, 13]. Two recent studies have addressed the impact of operative technique on objective voice and swallowing changes [14, 15]. One prospective study found that postoperative voice function was better after robotic thyroidectomy than after conventional open thyroidectomy, but subjective swallowing function did not differ between the two groups [15]. The other study including evaluation of subjective voice difficulties showed that subjective voice function outcomes were similar after robotic and conventional open thyroidectomy [14]. Therefore, prospective studies in large numbers of patients are needed to accurately assess the effects of the robotic technique on voice and swallowing function. The improvements in voice and swallowing outcomes after robotic surgery, as shown by both objective and subjective analyses, may have been due to the absence of cervical skin incisions, the lack of a midline dissection of the strap muscle and the reduced adhesion between the strap muscles, subcutaneous tissue, and skin during robotic thyroidectomy.

Operation Time and Surgical Learning Curve

Several studies have compared operation times in patients who underwent robotic versus endoscopic or open surgery [7–9, 13, 16, 17]. The total operation time required for the robotic procedure was significantly longer than the time required for the open procedure, but was similar or somewhat lower than the time required for endoscopic surgery. Robotic procedures include three stages – creating a working space, a docking stage, and a console (actual operation) stage. Unlike robotic abdominal surgery, no preformed space is available in the neck area, and flap dissection is always necessary. Thus, robotic thyroidectomy with or without neck dissection is usually more time consuming than open surgery. However, if the time required to create a working space and the docking stage were disregarded, the times required for robotic and conventional procedures would be similar. In addition, the operation time for patients undergoing robotic thyroidectomy with neck dissection will likely decrease as surgeons become more familiar with the robotic method.

A multicenter trial analyzed the perioperative parameters in patients undergoing robotic and endoscopic thyroidectomy, including operation time, complication rate, and other clinical outcomes [17]. For both procedures, the operation time gradually decreased with increasing surgeon experience and reached steady states for robotic thyroidectomy after 35–40 cases, and for endoscopic thyroidectomy after 55–60 patients. The advantages of robotic thyroidectomy may be due to superior vision, a stable camera platform, flexible instruments, and fine coordination of robotic hands, resulting in excellent manipulations.

Future Directions in Robotic Surgery for Thyroid Diseases

Most studies to date of robot use in thyroid surgery have been non-randomized retrospective studies and have included only a small number of prospective studies. Undoubtedly the lack of randomized studies is the greatest limitation in this field. Moreover, prospective randomized comparisons of robotic with endoscopic or open surgery are difficult to perform. Nevertheless, some of the non-randomized studies were of good or high quality, compared with previous studies analyzing safety, oncological efficacy and functional outcomes after surgery.

Clinicians should enhance their patients' appreciation of outcomes in robotic surgeries specific to their age, body habitus, disease grade and stage, relevant comorbidities, and safety. This may be accomplished by more thoughtful discussions with patients, especially of postoperative quantitative and qualitative results, based on

Table 1. Advantages and disadvantages of robotic compared with open (or endoscopic) thyroidectomy

	RT	versus	OT	RT	versus	ET
Oncologic outcomes	RT	similar to	OT	RT	better than	ET
Complication rate	RT	similar to	OT	RT	similar to	ET
Operation time	RT	worse than	OT	RT	better than	ET
Cost	RT	worse than	OT	RT	worse than	ET
Morbidity	RT	similar to	OT	RT	similar to or better than	ET
Cosmetic satisfaction	RT	much better than	OT	RT	no data available	ET
Pain	RT	similar to or better than	OT	RT	no data available	ET
Neck discomfort	RT	better than	OT	RT	no data available	ET
Swallowing discomfort	RT	similar to or better than	OT	RT	no data available	ET
Voice change	RT	similar to or better than	OT	RT	no data available	ET
Learning curve	RT	no data available	OT	RT	better than	ET
Surgeon's ergonomic consideration	RT	better than	OT	RT	much better than	ET

RT = Robotic thyroidectomy; OT = open thyroidectomy; ET = endoscopic thyroidectomy.

patient-specific parameters and intraoperative challenges. Furthermore, these discussions should be conducted while reporting outcomes specific to the counseling surgeon and his or her own experience and not based solely on published data from more experienced centers.

Although extensive studies have addressed the advantages and disadvantages of robotic thyroidectomy, consensus has yet to be reached. Due to persistence of the conventional method, some physicians will not find robotic techniques worthwhile using. Table 1 provides a comparison of the advantages and disadvantages of robotic thyroidectomy with those of open or endoscopic thyroidectomy.

Robotic thyroidectomy with neck dissection using a gasless transaxillary approach has been shown to be safe and oncologically effective when compared with conventional open or endoscopic surgery. Moreover, this technique shows a shorter learning curve than endoscopic surgery, and causes less musculoskeletal discomfort for surgeons than open or endoscopic surgery. Functionally, the robotic technique yielded several benefits including excellent cosmetic results, reduced neck pain and sensory changes, and reduced voice or swallowing discomfort after surgery. Despite these benefits, its ultimate impact remains uncertain. Large prospective randomized trials with longer-term periods are needed to determine whether robotic surgery is superior to conventional open or endoscopic surgery, as judged by both the patient and the surgeon.

Disclosure Statement

The authors have no conflicts of interest to disclose.

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