Robotic Parathyroidectomy

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Contents

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Summary Points

- The da Vinci Surgical Robot System is considered to be the latest addition to the endocrine surgeon's armamentarium to accomplish remote-access, targeted parathyroidectomy.
- This novel tool restores some of the fundamentals of the surgical technique that were lost in conventional endoscopic surgery, making it particularly advantageous in the restricted workspace afforded in this region of the body.
- Robotic parathyroidectomy avoids a cervical scar by concealing the incision in the axilla, infraclavicular area, or the retroauricular area. Mediastinal parathyroidectomy using the da Vinci robot is achieved through the intercostal space, depending on adenoma localization.
- Robotic parathyroidectomy represents an appealing option to patients with a tendency for hypertrophic or keloid scarring and those whom the cosmetic impact of a cervical scar has significant social stigma or concern.
- Preliminary results of robotic parathyroidectomy from small case series and case control studies have shown it to be equivalent to the conventional, transcervical targeted parathyroidectomy with regards to cure and complication rates.
- Limitations of robotic parathyroidectomy include its high cost and longer operative time compared to conventional techniques.

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- Ideal patient selection criteria are not well established and society guidelines are lacking. This particularly relates to the patient's body habitus and the presence, or lack of concordant imaging to localize the parathyroid lesion.
- Long-term prospective randomized control studies with larger sample sizes are needed to identify the role that robotic parathyroidectomy has to play in the management of patients with primary hyperparathyroidism.

Introduction

Historically until the 1990s, a low collar incision involving bilateral cervical exploration of all four parathyroid glands and removal of any that are grossly enlarged had been the standard surgical treatment for primary hyperparathyroidism (PHPT). This approach facilitates a safe dissection and is associated with low morbidity in experienced hands. Yet, some patients are still left with a noticeable cervical scar, most of which are women who are understandably concerned about limiting the cosmetic impact of the cervical incision. As a result, there has been a great desire among both surgeons and patients to minimize cervical incisions. Significant improvements in endoscopic instrumentation, preoperative localization studies, intraoperative adjuncts, and the increased understanding of the endoscopic cervical anatomy have facilitated the further growth of head and neck endoscopic and minimally invasive surgery [1]. The first unilateral approach for solitary parathyroid adenomas was reported by Tibblin et al. [2]. Since then, several targeted techniques have been described, including radioguided parathyroidectomy, endoscopic parathyroidectomy with gas insufflation, and video-assisted parathyroidectomy without gas insufflation [3–5]. These minimally invasive approaches have led to fewer complications, shorter operative time and hospitalization, quicker recovery, and greater patient satisfaction [6]. Minimally invasive, targeted parathyroidectomy is therefore recommended when a parathyroid adenoma is localized preoperatively, as it can be removed without visualizing the other glands, and the rapid intraoperative parathyroid hormone (IOPTH) assay is employed to confirm an adequate resection. Currently, this approach has replaced bilateral neck exploration in patients with localized disease, although a traditional cervical incision with bilateral neck exploration remains the optimal surgery for nonlocalized disease and cases of hyperplasia [4, 7].

Concurrent with these developments, other surgeons experimented with remote access techniques designed to relocate the surgical incisions outside the neck so that they are "invisible" incisions. These techniques emerged primarily in Asian centers, where there is a higher risk of hypertrophic scarring and a cultural emphasis on the cosmetic appearance of the anterior neck. As technology and training advanced, the da Vinci Surgical Robot System (Intuitive Surgical, Sunnyvale, CA, USA) facilitated the ability to perform parathyroid surgery without any visible cervical incisions via a gasless transaxillary approach [7–11]. Surgeons have found that the ability to control a high definition camera system and multiarticulated endoscopic arms through a single console restores some of the fundamentals of the surgical technique that were lost in conventional endoscopic surgery, making it particularly advantageous in the restricted workspace afforded in this region of the body [12–14].

As surgeons in the USA began to implement this approach, concerns emerged over the safety of the technique in patients with a larger body habitus [15–18]. The transaxillary approach also required placement of drains and necessitated hospital admission, which represented a step backwards from advances made in minimally invasive surgery during the prior decade. An alternate robotic remote access approach, the robotic facelift (retroauricular) approach, was recently developed to help overcome the concerns and limitations of the robotic transaxillary approach in the western patient population [19, 20].

To date there are no randomized control trials to assess how these innovative techniques compare to conventional targeted parathyroidectomy. There are only 6 nonrandomized studies that evaluate robotic parathyroidectomy [7, 9, 11, 21] in the literature, two of which compare robotic parathyroidectomy with targeted, transcervical parathyroidectomy [10, 22].

Indications

It was only during the last two decades that targeted parathyroidectomy was widely established. The development of high-resolution ultrasound (US), sestamibi scintigraphy, and introduction of the rapid IOPTH assay has greatly laid the foundation for minimally invasive and targeted parathyroidectomy [23, 24]. If preoperative localization studies allow for a more targeted approach, the IOPTH assay is able to intraoperatively confirm the success for surgery before the patient leaves the operating table [25].

The diagnosis of PHPT is mostly established by demonstrating hypercalcemia in the setting of an elevated intact PTH level. Familial hypocalciuric hypercalcemia and vitamin D deficiency must be ruled out by measuring the 24-h urine calcium and serum vitamin D levels, as surgery will not be required in these patients. PHPT is most commonly due to a single adenoma. However, approximately 15 % of cases may be a result of multiple gland disease (MGD), either due to 4-gland hyperplasia or double adenomas. While most commonly a sporadic disease, PHPT due to MGD can be part of a familial syndrome in a small subset of patients (5 %). Indications for parathyroidectomy are no different in patients with sporadic or familial PHPT [26, 27]. However, patients with sporadic primary hyperparathyroidism with an adenoma localized by preoperative imaging techniques are candidates for targeted parathyroidectomy.

Patient Selection

Robotic parathyroidectomy takes advantage of the endoscopic magnification that allows performing the same intervention through a remote, so-called scarless access. This is theoretically associated with a lower risk of complications due to optimal 3D visualization of neck structures, in particular the recurrent laryngeal nerve and parathyroid glands. Nonetheless, ideal patient selection criteria are not well established and society guidelines are lacking. The best candidates for this approach are small or average-sized (body mass index <30) young patients, with concerns of neck scarring, or have a history of keloid or hypertrophic scar formation. As mentioned above, this approach should only be offered to patients with a well-localized parathyroid adenoma preoperatively on imaging studies. Patients with higher possibility of MGD disease should not be offered this approach. This approach is usually deferred in patients with certain thyroid pathologies such as, locally advanced cancers, Graves' disease, Hashimoto's thyroiditis, or substernal goiter, and in patients with a previous history of surgery or irradiation of the neck. Patients should also be screened for contraindications that affect patient positioning during these procedures such as, rotator cuff pathology, shoulder/neck mobility problems, cervical spine disease, previous neck, chest, or axillary surgery.

Preoperative Considerations and Surgical Planning

Imaging before surgery can help guide the surgical approach by localizing the adenoma in many patients. Of all the imaging modalities US is the least expensive and least invasive, it does not involve radiation and is readily accessible. Parathyroid glands appear as well-circumscribed and oval, hypoechoic, and usually solid nodules. The sensitivity of US detection of parathyroid adenomas ranges from 27 to 95 %, with a specificity of 92–97 %. It is the operator experience that has the greatest effect and likely accounts for the wide range of reported sensitivity. The combination of US and Sestamibi scan may increase the accuracy of localization of a single adenoma to 94–99 %, as each modality contributes different data to help determine the gland location. Ultrasonography is more specific for anatomic location of the gland in relation to the thyroid, whereas scintigraphy is better at finding ectopic glands especially in the mediastinum [28]. The availability of US has led some surgeons to further use it in the operating room. It can be used for identifying the parathyroid adenoma and its anatomical location just prior to surgery. US may also assist in precisely localizing the incision once the patient is in the neck extension position. Lastly, US guided FNA can be considered to confirm intrathyroidal parathyroid adenomas or in selected cases of persistent or recurrent hyperparathyroidism after failed exploration. An elevated PTH washout concentration from the FNA can help identify parathyroid gland lesions.

Four-Dimensional Computed Tomography (4D-CT) Scan generates exquisitely detailed, multilane images of the neck and allows the visualization of differences in the perfusion characteristics of hyperfunctioning parathyroid glands (i.e., rapid uptake and washout), compared with normal parathyroid glands and other structures in the neck. The images that are generated by 4D-CT provide both anatomic information and functional information in a single study that the operating surgeon can interpret easily and may serve an important role in localization before both initial and reoperative parathyroid procedures [29].

To further improve the surgical success of targeted parathyroidectomy and to minimize the possibility of persistent or recurrent hyperparathyroidism after surgery, some have advocated the use of surgical adjuncts such as IOPTH monitoring. Intraoperative PTH is useful in assessing the adequacy of resection by functional means without the need to expose all the parathyroid glands. The ability to confirm complete removal of all hypersecreting glands and predict operative success minimized operative time, diminished the need for bilateral neck exploration, and improved cure rates [30]. Intraoperative PTH is based on the short half-life of circulating PTH. Parathyroid hormone is cleared from the blood in an early rapid phase with a half-life variously reported as 1.5–21.5 min in patients with normal renal function. PTH levels are measured preoperatively and at set post-excision times. A decline of more than 50 % in PTH level from the highest pre-incision or pre-excision level is associated with predictive cure in 94–97 % of cases [31–33], especially when the levels drop into the normal range.

Surgical Technique

One of the advantages of the robotic-assisted approach is its facilitation of an endoscopic neck surgery while maintaining a three-instrument approach. It also gives the surgeon the ability to retract, view target surgical anatomy, and still have two arms to operate, while maintaining traction and counter traction. The robotic-wristed instruments permit the surgeon to reduce physiological tremors and increase the surgeon's operative free dexterity of movement. Three robotic instruments (Maryland dissector, ProGrasp forceps, and Harmonic curved shears) and a dual-channel camera are needed. By placing the camera through the axillary/retroauricular incision and using an endoscope with 30° down orientation, principles from the conventional cervical approach can be applied safely to this endoscopic technique. During development of the working space, electrocautery, a vascular DeBakey forceps, and various retractors (army–navy, right-angled and lighted breast retractors) are used for subcutaneous flap dissection and elevation (Table 26.1).

It is important for the surgeon to determine the best way to organize the operating room prior to the procedure. The operating table should be positioned where the anesthesiologist has access to the patient's airway. The patient cart is covered with sterile drapes and positioned on the contralateral side of the operating table. The patient cart is initially kept away from the operating table during the development of the working space to allow space for the surgical assistant to work across the table and retract the thyroid gland. Dr. Kandil routinely performs continuous nerve monitoring of the ulnar, radial, and median nerves to avoid neuropraxia when using the transaxillary approach. We also use intraoperative nerve stimulation to definitively identify motor nerve structures during the procedure.

Table 26.1 Equipment needed for the robotic-assisted transaxillary/retroauticular approach

Development of the working space • Electrocautery with a short, regular, and long tip • Vascular DeBakey • Army–navy retractors • Right-angled retractors • Breast lighted retractors[a]
Table devices • Chung's retractor, or Marina retractor (Marina Medical, Sunrise, FL, USA) • Laparoscopic suction irrigation • Laparoscopic clip appliers for hemostasis • Endo Peanut 5-mm device
Robotic instrumentation • 5-mm Maryland dissector • 8-mm ProGrasp forceps • 5-mm Harmonic curved shears • 30° endoscope (used in the rotated down position)
Robotic arrangement • Arm 1- Maryland dissector • Arm 2- Harmonic shears • Arm 3- ProGrasp forceps • Endoscope

[a]Transaxillary approach only

Robotic Transaxillary Parathyroidectomy

Step 1—Patients are placed in a supine position while under general anesthesia, and then intubated with a NIM transoral endotracheal tube (Medtronic Xomed, Jacksonville, FL, USA) to allow intraoperative monitoring of the recurrent laryngeal nerve function.

Step 2—Appropriate placement of the NIM endotracheal tube is confirmed by direct laryngoscopy and by visualization of the electromyographic waveform on the NIMS monitor.

Step 3—The neck is slightly extended, and the arm ipsilateral to the lesion is placed cephalad and flexed above the head (Fig. 26.1). This optimizes exposure of the axilla and creates a short distance from the axillary skin to the thyroid gland, through which dissection would be performed.

Step 4—Blood is drawn for a baseline rapid PTH serum level prior to prepping the neck or palpating the neck.

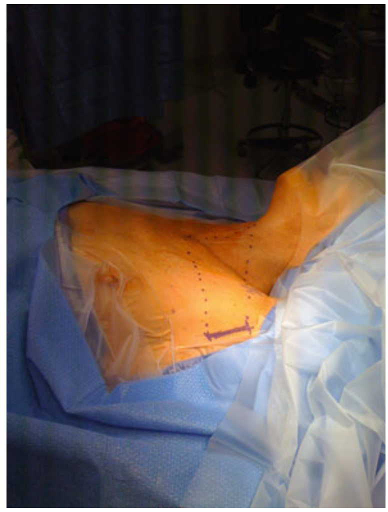

Fig. 26.1 Incision marking for robotic transaxillary parathyroidectomy

Step 5—The thyroid is identified by palpation and a vertical line is drawn from the midline of the thyroid to the sternal notch, demarcating the medical boundary of dissection. The inferior limit of dissection is drawn from the sternal notch to the ipsilateral axilla in a transverse manner. The superior limit of dissection is drawn in an oblique manner from the thyrohyoid membrane to the axilla (Fig. 26.1).

Step 6—Following infiltration with 10 mL of 1 % lidocaine with 1 in 200,000 adrenaline, a two-inch (5 cm) incision is then made with a scalpel from the intersection of the oblique line and the anterior axillary line as the superior limit and the intersection of the transverse line with the anterior axillary line as the inferior limit. Attention to detail in incising and handling the skin reduces cicatrix hypertrophy.

Step 7—Monopolar electrocautery under direct vision is then used to dissect to the pectoralis fascia. A subcutaneous flap is raised in the direction of the thyroid until the sternal and clavicular heads of the sternocleidomastoid muscle are visualized and opened.

Step 8—A retractor is used to elevate and retract the sternal head exposing the strap muscles. The natural dehiscence between the sternal and clavicular heads is entered using the Harmonic Scalpel (Ethicon, Somerville, NJ, USA), allowing identification of the carotid sheath and ipsilateral omohyoid and sternohyoid muscles.

Step 9—The strap muscles are then elevated off the thyroid gland providing exposure from the sternal notch to the superior pole and across the midline.

Step 10—A wound protector is placed to protect the axillary wound edges from any heat generated by the electrocautery or the harmonic scalpel.

Step 11—A specially designed retractor (Marina Medical, Sunrise, FL, USA) is placed under the strap muscles and secured to the table mount lift to maintain an adequate working space without gas insufflation. This facilitates access to the posterolateral thyroid lobe.

Step 12—The da Vinci Si robot system is docked from the side of the bed contralateral to the operative field. The robotic instruments used are the ProGrasp forceps (Intuitive Surgical, Sunnyvale, CA, USA), Maryland Dissector (Intuitive Surgical, Sunnyvale, CA, USA) and Harmonic scalpel (Ethicon, Somerville, NJ, USA). The 30° endoscope is used in a downward facing orientation. The robotic arms are equipped with the Maryland dissector, the ProGrasp forceps, and the Harmonic scalpel. The Maryland dissector and Harmonic scalpel should be as far apart as possible. This is important in minimizing the risk of collision of the arms during the procedure.

Step 13—The thyroid gland is turned medially and with cautious dissection the pathological parathyroid gland is identified.

Step 14—The middle thyroid vein is divided using the Harmonic scalpel.

Step 15—Identification of the inferior thyroid pedicle with dissection RLN in tracheoesophageal groove is then undertaken to minimize the risk of injury to either structure.

Step 16—A nerve stimulator is routinely used by the assistant surgeon to confirm correct identification of the RLN.

Step 17—Once the pedicle has been delineated, the Harmonic scalpel is used to hemostatically seal and divide the small branches of the inferior thyroid artery close to the capsule of the adenoma.

Step 18—The parathyroid lesion is then dissected, excised, and delivered through the axillary incision (Video Clip 26.1).

Step 19—After gland removal, a serum sample is drawn for rapid PTH analysis. A 50 % or greater drop in PTH level and within normal range predicts a successful single gland surgery. The patient is kept sedated and surgical field maintained until the laboratory results are received. Those patients with no change in PTH level or inadequate reduction of the PTH likely have a secondary adenoma (or less likely an unappreciated MEN patient).

Step 20—The wound is irrigated and inspected for hemostasis. A Jackson-Pratt drain is coursed through the axilla and sutured to the skin.

Step 21—Meticulous closure of subcutaneous tissues and skin is performed using subdermal and subcuticular closure with fine attention to detail.

Robotic Retroauricular (Facelift) Parathyroidectomy

Step1—Patients are placed supine on the operating room table. The head is turned to the side contralateral to the side of the diseased gland. Patients are intubated using a NIM endotracheal tube size 6.0 (Medtronic Xomed, Jacksonville, FL, USA) to allow intraoperative monitoring of RLN function.

Step 2—A small portion of postauricular hair is shaved for the extension of the planned incision lines into the hair-bearing skin.

Fig. 26.2 Incision marking for robotic retroauricular parathyroidectomy

Step 3—The retroauricular incision is then marked out just posterior to the earlobe, extending into the postauricular crease and adjacent to the occipital hairline at a position that will be covered completely by the ear and hair at rest (Fig. 26.2).

Step 4—Blood is drawn for a baseline rapid PTH serum level prior to prepping the neck or palpating the neck.

Step 5—The flap is created superficial to the platysma using a Metzenbaum scissor. Care is taken to preserve the greater auricular nerve. Dissection in the plane superficial to the platysma is performed until the head of the sternocleidomastoid muscle is visualized.

Step 6—The space between the strap muscles and the SCM is created with electrocautery or Harmonic scalpel (Ethicon, Somerville, NJ, USA). The working space is created all the way to just above the omohyoid muscle, which correlates with the superior pole of the thyroid lobe.

Step 7—A specially designated retractor (Marina Medical, Sunrise, FL, USA) is then secured to the table mount lift and placed under the strap muscles to allow continuous exposure of the surgical field, maximizing access to the parathyroid gland.

Step 8—The da Vinci Si system (Intuitive Surgical, Inc., Sunnyvale, CA, USA) is then docked using the 30° scope, Maryland dissector, and a Harmonic scalpel (The camera is positioned in the center of the field, a Maryland grasper is placed in the nondominant hand, and the Harmonic is placed in the dominant hand). The robot is docked from the contralateral side of the operative field, with the 30° down looking endoscope, Harmonic scalpel, and Maryland forceps entering via the retroauricular incision.

Step 9—The thyroid gland is turned medially and with cautious dissection the pathological parathyroid gland is identified.

Step 10—The middle thyroid vein is divided using the Harmonic scalpel.

Step 11—Identification of the inferior thyroid pedicle with dissection RLN in tracheoesophageal groove is then undertaken to minimize the risk of injury to either structure.

Step 12—A nerve stimulator is routinely used by the assistant surgeon to confirm correct identification of the RLN.

Step 13—Once the pedicle has been delineated, the Harmonic scalpel is used to hemostatically seal and divide the small branches of the inferior thyroid artery close to the capsule of the adenoma.

Step 14—The parathyroid lesion is then dissected, excised, and delivered through the incision.

Step 15—After gland removal, a serum sample is drawn for rapid PTH analysis. A 50 % or greater drop in PTH level and within normal range predicts a successful single gland surgery. The patient is kept sedated and surgical field maintained until the laboratory results are received.

Step 16—The wound is irrigated and inspected for hemostasis.

Step 17—Meticulous closure of subcutaneous tissues and skin is then performed.

Robotic Thoracoscopic Mediastinal Parathyroidectomy

The presence of a thoracic surgeon is usually required for this procedure. This surgery is not done on an outpatient basis and requires a chest tube to be placed. This approach is utilized to avoid open thoracotomy or median sternotomy.

Step1—A left or right sided approach is chosen according to the location of the ectopic parathyroid gland. The patient is placed in a lateral decubitus position (depending on adenoma localization) with contralateral single-lung ventilation.

Step 2—A 10-mm port for the robotic endoscope is positioned in the 6th intercostal space in the anterior axillary line, and two 8-mm robotic operating ports are placed in the 4th intercostal space, a handbreadth right and left of the first incision.

Step 3—An accessory port is placed in the midclavicular line through the 6th intercostal space, through which a flexible retractor (US Surgical, Norwalk, Conn) is inserted to hold the lung away.

Step 3—A second accessory port through the posterior axillary line in the 6th intercostal space is provided for eventual suction.

Step 4—Resection of the parathyroid adenoma is performed by the thoracic surgeon at the console. This is done by incising either the parietal pleura covering the aortopulmonary window or pericardium depending on the location. The identification of the vagal and recurrent laryngeal nerves are encouraged, but are not considered to be an essential part of the procedure.

Step 5—The vascular pedicle is controlled with the harmonic scalpel or clips and once freed, the adenoma is removed. Compared to conventional thoracoscopic surgery, the robotic operating system provides better visualization of the operating field and facilitates the movement of the instruments. Radioguided surgery can be used but usually there is significant background activity from the heart.

Robotic parathyroidectomy is usually performed as an outpatient procedure. The patients are discharged on anti-inflammatory pain medication with narcotics only for breakthrough discomfort. Patients are supplemented with calcitriol 0.25 mcg twice daily and elemental calcium 1 g twice daily unless signs or symptoms of hypocalcemia present. No laboratory studies are required following intraoperative verification of serum PTH normalization. The patient's first outpatient follow-up is at 1 week for pathology review, wound inspection and further instruction on wound care. Duration and extent of vitamin D and calcium supplementation are based on preoperative bone mineral density determination and interdisciplinary management with an endocrinologist.

Summary

The results of the two prospective studies, two retrospective studies, and two case control studies are summarized in Table 26.2. All the reports of robotic parathyroidectomy have been shown to be safe, feasible, and efficacious. There are not studies in the literature that evaluate the outcome of robotic parathyroidectomy using the retroauricular approach. The preliminary results for robotic transaxillary and infraclavicular parathyroidectomy have shown it to be equivalent to conventional parathyroidectomy with regards to cure and complication rates. Complications such as recurrent laryngeal nerve palsy and hypoparathyroidism are rare (<1 %), similar to the conventional cervical approach. The preliminary functional outcomes of robotic parathyroidectomy are encouraging. Long-term prospective outcome data are imminent and randomized clinical studies are warranted to evaluate potential advantages. The conversion rate associated with robotic parathyroid surgery is unknown due to the sparse data in the literature. Nonetheless, conversion to a wider access or conventional procedure for bilateral neck exploration should not be considered a complication; it is a limitation of

Table 26.2 Best evidence studies in the English medical literature from January 2000–May 2015

Study (year)	Level of evidence	Sample size	Cohort	Mean operative time	Outcomes	Limitations
Prospective studies						
Landry et al. (2011) [9]	Level IIIA	2 pts	2 pts underwent RP for a PA Follow-up duration unknown	108.5 ± 9.2 min	Successful parathyroidectomy with no conversion; no intraoperative or postoperative complications; Biochemical cure achieved postoperatively	Small sample size; absence of control group; follow-up period unknown; No evaluation of patient reported outcome measures
Tolley et al. (2011) [7]	Level IIIA	11 pts	11 pts underwent RP for a PA Mean follow-up 6 months	Flap creation time, 31 min; console time, 51 min	Successful parathyroidectomy in all but 1patient who required a conversion to an open approach due to BMI of 33.4 kg/m^2; 1 patient was found to have persistent PHPT (due to nondiagnosed MEN1); no intraoperative or postoperative complications; excellent cosmetic outcome and patient scar satisfaction; significant improvement in quality of life	Small sample size; absence of control group; multiple remote ipsilateral incisions (1 infraclavicular and 3 incisions along the ipsilateral anterior axillary line, the inferior one translocated to a periareolar incision if body habitus permitted)
Retrospective studies						
Noureldine et al. (2014) [11]	Level IV	9 pts	6 pts underwent RP for a PA; 2 pts underwent RT for intrathyroidal PA; 1 pt underwent RP and RT for an atypical PA Mean follow-up 6 months	119 ± 15.6 min	Curative resection was established in all 9 cases 1 Patient required conversion to a transcervical approach due to the presence of multigland disease; no intraoperative or postoperative complications; Subjective cosmetic results excellent; Biochemical cure achieved in all cases	Retrospective study; small sample size; absence of control group; no evaluation of patient reported outcome measures

(continued)

Table 26.2 (continued)

Study (year)	Level of evidence	Sample size	Cohort	Mean operative time	Outcomes	Limitations
Karagkounis et al. (2014) [21]	Level IV	8 pts	8 pts underwent RP for PA Median follow-up 29 months	184 ± 58 min	Curative resection was established in all pts; No conversion was required; no intraoperative complications and only one postoperative complication, a case of postoperative seroma that was managed conservatively	Retrospective study; small sample size; no evaluation of cosmetic satisfaction
Case control studies						
Foley et al. (2012) [10]	Level IIA	16 pts	4 Patients underwent RP for PA; 12 patients underwent transcervical targeted parathyroidectomy (matched controls) Mean follow-up 6.1 months	186 ± 84.2 min (Control, 86 ± 27.9 min)	Curative resection was established in all patients; no intraoperative complications and only 2 postoperative complication, wound infection, and seroma (both treated conservatively); a learning curve was demonstrated	Small sample; no evaluation of patient reported outcome measures; short follow-up for one patient (2 weeks)
Tolley et al. (2014) [22]	Level IIA	30 pts	15 pts underwent RP for PA; 15 patients underwent transcervical, focused lateral parathyroidectomy (matched controls) Minimum follow-up 12 months	119 min (control, 34 min)	Curative resection was established n 97 % of pts; conversion required in one case due to large body habitus (33.4 kg/m^2); a learning curve was demonstrated; excellent cosmetic outcome and patient scar satisfaction; significant improvement in quality of life	Although largest study, small sample size; multiple remote ipsilateral incisions (1 infraclavicular and 3 incisions along the ipsilateral anterior axillary line, the inferior one translocated to a periareolar incision if body habitus permitted)

PA parathyroid adenoma, *RP* robotic parathyroidectomy, *min* minutes, *pts* patients, *MEN1* multiple endocrine neoplasia type 1 the preoperative localization studies and focused surgical approach rather than a reflection of the robotic technique per se. Nevertheless, a high conversion rate may reflect poor patient selection. Additionally, prolonged paresthesia of the skin flap, and muscle stiffness has been described by some patients undergoing the transaxillary approach. The arm positioning can cause overtraction and brachial plexus neuropraxia. Using the intra-op somatosensory evoked potential responses (SSEP) nerve monitoring should help avoid these complications. After facelift parathyroidectomy, transient hypesthesia in the distribution of the greater auricular nerve is universal.

Another significant disadvantage of robotic surgery is the cost of the procedure. Studies of the transaxillary approach suggest that increased operative time, coupled with the capital expense of the robotic system and the specialized equipment required may significantly increase the cost of surgery. While compensation for robotic procedures is significantly higher than conventional approaches in Asia, there is not increased reimbursement in the USA.

Society Guidelines: N/A

Best Practices: N/A

Expert Opinion

Robotic parathyroidectomy approaches offer the distinct advantage over anterior cervical approaches of completely eliminating a visible neck scar. Precise preoperative imaging enables the careful planning of robot-assisted surgery for ectopic parathyroids located at relatively inaccessible regions such as the anterior mediastinum. Despite the advantages of the robotic technology and excellent results in terms of complication and cure rates, there are some concerns for its routine application in clinical practice. Experience of the entire surgical team with robotic technology is essential for optimizing outcomes using this procedure. Inserting and aligning the instruments requires a trained assistant and a team approach. We believe consistency of the team members including operating room staff yields the utmost improvements over time. In addition to mastering the technical aspects of the robotic surgical system, surgeons need to become familiar with the anatomic perspective of the lateral approach to the thyroid and parathyroid glands.

The adoption of new technology in the operating room offers potential benefits as well as economic challenges. The need for specific instrumentation has been considered a source of additional costs compared with conventional surgery. Operative time, which was considered one of the limits of the technique, has been demonstrated to decrease with increasing experience.

Robotic surgery in the head and neck is still in the developmental stages. There is no question that it has restored the two-handed wristed manipulation and depth-of-field visualization to surgical procedures that had lost these capabilities during a transition to endoscopic surgery. What remains to be performed is a balanced investigation with rigorous data analysis to fully explore and recognize its advantages and limitations. At present, robotic parathyroidectomy can only be justified in patients who are predisposed to keloid or hypertrophic scarring or have cultural considerations leading to the desire to avoid a neck scar.

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