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REVIEW ARTICLE

Remote Access Thyroid Surgery: A Review of Literature

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Abstract
Since the first description of endoscopic thyroid lobectomy in 1997, a variety of techniques have been developed to avoid the visible cervical scar conventionally been associated with thyroidectomy. These "remote access" approaches, which typically use either endoscopic or robotic instrumentation, have successfully avoided the anterior neck scar, which has a measurable impact on the patient's quality of life (Graves and Suh Surgery 168(5):845–850, 2020; Sakorafas World J Surg 34(8):1793–1804, 2010). The main advantage of these techniques is better cosmesis compared to conventional transcervical approaches (Graves and Suh Surgery 168(5):845–850, 2020) However, these techniques have failed to gain widespread acceptance in the surgical community because of the technical challenges, scepticism about oncological safety and cost factors. This review presents an overview of the various methods of remote access thyroid surgery (RATS) and also evaluates the selection criteria, oncological efficacy, training requirements and key advantages of this technique.

Keywords Thyroidectomy · Thyroid cancer · Remote access surgery · Minimal access surgery · Robotic surgery · Endoscopic thyroidectomy

Introduction

Thyroid surgery was historically considered to be the most aggressive procedure marked by high mortality and morbidity due to haemorrhage, asphyxia, gangrene and air embolism [1]. Over the years, with a better understanding of the anatomy coupled with technical developments in anaesthesia, antisepsis and surgery, it has become one of the safest surgical procedures [2]. There is a growing incidence of thyroid cancers worldwide, the majority of which are well-differentiated thyroid cancers which have an excellent prognosis [3]. These surgeries are generally performed through a cervical incision, which is generally safe and involves minimal morbidity; however, in some cases, the patients develop unsightly anterior neck scars. Many patients requiring thyroidectomy are young females, for whom scar is a major concern as it can significantly impact quality of life [4]. Consequently, minimally invasive and remote access surgical approaches have been explored to improve cosmesis, minimise pain and shorten the length of stay in the hospital, without compromising oncological outcomes and morbidity [5]. The most recent addition to these techniques is transoral endoscopic thyroidectomy via the vestibular approach (TOETVA) which is a true scar less thyroid surgery [6].

The initial attempt of minimally invasive thyroid surgery was pioneered by work of Miccoli et al. who performed a video-assisted thyroidectomy through a minimal access (2 cm) lateral cervical incision [4]. This technique was initially used for haemithyroidectomy and benign tumours and later adopted for total thyroidectomy and central compartment neck dissection in malignant tumours [4]. Even

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though the technique safely accomplished thyroid surgery, it still needed a cervical incision, which was problematic in some cases [7]. The proposition of avoiding the anterior neck scar in thyroid with remote access surgery became a reality with advances in endoscopic instrumentation and better understanding of endoscopic cervical anatomy. This led to the practice of endoscopic-assisted remote access through axilla, breast, axillo-breast and retroauricular approaches for thyroid surgery. The application of robotic surgery in head and neck started with the application of this novel technology in oropharyngeal cancer surgery. The experience distilled by this technique was later extended to perform remote access thyroid surgeries. The Korean experience documented excellent cosmetic outcomes and minimal morbidity, which evoked global interest [8–10]. The robotic technique has provided a three-dimensional magnified high-definition image on a stable platform with tremor-free endoscopic arms and instruments. This better surgical manoeuvrability has thus eliminated the drawbacks of endoscopic surgery.

In this review, we discuss patient selection, various remote access approaches and the associated outcomes.

Indications and Contraindications

The indications of RATS vary significantly with experience of the surgeon and their position in the learning curve. However, the accepted indications are malignant lesions < 4 cm in size, with little or no extrathyroidal extension. In addition to the technical difficulty with manipulating a large thyroid gland, specimen delivery through the incision devoid of any distortion is a significant challenge.

Contraindications include locally advanced malignancies involving surrounding vital structures, large tumours or previously surgery or irradiation. Some surgeons would consider thyroiditis as a relative contraindication given that inflammation in the surgical field and potential troublesome bleeding that can obscure vision [8–10].

Remote Access Approaches for Thyroid

Cervical Approach

The cervical approach involves placement of three to four small ports including a 12-mm endoscopic port. The working space is maintained by insufflating CO_2 at low pressures [11]. Instruments are inserted through the ports to access the thyroid gland.

Extra-cervical Endoscopic Approaches

Extra-cervical thyroidectomy approaches essentially access the neck and thyroid gland from the chest, breast, axilla or postauricular areas. In the truest sense, these are not minimally invasive surgeries. Additional surgical dissection is required to access these sites towards creating the tunnel/working space. These indirect approaches have been brought under the blanket term of minimal access but maximally invasive approach (MAMIA) [11].

The techniques are classified in terms of where the surgical trocars are introduced and the site of approach. This has an intimate relationship with cosmetic outcome, safety and level of invasiveness (Table 1). The approaches currently employed are the axillary approach, anterior/breast approach, axillary-bilateral breast approach, bilateral axillo-breast approach, postauricular approach and the transoral approach [12].

Transaxillary Endoscopic Thyroidectomy

Transaxillary endoscopic thyroidectomy was first described by Ikeda et al. [13]. The technique involves making a 1.5-cm to 3-cm incision in the axilla, and the platysma is exposed in the upper portion of the pectoralis major muscle via subcutaneous tunnelling. Standard trocars/ports are then placed in the axillary incision, and a tight seal is created for insufflation using purse-stringed sutures around them [13].

Table 1 Classification of robotic and endoscopic thyroidectomy

CO_2 insufflation method	Gasless method
Cervical approach	Minimally invasive video-assisted thyroidectomy
Anterior chest approach	Anterior chest approach
Axillary approach	Video-assisted neck surgery
Breast approach with parasternal approach	Axillary approach • Axillary approach with anterior chest port • Single-incision axillary approach • Gasless unilateral axillo-breast or axillary approach
Axillo-breast approach • Axillo-bilateral breast approach • Bilateral axillo-breast approach • Unilateral/bilateral axillo-breast approach	Facelift (retroauricular) approach
Transoral approach	Transoral approach

Gasless Transaxillary Approach

Chung and colleagues popularised the gasless transaxillary approach. This approach uses a longer 6-cm axillary incision and one small anterior chest incision for chest port. Similar to the other transaxillary technique, the platysma is exposed through subcutaneous tunnelling, and subplatysmal dissection along the heads of sternocleidomastoid leads the surgeon to the anterior neck. Further, the dissection is continued below the sternothyroid muscle to expose the gland [8].

The Anterior Chest Approach

In the anterior chest approach, with insufflation, three small ports are placed on the anterior chest wall. The larger 12-mm endoscope port and 5-mm ports are used for instrumentation. This approach has also been developed using similar port placement and a cervical region-lifting system. Some operators have initially used CO_2 insufflation to get the exposure followed by the use of the retractor system to maintain it.

Video-assisted neck surgery is another variation of the anterior chest approach or infraclavicular approach. Here, a 3–4-cm oblique incision is made below the clavicle, and smaller 5-mm incisions are made in the lateral neck for inserting the endoscope. Following the elevation of skin flap from the chest, the thyroid gland is exposed, and Kirschner wires are used to maintain the cervical working space without CO_2 insufflation [8, 14].

Anterior Breast Approach

In 2000, Ohgami et al. developed the anterior breast approach for endoscopic thyroidectomy. It was a popular approach for benign thyroid nodules measuring < 5 cm and for follicular neoplasm requiring hemithyroidectomy [15]. However, longer operating times, learning curve and need for additional equipment led to the evolution of the axillo-breast (hybrid) approach, a technical modification of this technique [16].

Axillary-Bilateral Breast Approach (ABBA)

In 2003, Shimazu et al. reported the axillary-bilateral breast approach (ABBA), yet another technical modification to the anterior breast approach [17]. In this approach, the parasternal incision is replaced by an axillary incision on the pathological side. Indications for the ABBA include low-risk (non-metastatic) thyroid carcinomas not larger than 1 cm, follicular neoplasms less than 3 cm and benign thyroid lesions. The axillary incision provided better exposure, and the better visualisation reduced instrument collision and additionally improved the cosmesis. The multi-angle approach provided better instrument handling and also reduced the operating time [18].

The gasless transaxillary approach initially used two incisions, a 6-cm axillary incision and a small anterior chest port. With further refinement, surgery today can be accomplished using just the axillary incision. Tae et al. furthered these refinements and described the gasless unilateral axillo-breast (GUAB) approach. The GUAB approach uses a unilateral breast port around the areola and the axillary incision. The breast port provides a broad front of dissection, reducing instrument collision and "sword fighting" [8, 18].

Bilateral Axillo-Breast Approach (BABA)

Choe et al. modified the ABBA technique and developed the bilateral axillo-breast approach (BABA) [19]. With the addition of the contralateral axillary port, the approach provides optimal visualisation for total thyroidectomy. Slated advantage includes better exposure and orientation similar to that in conventional thyroidectomy. It also reduces the chances of instrument collision and makes central compartment clearance easier.

The technique involves making incisions on both the upper circumareolar areas and creating tunnels to reach up to the upper border of thyroid cartilage. Using vascular tunnellers, additional axillary ports are made. An endoscope is placed through the 12-mm right breast port, and the left 12-mm breast port is used for the operating instruments. The working space is maintained using CO_2 insufflation at low pressures, and other instruments are inserted through the axillary port.

A potential drawback to both ABBA and BABA techniques is the scar over the breast, which could be unacceptable to younger females, a group which is more susceptible to thyroid disorders.

Retroauricular Approach

This technique utilises the postauricular approach with or without two axillary ports. Indications for the postauricular or retroauricular approach include benign thyroid lesions < 4 cm in its largest diameter, low-risk micropapillary thyroid carcinoma, follicular neoplasm < 3 cm in size and parathyroid surgery [17]. The main advantage of this incision is bypassing the breast incisions to avoid visible scars. Also, the postauricular dissection is more familiar to head and neck surgeons [20, 21]. The technique can also be gasless and requires specially designed retractors.

Transoral Approach

In 2010, Wilhelm first described the transoral approach for thyroid surgery; the technique is particularly popular in Eastern Asia [22]. The approach was envisioned to establish a truly scarless technique and to reduce the extent of tissue dissection for access. Of the transoral approaches, the transoral vestibular approach has evolved to become the most popular.

The surgeon must be oriented to the craniocaudal approach and requires a comprehensive knowledge of anatomy. Kahramangil et al. [18] noted that despite the direct access, the dissection of the lateral borders of the thyroid lobes posed a key challenge. Another potential risk includes oro-cervical communication and anterior neck infection. There are few case series reporting mental nerve palsies as a potential complication.

In this approach, a 1.5–2-cm horizontal incision is made at the end of the lower lip frenulum. Lateral incisions are made on either side of the central incision and close to the oral commissure to avoid injury to the mental nerve. Blunt dissection of the submental area is performed to introduce the ports. A 30-degree rigid endoscope is placed in the centre, and the lateral ports used for instrumentation. The CO_2 insufflation pressure is set at 5–6 mmHg. An external stitch is often made to retract the strap muscles laterally [8].

Extra-cervical Robotic Approaches

In what is a seemingly, natural progression along the minimally invasive surgery continuum, robotic surgery provides advantages similar to endoscopic surgery (less pain, shorter hospitalisations, smaller incisions) while affording a variety of unique benefits (increased dexterity and tissue manipulation and dissection, tremor filtration and three-dimensional magnification with improved visualisation of the operative field) [23, 24]. It was only a matter of time before this new technology was applied to thyroid surgery. In 2009, Kang et al. [24] reported the first large case series ($n = 100$) of robot-assisted endoscopic thyroid surgery via a gasless, transaxillary approach using four robotic arms (a 12-mm telescope and three 8-mm instruments) for patients with benign thyroid disease and PTC [25, 26]. They noted no serious postoperative complications, and patients were back home by the third postoperative day. Mirroring the creativity and variety seen in endoscopic thyroidectomies, robotic thyroidectomy approaches included a robotic bilateral axillary, bilateral areolar approach described in 2009; a single-incision transaxillary approach designed to alleviate some of the anterior chest symptoms experienced due to anterior chest access (2010) and, recently, an alternative, non-axillary approach using a retroauricular facelift incision to avoid potential morbidities (brachial plexopathy, oesophageal perforation and transection and high-volume blood loss) as per a study of the transaxillary experience in North America. Similar to endoscopic approaches, robotic thyroidectomy has an appreciable learning curve. In their original series, Kang et al. reported a significant decrease in console operating time after 40 to 50 cases with a subsequent and unexplained gradual rise in operating time that remained below the operative time noted for the first ten cases [24]. Studies by Lee et al. and Kandil et al. further examined the learning curve and operative time for robotic thyroid surgeries of a single surgeon with similar results of reduced operating time after approximately 45 surgeries [27, 28]. Apart from analysing operating times, Kandil et al. examined the effect of body mass index (BMI, calculated as weight in kilogrammes divided by the square of height in metres) on operative time and found a significantly increased operative time in patients with BMI greater than 30 (137.1 vs 99.7 min), lending credence to the assertion that robotic transaxillary thyroidectomy may be less applicable to overweight and obese patients [13, 29].

Outcome Analysis

A handful of systematic reviews and meta-analysis focusing on primary (pain, postoperative hypocalcaemia, postoperative RLN injury) and secondary outcome measures (operative time, blood loss, cosmesis) have shown that MIVAT is safe as open thyroidectomy with better cosmesis, no differences in postoperative hypocalcemia, no blood loss or RLN injury and decreased pain [4, 30–34]. Studies have shown that MIVAT costs were similar to those of the open procedure for haemithyroidectomy and total thyroidectomy [35]. The transaxillary endoscopic approach has a steep learning curve but is a safe procedure in experienced hands and has the wonderful benefit of excellent surgical cosmesis. Endoscopic thyroidectomy approaches combine the advantages of minimal access techniques providing better visualisation and precise anatomic details through a greatly magnified view, decreased pain, better cosmetic results, reduced functional deficits and shorter hospital stay [35].

Operative Time and Learning Curve

Sung et al. showed that the transaxillary and the facelift approach required similar OT time [36]. Kandil et al. reported that robotic approaches added 43.5 min to the operative time. Robotic and endoscopic procedures roughly require the same operative times [27]. Lee et al. and Song et al. both estimated the learning curve for robotic thyroidectomy via the transaxillary approach to between 35 and 50 cases, and Liu et al. reported the learning curve of the BABA is about 40 cases [28, 37, 38]. This was an outcome of the intricacies of flap dissection and manipulation of robotic instruments.

Surgical Adequacy and Oncologic Outcomes

Thyroglobulin (Tg) levels are often considered surrogate markers for surgical completeness. Significantly higher Tg levels were reported in robotic approaches compared to open surgery in a meta-analysis [6]. Lee et al. stated that surgical clearance with BABA was comparable to open approaches; however, Lang et al. in their meta-analysis showed that lymph node yield in the robotic approach was significantly lower [39, 40].

The early oncological outcomes with minimal invasive approaches and conventional open approaches in select cases remain comparable [41–43]. As these approaches are relatively new, the follow-up period of the existing studies is too brief for DTC and still remains a point of concern. However, careful case selection can help mitigate the concern.

Cosmetic and Quality of Life

The cosmetic fruition is higher in the transaxillary approach than in open thyroidectomy [44]. In terms of voice outcomes, there exist reports of similar postoperative voice outcomes in both transaxillary and conventional thyroidectomy. However, studies have depicted a better subjective voice recovery and results in acoustic parameters of voice pitch in robotic thyroidectomy via the gasless transaxillary approach compared to conventional surgery [45, 46]. Nevertheless, well-designed prospective studies are required for a comprehensive evaluation.

Patients who undergo gasless transaxillary thyroidectomy experience longer pain and sensory disturbance in the anterior chest area compared to patients undergoing conventional thyroidectomy [47]. Minimal anterior chest dissection may help address this issue. It is noteworthy that the quality of life after transaxillary robotic thyroidectomy has been shown to be comparable to quality of life after open thyroidectomy [48].

A 2012 meta-analysis and systematic review by Jackson et al. compared robotic thyroidectomy to endoscopic and conventional thyroidectomy focused on the following outcomes: operative time, hospital stay, postoperative complications and cosmetic fruition [49]. As many as nine significant papers were included in this meta-analysis: 4 open thyroidectomy vs. robotic thyroidectomy, 4 endoscopic thyroidectomy vs robotic thyroidectomy and 1 open thyroidectomy vs endoscopic thyroidectomy vs robotic thyroidectomy. On operative time, robotic thyroidectomy was significantly longer than open thyroidectomy by 42 min on average without a significant difference compared to endoscopic surgery. In terms of hospital stay, compared to robotic thyroidectomy and endoscopic thyroidectomy, open thyroidectomy length of stay was "significantly increased", but no difference was found between robotic thyroidectomy and endoscopic thyroidectomy. Postoperative complications were similar between the three groups. Notably, the robotic thyroidectomy group posed a higher risk of transient hypocalcaemia. In terms of postoperative pain, all 4 studies compared robotic thyroidectomy vs open thyroidectomy, and the results were less straightforward due to the varied measurement methods used in the individual studies. Overall, robotic thyroidectomy patients had increased anterior chest pain and paraesthesia of varying duration, and open thyroidectomy patients had increased neck paraesthesia and hyperaesthesia which is not surprising given the surgical approaches. Cosmetic fruition was significantly higher in the robotic thyroidectomy group, compared to the open thyroidectomy group. The review and analysis upheld the belief that robotic thyroidectomy is a safe alternative to endoscopic and open thyroidectomy [49]. Notably, the reported rates of seroma formation in the postoperative period were higher in minimally invasive remote access surgeries and called for aspirations postoperatively on several occasions.

Complication Rates

The major concerns common to open approaches are hypocalcaemia and recurrent laryngeal nerve injury, while concerns that are unique to minimal access approaches are rate of conversion to open surgery and neuropraxias.

a) **Hypocalcaemia:** Although the definition of temporary and permanent hypoparathyroidism varies between studies, in eighteen studies comparing robotic and open thyroidectomy, these rates were comparable in all except three studies, in which hypoparathyroidism was more common in the robotic group [50]. It is likely that the learning curve plays a role here. Additionally, newer technologies like indocyanine green [51] may help reduce this risk early in the learning curve, but to what extent is unclear.
b) **Recurrent laryngeal nerve injury:** In terms of voice outcomes, there exist reports of similar postoperative voice outcomes in both transaxillary and conventional thyroidectomy. However, studies have depicted a better subjective voice recovery and results in acoustic parameters of voice pitch in robotic thyroidectomy via the gasless transaxillary approach compared to conventional surgery [45, 46]. Nevertheless, well-designed prospective studies are required for a comprehensive evaluation. Several meta-analyses have compared the outcomes in open and robotic approaches. Transient RLN palsy was higher in robotic approaches, and the rate of injury was

more frequent early in the learning curve, more frequently with low-volume surgeons [27, 40, 52, 53].

c) **Rate of conversion to open surgery:** The major reason for conversion from any minimal access approach is if bleeding or injury to surrounding structures precludes safe continuation. Large series has shown the risk of major bleeding and haematoma was under 2–3% and comparable with open approaches [54–58]. Mention of conversion to open procedures is rare, with incidences of < 5% [59, 60].

d) **Neuropraxias:** Unusual complications such as transient brachial plexus injury were reported in the transaxillary approach (0.2%) [52], which can be minimised with appropriate positioning. As these remote access procedures start at unconventional sites, they pose a risk to the adjacent nerves. Marginal mandibular nerve is at risk in the postauricular approach as one makes the tunnel to access the central neck. Transoral approach takes into account the mental nerve, yet mental nerve palsy or paresis are known complications [52, 53].

Conclusion

Remote access thyroid surgery is here to stay, though it is largely up to the surgeon to comprehend the indications and limitations of these procedures aimed at safe and effective use. Although the approaches are diverse, the philosophy is consistent in achieving oncologically sound, safe and reliable outcomes. Ascertaining and measuring the enduring benefits of these approaches over and above their redressal of cosmetic concerns call for elaborate and well-designed trials.

References

1. Graves CE, Suh I (2020) The current status of remote access thyroidectomy in the United States. Surgery 168(5):845–850. https://doi.org/10.1016/j.surg.2020.05.021
2. Sakorafas GH (2010) Historical evolution of thyroid surgery: from the ancient times to the dawn of the 21st century. World J Surg 34(8):1793–1804
3. Sanabria A, Kowalski LP, Shah JP, Nixon IJ, Angelos P, Williams MD et al (2018) Growing incidence of thyroid carcinoma in recent years: factors underlying overdiagnosis. Head Neck 40(4):855–866
4. Miccoli P, Materazzi G, Berti P (2010) Minimally invasive thyroidectomy in the treatment of well differentiated thyroid cancers: indications and limits. Curr Opin Otolaryngol Head Neck Surg 18(2):114–118
5. Alvarado R, McMullen T, Sidhu SB, Delbridge LW, Sywak MS (2008) Minimally invasive thyroid surgery for single nodules: an evidence-based review of the lateral mini-incision technique. World J Surg 32(7):1341–1348
6. Dueñas JP, Duque CS, Cristancho L, Méndez M (2020) Completion thyroidectomy: is timing important for transcervical and remote access approaches? World J Otorhinolaryngol Head Neck Surg 6(3):165–170. https://doi.org/10.1016/j.wjorl.2020.02.006
7. Ikeda Y, Takami H, Sasaki Y, Takayama J, Niimi M, Kan S (2003) Clinical benefits in endoscopic thyroidectomy by the axillary approach. J Am Coll Surg 196(2):189–195. https://doi.org/10.1016/S1072-7515(02)01665-4
8. Tae K, Ji YB, Song CM, Ryu J (2019) Robotic and endoscopic thyroid surgery: evolution and advances. Clin Exp Otorhinolaryngol 12(1):1–11
9. Tae K, JiYB Jeong JH, Lee SH, Jeong MA, Park CW (2011) Robotic thyroidectomy by a gasless unilateral axillo-breast or axillary approach: our early experiences. Surg Endosc 25(1):221–228
10. Tae K, Ji YB, Cho SH, Lee SH, Kim DS, Kim TW (2012) Early surgical outcomes of robotic thyroidectomy by a gasless unilateral axillo-breast or axillary approach for papillary thyroid carcinoma: 2 years' experience. Head Neck 34(5):617–625
11. Huscher CS, Chiodini S, Napolitano C, Recher A (1997) Endoscopic right thyroid lobectomy. Surg Endosc 11(8):877
12. Sephton BM (2019) Extracervical approaches to thyroid surgery: evolution and review. Minim Invasive Surg 2019:5961690. Published 2019 Aug 20. https://doi.org/10.1155/2019/5961690
13. Tucker N, Mitchem J, Gillanders W (2013) Minimally invasive surgical techniques in the management of differentiated thyroid cancer. Otorinolaringologia 63(2):53–61
14. Ikeda Y, Takami H, Tajima G, Sasaki Y, Takayama J, Kurihara H et al (2002) Total endoscopic thyroidectomy: axillary or anterior chest approach. Biomed Pharmacother 56(Suppl 1):72s–78s
15. Ohgami M, Ishii S, Arisawa Y et al (2000) Scarless endoscopic thyroidectomy: breast approach for better cosmesis. Surg Laparosc Endosc Percutan Tech 10(1):1–4
16. Liu S, Qiu M, Jiang D (2009) The learning curve for endoscopic thyroidectomy: a single surgeon's experience. Surg Endosc 23(8):1802–1806
17. Shimazu K, Shiba E, Tamaki Y, Takiguchi S, Taniguchi E, Ohashi S, Noguchi S (2003) Endoscopic thyroid surgery through the axillo-bilateral-breast approach. Surg Laparosc Endosc Percutan Tech 13(3):196–201. https://doi.org/10.1097/00129689-200306000-00011
18. Shimazu K, Shiba E, Tamaki Y (2003) Endoscopic thyroid surgery through the axillo-bilateral-breast approach. Surg Laparosc Endosc Percutan Tech 13(3):196–201
19. Choe J-H, Kim SW, Chung K-W et al (2007) Endoscopic thyroidectomy using a new bilateral axillo-breast approach. World J Surg 31(3):601–606
20. Lee KE, Kim HY, Park WS (2009) Postauricular and axillary approach endoscopic neck surgery: a new technique. World J Surg 33(4):767–772
21. Terris DJ, Singer MC (2012) Qualitative and quantitative differences between 2 robotic thyroidectomy techniques. Otolaryngol Head Neck Surg 147(1):20–25
22 Wilhelm T, Harlaar J, Kerver A, Kleinrensink GJ, Benhidjeb T (2010) Transoral endoscopic thyroidectomy. Part 1: rationale and anatomical studies. Chirurg 81(1):50–55
23. Ryu HR, Kang SW, Lee SH, Rhee KY, Jeong JJ, Nam KH, Chung WY, Park CS (2010) Feasibility and safety of a new robotic thyroidectomy through a gasless, transaxillary single-incision approach. J Am Coll Surg 211(3):e13-19
24. Kang SW, Jeong JJ, Yun JS, Sung TY, Lee SC, Lee YS, Nam KH, Chang HS, Chung WY, Park CS (2009) Robot-assisted endoscopic surgery for thyroid cancer: experience with the first 100 patients. Surg Endosc 23(11):2399–2406
25. Kang SW, Jeong JJ, Nam KH, Chang HS, Chung WY, Park CS (2009) Robot-assisted endoscopic thyroidectomy for thyroid malignancies using a gasless transaxillary approach. J Am Coll Surg 209(2):e1-7

26. Kang SW, Lee SC, Lee SH, Lee KY, Jeong JJ, Lee YS, Nam KH, Chang HS, Chung WY, Park CS (2009) Robotic thyroid surgery using a gasless, transaxillary approach and the da Vinci S system: the operative outcomes of 338 consecutive patients. Surgery 146(6):1048–1055
27. Kandil E, Hammad AY, Walvekar RR, Hu T, Masoodi H, Mohamed SE et al (2016) Robotic thyroidectomy versus nonrobotic approaches: a meta-analysis examining surgical outcomes. Surg Innov 23(3):317–325
28. Lee J, Yun JH, Nam KH, Soh EY, Chung WY (2011) The learning curve for robotic thyroidectomy: a multicenter study. Ann Surg Oncol 18(1):226–232
29. Kandil EH, Noureldine SI, Yao L, Slakey DP (2012) Robotic transaxillary thyroidectomy: an examination of the first one hundred cases. J Am Coll Surg 214(4):558–564. discussion 564–556. [PubMed] [Google Scholar]
30. Radford PD, Ferguson MS, Magill JC, Karthikesalingham AP, Alusi G (2011) Meta-analysis of minimally invasive video-assisted thyroidectomy. Laryngoscope 121(8):1675–1681. https://doi.org/10.1002/lary.21864
31. Zhang P, Zhang HW, Han XD, Di JZ, Zheng Q (2015) Meta-analysis of comparison between minimally invasive video-assisted thyroidectomy and conventional thyroidectomy. Eur Rev Med Pharmacol Sci 19(8):1381–1387
32. Sgourakis G, Sotiropoulos GC, Neuhäuser M, Musholt TJ, Karaliotas C, Lang H (2008) Comparison between minimally invasive video-assisted thyroidectomy and conventional thyroidectomy: is there any evidence-based information? Thyroid 18:721–727
33. Pisanu A, Podda M, Reccia I, Porceddu G, Uccheddu A (2013) Systematic review with meta-analysis of prospective randomized trials comparing minimally invasive video-assisted thyroidectomy (MIVAT) and conventional thyroidectomy (CT). Langenbecks Arch Surg 398:1057–1068
34. Liu J, Song T, Xu M (2012) Minimally invasive video-assisted versus conventional open thyroidectomy: a systematic review of available data. Surg Today 42:848–856
35. Byrd JK, Nguyen SA, Ketcham A, Hornig J, Gillespie MB, Lentsch E (2010) Minimally invasive video- assisted thyroidectomy versus conventional thyroidectomy: a cost-effective analysis. Otolaryngol Head Neck Surg 143(6):789–794. [PubMed: 21109079]
36. Sung ES, Ji YB, Song CM, Yun BR, Chung WS, Tae K (2016) Robotic thyroidectomy: comparison of a postauricular facelift approach with a gasless unilateral axillary approach. Otolaryngol Head Neck Surg 154(6):997–1004
37. Song CM, Jang YI, Ji YB, Park JS, Kim DS, Tae K (2018) Factors affecting operative time in robotic thyroidectomy. Head Neck 40(5):893–903
38. Liu SY, Kim JS (2017) Bilateral axillo-breast approach robotic thyroidectomy: review of evidences. Gland Surg 6(3):250–257
39. Lee KE, Koo DH, Im HJ, Park SK, Choi JY, Paeng JC et al (2011) Surgical completeness of bilateral axillo-breast approach robotic thyroidectomy: comparison with conventional open thyroidectomy after propensity score matching. Surgery 150(6):1266–1274
40. Lang BH, Wong CK, Tsang JS, Wong KP, Wan KY (2015) A systematic review and meta-analysis evaluating completeness and outcomes of robotic thyroidectomy. Laryngoscope 125(2):509–518
41. Tae K, Song CM, Ji YB, Sung ES, Jeong JH, Kim DS (2016) Oncologic outcomes of robotic thyroidectomy: 5-year experience with propensity score matching. Surg Endosc 30(11):4785–4792
42. Lee SG, Lee J, Kim MJ, Choi JB, Kim TH, Ban EJ et al (2016) Long-term oncologic outcome of robotic versus open total thyroidectomy in PTC: a case-matched retrospective study. Surg Endosc 30(8):3474–3479
43. Sung TY, Yoon JH, Han M, Lee YH, Lee YM, Song DE et al (2016) Oncologic safety of robot thyroid surgery for papillary thyroid carcinoma: a comparative study of robot versus open thyroid surgery using inverse probability of treatment weighting. PLoS One 11(6):e0157345
44. Ji YB, Song CM, Bang HS, Lee SH, Park YS, Tae K (2014) Long-term cosmetic outcomes after robotic/endoscopic thyroidectomy by a gasless unilateral axillo-breast or axillary approach. J Laparoendosc Adv Surg Tech A 24(4):248–253
45. Song CM, Yun BR, Ji YB, Sung ES, Kim KR, Tae K (2016) Long-term voice outcomes after robotic thyroidectomy. World J Surg 40(1):110–116
46. Tae K, Kim KY, Yun BR, Ji YB, Park CW, Kim DS et al (2012) Functional voice and swallowing outcomes after robotic thyroidectomy by a gasless unilateral axillo-breast approach: comparison with open thyroidectomy. Surg Endosc 26(7):1871–1877
47. Song CM, Ji YB, Bang HS, Park CW, Kim H, Tae K (2014) Long-term sensory disturbance and discomfort after robotic thyroidectomy. World J Surg 38(7):1743–1748
48. Song CM, Ji YB, Bang HS, Park CW, Kim DS, Tae K (2014) Quality of life after robotic thyroidectomy by a gasless unilateral axillary approach. Ann Surg Oncol 21(13):4188–4194
49. Jackson NR, Yao L, Tufano RP, Kandil EH (2014) Safety of robotic thyroidectomy approaches: meta-analysis and systematic review. Head Neck 36(1):137–143. https://doi.org/10.1002/hed.23223
50. Liu SY, Ng EK (2016) Robotic versus open thyroidectomy for differentiated thyroid cancer: an evidence-based review. Int J Endocrinol 2016
51. Yu HW, Chung JW, Yi JW, Song RY, Lee JH, Kwon H, Kim SJ, Chai YJ, Choi JY, Lee KE (2017) Intraoperative localization of the parathyroid glands with indocyanine green and Firefly (R) technology during BABA robotic thyroidectomy. Surg Endosc 31(7):3020–3027
52. Lang BH, Wong CK, Tsang JS, Wong KP, Wan KY (2014) A systematic review and meta-analysis comparing surgically-related complications between robotic-assisted thyroidectomy and conventional open thyroidectomy. Ann Surg Oncol 21(3):850–861
53. Sun GH, Peress L, Pynnonen MA (2014) Systematic review and meta-analysis of robotic vs conventional thyroidectomy approaches for thyroid disease. Otolaryngology—Head and Neck Surgery 150(4):520–532
54. Jackson NR, Yao L, Tufano RP, Kandil EH (2014) Safety of robotic thyroidectomy approaches: meta-analysis and systematic review. Head Neck 36(1):137–143
55. Shen H, Shan C, Qiu M (2014) Systematic review and metaanalysis of transaxillary robotic thyroidectomy versus open thyroidectomy. Surg Laparosc Endosc Percutan Tech 24(3):199–206
56. Kandil E, Hammad AY, Walvekar RR et al (2015) Robotic thyroidectomy versus nonrobotic approaches: a meta-analysis examining surgical outcomes. Surg Innov
57 Sun GH, Peress L, Pynnonen MA (2014) Systematic review and meta-analysis of robotic vs conventional thyroidectomy approaches for thyroid disease. Otolaryngol Head Neck Surg 150(4):520–532
58. Shen H, Shan C, Qiu M (2015) Systematic review and metaanalysis of transaxillary robotic thyroidectomy versus open thyroidectomy. Surg Laparosc Endosc Percutan Tech 24(3):199–206
59. Johri G, Chand G, Gupta N, Sonthineni C, Mishra A, Agarwal G, Mayilvaganan S, Verma AK, Mishra SK (2018) Feasibility of endoscopic thyroidectomy via axilla and breast approaches for larger goiters: widening the horizons. J Thyroid Res 2018

60. Pons Y, Vérillaud B, Blancal JP, Sauvaget E, Cloutier T, Le Clerc N, Herman P, Kania R (2013) Minimally invasive video-assisted thyroidectomy: learning curve in terms of mean operative time and conversion and complication rates. Head Neck 35(8):1078–1082