Review Article

Transoral Robotic Thyroid Surgery: Technical Considerations

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ABSTRACT

Recently, many surgeons worldwide have adopted the transoral thyroidectomy approach owing to the associated advantages of less surgical morbidity, excellent cosmesis, and superior postoperative vocal outcomes. Specifically, transoral robotic thyroidectomy, in which a surgical robot is used, has been performed to hide or avoid visible neck scars and overcome the limitations associated with the endoscopic procedure. The transoral robotic thyroidectomy technique involves creation of three oral vestibular incisions and use of an additional axillary port, if indicated. Transoral robotic thyroidectomy is feasible and comparable to conventional transcervical thyroidectomy for highly selected patients. However, some unusual complications, such as CO_2 embolism, mental nerve injury, surgical site infection, and skin burn and trauma, are noted. Appropriate patient selection is important for the safety and success of this surgery.

Key words: Endoscopic thyroidectomy, remote access thyroidectomy, robotic thyroidectomy, transoral thyroidectomy

INTRODUCTION

Visible neck scars and cosmesis are major concerns after thyroidectomy.[1-3] In the past 20 years, various remote access robotic and endoscopic thyroidectomy techniques have been developed to avoid or hide visible neck scars.[4-6] Of these, the transoral approach has been recently highlighted and adopted by many surgeons worldwide owing to the numerous associated advantages.[4-15] The most significant advantages of transoral thyroidectomy are low surgical morbidity, superior postoperative cosmesis, and good preservation of functional voice. Song *et al*. reported the highest and broadest frequency and pitch range in the transoral robotic thyroidectomy group compared to that in the conventional transcervical group postoperatively.[7]

The transoral approach is considered a type of natural orifice transluminal endoscopic surgery. The invasiveness of the transoral approach to create a working space is less than that of the bilateral axillo-breast approach and transaxillary approach because the distance from the oral vestibular incisions to the thyroid gland is small.[4-6] Postoperative cosmesis is potentially better than that noted with other remote access procedures because no visible neck scar is observed after this procedure.[2] The transoral approach enables surgeons to perform bilateral total thyroidectomy because it is a midline approach. In addition, complete central neck dissection is possible, even up to level VII because it is a superior to inferior direction approach.[4-6] Here, I review the history of surgical techniques, relevant tips and tricks, and complications and safety of the transoral robotic thyroidectomy.

HISTORY AND EVOLUTION OF THE TRANSORAL THYROIDECTOMY TECHNIQUES

The concept of transoral approach was first introduced by Witzel *et al*. in cadavers and a pig model in 2008.[16] They created a 15-mm incision in the central sublingual area to place a modified axilloscope and two 3.5-mm lateral incisions on the external neck skin, 15 mm below the larynx, to insert two endoscopic instruments. Karakas *et al*. introduced another technique of transoral approach in pigs and cadavers in 2009.[17] They created a 2-cm oral mucosal incision on the lateral floor of the mouth and approached the thyroid and parathyroid glands obliquely through lateral to medial direction. They attempted this technique when performing parathyroidectomy in a few human patients. However, the working space was narrow, and unusual complications, such as hypoglossal nerve injury, were noted when this technique was performed.[17,18] None of the patients wanted to undergo

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this technique; hence, this technique is no longer used in the clinical setting.

Benhidjeb *et al*. and Wilhelm *et al*. performed transoral endoscopic thyroidectomy in cadavers and humans, using one sublingual port and two oral vestibular ports in 2009 and 2010, respectively.[19,20] This technique was initially attractive. However, it was not widely used; this technique has been performed only in some centers in Germany and China.[21,22]

The transoral vestibular approach using three oral vestibular incisions was first described by Richmon *et al*. in a cadaveric model using the da Vinci surgical system (Intuitive Surgical, Inc., Sunnyvale, CA, USA) in 2011.[23] This approach provided the basics of the transoral vestibular approach using endoscopy or surgical robots, which are commonly used presently.

In 2013, Nakajo *et al*. performed gasless transoral video-assisted neck surgery using a single 2.5-cm incision in the central oral vestibule.[24] They used the wire and external retraction system to maintain the working space without CO_2 insufflation. However, they reported a high rate of mental nerve injury postoperatively, which might be associated with the 2.5-cm long incision in the mid-portion of the oral vestibule.[24] Woo reported a case of transoral endoscopic thyroidectomy using a frenotomy incision in 2014.[25] He created a single sublingual vertical incision on the lingual frenulum. However, the working space was very narrow with this technique; hence, it is not used in the clinical settings anymore.

Transoral endoscopic thyroidectomy via the oral vestibular approach in human patients was first reported by Wang *et al*. in China in 2014.[26] However, the oral vestibular approach was popularized after publication of the report of 60 cases by Anuwong under the name "Transoral Endoscopic Thyroidectomy Vestibular Approach," in 2016.[27] In 2018, Kim *et al*. reported the feasibility and early experiences of transoral robotic thyroidectomy through 3 oral vestibular ports and an additional axillary port using the da Vinci Si surgical system (Intuitive Surgical, Inc., Sunnyvale, CA, USA) in humans.[28] Studies conducted by Razavi *et al*. and Tae *et al*. compared the robotic procedure to the endoscopic procedure with respect to the transoral vestibular approach in 2018 and 2019, respectively.[29,30] They showed that the surgical outcomes were not different between the robotic and endoscopic procedures, except for the operative time. The operative time for the robotic procedure was longer than that for the endoscopic procedure.[29,30]

In 2019, Park *et al*. introduced the gasless transoral endoscopic vestibular approach for thyroidectomy in which the external retraction system without CO_2 insufflation was used.[31] The advantage of the gasless method is the absence of complications associated with CO_2 insufflation. However, the placement of the external retractor blade narrowed the central oral port space. Therefore, they used a small 5-mm endoscope instead of a 10-mm endoscope because of the insufficient space. In addition, it is not easy to maintain a good working space when using the gasless method compared to that when using the CO_2 insufflation method. The surgical view is inferior to that noted with the CO_2 insufflation method. Transoral robotic thyroidectomy performed using the da Vinci single port (SP) surgical system (Intuitive Surgical, Inc., Sunnyvale, CA, USA) via the CO_2 insufflation or gasless method was introduced in 2019.[32-34] However, the da Vinci SP system does not offer major advantages over the da Vinci Si or Xi system for transoral thyroidectomy.[6] Further studies are necessary to determine the role and efficacy of gasless transoral endoscopic thyroidectomy and transoral robotic thyroidectomy using the da Vinci SP system.

INDICATIONS AND CONTRAINDICATIONS

The indications of transoral thyroidectomy can be expanded according to the experience of the surgeon and advancements in the surgical techniques. The indications for transoral thyroidectomy may include benign thyroid nodules measuring <5 cm in diameter and differentiated thyroid carcinomas measuring <3 cm with or without minimal extrathyroidal extension and central compartment lymph node metastasis.[12,30] In the transoral approach, the size of the tumor and volume of the thyroid itself can influence the surgical indication because it is difficult to remove a sizable surgical specimen through a small oral incision port. There are no absolute criteria for transoral thyroidectomy with respect to the tumor size and thyroid volume. However, the ideal tumor size and thyroid volume for transoral thyroidectomy may be <2 cm and 40 ml, respectively, when taking out the surgical specimen through the central oral incision port. However, if the axillary port is used, the tumor size criteria can be extended for larger tumors.

The exclusion criteria for transoral thyroidectomy include gross extrathyroidal extension invading the surrounding structures and large and multiple metastatic lymph nodes in the lateral compartment. Large goiters with Grave's disease or Hashimoto's thyroiditis may be relative contraindications owing to increased intraoperative bleeding and fragility of the thyroid tissue. Patients with a history of previous neck or thyroid surgery or neck irradiation are also contraindicated for transoral thyroidectomy.[12,30]

SURGICAL PROCEDURES OF TRANSORAL ROBOTIC THYROIDECTOMY

Positioning of the patient

The patient is placed in a supine position. Orotracheal intubation using a nerve monitoring tube is performed, and general anesthesia is induced. Usually, nasotracheal intubation is not necessary. Orotracheal intubation does not interfere with the surgery, and it is better to place a nerve monitoring tube. The neck is extended using a shoulder pillow, and the patient's head is fixed to the operating table using plaster to prevent rotation during the operation. The oral cavity is disinfected with povidone solution, and skin preparation and draping are performed in the usual manner.

Intraoperative neural monitoring

The standardized intermittent intraoperative neural monitoring (IONM) protocol for the recurrent laryngeal nerve (RLN) and the vagus nerve recommended by the International Neural Monitoring Study Group is performed. In addition, neural monitoring of the external branch of the superior laryngeal nerve (EBSLN) is done routinely by obtaining V1-S1-S2-R1-R2-V2 signals, in principle.[35] We used the robotic instrument itself as a stimulating probe by connecting it to the neural monitoring system.

Rocuronium is used as the nondepolarizing muscle relaxant, with the administration of a 5 mg/kg dose once at the induction of anesthesia. The C2 NerveMonitor with Laryngeal Electrode Select (Inomed Medizintechnik GmbH, Germany) is used for IONM. The proper position of the laryngeal electrode and neck extension are routinely checked after intubation using laryngofiberscopy.

Design of oral incisions and elevation of the skin flap

A 1.5–2-cm central incision is created near the base of the lower lip frenulum, and two lateral incisions are crated close to the oral commissure to avoid mental nerve injury [Figure 1]. After the central mucosal incision is created using monopolar electrocautery, dissection is performed to the chin over the periosteum of the mandible and extended to the submental area using clamps. Blunt dissection of the submental area is performed with a Hegar dilator in the midline and on both sides of the midline in a fan-like shape. We no longer inject diluted epinephrine for hydrodissection in the submental area and the central neck, because we have found from our early experiences that hydrodissection is not helpful for the elevation of the skin flap. A 12-mm trocar for the endoscope is inserted, and carbon dioxide is insufflated at 5–6 mmHg pressure. The lateral mucosal incisions are created, and 5 mL of epinephrine diluted in saline (1:400,000) is injected over the periosteum of the mandible with a Veress needle syringe for hydrodissection. Two trocars are inserted through the lateral oral vestibular incisions on either side of the endoscope. When inserting the two lateral trocars, care is taken not to perforate the facial skin because the skin and soft tissue of the lower lip and chin are usually thin. This explains why we use diluted epinephrine for hydrodissection in this area. It helps to prevent face skin perforation.

After inserting the three trocars [Figure 2], a 30° endoscope is inserted centrally. Laparoscopic dissectors and a hook bovie are then inserted through the lateral trocars. The exact plane of the subplatysmal layer is identified in the submental area, and the skin flap is elevated through this plane using the laparoscopic dissectors and hook bovie [Figure 3].

Docking of the da Vinci surgical robot

After the elevation of the skin flap in the submental area, a da Vinci Si surgical system (Intuitive Surgical, Inc., Sunnyvale, CA, USA) is placed and docked on the left lateral side of the patient. A dual-channel 30° endoscope is placed face-down in the central oral port, and two robotic instruments, either monopolar scissors or Maryland forceps, are placed on either side of the endoscope. After docking the da Vinci robot, the elevation of the skin flap is continued inferiorly to the level of the sternal notch and laterally to the lateral border of the sternocleidomastoid muscle. If we use the da Vinci robot, we can easily elevate the skin flap in the exact plane of the subplatysmal layer using a 3-dimensional magnified view and wristed robotic instruments. We do not use the external hanging suture to suspend the skin flap; usually it is not necessary. On creating a sufficient working space, a 1-cm incision is created in the right axillary fossa and a long robotic cannula is inserted, if indicated. A third

Figure 1: Oral incisions created during transoral robotic thyroidectomy. Two lateral incisions are created close to the oral commissure

robotic instrument, such as Cardinal forceps, is inserted through the right axillary port [Figure 4].

Robotic dissection for thyroid lobectomy

The midline fascia between the strap muscles is divided [Figure 5a] and the sternohyoid and sternothyroid muscles are dissected to expose the thyroid gland [Figure 5b]. The pyramidal lobe is dissected, and the isthmus is divided and dissected from the trachea for better mobilization of the thyroid gland [Figure 5c]. The superior pole of the thyroid gland is dissected from the larynx in the avascular space, and the superior thyroid vessels are cut individually close to the thyroid gland to preserve the EBSLN [Figure 5d]. The superior parathyroid gland is identified and carefully preserved with an intact blood supply [Figure 5e]. The thyroid gland is then retracted medially, and the middle thyroid vein is divided. Then, the RLN is identified and confirmed using an IONM stimulating probe [Figure 5f]. The perithyroidal soft tissue is dissected while tracing the RLN with great care to preserve it [Figure 5g]. The inferior parathyroid gland is also preserved. The Berry's ligament is dissected, and the thyroid lobectomy is completed [Figure 5h].

Removal of the surgical specimens and closure of the wound

The resected specimen is extracted using a plastic endobag through the central oral incision port or the axillary port [Figure 5i]. In the cases of total thyroidectomy, contralateral lobectomy is performed in a similar manner. The strap muscles are re-approximated using V-Lock sutures [Figure 5j]. The oral vestibular mucosal incisions are closed with resorbable sutures, and no drain is inserted.

COMPLICATIONS OF TRANSORAL THYROIDECTOMY

The surgical outcomes and safety of transoral robotic or endoscopic thyroidectomy are feasible and comparable to those of conventional thyroidectomy. However, the complication rates of transoral thyroidectomy might be potentially higher, especially during the learning curve and in the case of low-volume surgeons and low-volume centers. The incidence of common complications, including RLN palsy, hypoparathyroidism, hematoma, and seroma, has been reported as being similar to that of conventional thyroidectomy.[8-15] There are additional complications associated with the transoral approach including mental nerve injury, CO_2 embolism, surgical site infection, skin burns and trauma, tracheal injury, dimpling of the chin, and oral commissure tearing.[8-15,21,22,24,26-34]

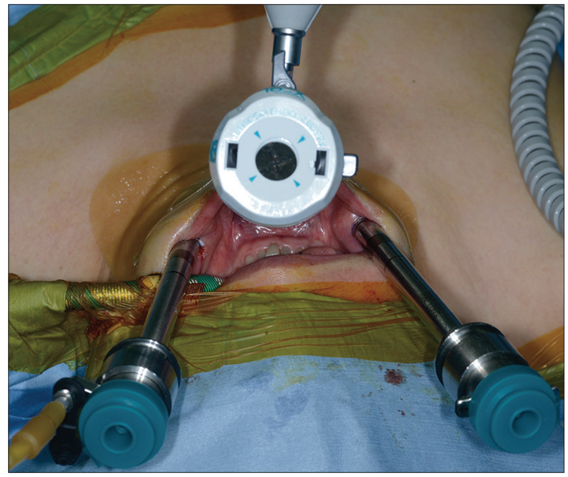

Figure 2: A 12-mm trocar is inserted for a 30° rigid endoscope, and two lateral 8-mm trocars are inserted for the robotic instruments

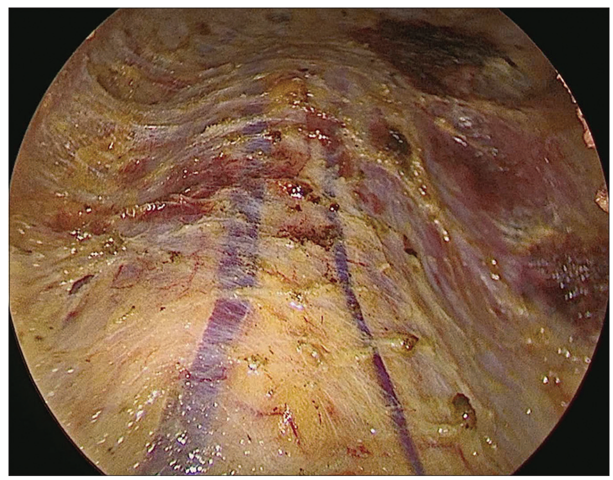

Figure 3: The skin flap is elevated under the endoscope in the plane of the subplatysmal layer

Figure 4: Docking of the da Vinci surgical robot. Three trocars for an endoscope and two robotic instruments are placed in the oral vestibule, and a fourth robotic trocar for a third robotic instrument is inserted through the right axillary incision

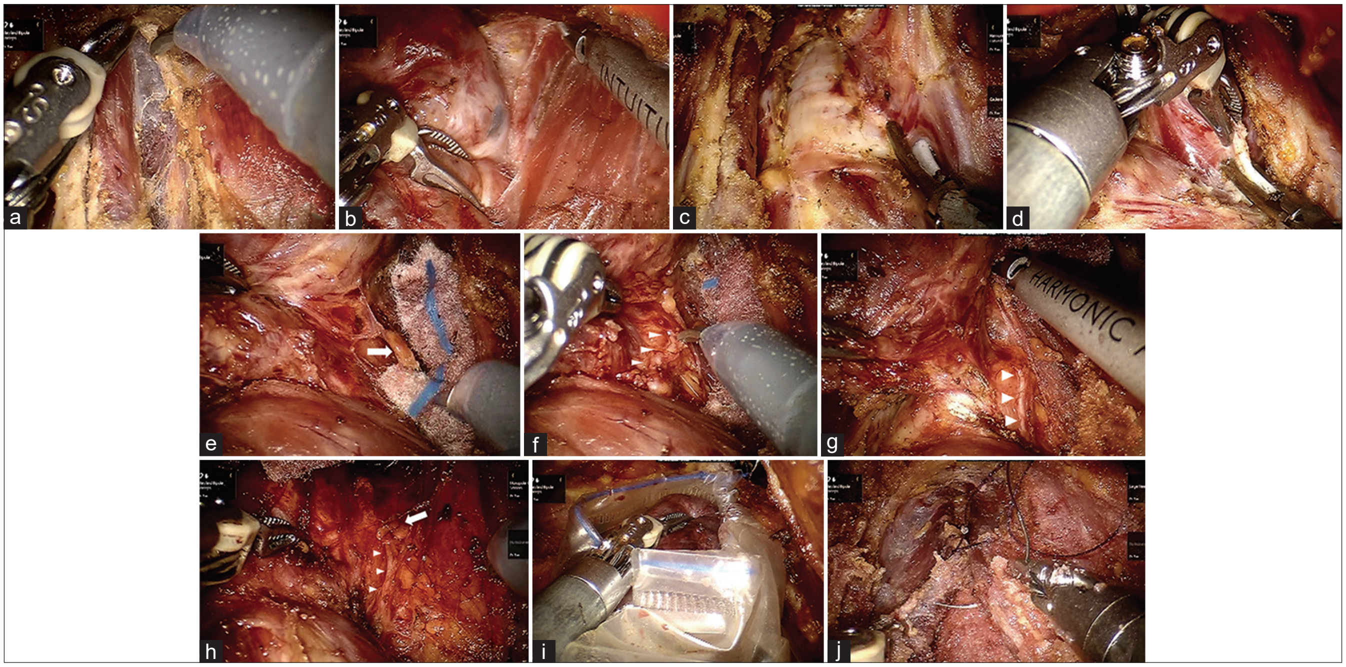

Figure 5: Procedures for transoral robotic thyroidectomy. (a) The fascia between the strap muscles is divided. (b) The sternohyoid and sternothyroid muscles are dissected to expose the thyroid lobe. (c) The isthmus is divided and dissected from the trachea for better mobilization of the thyroid gland. (d) The superior thyroid vessels are divided individually close to the thyroid gland. (e) The superior parathyroid gland is identified and preserved. (f) The recurrent laryngeal nerve is identified using an intraoperative nerve monitoring probe. (g) The perithyroidal soft tissue is dissected, while tracing the recurrent laryngeal nerve with great care to preserve it. (h) Surgical view after completion of thyroidectomy. The recurrent laryngeal nerve and superior parathyroid gland are well-preserved. (i) The resected specimen is extracted in an endobag through the axillary port. (j) The strap muscles are re-approximated using V-Lock sutures. Arrow heads: Recurrent laryngeal nerve; Arrows: Superior parathyroid gland

CO_2 embolism and subcutaneous emphysema

The CO_2 insufflation method can result in CO_2-related complications such as subcutaneous emphysema, hypercapnia, respiratory acidosis, cerebral edema, and CO_2 embolism.[4,36] CO_2 embolism, a serious intraoperative complication that could lead to cardiac arrest requiring resuscitation, can happen in transoral thyroidectomy although the incidence is low.[36] CO_2 embolism develops mainly due to tearing of the anterior jugular vein during skin flap elevation.[12,30,36] To prevent CO_2 embolism, it is crucial to perform blunt dissection with a dilator only in the submental area, in order to minimize the chance of tearing the anterior jugular vein.[12,30] In addition, it is important to identify the platysma muscle and elevate the skin flap precisely in the plane of the subplatysmal layer under the guidance of the endoscope. During skin flap elevation, an energy-based device is safer than a monopolar bovie because it divides and seals off the vessel rather than cutting it. Moreover, the CO_2 insufflation pressure should be set as low as possible, usually at 4–6 mmHg, and the CO_2 flow rate should be <8–10 L/min.[12]

Subcutaneous emphysema, presenting as crepitus in the neck and upper chest area, can develop after transoral thyroidectomy. However, in most cases, subcutaneous emphysema resolves spontaneously with conservative management. The possible causes of subcutaneous emphysema may include high CO_2 pressure and long operative time.[12] Therefore, surgery should be completed reasonably quickly to prevent the development of emphysema.

Mental nerve injury

A unique complication associated with the transoral approach is mental nerve injury. Mental nerve injury causes unilateral or bilateral numbness of the lower lip and chin, and the medial and lateral inferior labial branches of the mental nerve are vulnerable to surgical trauma.[37] The incidence of mental nerve injury varies greatly in previously published studies. Mental nerve injury is poorly defined, with some authors defining it as severe sensory loss in the chin, while others define it as any mild or moderate sensory disturbance and paresthesia.[37] Some studies published when the transoral thyroidectomy procedure was initially initiated demonstrate a high rate of mental nerve injury ranging from 75% to 100%.[21,24,28] This high rate of mental nerve injury may be related to the learning curve and technical complexity of the procedure. However, recent papers reported lower rates of mental nerve injury ranging from 0% to 2.5%.[8,9,12]

Tae *et al*. objectively evaluated the sensory changes in the chin and neck after transoral thyroidectomy using the Semmes-Weinstein monofilaments test.[37] They did not report mental nerve injury, and the pressure thresholds of the chin and lower lip innervated by the mental nerve were not different preoperatively and postoperatively. Only approximately 10% of the patients showed a transient mild sensory disturbance on the chin at 1 week postoperatively, and the baseline condition was restored at 1 month postoperatively.[37] These results provide evidence that mental nerve damage rarely occurs during transoral thyroidectomy, if the operation is performed through the oral vestibular incisions created at the appropriate sites with minimal soft tissue dissection in the chin area.[37] In addition to the main causes of mental nerve injury, such as inappropriate oral vestibular incisions and direct nerve damage, injury can also be caused by mechanical stretching and compression owing to a large sized trocar, trocar movement during the operation, and long operative times.[37-39] Therefore, to avoid mental nerve injury, the oral vestibular incisions should be created at the appropriate sites and soft-tissue dissection and damage of the chin and central oral vestibular area should be minimized.

Surgical site infection

One important and interesting complication in the transoral approach is surgical site infection. This could be due to the numerous bacteria in the oral cavity, even in the normal flora. Several studies have reported only a few cases of wound infections after transoral thyroidectomy.[8-11,22,26-28] The rates of surgical site infection in a few meta-analyses were also very low (0.1%–1%).[40-43] However, Tae *et al*. reported a high incidence (6%) of surgical site infection, including even mild swelling and skin redness, after transoral thyroidectomy, despite the 1- to 2-week routine use of antibiotics preoperatively and postoperatively.[12] There is no standard definition for surgical site infection. However, we should be aware of the possibility of surgical site infection after transoral thyroidectomy, and appropriate antibiotics should be administered preoperatively and postoperatively.

Skin perforation, burn, and trauma

Skin flap perforation in the anterior neck area, lower lip, and chin can occur in transoral thyroidectomy. Care should be taken not to perforate the skin when elevating the skin flap using a monopolar bovie or when inserting the lateral trocars, especially in those patients with a thin skin.

In addition, there were skin flap burns and injuries in transoral thyroidectomy due to mechanical trauma and heating from the endoscope tip.[12,30] Although most skin burns and traumas are mild, and resolve without any sequela, some severe burns and trauma can result in skin pigmentation, contracture, and dimpling. Therefore, we need to be careful to avoid burning and injuring the skin flap during the transoral procedure.

Conversion of the procedure

Sometimes, among the transoral robotic and endoscopic procedures, there are conversions to the conventional transcervical approach or other types of remote access thyroidectomies. The possible causes of conversion may include severe CO_2 embolism, uncontrollable intraoperative bleeding, and inability to remove the entire tumor.[12,30]

COMPARISON OF THE ENDOSCOPIC AND ROBOTIC PROCEDURES IN THE TRANSORAL APPROACH

In the transoral approach through the oral vestibule, despite the many advantages of the robotic procedure, the endoscopic procedure is commonly performed worldwide. This phenomenon might be related to the high cost of the robotic procedure and the robotic system, and the availability and need for training on the surgical robot.[6] In addition, the robotic procedure takes more time than the endoscopic procedure in transoral thyroidectomy.[29,30]

However, transoral robotic thyroidectomy using the da Vinci Si or Xi system has many advantages than the transoral endoscopic procedure.[6,12,30] The main advantages of the da Vinci surgical system are the three-dimensional magnified view and innovative instrumentation with extended freedom of motion. In addition, it provides the ability to use three robotic instruments simultaneously with the axillary port to obtain counter traction. Counter traction is crucial, as it facilitates dissection and improves surgical dexterity and ergonomics with the robotic procedure. In addition, it is very convenient when taking out the large surgical specimens through the axillary port.[6]

CONCLUSIONS

Transoral robotic thyroidectomy is feasible and safe for highly selected patients. However, some unusual complications, such as CO_2 embolism, mental nerve injury, surgical site infection, and skin burns and trauma, are noted. Appropriate patient selection and recognition of the possibility of unusual complications are important for patient safety and success of the surgery. An appropriate training program is also definitively required.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Disclosure

This material has never been published and is not currently under evaluation in any other peer reviewed publication.

Ethical approval

The permission was taken from Institutional Ethics Committee prior to starting the project. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

REFERENCES

1. Ji YB, Song CM, Bang HS, Lee SH, Park YS, Tae K. Long-term cosmetic outcomes after robotic/endoscopic thyroidectomy by a gasless unilateral axillo-breast or axillary approach. J Laparoendosc Adv Surg Tech A 2014;24:248-53.
2. Lee DW, Ko SH, Song CM, Ji YB, Kim JK, Tae K. Comparison of postoperative cosmesis in transaxillary, postauricular facelift and conventional transcervical thyroidectomy. Surg Endosc 2020;34:3388-3397. [doi: 10.1007/s00464-019-07113-1].
3. Juarez MC, Ishii L, Nellis JC, Bater K, Huynh PP, Fung N, *et al*. Objectively measuring social attention of thyroid neck scars and transoral surgery using eye tracking. Laryngoscope 2019;129:2789-94.
4. Tae K, Ji YB, Song CM, Ryu J. Robotic and Endoscopic Thyroid Surgery: Evolution and Advances. Clin Exp Otorhinolaryngol 2019;12:1-1.
5. Tae K. Transoral thyroidectomy: Is it a real game changer? Clin Exp Otorhinolaryngol 2020;13:93-4.
6. Tae K. Transoral robotic thyroidectomy using the da Vinci single-port surgical system. Gland Surg 2020;9:614-616. [doi: 10.21037/gs. 2020.03.37].
7. Song CM, Park JS, Park HJ, Tae K. Voice outcomes of transoral robotic thyroidectomy: Comparison with conventional trans-cervical thyroidectomy. Oral Oncol 2020;107:104748.
8. Anuwong A, Ketwong K, Jitpratoom P, Sasanakietkul T, Duh QY. Safety and outcomes of the transoral endoscopic thyroidectomy vestibular approach. JAMA Surg 2018;153:21-7.
9. Kim HK, Chai YJ, Dionigi G, Berber E, Tufano RP, Kim HY. Transoral robotic thyroidectomy for papillary thyroid carcinoma: Perioperative outcomes of 100 consecutive patients. World J Surg 2019;43:1038-46.
10. Russell JO, Razavi CR, Shaear M, Chen LW, Lee AH, Ranganath R, *et al*. Transoral vestibular thyroidectomy: Current state of affairs and considerations for the future. J Clin Endocrinol Metab 2019; 104:3779-84.
11. Dionigi G, Bacuzzi A, Lavazza M, Inversini D, Boni L, Rausei S, *et al*. Transoral endoscopic thyroidectomy: Preliminary experience in Italy. Updates Surg 2017;69:225-34.
12. Tae K, Ji YB, Song CM, Park JS, Park JH, Kim DS. Safety and efficacy of transoral robotic and endoscopic thyroidectomy: The first 100 cases. Head Neck 2020;42:321-9.
13. Fernandez-Ranvier G, Meknat A, Guevara D, Taye A, Suh H, Inabnet WB 3rd. Transoral endoscopic thyroidectomy vestibular approach: A single-institution experience of the first 50 cases. Surg Innov 2020. doi: 10.1177/1553350620927611.
14. Ahn JH, Yi JW. Transoral endoscopic thyroidectomy for thyroid carcinoma: Outcomes and surgical completeness in 150 single-surgeon cases. Surg Endosc 2020;34:861-7.
15. Kim WW, Park CS, Lee J, Jung JH, Park HY, Tufano RP. Real scarless transoral robotic thyroidectomy using three ports without axillary incision. J Laparoendosc Adv Surg Tech A 2020. Doi: 10.1089/lap.2020.0102.
16. Witzel K, von Rahden BH, Kaminski C, Stein HJ. Transoral access for endoscopic thyroid resection. Surg Endosc 2008;22:1871-5.
17. Karakas E, Steinfeldt T, Gockel A, Westermann R, Kiefer A, Bartsch DK. Transoral thyroid and parathyroid surgery. Surg Endosc 2010;24:1261-7.
18. Karakas E, Steinfeldt T, Gockel A, Schlosshauer T, Dietz C, Jäger J, *et al*. Transoral thyroid and parathyroid surgery–development of a new transoral technique. Surgery 2011;150:108-15.
19. Benhidjeb T, Wilhelm T, Harlaar J, Kleinrensink GJ, Schneider TA, Stark M. Natural orifice surgery on thyroid gland: Totally transoral video-assisted thyroidectomy (TOVAT): Report of first experimental results of a new surgical method. Surg Endosc 2009;23:1119-20.
20. Wilhelm T, Harlaar J, Kerver A, Kleinrensink GJ, Benhidjeb T. Transoral endoscopic thyroidectomy. Part 1: Rationale and anatomical studies. Chirurg 2010;81:50-5.
21. Wilhelm T, Metzig A. Endoscopic minimally invasive thyroidectomy (eMIT): A prospective proof-of-concept study in humans. World J Surg 2011;35:543-51.
22. Fu J, Luo Y, Chen Q, Lin F, Hong X, Kuang P, *et al*. Transoral endoscopic thyroidectomy: Review of 81 cases in a single institute. J Laparoendosc Adv Surg Tech A 2018;28:286-91.
23. Richmon JD, Holsinger FC, Kandil E, Moore MW, Garcia JA, Tufano RP. Transoral robotic-assisted thyroidectomy with central neck dissection: Preclinical cadaver feasibility study and proposed surgical technique. J Robot Surg 2011;5:279-82.
24. Nakajo A, Arima H, Hirata M, Mizoguchi T, Kijima Y, Mori S, *et al*. Trans-oral video-assisted neck surgery (TOVANS). A new transoral technique of endoscopic thyroidectomy with gasless premandible approach. Surg Endosc 2013;27:1105-10.
25. Woo SH. Endoscope-assisted transoral thyroidectomy using a frenotomy incision. J Laparoendosc Adv Surg Tech A 2014;24:345-9.
26. Wang C, Zhai H, Liu W, Li J, Yang J, Hu Y, *et al*. Thyroidectomy: A novel endoscopic oral vestibular approach. Surgery 2014;155:33-8.
27. Anuwong A. Transoral endoscopic thyroidectomy vestibular approach: A series of the first 60 human cases. World J Surg 2016;40:491-7.
28. Kim HY, Chai YJ, Dionigi G, Anuwong A, Richmon JD. Transoral robotic thyroidectomy: Lessons learned from an initial consecutive series of 24 patients. Surg Endosc 2018;32:688-94.
29. Razavi CR, Khadem MGA, Fondong A, Clark JH, Richmon JD, Tufano RP, *et al*. Early outcomes in transoral vestibular thyroidectomy: Robotic versus endoscopic techniques. Head Neck 2018;40:2246-53.
30. Tae K, Lee DW, Song CM, Ji YB, Park JH, Kim DS, *et al*. Early experience of transoral thyroidectomy: Comparison of robotic and endoscopic procedures. Head Neck 2019;41:730-8.
31. Park JO, Park YJ, Kim MR, Sun DI, Kim MS, Koh YW. Gasless transoral endoscopic thyroidectomy vestibular approach (gasless TOETVA). Surg Endosc 2019;33:3034-9.
32. Park D, Shaear M, Chen YH, Russell JO, Kim HY, Tufano RP.

Transoral robotic thyroidectomy on two human cadavers using the intuitive da vinci single-port robotic surgical system and CO2 insufflation: Preclinical feasibility study. Head Neck 2019;41:4229-33.
33. Chan JYK, Koh YW, Richmon J, Kim J, Holsinger FC, Orloff L, *et al*. Transoral thyroidectomy with a next generation flexible robotic system: A feasibility study in a cadaveric model. Gland Surg 2019;8:644-7.
34. Park YM, Kim DH, Moon YM, Lim JY, Choi EC, Kim SH, *et al*. Gasless transoral robotic thyroidectomy using the Da Vinci SP system: Feasibility, safety, and operative technique. Oral Oncol 2019;95:136-42.
35. Ji YB, Ko SH, Song CM, Sung ES, Lee BJ, Wu CW, *et al*. Feasibility and efficacy of intraoperative neural monitoring in remote access robotic and endoscopic thyroidectomy. Oral Oncol 2020;103:104617.
36. Kim KN, Lee DW, Kim JY, Han KH, Tae K. Carbon dioxide embolism during transoral robotic thyroidectomy: A case report. Head Neck 2018;40:E25-8.
37. Tae K, Lee DW, Bang HS, Ahn YH, Park JH, Kim DS. Sensory change in the chin and neck after transoral thyroidectomy: Prospective study of mental nerve injury. Head Neck 2020;42:3111-7.
38. Zhang D, Fu Y, Dionigi G, Pontin A, Caruso E, Antonella P, *et al*. Human cadaveric model for studying the preservation of mental nerve during transoral endoscopic thyroidectomy. Surg Radiol Anat 2020;42:55-62.
39. Yang HM, Shin KJ, Min J, Woo SH. Anatomical study of gasless transoral thyroidectomy and clinical application. Surg Endosc 2020;34:3414-23.
40. Shan L, Liu J. A systemic review of transoral thyroidectomy. Surg Laparosc Endosc Percutan Tech 2018;28:135-8.
41. Camenzuli C, Schembri Wismayer P, Calleja Agius J. Transoral endoscopic thyroidectomy: A systematic review of the practice so far. JSLS 2018;22:e2018.00026.
42. Tartaglia F, Maturo A, Di Matteo FM, De Anna L, Karpathiotakis M, Pelle F, *et al*. Transoral video assisted thyroidectomy: A systematic review. G Chir 2018;39:276-83.
43. Chen S, Zhao M, Qiu J. Transoral vestibule approach for thyroid disease: A systematic review. Eur Arch Otorhinolaryngol 2019;276:297-304.