Review Article

The evolution and clinical impact of single-port transaxillary robotic thyroidectomy: a comprehensive review

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Abstract: Single-port (SP) transaxillary robotic thyroidectomy represents a significant innovation in the field of endocrine surgery, offering a minimally invasive approach that combines oncological efficacy with enhanced cosmetic outcomes. The introduction of the SP robotic system has enabled surgeons to perform thyroidectomy and lateral neck dissection through a single axillary incision, resulting in a scarless neck and reduced postoperative morbidity. This review explores the current practices and surgical techniques associated with SP transaxillary robotic thyroidectomy, emphasizing the benefits of the SP robotic system over traditional multi-port and open approaches. The system's enhanced precision, due to its articulated instruments and high-definition three-dimensional visualization, allows for meticulous dissection, minimizing the risk of complications such as recurrent laryngeal nerve injury and hypocalcemia. The SP design simplifies the surgical process, reducing trauma to surrounding tissues and leading to faster recovery times and improved patient satisfaction. Clinical outcomes of the SP approach are promising, with studies indicating comparable oncological safety to conventional methods and superior cosmetic results. Patient satisfaction is notably high, particularly regarding the absence of visible neck scarring. However, the technique's adoption is limited by its steep learning curve and the high cost of the SP robotic system. This review also highlights the need for further long-term studies to fully assess the sustainability of the SP robotic system's benefits, especially in terms of oncological outcomes and cost-effectiveness. The potential of the SP transaxillary approach to become a standard option in thyroid surgery is discussed, alongside the importance of continued research and surgeon training to optimize its use. In conclusion, SP transaxillary robotic thyroidectomy offers a compelling alternative to traditional approaches, with the potential to significantly enhance patient outcomes and satisfaction in thyroid surgery.

Keywords: Robotic surgery; single-port robotic system (SP robotic system); trans-axillary; thyroidectomy

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Introduction

Thyroidectomy is a common procedure performed for a variety of benign and malignant thyroid diseases (1-3). Traditionally, thyroidectomy has been performed through a cervical incision, which, although effective, results in a visible scar on the anterior neck (4-6). The desire to improve cosmetic outcomes without compromising surgical effectiveness has led the development of minimally invasive techniques, including endoscopic and robotic-assisted thyroidectomy.

Robotic thyroidectomy, especially via the transaxillary approach, represents a significant advancement in minimally invasive surgery. The globally acknowledged robotic thyroidectomy using the gasless transaxillary approach has been first performed by Chung in South Korea (7). Introduced in the 2007, the transaxillary robotic thyroidectomy allows surgeons to access the thyroid gland through an incision made in the axilla, effectively avoiding any visible neck scars. This approach is favored by both surgeons and patients due to the robotic system's enhanced precision, three-dimensional (3D) visualization, and tremor-free movements, which collectively contribute to improved surgical outcomes and patient satisfaction (8-11).

Despite its advantages, the traditional multi-port robotic system used in transaxillary thyroidectomy presents certain challenges, including the complexity of the surgical setup and the need for relatively wide incisions, typically ranging from 5 to 7 cm, which can increase the risk of complications (8,12-14). A new platform of the fourth-generation da Vinci single-port (SP) robotic system (Intuitive Surgical, Sunnyvale, CA, USA) was initially designed, which might be more suitable for procedures with long and narrow working spaces. This system has a single arm that delivers three multi-jointed instruments and a fully wristed 3D high-definition (HD) camera for visibility and control in a narrow working space; its operation needs only 3 to 4 cm skin incisions. This innovation has the potential to enhance surgical outcomes and increase patient satisfaction by minimizing trauma and improving cosmetic results.

The SP robotic system has expanded the possibilities of robotic thyroidectomy, enabling surgeons to perform complex procedures such as total thyroidectomy and lateral neck dissection with greater ease and precision (15-18). The SP robotic system's unique design and advanced capabilities have positioned it as a game-changer in the field of endocrine surgery, offering a minimally invasive option that prioritizes both superior cosmetic and clinical outcomes for patients.

This review aims to provide a comprehensive overview of SP transaxillary robotic thyroidectomy, focusing on its evolution, surgical technique, clinical outcomes, and future directions. By analyzing the latest literature and clinical experiences, we seek to highlight the advantages of the SP robotic system and discuss its potential role in the ongoing advancement of thyroid surgery.

Overview of the da Vinci SP robotic system

The SP robotic system represents a significant technological advancement in the field of robotic surgery. Unlike the multi-port robotic systems previously used for robotic thyroidectomy, the SP robotic system utilizes a single port through which all instruments, including a fully wristed, flexible camera, are introduced. This SP approach reduces the need for multiple incisions, thereby minimizing surgical trauma and significantly enhancing cosmetic outcomes. The system is designed to provide enhanced dexterity and precision, particularly in confined anatomical spaces such as the neck.

The SP robotic system features a single 2.5 cm port that accommodates three multi-jointed instruments and a flexible camera. These instruments are articulated to mimic the natural movements of the surgeon's hands, providing a high degree of control and precision. The SP robotic system's camera offers 3D HD visualization, which is critical for accurately identifying and preserving delicate structures such as the recurrent laryngeal nerve (RLN) and parathyroid glands during thyroidectomy.

Patient selection criteria

Proper patient selection is paramount to the success of SP transaxillary robotic thyroidectomy. Ideal candidates for this procedure typically include those with benign thyroid nodules, differentiated thyroid cancer confined to the thyroid gland, or patients who prioritize cosmetic outcomes. Patients with larger thyroid nodules (>10 cm), extensive cervical lymphadenopathy, or significant comorbidities that complicate the transaxillary approach may not be suitable candidates for this technique. However, in the hands of an experienced surgeon, SP transaxillary robotic thyroidectomy can be successfully performed in a broader range of thyroid diseases, including more complex cases. The surgeon's expertise plays a crucial role in expanding the indication of the SP approach, ensuring safe and effective outcomes even in more challenging cases.

In the context of oncological surgery, careful preoperative assessment, including ultrasound and cross-sectional imaging, is essential to determine the extent of the disease and to plan the surgical approach. For patients requiring more extensive surgical intervention, such as lateral neck dissection, the SP robotic system's enhanced dexterity can facilitate a more comprehensive removal of lymph nodes while minimizing the risk to adjacent structures (19).

Surgical procedures of lobectomy

The detailed surgical procedures and techniques for all types of SP transaxillary robotic thyroidectomy, including lobectomy, total thyroidectomy, and lateral neck dissection, have been described in previous studies (15,16,18,19).

The patients were placed in the supine position on the operating table with a soft pillow below their shoulders to allow slight neck extension under general anesthesia. The lesion-side arm was raised and fixed to expose the axilla

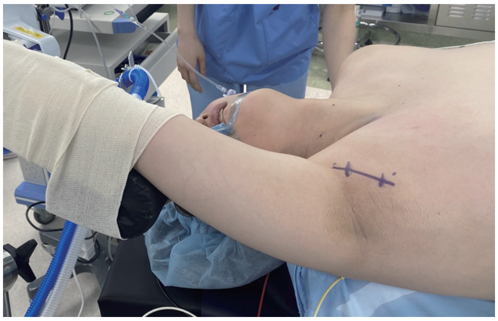

Figure 1 SP transaxillary robotic thyroidectomy position for lobectomy and total thyroidectomy with the arm on the lesion side raised. SP, single-port.

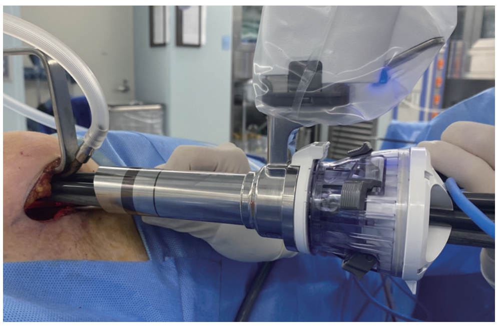

Figure 2 The robotic instruments inserted through the single cannula.

(*Figure 1*). A 3.5-cm incision is made in the axilla, following the natural axillary skin crease. Through this small initial incision, a subcutaneous skin flap is carefully created over the pectoralis major muscle and clavicle, extending toward the midline of the anterior neck under direct visualization until the sternocleidomastoid muscle (SCM) is identified. Dissection continues through the bifurcation of the SCM, which is carefully split into its sternal and clavicular heads. Upon identifying the strap muscles, further dissection is performed beneath them to expose the thyroid gland. The upper pole of the ipsilateral thyroid lobe and the anterior surface of the contralateral lobe are exposed, and the entire flap is elevated using an external retractor. The robotic arms are then introduced through a single cannula placed within the 3.5 cm skin incision. A camera is positioned at the bottom of the cannula to provide a comprehensive view of the surgical field. Two Maryland bipolar dissectors are mounted on the both lateral arms, allowing for precise dissection and hemostasis, while a Cadiere forcep is positioned on the superior arm for tissue manipulation (*Figure 2*).

The surgeon utilizes the Cadiere forcep to gently pull the thyroid in a caudal direction, while the Maryland forceps are employed to meticulously dissect the upper pole of the thyroid. During this stage, the superior thyroidal artery should be ligated close to the thyroid to minimize the risk of injuring the external branch of the superior laryngeal nerve. Once the parathyroid glands are identified, they are carefully preserved. The Cadiere forcep is then used to elevate the thyroid superiorly, providing a clear view of the RLN. To avoid RLN injury, the adjacent soft tissue surrounding the thyroid gland is meticulously excised. The thyroid is then dissected free from the trachea and extracted. The surgical specimen is removed through the skin incision by an assistant using endoscopic forceps. Throughout the procedure, intraoperative neuromonitoring is employed to ensure RLN preservation. Finally, a closed suction drain is inserted through the incision, and the wound is meticulously closed.

Surgical procedures of total thyroidectomy

The skin incision, measuring 3.5 cm, is identical to that used for lobectomy, with the choice of the incision side determined by the tumor's location and the patient's handedness. The method for creating the flap is the same as that for lobectomy; however, the flap is extended beyond the isthmus to ensure full exposure of the contralateral thyroid lobe.

Total thyroidectomy begins with the ipsilateral thyroid lobe, following the same technique used for lobectomy. After the ipsilateral thyroid specimen is removed, dissection proceeds from the isthmus to the contralateral upper pole. In the contralateral thyroidectomy, the upper pole is mobilized first, followed by the lower pole, with dissection carried out in a medial-to-lateral direction along the subcapsular plane. Completion thyroidectomy is then performed, ensuring careful identification and preservation of the RLN and parathyroid glands. Finally, a closed suction drain is inserted, and the wound is meticulously closed.

Surgical procedures of lateral neck dissection

While under general anesthesia, the patient is positioned supine with a cushion placed under the shoulders and the neck slightly extended. Unlike the positioning for lobectomy or total thyroidectomy, the arm on the side designated for lateral neck dissection is extended outward,

Figure 3 SP transaxillary robotic thyroidectomy position for lateral neck dissection with the arm on the lesion side extended outward. SP, single-port.

parallel to the operating bed, with the patient's head turned to the opposite side to maximize exposure of the axilla and lateral neck (*Figure 3*). A 6–7 cm incision is made along the anterior axillary fold. For patients requiring bilateral lateral neck dissection, access is gained from both axilla. The lateral neck dissection flap is carefully dissected medially to the anterior boundary of the SCM, inferiorly to the sternal notch, superiorly to the submandibular gland, and laterally to the anterior border of the trapezius muscle.

Following total thyroidectomy, lateral neck dissection is performed using the same technique as in conventional open surgery, but with robotic docking executed in two stages. Initially, lymph node dissection at levels III, IV, and V is carried out with the robot docked in the same position used for thyroidectomy. Dissection begins with levels III and IV, targeting the anterior and posterior aspects of the internal jugular vein (IJV) until the common carotid artery and Vagus nerve are exposed. After dissection is completed in each compartment, the lymph node specimens are extracted through the skin incision by an assistant using endoscopic forceps. The dissection continues inferiorly along the IJV to its junction with the subclavian vein, proceeding laterally along the subclavian vein, where care is taken to avoid injury to the transverse cervical artery and phrenic nerve. A level V dissection is then performed, extending to the anterior border of the trapezius muscle. To begin level II dissection, the external retractor is rotated toward the submandibular gland, and the robot is re-docked to ensure optimal visibility. Level II dissection proceeds along the anterior surface of the carotid artery and IJV, extending to the submandibular gland and the posterior belly of the digastric muscle. The procedure is finalized by inserting a drain and carefully closing the wound (20).

Clinical outcomes

Oncological safety

The oncological safety of robotic thyroidectomy, including the SP transaxillary approach, is a critical consideration, especially for patients with thyroid cancer. Several studies have demonstrated that the SP robotic system provides oncological outcomes comparable to those of conventional open and multi-port robotic thyroidectomy. The precision of the SP robotic system allows for meticulous dissection and complete resection of the thyroid gland, which is essential for minimizing the risk of residual disease and recurrence. In a study conducted by An *et al.*, the oncological outcomes of robotic thyroidectomy were evaluated in patients with thyroid cancer. This study demonstrated that SP transaxillary robotic thyroidectomy can be appropriately used for thyroid cancer surgery (18). These findings indicate that the SP robotic system can achieve oncological safety comparable to more invasive techniques, along with the superior cosmetic results. Moreover, the use of SP robotic systems in lateral neck dissection, as highlighted by Ho *et al.*, has demonstrated promising outcomes in terms of lymph node yield and the preservation of vital structures, such as the spinal accessory nerve (19). This is particularly important in advanced thyroid cancers requiring extensive dissection, where oncological efficacy must be carefully balanced with minimizing morbidity.

Complications

The complication profile of SP transaxillary robotic thyroidectomy plays a crucial role in determining its overall safety and feasibility. Common thyroid surgery complications, such as RLN injury, hypocalcemia, and hematoma, have been reported in various studies assessing robotic techniques (13,21-23). One of the notable advantages of the SP robotic system is its potential to reduce the incidence of RLN injury due to the enhanced visualization and precision of dissection (24). Permanent RLN injury was rare, further underscoring the safety of robotic approaches when performed by experienced surgeons. Hypocalcemia, often caused by accidental injury or devascularization of the parathyroid glands, remains a significant concern in total thyroidectomy (25-28). However, the incidence of permanent hypocalcemia is reported to be low with the SP approach (18). This can be attributed to the meticulous technique and superior visualization offered by the robotic system, which facilitates the precise identification and preservation of the parathyroid glands. The overall complication rate for SP transaxillary robotic thyroidectomy is comparable to, and in some cases lower than, that of conventional techniques. Kim *et al.* reported a very low complication rate, which is consistent with rates observed in open and multi-port robotic thyroidectomy (24). These findings further highlight the safety of the SP robotic system, especially when performed by experienced surgeons.

Cosmetic outcomes and patient satisfaction

Cosmetic outcomes are a major benefit of the SP transaxillary approach, especially for patients concerned about visible scar on the anterior neck. The SP robotic system enables the entire procedure to be performed through a small incision in the axilla, resulting in a scar that is well-hidden and less noticeable than the traditional neck incision. SP transaxillary robotic thyroidectomy will greatly benefit younger patients, as well as those with a history of keloid formation who desire a scarless procedure. The psychological impact of scar visibility is an important consideration, and the SP robotic system provides a significant benefit in this regard. Patients who undergo SP transaxillary thyroidectomy often report greater confidence and satisfaction with their postoperative appearance, which can have a positive effect on their overall quality of life. Studies on cosmetic outcomes and patient satisfaction are still lacking. Further research is needed.

Postoperative outcomes

Another advantage of the SP transaxillary thyroidectomy is the potential to reduce postoperative pain and accelerate recovery. The minimally invasive nature of the SP approach, combined with minimized trauma to the neck tissues, typically results in less postoperative discomfort and a faster return to normal activities. This reduction in pain was associated with shorter hospital stays and earlier return to daily activities, making the SP robotic system a more patient-friendly and efficient option.

Long-term follow-up data on SP transaxillary robotic thyroidectomy are still in the early stages, but early results are promising. Studies suggest that patients experience sustained benefits from the procedure, including low rates of complications, and persistent satisfaction with cosmetic outcomes. Additionally, the studies reported low rates of complications such as hypocalcemia and RLN injury, reinforcing the safety profile of the procedure (16,18,24).

As the SP robotic system is a relatively recent development, it may be premature to discuss long-term outcomes at this stage. More time is needed to fully evaluate the long-term safety and efficacy. Ongoing and future studies will be crucial in providing a clearer understanding of the SP transaxillary robotic thyroidectomy's long-term clinical benefits.

Discussion

This review has examined the current practices, surgical techniques, and clinical outcomes associated with SP transaxillary robotic thyroidectomy, focusing on its advantages, and outcomes. The SP robotic system represents a significant advancement in robotic thyroid surgery, offering enhanced precision and reduced invasiveness while maintaining oncological safety. Clinical outcomes, including complication rates and patient satisfaction, indicate that the SP approach is both safe and effective, with added benefits in cosmetic outcomes and postoperative recovery.

The introduction of the SP robotic system has overcome several limitations of multi-port robotic systems, such as the need for larger incisions and complex instrument manipulation (12,29,30). By integrating all surgical instruments into a single port, the SP robotic system simplifies the surgical approach and minimizes trauma to surrounding tissues. This has resulted in lower complication rates, particularly in terms of RLN injury and hypocalcemia, both of which are critical concerns in thyroid surgery.

One of the main strengths of the SP transaxillary approach is its ability to provide a scarless neck, which significantly enhances patient satisfaction, particularly among younger patients and those with a high concern for cosmetic outcomes. In addition, the SP robotic system helps reduce postoperative pain and accelerates recovery, both of which contribute to improved patient satisfaction. However, the SP robotic system is not without its limitations. While the SP design offers several advantages, it also introduces challenges, such as instrument crowding and restricted working space, which can complicate the procedure. Surgeons must undergo specialized training to adapt to the unique dynamics of the SP robotic system, and mastering this technique involves a steep learning curve. Furthermore, the high cost of the SP robotic system and its associated equipment may limit its widespread adoption, particularly in resource-limited settings. Another limitation is the current lack of long-term data on outcomes specific to the SP transaxillary robotic thyroidectomy. While early results are promising, particularly in terms of oncological safety and patient satisfaction, further studies with long-term follow-up are necessary to fully assess the efficacy and safety of this technique. The availability of such data will be crucial in establishing the SP robotic system as a standard approach in thyroid surgery.

The findings of this review are consistent with those reported in previous studies comparing robotic and conventional thyroidectomy techniques. Studies have consistently demonstrated that robotic thyroidectomy, including both multi-port and SP approaches, offers similar oncological outcomes to open surgery, with the added benefits of improved cosmetic results and reduced postoperative morbidity (31-33). In particular, the SP robotic system has shown comparable or superior outcomes relative to its multi-port robotic systems, especially in terms of reducing visible scarring and postoperative pain.

Compared to transoral and other robotic thyroidectomy techniques, the SP transaxillary approach offers a unique balance of minimal invasiveness and technical feasibility. While transoral robotic thyroidectomy may also provide a scarless neck, it is associated with higher risks of complications such as infection and mental nerve injury (34,35). In contrast, the SP transaxillary robotic thyroidectomy maintains the benefits of remote-access surgery while minimizing these risks, making it a preferable option for many patients.

The positive outcomes associated with the SP transaxillary robotic thyroidectomy can be attributed to several factors. First, the enhanced visualization and precision offered by the SP robotic system allow for meticulous dissection and preservation of critical structures, such as the RLN and parathyroid glands. This reduces the risk of complications that are commonly associated with thyroid surgery. Second, the minimally invasiveness nature of the SP approach contributes to lower postoperative pain and quicker recovery times. By minimizing trauma to the neck tissues and reducing the number of incisions, the SP robotic system decreases the overall surgical burden on the patient, promoting a more comfortable and expedited recovery. Finally, the high patient satisfaction with cosmetic outcomes can be explained by the hidden axillary incision, which avoids the visible scarring associated with conventional neck incisions. This feature is especially important for patients who prioritize aesthetics and is a major factor contributing to the growing popularity of the SP approach.

The findings of this review have several important implications for the future of thyroid surgery. The SP transaxillary robotic thyroidectomy offers a viable and attractive option for patients seeking a minimally invasive, scarless thyroidectomy. As more surgeons gain proficiency with the SP robotic system, its adoption is expected to increase, particularly in high-volume centers that prioritize patient satisfaction and cosmetic outcomes.

However, further research is necessary to address the current limitations of the SP robotic system. Specifically, studies with longer follow-up periods are required to evaluate the long-term oncological and functional outcomes in patients undergoing SP transaxillary robotic thyroidectomy. Additionally, efforts should be made to reduce the cost of the SP robotic system, improving its accessibility to a wider range of healthcare facilities.

In clinical practice, it is important for surgeons to carefully select patients who are appropriate candidates for the SP robotic system, considering factors such as tumor size, extent of disease, and patient preferences. Continuous education and training programs are also essential to ensure that surgeons can perform this complex procedure safely and effectively.

Looking ahead, the ongoing advancement of robotic technology offers tremendous potential for further improving outcomes in thyroid surgery. Innovations in instrumentation, imaging, and robotics may enable even less invasive approaches, with increased precision and reduced operative times. The incorporation of artificial intelligence and machine learning into robotic systems could further enhance intraoperative decision-making, ultimately leading to better patient outcomes. Additionally, as more data becomes available, it will be important to refine patient selection criteria and establish standardized protocols for SP transaxillary robotic thyroidectomy. This will help to ensure that patients receive the most appropriate and effective treatment based on their individual clinical profiles.

Conclusions

SP transaxillary robotic thyroidectomy represents a significant advancement in the field of endocrine surgery. While there are challenges associated with its adoption, the benefits in terms of patient outcomes and satisfaction are clear. With ongoing research and technological innovation, the SP robotic system is likely to play an increasingly important role in the management of thyroid diseases.

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Footnote

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References

1. Haugen BR, Alexander EK, Bible KC, et al. 2015 American Thyroid Association Management Guidelines for Adult Patients with Thyroid Nodules and Differentiated Thyroid Cancer: The American Thyroid Association Guidelines Task Force on Thyroid Nodules and Differentiated Thyroid Cancer. Thyroid 2016;26:1-133.
2. Cabanillas ME, McFadden DG, Durante C. Thyroid cancer. Lancet 2016;388:2783-95.
3. Dionigi G, Lavazza M, Wu CW, et al. Transoral thyroidectomy: why is it needed? Gland Surg 2017;6:272-6.
4. Chung YS, Choe JH, Kang KH, et al. Endoscopic thyroidectomy for thyroid malignancies: comparison with conventional open thyroidectomy. World J Surg 2007;31:2302-6; discussion 2307-8.
5. Kim W, Yu HW, Kim SJ, et al. The anterior neck scar outcomes of conventional thyroidectomy using a wound protector: a multicenter double-blinded randomized controlled trial. Int J Surg 2024;110:3425-32.
6. Anuwong A, Ketwong K, Jitpratoom P, et al. Safety and Outcomes of the Transoral Endoscopic Thyroidectomy Vestibular Approach. JAMA Surg 2018;153:21-7.
7. Kang SW, Jeong JJ, Yun JS, et al. Robot-assisted endoscopic surgery for thyroid cancer: experience with the first 100 patients. Surg Endosc 2009;23:2399-406.
8. Prete FP, Marzaioli R, Lattarulo S, et al. Transaxillary robotic-assisted thyroid surgery: technique and results of a preliminary experience on the Da Vinci Xi platform. BMC Surg 2019;18:19.
9. Abramovici L, Cartier C, Pierre G, et al. Robot-assisted transaxillary thyroidectomy: surgical technique. Eur Ann Otorhinolaryngol Head Neck Dis 2015;132:153-6.
10. Foley CS, Agcaoglu O, Siperstein AE, et al. Robotic transaxillary endocrine surgery: a comparison with conventional open technique. Surg Endosc 2012;26:2259-66.
11. Kandil E, Hammad AY, Walvekar RR, et al. Robotic Thyroidectomy Versus Nonrobotic Approaches: A Meta-Analysis Examining Surgical Outcomes. Surg Innov 2016;23:317-25.
12. Chang EHE, Kim HY, Koh YW, et al. Overview of robotic thyroidectomy. Gland Surg 2017;6:218-28.
13. Kim JK, Lee CR, Kang SW, et al. Expansion of thyroid surgical territory through 10,000 cases under the da Vinci robotic knife. Sci Rep 2024;14:7555.
14. Choo JM, You JY, Kim HY. Transoral Robotic Thyroidectomy: The Overview and Suggestions for Future Research in New Minimally Invasive Thyroid Surgery. J Minim Invasive Surg 2019;22:5-10.
15. Kim K, Kang SW, Kim JK, et al. Robotic Transaxillary Hemithyroidectomy Using the da Vinci SP Robotic System: Initial Experience With 10 Consecutive Cases.

Surg Innov 2020;27:256-64.
16. Kang IK, Park J, Bae JS, et al. Safety and Feasibility of Single-Port Trans-Axillary Robotic Thyroidectomy: Experience through Consecutive 100 Cases. Medicina (Kaunas) 2022;58:1486.
17. Park J, Kang LK, Kim K, et al. The learning curve for single-port transaxillary robotic thyroidectomy (SP-TART): experience through initial 50 cases of lobectomy. Updates Surg 2023;75:691-700.
18. An S, Park J, Kim K, et al. Safety and surgical outcomes of single-port trans-axillary robot-assisted thyroidectomy: Experience from a consecutive series of 300 patients. J Robot Surg 2024;18:13.
19. Ho J, Kim D, Lee JE, et al. Single-Port Transaxillary Robotic Modified Radical Neck Dissection (STAR-RND): Initial Experiences. Laryngoscope 2023;133:709-14.
20. Celotto F, Ramacciotti N, Mangano A, et al. Da Vinci single-port robotic system current application and future perspective in general surgery: A scoping review. Surg Endosc 2024;38:4814-30.
21. Rossi L, Buoni V, Fregoli L, et al. Postsurgical complications after robot-assisted transaxillary thyroidectomy: critical analysis of a large cohort of European patients. Updates Surg 2022;74:511-7.
22. Park J, Kim K. Current and Future of Robotic Surgery in Thyroid Cancer Treatment. Cancers (Basel) 2024;16:2470.
23. Aidan P, Arora A, Lorincz B, et al. Robotic Thyroid Surgery: Current Perspectives and Future Considerations. ORL J Otorhinolaryngol Relat Spec 2018;80:186-94.
24. Kim JK, Choi SH, Choi SM, et al. Single-port transaxillary robotic thyroidectomy (START): 200-cases with two-step retraction method. Surg Endosc 2022;36:2688-96.
25. Lorente-Poch L, Sancho JJ, Muñoz-Nova JL, et al. Defining the syndromes of parathyroid failure after total thyroidectomy. Gland Surg 2015;4:82-90.
26. Falch C, Hornig J, Senne M, et al. Factors predicting hypocalcemia after total thyroidectomy - A retrospective cohort analysis. Int J Surg 2018;55:46-50.
27. Lee JS, Lee JS, Yun HJ, et al. No Change in Complications Following Thyroidectomy Despite Increase in Thyroid Cancer Surgeries: A Meta-Regression Analysis. Yonsei Med J 2024;65:348-55.
28. Košec A, Gašić A, Hergešić F, et al. Assessing Symptomatic Hypocalcemia Risk After Total Thyroidectomy: A Prospective Study. Int Arch Otorhinolaryngol 2024;28:e12-21.
29. Biswas P, Sikander S, Kulkarni P. Recent advances in robot-assisted surgical systems. Biomedical Engineering Advances 2023:100109.
30. Ditonno F, Licari LC, Franco A, et al. Current Expectations and Opinions on Single-port Robotic Surgery: A Survey Among European Experts by the SPARC Collaborative Group. Eur Urol Open Sci 2024;60:54-7.
31. Pan JH, Zhou H, Zhao XX, et al. Robotic thyroidectomy versus conventional open thyroidectomy for thyroid cancer: a systematic review and meta-analysis. Surg Endosc 2017;31:3985-4001.
32. Zhang X, Yu J, Zhu J, et al. A meta-analysis of unilateral axillary approach for robotic surgery compared with open surgery for differentiated thyroid carcinoma. PLoS One 2024;19:e0298153.
33. Pavlidis ET, Psarras KK, Symeonidis NG, et al. Robot-Assisted Thyroidectomy Versus Open Thyroidectomy in the Treatment of Well Differentiated Thyroid Carcinoma. JSLS 2021;25:e2021.00032.
34. Kang YJ, Cho JH, Stybayeva G, et al. Safety and Efficacy of Transoral Robotic Thyroidectomy for Thyroid Tumor: A Systematic Review and Meta-Analysis. Cancers (Basel) 2022;14:4230.
35. Oh MY, Chai YJ, Yu HW, et al. Transoral endoscopic thyroidectomy vestibular approach vs. transoral robotic thyroidectomy: systematic review and meta-analysis. Updates Surg 2023;75:1773-81.

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