First Experience of Single-Port Robotic Areolar Approach Thyroidectomy (SPRA)

Running title: Single-port Robotic Thyroidectomy

Keywords: Thyroid, Robotic surgery, Minimally invasive surgery

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No potential conflicts of interest relevant to this article are reported.

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The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of Inha University Hospital.

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Disclosure

None declared

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Abstract

Objectives

Various minimally invasive thyroidectomy methods have been developed and actively used in several hospitals worldwide. Herein, we describe a newly developed minimally invasive thyroidectomy method that uses the da-Vinci SP and report the initial clinical results of single-port robotic areolar thyroidectomy (SPRA).

Methods

A 3 cm semi-circular incision on the right areola and an 8 mm small incision on the left areola were created. A subcutaneous skin flap was created from the areola to the thyroid cartilage using hydro-dissection and an advanced bipolar device. The da-Vinci SP was docked through the right areolar incision. Twenty-one SPRA surgeries were performed between December 2022 and March 2023. The patient’s medical records and surgery videos were reviewed.

Results

Lobectomy was performed in 17 patients, isthmectomy in 2 patients, and total thyroidectomy was performed in 2 patients. The mean flap time was 14.905 ± 4.206 min and the console time was 62.381 ± 17.119 min. The tumor size was 0.886 ± 0.649 cm and the number of retrieved lymph nodes was 3.765 ± 4.024 (range 0–12). No vocal cord palsy and hypoparathyroidism was observed.

Conclusions

We successfully started the novel SPRA for the first time in the world. Compared to other robotic surgery methods, SPRA is minimally invasive and does not leave scars. This method uses a high-end single-port robotic device. However, more cases should be analyzed and
comparative studies should be performed in the near future to evaluate the effectiveness of this technique.

**Keywords:** Thyroid, Robotic surgery, Minimally invasive surgery

**Highlight**

- We developed new minimally invasive thyroidectomy method using da-Vinci SP, first in worldwide.
- SPRA is minimally invasive and dose not leave neck and axillar scars.
- SPRA reduced flap area compare to BABA approach.
Introduction

Thyroidectomy is a common surgical procedure worldwide that is used for various indications, including thyroid cancer, suspicious thyroid nodules, hyperthyroidism, and goiter. Among various thyroid disorders, the incidence of thyroid cancers is increasing worldwide over the past few decades, particularly in developed countries (1, 2). Therefore, the incidence of thyroid surgery has also increased worldwide since the definite treatment of thyroid cancer is surgical resection of the thyroid gland and surrounding lymph nodes. According to the national statistics of South Korea, more than 30,000 thyroid surgeries have been performed each year, from 2018 to 2022 (3).

After introducing the modern thyroid surgery technique by Sir Theodor Billroth and Theodor Kocher, the anterior transcervical approach has been performed for more than 100 years and is still considered as the standard thyroid surgery procedure in these days (4). However, transcervical thyroid surgery inevitably leaves a long scar on the anterior side of the neck. Since thyroid cancer mainly affects young women who are socially active, surgical scars on the neck, which are easily visible, act as a cause of psychological atrophy and stress (5). During the past 20 years, there has been a shift towards minimally invasive techniques, including endoscopic and robotic-assisted approaches (6, 7). Among them, the bilateral axillary breast approach (BABA), transaxillary approach (TA), and transoral approach are most commonly performed worldwide, especially in robot-assisted surgeries (8).

The endoscopic BABA method was originally developed by the group of Professor YK Yoon in 2001, and the robotic BABA method was also introduced by the same group in 2008 (9, 10). The robotic BABA technique is associated with not only good cosmetic outcomes but also safe oncologic completeness and low complication rates (8, 11). However, robotic BABA surgery has structural disadvantages as it requires dissection of a wide subcutaneous
tissue region for flap creation, from the bilateral axilla and bilateral breast via the anterior chest up to the neck (12). This problem is due to the da-Vinci surgical robots (S, Si, and Xi) that provide robotic instruments through four separate robotic arms. In 2018, a new single-port based da-Vinci SP system was released, and we developed a new thyroid surgical method and termed it single-port robotic areolar thyroidectomy (SPRA). It evolved from the BABA method but does not require bilateral axillary access, thus minimizing flap dissection. This method is less invasive compared to the BABA. Herein, we present our early experience with SPRA and describe this novel surgical method in this paper.

**Material and Methods**

**Surgical procedure**

General anesthesia was administered using endotracheal intubation with NIM-3.0 neuromonitoring tube (Medtronic Xomed, Jacksonville, FL, USA) to all patients. The flap design for SPRA is shown in Figure 1-A. A 3 cm circumareolar incision on the right breast was made for da-Vinci SP docking. Another 8 mm incision was made for flap dissection and making a channel for suction irrigation. Epinephrine (1:200,000 in saline) was then injected under the subcutaneous layer (hydro-dissection) around the designed flap area, from the breast to the border of the thyroid cartilage. A right 3 cm and left 8 mm circumareolar incision were created and blunt dissection using a vascular tunneller was performed. Further flap dissection was performed using an advanced bipolar device, as previously reported (12). After flap elevation from the breast and neck, the da-Vinci SP trocar was placed through the right areolar incision, as shown in Figure 1-B. An 8 mm trocar was installed on the left side, which was used as a passage for air circulation and small instruments. The da-Vinci SP robot was docked with the
right 3 cm diameter trocar, as shown in Figure 1-C.

After the robot was docked, thyroidectomy proceeded in the order shown in Figure 2. The midline of the strap muscle and thyroid isthmus was divided (Figure 2-A). The thyroid gland was retracted to the opposite side and the area between the thyroid gland and strap muscle was dissected (Figure 2-B). The thyroid gland was then pulled up and the recurrent laryngeal nerve was identified (Figure 2-C). The inferior parathyroid gland was saved and the thyroid gland was detached from the trachea (Figure 2-D). The thyroid gland was mobilized to the superior pole and Berry’s ligament was dissected (Figure 2-E). The superior parathyroid gland was identified and saved, and thyroidectomy was performed after superior thyroid vessels were coagulated (Figure 2-F). Level 6 central lymph node dissection between the carotid artery and trachea was performed without affecting the recurrent laryngeal nerve (Figure 2-G). After thyroidectomy, the recurrent laryngeal nerve and the two parathyroid glands were well preserved (Figure 2-H). The excised thyroid and lymph node tissues were placed in a plastic bag and extracted through the right 3 cm trocar. The midline of the strap muscle was closed using a barbed suture (V-Loc, Medtronic, Sunnyvale, CA, USA). One Jackson-Pratt drain was placed under the flap through the left breast wound. The skin incision was closed using the Vicryl 4-0 knot-bearing suture.

Both right thyroidectomy and left thyroidectomy can be performed with the same right areolar docking of the da-Vinci SP. During the surgery, CO2 gas at 6–7 mmHg pressure and a flow rate of 10–15 L/min was used for inflation. The cable used for neuromonitoring was custom-made by the hospital's medical engineering department and was selectively connected to the bipolar robotic arm. All surgeries were performed by a single endocrine surgeon in our hospital with an experience in more than 900 robotic BABA thyroidectomy surgeries (13).

Patients
This study included 21 patients who underwent SPRA between December 2022 and March 2023 at our hospital. The surgery was performed by a single endocrine surgeon. Indications for SPRA were as follows: tumor size under 4 cm for benign or follicular neoplasms and under 2 cm for malignant tumors, no radiologic evidence of lateral neck node metastasis, tumor location was not too close to adjacent structures, such as the trachea, esophagus, carotid artery, or jugular veins, no history of surgery or radiation exposure to the neck and breasts, and no severe medical conditions or coagulation disorders. We reviewed the patient’s electronic medical records and surgery videos retrospectively.

Flap time was defined as the time required for flap creation before robot docking, console time was the time that the surgeon spent while sitting on the robotic console to operate the instrument, and total operation time was defined as the total time from the start of the first skin incision to final skin closure. Information on visual analog scales (0 to 10) was collected at 6:00 am were included in statistics for pain score analysis. Patients were discharged if the daily drainage volume was less than 50 cc. For postoperative outcomes, vocal cord function was checked by ENT specialist using laryngoscopy before and after surgery. Hypoparathyroidism was defined as serum parathyroid hormone (PTH) levels under 10 pg/mL after surgery. Due to the short follow-up period, we only evaluated transient period vocal cord palsy and hypoparathyroidism.

This study was approved by the Institutional Review Board of our hospital (IRB number: 2023-03-030). R programming language version 4.2.2 (R Foundation for Statistical Computing, Vienna, Austria) was used for descriptive statistics and for computing the mean and standard deviation.

Results
The clinical characteristics of the 21 patients who underwent SPRA thyroidectomy are shown in Table 1. The mean age of the patients was 41.267 ± 9.893 years (range 29–64) and all patients were women. The mean body mass index (BMI) was 23.722 ± 3.556 kg/m² (range 18.59–29.96). Fine needle aspiration cytology results showed malignancy in 6 patients, suspicious for malignancy in 10, follicular neoplasm in 4, and atypical of undetermined significance in 1 patient. In 14 patients, the main tumor was located on the right side while it was located on the left side in 3 patients. Furthermore, in two patients, the tumor was located in the isthmus and bilateral tumors were present in two patients.

Regarding surgical extent, isthmectomy was performed in 2 cases, lobectomy in 17, and total thyroidectomy. The mean flap time before the robot docking was 14.905 ± 4.206 min (range 6–29) and the console time was 62.381 ± 17.119 min (range 30–103). The total operation time was 121.667 ± 25.017 min (range 85–165). The estimated mean blood loss was 24.286 ± 27.308 mL (range 0–100). The postoperative hospital stay was 2.857 ± 0.573 days (range 2–4). The mean pain score after surgery was 2.810 ± 0.512 on postoperative day 1 and 2.381 ± 0.590 on postoperative day 2.

Table 2 shows the pathologic details and complications. Final pathologic diagnoses were papillary thyroid carcinoma (PTC) in 17 patients, noninvasive follicular thyroid neoplasm with papillary-like nuclear features (NIFTP) in 1, and benign nodules in 2 patients. The mean tumor size was 0.886 ± 0.649 cm (range 0.3–2.7). The number of retrieved central lymph nodes was 3.944 ± 3.977 (range 0–12). The number of metastatic lymph nodes was 0.833 ± 1.425 (range 0–5). The microscopic extrathyroidal extension was observed in six patients but no gross extrathyroidal extension was observed. All surgical margins were clear. Two patients showed lymphatic invasion and no patient had a microvascular invasion. \(BRAF^{V600E}\) mutation was observed in 17 patients.
There was no vocal cord palsy in all patients. Hypoparathyroidism was also not observed in two patients who underwent total thyroidectomy. In one patient, hemorrhage occurred in the robot-docked right breast area; however, it was resolved through hematoma evacuation. Cosmetic outcome on day 3 after SPRA was excellent, as shown in Figure 3.

Discussion

With the development of novel ultrasound imaging and diagnosis techniques since the 2000s, the incidence of thyroid cancer has rapidly increased worldwide (1, 2, 14). Since thyroid cancer occurs in the younger age group, the demand for scarless surgery has increased (15, 16). Various remote-access thyroid surgery methods have been developed in recent years (7). Recently, da-Vinci robot-assisted thyroid surgery has become increasingly popular as an alternative to conventional endoscopic/laparoscopic thyroid surgery. The advantages of da-Vinci robot-assisted surgery include easy control of the surgical instruments since the robot can transmit the movement of a surgeon’s hand to the surgical instrument. Furthermore, the technique provides a wide range of motions by endo-wrist function and a higher resolution with full 3-D vision using two-eye cameras similar to human eyes (8).

There are several representative approaches to robot-assisted thyroid surgery, including the TA, BABA, retroauricular, and trans-oral approaches (6-8). Transaxillary robotic thyroidectomy was introduced by the group led by Professor WY Chung in 2009, who reported the accumulated 5000 TA cases in 2018 (17, 18). TA robotic surgery provides good exposure of the thyroid gland from the lateral side and easy access to the lateral neck node area along the jugular vein and carotid artery chain. However, performing the contralateral thyroid gland surgery is difficult and requires proper training for making the appropriate access before the
robot docking, from the axilla incision through the sternocleidomastoid muscle and exposure of the thyroid gland. The retroauricular robotic approach was developed by Terris et al. (19). It uses a postauricular hairline incision that is familiar to head & neck surgeons. Compared to the TA and BABA methods, it requires a shorter distance from the incision site to the thyroid gland. However, narrow working space and difficulty to access the opposite site of the thyroid gland are disadvantages. Transoral robotic approaches are the most recently developed method that uses oral vestibular access (20). This method requires the shortest distance from the incision site to the thyroid gland and no skin incision. Moreover, it provides easy access to bilateral thyroid glands and bilateral level 6 neck nodes using the top-down view. However, the technique requires a lot of cumulative experience compared to other methods.

BABA robotic thyroidectomy was started in 2008 at Seoul National University Hospital and more than 5,000 surgeries have been performed till 2023 (10, 11, 21, 22). This method provides a similar operative view of bilateral thyroid lobes as in conventional transcervical thyroidectomy and surgeons can perform the same operative procedures. With the proper learning, surgeons can perform almost all kinds of thyroid surgeries using the BABA robotic method, including those for large tumors, Graves’ disease, and modified radical neck dissection (23-25). However, BABA thyroid surgery requires a vast area for subcutaneous flap dissection and skin incisions in the axilla and breasts for the docking of four robotic arms. Therefore, this requirement of a wide flap has led some surgeons to consider that the BABA method is not minimally invasive but maximally invasive (7, 8, 26). To overcome this limitation, Kim et al. reported their experience with the “Reduced BABA” method that only uses the bilateral axilla and right breast port (27). However, this method was only used to perform isthmectomy, not thyroid lobectomy or total thyroidectomy.

A previous study reviewed the BABA thyroid surgeries performed since late 2018 and
reported the experience with 500 robotic BABA thyroid surgeries (13, 28). In December 2022, our hospital installed a state-of-the-art da-Vinci SP robotic system. The SPRA method is the evolved BABA method and is minimally invasive that uses the da-Vinci SP. Since the SPRA method requires smaller flap dissection from the right breast to the neck, it eliminates the dissection requirement of both axillar areas, thus reducing the flap area by more than 50% as shown in Figure 1-A. After the da-Vinci SP is docked, the thyroidectomy procedure can be performed in the same way as the conventional BABA method (Figure 2). In the BABA method, camera port usually set up through the right breast port. Vision from right breast port camera is familiar to surgeons who have been performed BABA surgery previously. That’s the reason why we started SPRA using right breast access. However, SPRA can be modified to the left breast access according to the patients’ status such as previous history of right breast surgery or left-handed surgeon who accustomed to the robotic arm handling by left hand preferences.

SPRA thyroid surgery is advantageous since thyroidectomy can be performed in the same way as open surgery through the same field of view. In addition, it is possible to operate on both the right and the left thyroid glands in the same field of view without changing the position of the robotic surgical instrument. The time required for flap creation before robot docking is approximately 15 min, which is about two times shorter than the flap time of the BABA surgery method (30–40 min) (12, 13). Furthermore, the length of hospital stay after SPRA surgery is reportedly shorter than that following BABA surgery (2.857 ± 0.573 in SPRA vs. 3.48 ± 0.97 days in BABA) (13). This is because the flap area is smaller for SPRA compared to BABA. Therefore, the SPRA method is advantageous over the existing BABA surgery as it significantly reduces the flap area and is minimally invasive robotic thyroid surgery. Currently, our indication of SPRA was narrow, less than 4cm in large tumors because it is just the start period. Surgical indication of SPRA will be expanded according to we accumulate the surgical
experiences. For the large tumor, specimen extraction may be also safely achieved through the right breast port, because 3cm diameter of da-Vinci SP trocar site gives about $7.07 \text{ cm}^2 (\pi r^2)$ of circular area and subcutaneous breast tissue is redundant.

Our study has several limitations. Since this study is the first reporting SPRA thyroid surgery, the number of cases was small and the information on long-term follow-up was lacking. Furthermore, we have not performed a comparative analysis with other surgical methods, such as conventional open surgery or BABA. However, as SPRA cases accumulate, we will be able to report the clinical results of a large number of patients with long-term follow-up and perform a comparative study with SPRA and other types of surgical methods in the future. In addition, although total thyroidectomy and central lymph node dissection are possible using this method, lateral cervical lymph node dissection has not been attempted yet. Similarly, SPRA has not yet been performed in male patients. These technical limitations will be addressed once surgeons gain more SPRA experience in the future. Lastly, the surgeon who initiated SPRA at our institution was an experienced surgeon with more than 900 BABA surgeries, thus initial results can be obtained without problems.

Conclusion

We firstly developed new minimal invasive thyroid surgery method named SPRA. This method only requires da-Vinci SP docking through the 3cm right breast access along the natural border between skin and areolar. It eliminated subcutaneous flap dissection from the bilateral axillary area which need in BABA method. According to our initial results, patients showed good outcomes without significant complications. More accumulated cases will be required to make a comparative analysis between SPRA and other robot thyroid surgery approaches.
**Tables and Figure legends**

Figure 1. Flap making for SPRA and da-Vinci SP docking. (A) Flap making for SPRA. (B) Port insertion status for SPRA. (C) Da-Vinci SP docking status for SPRA.

Figure 2. SPRA operation procedure. (A) The midline of the strap muscle and thyroid isthmus was divided. (B) The thyroid gland was retracted to the opposite side and the region between the thyroid gland and strap muscle was dissected. (C) The thyroid gland was then pulled up and the recurrent laryngeal nerve was identified. (D) The inferior parathyroid gland was saved and the thyroid gland was detached from the trachea. (E) The thyroid gland was mobilized to the superior pole and Berry’s ligament was dissected. (F) The superior parathyroid gland was identified and saved, and thyroidectomy was performed after superior thyroid vessels were coagulated. (G) Level 6 central lymph node dissection between the carotid artery and trachea was performed without affecting the recurrent laryngeal nerve. (H) The recurrent laryngeal nerve and the two parathyroid glands were well preserved.

Figure 3. Post-operative wound after SPRA.

Table 1. Clinical characteristics of patients.
Table 2. Pathologic findings and postoperative outcomes

**Conflict of Interest**

No potential conflicts of interest relevant to this article are reported.

**Institutional Review Board Statement**

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of [Institution].

(IRB number: [Number]).
Acknowledgments

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Disclosure

None declared

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Funding acquisition: Jin Wook Yi
Investigation: Yun Suk Choi, Jin Wook Yi
Methodology: Jin Wook Yi
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References

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Table 1. Clinical characteristics of patients.

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<td>Postoperative day 2</td>
<td>2.381 ± 0.590 (1–3)</td>
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*BMI: Body mass index, kg/m²

†VAS: Visual Analogue Scale
Table 2. Pathologic findings and postoperative outcomes

<table>
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*NIFTP*: noninvasive follicular thyroid neoplasm with papillary-like nuclear features

†PTC: Papillary Thyroid Cancer