The intuitive da Vinci single port surgical system and feasibility of transoral thyroidectomy vestibular approach

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Abstract: Remote-access thyroid surgery is increasingly implemented to reduce the morbidity of an anterior cervical incision resulting from traditional thyroid surgery. While most remote-access approaches leave a cutaneous scar, the recent development of the transoral vestibular approach (TOVA) enables the achievement of a truly scarless surgery, as all incisions are made in the oral vestibule. Unfortunately, the adoption of the robotic system in transoral thyroid surgery has been limited by the need for an additional axillary incision, prohibitive cost, and steep learning curve of robotic surgery. The Intuitive da Vinci single port (SP) robotic surgical system (Intuitive Surgical, Inc., Sunnyvale, CA, USA), introduced in 2018, may enable transoral robotic thyroid surgery without an axillary port. Additionally, the new SP system is equipped with two "joggle joints" in the robotic arms and endoscope, allowing for additional flexibility in a narrow workspace. Compared to previous generations, the SP robot offers a greater range of motion and more precise surgical control, a derivative of fully articulating instruments on a similar console like the Xi system. This review provides an overview of literature on the application of the intuitive da Vinci SP robotic surgical system via the TOVA in thyroid surgery.

Keywords: Transoral endoscopic thyroidectomy vestibular approach (TOETVA); TransOral robotic thyroid surgery; TORT; scarless thyroid surgery; single port robot (SP robot)

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Introduction

The transcervical approach is the gold standard technique for accessing the central neck in thyroid and parathyroid surgery; however, an anterior neck scar is inevitable (1). The presence of a central neck scar has been demonstrated to negatively impact patient quality of life (QOL) irrespective of scar severity (2-5).

Accordingly, remote-access approaches to the thyroid emerged to address the morbidity of the cervical incision. These approaches employ traditional endoscopic instruments as well as robotic surgical systems with documented efficacy and feasibility (6-9). Many of these approaches utilize dissection planes unfamiliar to traditional thyroid surgeons and are associated with increased costs, longer operative times, increased postoperative pain, technique-specific injuries, and a steep learning curve (10). Notably, these approaches are only able to displace the location of the cutaneous scar from the anterior neck to a less cosmetically conspicuous site. As a result, these techniques were slow

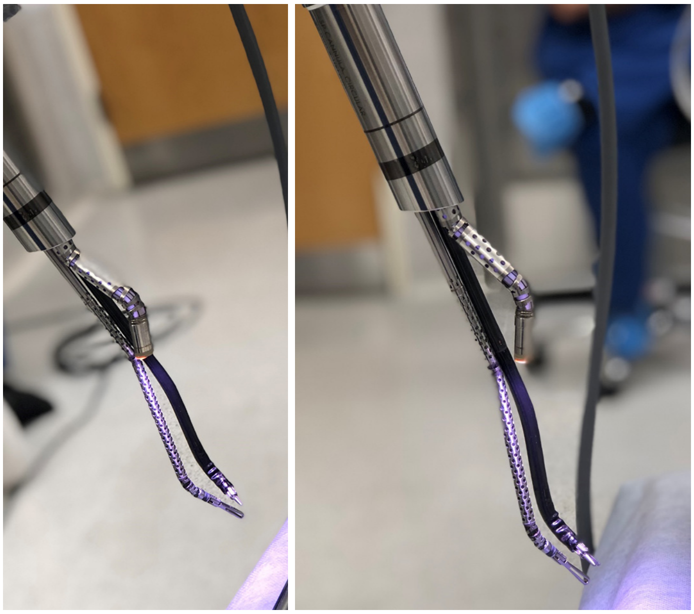

Figure 1 Flexible 3DHD camera and 2 EndoWrist instruments with additional two joints.

to be adopted, especially in the West. In 2007, the New European Surgical Academy (NESA) proposed Transoral Thyroid Surgery as part of their natural orifice surgery project, which demonstrated that the central neck could be successfully accessed using a sublingual incision, sparking the development of novel thyroidectomy approaches (11-16). Subsequently, Wilhelm *et al.* performed a prospective proof-of-concept study on endoscopic minimally invasive thyroidectomy via the sublingual approach; this approach was ultimately abandoned due to associated serious complications such as severe tissue damage and increased conversion rate (17). In 2011, Richmon *et al.* described a tri-vestibular approach using a submental and subplatysmal approach (18,19). Later in 2015, Lee *et al.* published the first transoral robotic thyroidectomy series in four patients (20,21). Following this, Anuwong *et al.* published in 2016 the first case series of patients who underwent transoral endoscopic thyroidectomy vestibular approach (TOETVA) with excellent outcomes (22). The success of TOETVA has prompted many institutions around the world to adopt transoral vestibular approach (TOVA) using endoscopic or robotic surgical systems (8,23-31).

Robotic surgical systems offer theoretical advantages over endoscopic surgery, including 3D magnified visualization of the surgical field and increased dexterity with enhanced range of motion within the confined working space. In spite of this, endoscopic techniques have been more widely adapted than robotic surgical systems due to the high cost of operation, extensive learning curve, and technical limitations of robotic systems (32-34). For instance, a fourth accessory axillary incision is required when performing thyroidectomy with the da Vinci Si and Xi surgical systems (Intuitive, Inc., Sunnyvale, CA, USA) for counter-traction and drain insertion (35-37). Moreover, with the previous generation of the da Vinci robotic surgical system (Si and Xi), instrument movement is particularly unwieldly during dissection of the superior pole of the thyroid gland. As a result, an assistant familiar with the robotic system must be at the field to address arm collisions and camera positioning. In contrast, the new da Vinci single port (SP) robotic system has the capability of inserting 3 multi-jointed instruments in addition to a fully wristed 3DHD camera for high-definition visualization of the detailed anatomy of the surgical field through a 2.5 cm incision (*Figure 1*) (38). Therefore, the da Vinci SP system's improved design may offer advantages in thyroid and parathyroid surgery. In this review article, we have provided a summary of existing literature on the SP system and its feasibility in the TOVA.

SP and transoral thyroid surgery vestibular approach in the literature

In 2018, the FDA approved the use of the da Vinci SP surgical system for SP urological procedures in adults. The

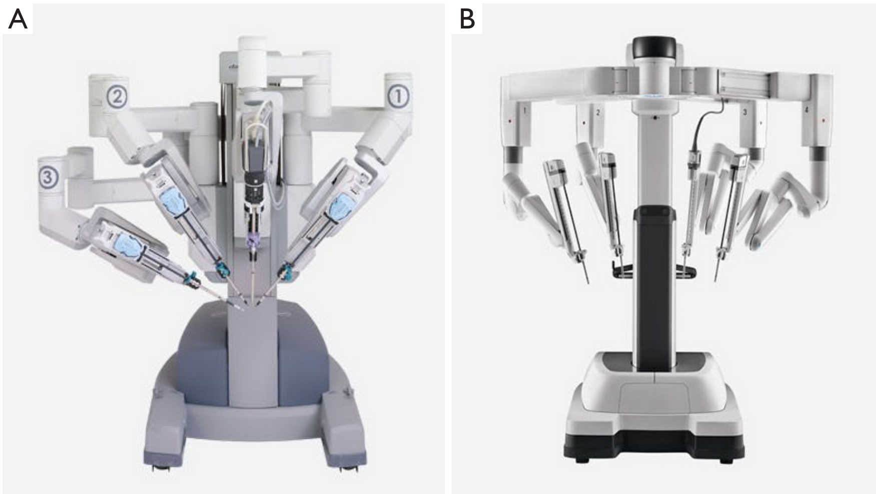

Figure 2 da Vinci Si (A) and Xi (B) (Courtesy of Intutive website).

following year, the FDA cleared the SP robot for radical tonsillectomy and tongue base resection. They stated, "The intuitive Surgical Endoscopic Instrument Control System (da Vinci SP Surgical System, Model SP1098) is intended to assist in the accurate control of Intuitive Surgical EndoWrist® SP Instruments during urologic surgical procedures that are appropriate for a SP approach and transoral otolaryngology surgical procedures in the oropharynx restricted to benign tumors and malignant tumors classified as T1 and T2…" (39). Because of limited FDA-approved indications for urological and oropharyngeal procedures, there is a paucity of original research on usage of the SP robot in endocrine procedures. Nonetheless, only three studies have explored the use of SP robot in performing the transoral thyroid surgery. Two studies were done on cadavers and the other is a 10-patient case-series. One of the studies done on cadavers is from our team and it demonstrates the preclinical feasibility study of SP surgical system in transoral thyroid surgery (40,41). The other preclinical study was conducted by Chan *et al.* and seeks to evaluate the next generation robotic system in transoral thyroidectomy (41). In addition, Park *et al.* published a case-series of 10 patients in South Korea who successfully underwent robotic transoral thyroid surgery using the da Vinci SP robotic surgical system (42).

Robotic surgical systems used in transoral thyroid surgery

The da Vinci Si and Xi systems have previously been employed in the transoral thyroidectomy vestibular approach (*Figure 2*) (35). The da Vinci Xi was the latest generation utilized for transoral thyroid surgery, and consequently most reported cases employed the Xi system, which often requires an additional axillary incision. Unlike Si and Xi, The SP robotic system is a SP system containing a 25 mm cannula that allows for the passage of a full-wristed endoscopic 3DHD camera along with three multi-jointed EndoWrist® SP instruments, significantly increasing the viability of robotic surgery without the need for an axillary port. The EndoWrist® SP instruments have two additional degrees of freedom compared to previous generations, facilitating enhanced external and internal ranges of motion. This allows for more precise surgical control in narrow spaces. The location and axis of the camera in the SP system offers 360 degrees of rotation and can be adjusted through the surgeon console, obviating the necessity of a bedside assistant. Additionally, the endoscope of the SP is covered by an insulator, minimizing the risk of thermal damage to surrounding tissues.

The da Vinci SP surgical system is made of three main components, similar to previous generations: the patient cart, the vision cart, and the surgeon console (*Figure 3*). Whereas the Xi system continues to utilize the 4-arm design, the SP is designed with only one arm with up to three flexible instruments that can emerge from this single arm (43).

Operative technique and the differences between SP and previous generations

In the preclinical study conducted by our group, we created

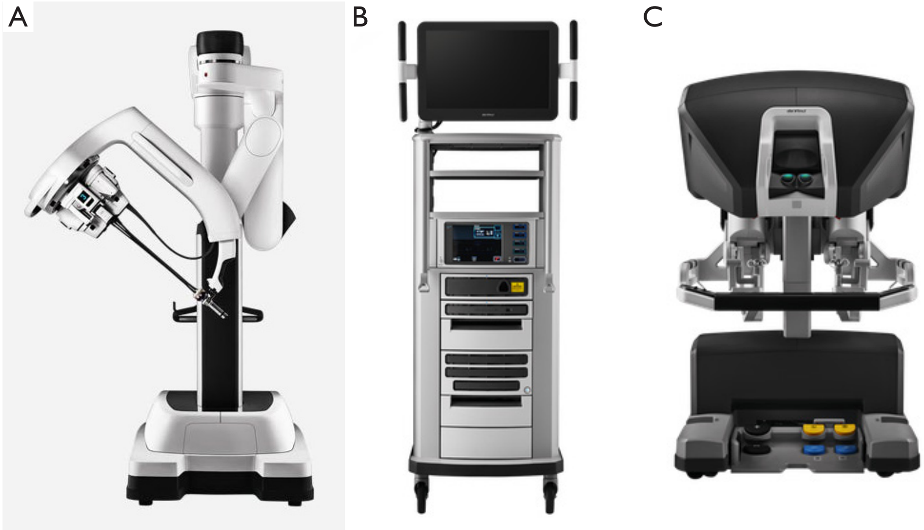

Figure 3 da Vinci SP surgical system (Courtesy of Intuitive website). (A) The patient cart; (B) the vision cart; (C) the surgeon console.

the submental and subplatysmal space using laparoscopic instruments prior to docking the SP robot (patient cart), and CO2 gas insufflation was used to maintain the working space (33). In Chan *et al.*, subplatysmal planes in the initial dissection were raised utilizing endoscopic guidance as in TOETVA. Then, a monopolar cautery and Kelly clamp forceps were employed to develop a plane over the periosteum of the mentum (41). Similar to Chen *et al.*, the clinical study by Park *et al.* utilized monopolar cautery to create the working space with the midline incision measuring 25 mm prior to docking the robot (37).

In Park *et al.*, following creation of the subplatysmal flap, a self-retaining retractor system was used instead of CO2 gas insufflation to maintain the working space. The patient cart containing the SP robot was docked perpendicular to the head of the surgical bed and the cannula was fixed 10 cm away from the midline incision. In both preclinical studies, CO2 gas insufflation was used to maintain the working space, similar to traditional TOVA. In our study, this was achieved by employing an Alexis (Applied Medical, Rancho Santa Margarita, CA, USA) wound retractor (XXS size) through the midline incision. The lower part of the Alexis was secured under the inferior edge of the mandible to prevent its slippage. Subsequently, we created a sealed tunnel between the working space and the SP cannula (located 6 cm from the inferior angle of the mandible) by tightly wrapping a Penrose drain around the upper end of the Alexis to prevent CO2 leakage and loss of the working space (*Figure 4*). A 30° endoscope was inserted through the upper slot while a ProGrasp Forceps, Maryland dissector and a monopolar curved scissors were inserted through the left, right and lower slots respectively in our study. On the other hand, in the study by Chan *et al.*, two 5 mm cuts medial to the canines were made vertically to allow the placement of two trocars where a Maryland dissector and a hook cautery were used to create the working space deep to the platysma. The 5 mm port incisions were then closed to limit the gas leakage and an extra small wound protector (Applied Medical, Rancho Santa Margarita, CA, USA) was placed through the vestibular incision. In addition to the camera, three other instruments were used: the Maryland bipolar, fenestrated bipolar graspers, and monopolar scissors (41). Park *et al.* utilized only 2 incision ports (left side for Maryland forceps and the right for scissors) in addition to the camera. The transoral thyroidectomy is carried out in a similar fashion as endoscopic technique as described the literature as follows: (I) dissection of median raphe; (II) separation of strap muscles; (III) dividing the isthmus; (IV) upper pole dissection and ligation of the superior pedicle; (V) cephalocaudal dissection of the RLN; (VI) separation of the thyroid lobe off the trachea. Although the Harmonic (Harmonic Ace^{+}, Ethicon Endo-Surgery, Cincinnati, OH, USA) is not currently included within EndoWrist SP instruments, our group successfully tried the endoscopic Harmonic HDI1000 through the lateral incision in addition to the three EndoWrist SP instruments to divide the median raphe, divide the isthmus and other steps where an energy device is typically used

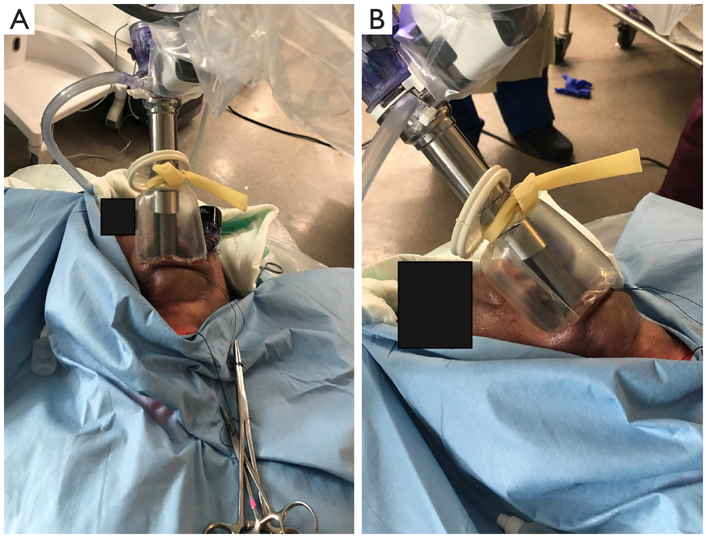

Figure 4 Sealed tunnel between the working space and the SP cannula. SP, single port.

Table 1 Comparison between all three techniques

Procedural steps	Preclinical study (1): Park *et al.*	Preclinical study (2): Chan *et al.*	Case-series: Park *et al.*
Creation of the working space	Laparoscopic as TOETVA	Endoscopic guidance as in TOETVA	Using monopolar cautery
Maintenance of the working space	CO2 gas insufflation secured by a tunnel made using Alexis wound retractor and Penrose drain	CO2 gas insufflation and maintained at a pressure of 6 mmHg	Self-retaining retractor instead of CO2 gas insufflation
Docking of the SP robot	6 cm from the lower angle of mandible	13 cm from the vestibular incision	10 cm from the midline incision
Surgical technique	Harmonic ultrasonic shears were experimented via the lateral incisions to aid in dissection, cutting and sealing	A fenestrated bipolar was used to grasp the thyroid gland while Maryland bipolars and monopolar scissors were used to mobilize each hemi lobe of the thyroid	Only 2 robotic arms were utilized instead of 3, lateral vestibular incisions were utilized to insert suction device and Maryland forceps

SP, single port; TOETVA, transoral endoscopic thyroidectomy vestibular approach.

when performing TOETVA. Chan *et al.* described the use of a suction catheter through one of the ports if smoke occurs during the surgery. In addition to two EndoWrist instruments, Park YM *et al.* utilized a suction device and Maryland forceps inserted into the lateral incision through an endoscopic trocar that was controlled by the bedside assistant. *Table 1* shows the differences between all three techniques.

Advantages and limitations of SP in transoral thyroid surgery

The advantages and limitations of SP robot in transoral thyroid surgery are summarized in *Tables 2,3* respectively.

Outcomes and perioperative complications

In the series by Park *et al.*, all cases were completed successfully using the SP robot with a mean operative time of 177 min after SP robot docking, which required a mean of 47 minutes. No postoperative RLN injury or hypoparathyroidism were reported. Three out of ten patients complained of paresthesia along the cutaneous area supplied by the mental nerve, which resolved spontaneously within 1 month. All patients were extremely satisfied with the cosmetic outcome. Additionally, in both preclinical

Table 2 Advantages of SP robot in transoral thyroid surgery

Easier docking
Suitable for narrow working spaces
Midline incision can take 3 instruments (6 mm each) in addition to the camera (8 mm)
Lateral incisions can be used for additional instruments controlled by the bedside assistant
Better ergonomics
Better visualization and full control of the camera from the surgeon's console (except when cleaning is needed)
More flexible instruments (with 2 additional joints)

SP, single port.

Table 3 Limitations of SP robot in transoral thyroid surgery

High cost of operation
Longer learning curve
Longer midline incision

SP, single port.

studies, thyroidectomy was completed successfully on human cadavers with preservation of parathyroid glands and recurrent laryngeal nerves.

Discussion

Over the last 3 decades proponents of minimally invasive surgery have touted the favorable surgical cosmesis in addition to potentially decreased postoperative pain, reduced length of hospital stay, and ultimately increased patient satisfaction with these procedures. While TOVA is not a minimally invasive surgery, some of the same benefits may apply (44). The introduction of the Davinci SP robot, with its advanced 3DHD camera and the versatile EndoWrist instruments, can potentially expand the selection criteria for transoral thyroid surgery to include patients with malignant nodules as well as those who might require concurrent central neck dissection. Thus, expanding these potential benefits to a greater patient population (45).

Robotic surgical systems, including the SP robot, however, have limitations that may continue to discourage widespread adoption. For instance, the cost of purchasing and maintenance is high compared to the cost of the traditional and laparoscopic techniques, limiting their availability to specialized institutions. Moreover, there is a steeper learning curve associated with robotic compared to endoscopic surgery (32,46). Furthermore, more studies are needed to evaluate mental nerve protection with use of the SP technique.

Although TOVA has proven to be safe and feasible, injury of the mental nerve is a technique-specific adverse event associated with TOVA. In TOETVA, a 15 mm midline incision is used compared to a 25 mm when using the SP robot. Further, as described in the study by Chan *et al.*, at the end of the procedure the author noticed an increase of the vestibular incision to 35 mm. Despite this, there have been no reports of permanent mental nerve injury with the SP robot, although data is limited. In Park *et al.* however, only 2 instruments were used through the midline incision in addition to the camera, presumably to lower the risk of mental nerve injury. The author emphasized avoiding exceeding the premolar area when lifting the periosteal flap to stay away from the mental foremen and the main branch of the mental nerve. The mental foramen is positioned in line with longitudinal axis of the 2nd premolar tooth at the level of the vestibular fornix and about one finger breadth of the lower border of the mandible in 63% of individuals (47). Further studies are needed to evaluate the risk of mental nerve injury when performing transoral thyroid surgery and especially when making a larger incision then what is typically required with the solely endoscopic approach (48-50).

Conclusions

The SP robotic surgical system offers enhanced dexterity, while using a single central vestibular incision. Additionally, it allows for use a third robotic arm. These capabilities, when taken together, may increase the extent and complexity of thyroid surgery that may be performed via a vestibular approach. Limited evidence supports the widespread adoption of robots in thyroid surgery at this time.

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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