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ORIGINAL ARTICLE

Operative outcomes of robot-assisted transaxillary thyroid surgery for benign thyroid disease: early experience in 50 patients

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Abstract
Purpose The main benefits of robot-assisted transaxillary thyroid surgery are to overcome the technical limitations of other endoscopic procedures for this surgical pathology and to avoid any cervical skin incision. This article describes the first experience of a Romanian team with the endoscopic robot-assisted thyroid surgery.
Material and methods We used the da Vinci SI intuitive surgical system to carry out 50 thyroid operations: 33 unilateral total lobectomies with isthmectomy (TL), 8 unilateral total lobectomies, with contralateral subtotal lobectomy, and 9 total thyroidectomies. Preoperatively, the patients were diagnosed with nodular goiter in 42 cases, nodular autoimmune thyroiditis in 3 cases, Basedow disease in 2 cases, toxic thyroid adenoma in 2 cases, and diffuse goiter in 1 case. We analyzed the clinical characteristics, size and location of the nodules, surgery duration, postoperative complications, pain medication, histopathological findings and postoperative cosmetic results.
Results All surgical procedures were carried out without major incidents. One case required conversion to open approach. The mean length of surgery was 159±38.2 min and the average console time was 68±39.9 min; postoperatively, we recorded one case of transient brachial plexus neurapraxia, one transient vocal cord paresis, one transient hypocalcemia, and four postoperative wound complications. The final histopathological examination revealed two cases of well-differentiated carcinoma.
Conclusions This paper reports the largest series to date in Southeast Europe about robot-assisted transaxillary thyroidectomy. On a group of selected Caucasian patients, postoperative results were similar to open cervicotomy in terms of postoperative complications. The major cosmetic advantage is the absence of scar in the anterior cervical region.

Keywords Robotic surgery · Thyroidectomy · Transaxillary approach · Endoscopy

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Introduction

Conventional cervicotomy is a safe and standardized surgical technique with low morbidity and mortality. However, some of its disadvantages, such as the size of the incision and its location at the base of the anterior cervical region, risks of hypertrophic or keloid scars and possible local paresthesia led to the development of other surgical

techniques over the last two decades. These techniques include mini-incision approaches, video-assisted surgery, and endoscopic thyroidectomies.

In 1996, Gagner reported the first endoscopic subtotal parathyroidectomy while the first endoscopic thyroidectomy was performed by Hüscher et al. in 1997 [1, 2]. The development of these new interventions has enabled various surgical approaches: cervical, laterocervical, axillary, axillo-bilateral-breast (ABBA), bilateral axillo-breast (BABA), or retroauricular [3-7].

Although various techniques are now available, endoscopic thyroid surgery is not carried out extensively. This is mainly due to its limitations, such as prolonged learning curve, use of laparoscopic instruments with limited degrees of freedom, difficulty in manipulating delicate anatomical structures in a reduced operating space, bidimensional images or difficulty in maintaining the working room. Complications such as increased carbon dioxide partial pressure, tachycardia, and subcutaneous emphysema were also reported in cases of carbon dioxide insufflation.

Technical advantages of surgical robots-7 degrees of freedom of motion through the use of multi-articulated instruments allowing complex interventions in restrained space, three-dimensional working field, magnified full high-definition view, excellent ergonomics, tremor elimination, and ambidextrous capability have expanded their use to thyroid surgery.

In 2007, in South Korea, Chung carried out the first robot-assisted thyroidectomy using a gasless axillary approach [8]. This technique has developed rapidly in some surgical groups and is currently used in both Europe [9] and North America [10].

The goal of this paper is to present, analyze, and share the experience and early outcomes in 50 patients, over a period of 1.5 years. We carried out the first robot-assisted unilateral total lobectomy using a transaxillary approach in November 2010 and subsequently extended to total thyroidectomy.

Material and methods

The study was conducted in accordance with the guidelines proposed in The Declaration of Helsinki and approved by the ethic committee of the hospital. All patients gave their informed consent. The prospective study included 50 patients referred for surgery at the Fifth Surgical Clinic of the Cluj-Napoca Municipal Clinical Hospital between November 2010 and March 2012 (22.9 % of all performed thyroidectomies). All surgical procedures were carried out by the same surgical team.

The patients were diagnosed and evaluated by a multidisciplinary team of endocrinologists, surgeons, and anesthesiologists. All patients underwent clinical and ultrasound examinations as well as thyroid function tests. Some patients also had ultrasound-guided fine needle aspiration biopsy (FNAB), scintigraphy, and computed tomography. The extemporaneous histological examination was performed in all cases.

The function of the recurrent laryngeal nerve (RLN) was assessed preoperatively for all patients using indirect laryngoscopy. Postoperatively, this examination was systematically repeated in 34 patients. Sixteen patients (32 %) without any clinic phonation problems did not repeat the laryngoscopy postoperatively for organizational reasons.

Patients with benign thyroid pathology were selected according to the following inclusion criteria: the patient's consent to robotic surgery, the presence of unilateral or bilateral nodules or nodular masses smaller than 6 cm and no suspicion of malignancy according to clinical and imaging investigations or FNAB.

The exclusion criteria included previous surgery on the anterior cervical region, malignant nodules confirmed by FNAB, Basedow disease with large and highly vascularized goiter on ultrasound examination, retrosternal goiter, neurological or cervical spine disorders of the brachial plexus, as well as a history of traumatic bone lesions affecting the pectoral girdle on the side of the operation.

The following variables were recorded: age, gender, body mass index (BMI), thyroid and thyroid lobe volume, ultrasound size of the nodule or nodular mass, type and duration of surgery, intraoperative and postoperative complications, duration and quantity of the postoperative drainage, postoperative pain medication, and number of postoperative hospitalization days.

According to the gender distribution, there were 49 females and 1 male patient. Mean patient age was 47.5 years (between 18 and 75). The patients' BMI ranged between 17.2 and 38, with a mean of 26.5±4.5 kg/m^2, 70.3 % of the patients being overweight or obese (BMI ≥25 kg/m^2). The mean size of the lesions—nodules or nodular masses—was 3.24±1.09 cm (between 1.5 and 7 cm) (Table 1).

Preoperatively, the patients were diagnosed with nodular goiter in 42 cases (84 %), nodular autoimmune thyroiditis in 3 cases (6 %), Basedow disease in 2 cases (4 %), toxic

Table 1 Clinical and pathological characteristics of patients

Characteristic (n=50)	Value
Age (yrs)	47.5±15.24 (range 18–75)
Gender ratio (male/female)	1:49
BMI	26.55±4.53 (range 17.2–38)
overweight (25≤BMI <30)	43.24 %
obese (BMI ≥30)	27.02 %
Size of tumor (cm)	3.24±1.09 (range 1.5–7)
Size of largest lobe (cm)	5.07±0.64 (range 3.5–7)
Volume of largest lobe (ml)	19±7.8 (range 5.19–44.94)

BMI body mass index

thyroid adenoma in 2 cases (4 %), and 1 case of diffuse goiter (2 %). For all patients, calcemia and parathormone were systematically assessed preoperatively. Clinical examination was conducted and calcemia was assessed daily after thyroidectomy.

The duration of the surgical intervention included the following: dissection, access to the thyroid, and insertion of Chung's retractor, docking time, and console time. The robotic surgery instruments used were EndoWrist 5-mm Maryland dissector and ProGrasp forceps, energy instrument: Harmonic curved shears, 30 ° down endoscope and an irrigator-aspirator cannula for laparoscopy. Cosmetic results were evaluated by the patients 3 months after surgery using a five possible response questionnaire: extremely satisfied, very satisfied, satisfied, unsatisfied, and very unsatisfied.

Surgical technique

All procedures were carried out by the same team using the da Vinci SI intuitive surgical system (Sunnyvale, CA).

The patients were operated on under general anesthesia with orotracheal intubation after being placed in the supine position on the operating table, with the neck slightly extended. The arm ipsilateral to the lesion or to the larger lobe was placed cephalad and held in abduction, parallel with the head, on a special extension of the table, in order to obtain the shortest distance between the axilla and the anterior neck (Fig. 1).

The same axillary approach on the side of the lesion was used in all patients, without carbon dioxide insufflation, the working room being maintained with Chung's retractor. The surgical technique was previously described by South Korean authors [8, 11-13] and it mainly supposes three stages: dissection and creation of the access tunnel to the thyroid, robot docking, and console time, i.e., the thyroidectomy per se.

A 4–5-cm vertical incision was made in the axilla on the side of the lesion, parallel and posterior to the lateral margin of the pectoralis major muscle (PM) (Fig. 1). Subcutaneous tissue was sectioned to reveal the margin of PM, dissection progressed in the fascial layer of the PM without problems of hemostasis, beneath the platysma muscle up to the level of the clavicle and sternoclavicular joint. After identifying the sternal insertion of the sternocleidomastoid muscle, we advanced towards the thyroid between the sternal and clavicular heads. We moved forward beneath the subhyoid muscles up to the thyroid capsule in order to reach the contralateral lobe and then we placed Chung's retractor (Fig. 2).

Next, the robot was docked. The instruments for the first two arms and the endoscope were inserted through the axillary incision while the instrument for the third arm was introduced through an 8-mm laterosternal incision, on the side of the operation.

The thyroidectomy was carried out similar to the conventional open procedure through a lateral approach. The vascular pedicles were dissected, the vessels were sealed and sectioned, RLN and parathyroid (PT) glands were dissected with the preservation of their vascularization (Figs. 3–4). Dissection then followed the surface of the trachea, from posterior to anterior, with the section of the Berry ligament followed by isthmectomy. The contralateral lobe was approached from the inferior pole, the branches of the inferior thyroid artery were sealed and sectioned, the RLN was isolated and the lobe was progressively exposed from caudal to cranial direction.

Results

Between November 2010 and March 2012, robot-assisted transaxillary thyroid surgery was carried out on 50 patients with surgical thyroid pathology. On the overall group, there were 33 total lobectomies (66 %), 8 total thyroidectomies (16 %), and 8 total ipsilateral lobectomies with subtotal contralateral lobectomies (16 %) performed. The first total

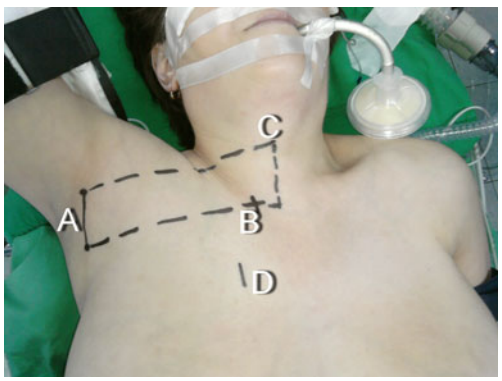

Fig. 1 Position on the operating table. *A* incision line, *B* sternoclavicular joint, *C* thyroid cartilage, *D* arm 3-port 8-mm incision

Fig. 2 Chung's retractor position

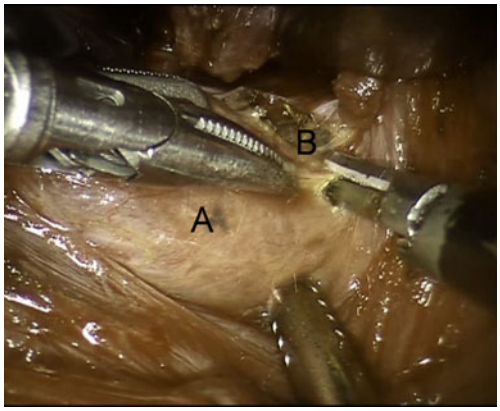

Fig. 3 Dissection of the superior pedicle vessels: *A* left thyroid lobe; *B* superior pedicle branches

thyroidectomy was performed after 20 total lobectomies. The types of robot-assisted procedures and extension of exeresis are presented in Table 2. The RLN and at least one PT gland on the side of the lesion were identified and preserved in unilateral lobectomies. The contralateral RLN was identified only in total thyroidectomies. When we encountered technical difficulties in identifying or dissecting the RLN on the opposite side of the approach, in order to avoid RLN injuries, we decided to perform contralateral subtotal lobectomy.

Out of 50 patients, we recorded 1 conversion (2 %) to the conventional cervical approach, in a female patient with Basedow disease who had undergone antithyroid drug therapy for extended periods of time. This was caused by bleeding from the internal jugular vein due to a tangential lesion that occurred when the lateral margin of the lobe was dissected and released using Harmonic curved shears.

The following postoperative wound complications were recorded: three seromas in the prepectoral region that required conservative treatment or aspirative needle puncture and one suppuration of the axillary wound that required drainage, antiseptic lavage, and antibiotherapy in a female patient with abundant axillary fat tissue and a difficult approach, the third patient of our series.

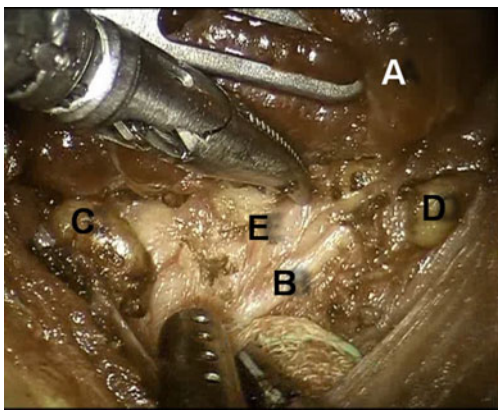

Fig. 4 Complete dissection of the posterior margin of the left thyroid lobe: *A* left thyroid lobe, *B* left recurrent laryngeal nerve, *C* inferior parathyroid gland, *D* superior parathyroid gland, *E* trachea

One patient with total thyroidectomy developed transient hypocalcemia that ceased after 1-day intravenous treatment with calcium gluconate followed by a 7-day oral administration of calcium supplements and vitamin D. One case of transient hoarseness was registered (2.9 % of available postoperative laryngoscopies carried out during hospitalization). The laryngoscopy revealed vocal cord paresis on the ipsilateral side of the approach in a total lobectomy (the seventh patient of our series), that solved in 2 weeks of anti-inflammatory medication. No permanent RLN injuries were recorded. There was no postoperative bleeding or hematoma and none of the patients required additional surgical interventions. We had one case (2 %) of transient brachial plexus neurapraxia that required neurological rehabilitation treatment, without sequela within 3 months (Table 3). Three months postoperatively, five female patients (10 %) still reported slight paresthesia or hypoesthesia in the prepectoral or clavicular region superjacent to the dissection plane.

All patients underwent extemporaneous histological examination. However, the final histological examination revealed well-differentiated thyroid carcinoma (papillary carcinoma) in two patients subjected to lobectomy, who subsequently underwent total thyroidectomy through cervicotomy during the same hospital stay. Overall pathologic findings are shown in Table 2.

The operative duration was represented by the total length of the surgery including access to the thyroid and placement of Chung's retractor, docking time, as well as console or thyroidectomy time. Considering all procedures, the average total operative time was 159 min, ranging from 131 min for total lobectomies to 188 min for total thyroidectomies. Mean console time was 68 min (52 min for total lobectomies and 117 min for total thyroidectomies) (Table 4).

The mean duration of postoperative hospital stay was 4.3±1.6 days; most of the patients were discharged 24 h after the removal of suction drains. All patients were admitted 1 day before surgery that counts for total hospitalization. The first patients of our series were probably kept under surveillance more than necessary. Later patients were discharged usually 48 h after procedure.

Postoperative cosmetic results were highly appreciated by patients. There were no anterior cervical scars or visible postoperative axillary scars when the patient's arm was in a normal position for all 47 patients who did not require conversion or reintervention (Fig. 5). 43 patients (91.5 %) were "extremely satisfied" with the cosmetic results and the other 4 (8.5 %) were "very satisfied".

Table 2 Pathologic findings and extension of exeresis

Pathologic findings		Robot-assisted TL *n*=33 (66 %)	Robot-assisted TL + STL *n*=8 (16 %)	Robot-assisted TT *n*=8 (16 %)	Total thyroidectomy by cervicotomy
Multinodular goiter	25 (50 %)	14	5	6	
Follicular adenoma	13 (26 %)	13			
Toxic adenoma	2 (4 %)	2			
Hurthle cell adenoma	2 (4 %)	2			
Basedow disease	2 (4 %)			1	1 conversion
Papillary carcinoma	2 (4 %)	2[a]			2 reinterventions
Nodular autoimmune thyroiditis	3 (6 %)		3		
Diffuse goiter	1 (2 %)			1	

TL total lobectomy, *STL* subtotal lobectomy, *TT* total thyroidectomy

[a] final histological examination revealed well-differentiated thyroid carcinoma in two patients who underwent conventional total thyroidectomy with central compartment lymph node dissection

Discussion

A significant number of minimally invasive, video-assisted, or endoscopic thyroid surgery techniques have been developed in the last two decades [14]. However, despite the numerous technical solutions currently available, these new procedures for thyroid surgery are not routinely performed except in highly specialized surgical centers, mainly due to its limitations. The technical difficulty of endoscopic operations requires a prolonged learning curve compared with robot-assisted operations [15-18]. The images are bidimensional and unstable and the optic endoscope must be operated by the assistant surgeon. Delicate anatomical structures such as the RLN and the Berry region are dissected and handled with difficulty [19] using techniques and instruments borrowed from laparoscopic abdominal surgery.

Robot-assisted cardiac and urologic surgery (mainly prostate) has continuously developed. There are several technical advantages brought by the use of robots in interventions requiring complex movements in tight spaces [20]. Therefore, robot-assisted operations have been introduced in cervical surgery, especially thyroid and parathyroid surgery, in order to surpass the technical limitations of endoscopic surgery. Robotic surgery offers obvious advantages such as stable, three-dimensional high-definition images, instruments with 7 degrees of freedom, 90 ° of articulation, the absence of physiological tremor, and last but not least, the ergonomic position of the surgeon [11, 12, 21]. Motion scaling associated with digital image zooming allow the performance of high-precision microsurgical movements.

Table 3 Complications after robot-assisted thyroidectomy

Major complications: *n*=1	
Permanent ipsilateral RLN injury	0
Permanent hypocalcemia	0
Hemorrhage/Hematoma	1 (2 %)
Tracheal injury	0
Minor complications: *n*=7	
Wound seroma	3 (6 %)
Wound infection	1 (2 %)
Transient hoarseness	1 (2 %)
Transient hypocalcemia from eight total thyroidectomy	1 (12.5 %)
Brachial plexus neurapraxia	1 (2 %)

RLN recurrent laryngeal nerve

The transaxillary dissection performed in order to gain access to the thyroid gland requires a lateral surgical approach of the homolateral lobe, especially for the RLN and PT glands on the side of the lesion, which enables the safe dissection of these structures. This was the rationale behind the choice of the side on which to perform the operation in cases of bilateral lesions requiring complete gland removal. Thus, we always chose to approach the side with the larger lesion, without taking into consideration the possible advantages of directly approaching the right lobe and the right RLN in the first operative time.

A longer mean operative time was obtained in our series of patients compared with conventional anterior cervicotomy [22, 23], mainly due to the dissection time required to access the thyroid, the placement of Chung's retractor, and robot docking. This period decreased with increasing experience but was still longer than reported by South Korean authors for robot-assisted transaxillary thyroid surgery [11, 12, 23]. In our opinion, there could be two explanations: the learning curve in the first 50 patients' series and different anthropometric characteristics of Asian subjects who have smaller BMI and height and therefore smaller length of the clavicle and musculocutaneous flap dissected and elevated using Chung's retractor.

Table 4 Mean total operation time, flap creation time, robot docking time, and postoperative hospital stay according to the extent of surgery

	All procedures	TL n=33	TL + STL n=8	TT n=8
Total operative time (min)	159±38.2	131±31.3	162±21.1	188.75±19.6
Flap creation time (min)	70.3±17.3			
Robot docking time (min)	9.6±2.9			
Console time (min)	68±39.9	52±27.3	83±23.1	117±38.2
Volume of thyroid resected (ml)	22.9±12.1	17.7±7.2	34.9±16.7	32.7±9.9
Postoperative hospital stay (days)	4.3±1.6	4.3±1.7	4.2±1.2	4.5±1.5

TL total lobectomy, *STL* subtotal lobectomy, *TT* total thyroidectomy

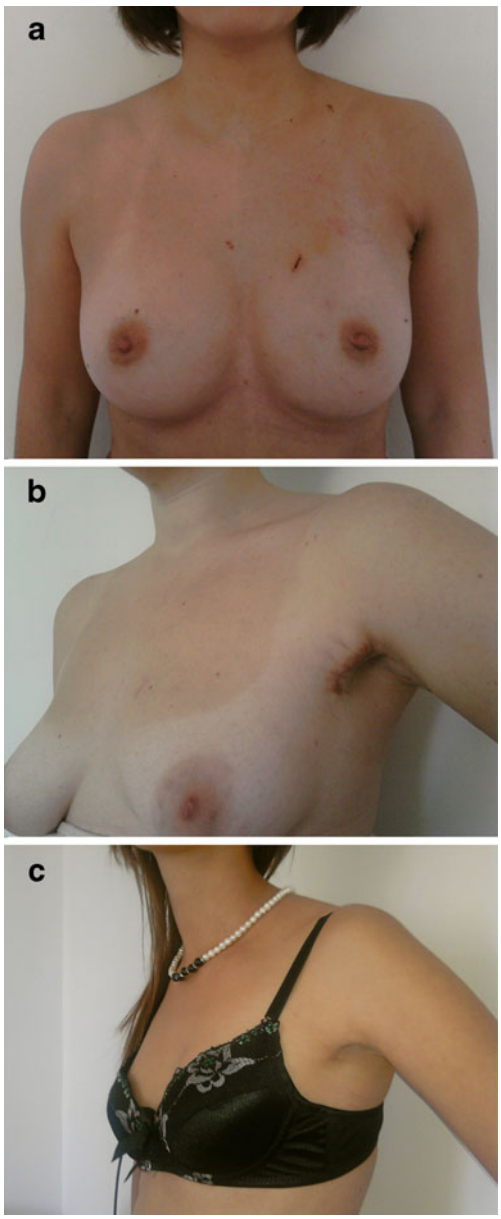

Fig. 5 Postsurgical aspects. **a** 1 week. **b** 2 weeks. **c** 3 months postoperatively

The rate of intraoperative and postoperative complications was low in our series of patients and the results were comparable with the experience of centers that designed and perfected this technique [11, 12, 24]. We registered one case (2 %) of brachial plexus neurapraxia caused by the intraoperative position of the arm in a 31-year-old female patient. The brachial plexus paresis required 3 months of neurological rehabilitation treatment which led to the recovery of the upper limb function [9, 10, 24]. In order to avoid similar complications and to improve arm positioning before anesthesia, we carried out intraoperative neurophysiological monitoring of the brachial plexus, i.e., monitoring of the somatosensory evoked potentials (SSEP) through the stimulation of the peripheral nerves of the upper limb, especially the median nerve. Depending on the intraoperative SSEP, the position of the arm was modified in order to prevent further lesions. The angle between the limb and the surface of the operating table was increased and the operation was completed in this new position under neurophysiological monitoring.

One female patient (the third of our series) developed a suppuration of the axillary wound, probably secondary to tunnel dissection. This was confirmed by culture and required surgical and antibiotic management. The overall rate of wound infections supported by objective data is 2 %.

Out of eight total thyroidectomies, we recorded one case of transient hypocalcemia that rises the percentage of postoperative hypocalcemia to 12.5 %. This rate is comparable to those observed in thyroidectomy by cervicotomy [25].

According to the results reported by other authors, the incidence of permanent RLN injury in robot-assisted transaxillary thyroid surgery was of 0.5–0.8 % [11, 24]. No such cases were recorded in our group of patients. In our series, 34 patients (68 %) were submitted to laryngoscopy during hospitalization. The single case reported of transient hoarseness due to vocal cord paresis means 2.9 % of the above available postoperative laryngoscopies. Out of 16 patients discharged without postoperative control, 14 carried out this examination in the outpatient and were all normal.

10 % of the patients still reported slight paresthesia or hypoesthesia in the prepectoral or clavicular region, 3 months after surgery. Previous studies recognize and present a rate of 8–40 % for this specific morbidity [22].

Conversion to the conventional open approach was required in one case of bleeding caused by tangential injury of the internal jugular vein. The lesion was produced during console time due to the size and the anatomical characteristics of the thyroid lobe, especially its vicinity to the jugular vein. The few studies published have reported zero or low conversion rates primarily caused by bleeding [10].

For 47 out of 50 patients, there were no cervical incisions and therefore, no risks of visible keloid hypertrophic or postoperative scars while standing with arms in the natural position. All patients were very satisfied with the cosmetic results. In order to improve these results, total transaxillary robot-assisted procedure without laterosternal incision should be taken in consideration.

However, there are also disadvantages to robot-assisted transaxillary thyroid surgery. Thus, as far as the surgical technique is concerned, longer operative and anesthesia times are required compared with conventional surgery. The dissection needed to reach the thyroid from the axilla is minute and sometimes difficult. The approach of the contralateral lobe, especially of the upper pole, raises a challenge and thyroid tissue fragments might be left behind in the area of the Berry ligament [11]. At this time, there are no long term follow-up studies concerning the danger of seeding of malignant cells when the specimen is extracted through a relatively long tissue channel.

Finally yet importantly, the high cost of this type of surgery might be an inconvenience. The consumables are very expensive, especially the robotic instruments which, unlike laparoscopic instruments, have a limited number of uses imposed by the manufacturer. On one hand, the high cost is due to the complexity of the instruments and their finite number of uses; on the other hand, the cost also depends on the manufacturer of the still unique da Vinci platform.

Conclusion

Although this technique is complex, surgical results were similar to those obtained by open cervicotomy, with few postoperative complications. The use of the da Vinci robotic system provided very good cosmetic results through a safe and feasible technique on a selected group of Caucasian patients with benign thyroid pathology. This supports the usefulness and efficiency of the robotic technique in thyroid surgery.

Acknowledgments None

Conflicts of interest None.

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