Received: 3 December 2021 | Revised: 23 May 2022 | Accepted: 23 May 2022

DOI: 10.1002/hed.27114

WILEY

OPERATIVE TECHNIQUES

This article supplements the Operative Techniques video presentation, which can be viewed online on Head & Neck's home page at http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1097-0347

The robotic-assisted extended "Sistrunk" approach for tumors of the upper aerodigestive tract with limited transoral access: First description of oncological and functional outcomes

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Abstract

We report on the first clinical experience with the robotic-assisted extended "Sistrunk" approach (RESA) for access to constrained spaces of the upper aerodigestive tract. This prospective case cohort study include six patients that underwent RESA if transoral exposure could not be achieved. Three patients received previous radiation. Patients were postoperatively followed until week 16 for perioperative complications, surgical margins, and functional outcomes. In all patients RESA allowed adequate exposure and resection with negative margins. Three patients who underwent salvage surgery experienced a minor or intermediate grade postoperative bleeding. No patient developed a pharyngocutaneous fistula. Three patients recovered their swallowing to their preoperative status and the remaining three experienced an improvement. All patients experienced complete recovery of their voice. RESA has the potential to provide a new organ preservation approach for head and neck cancer (HNC) not amenable to transoral exposure and thus warrants further prospective clinical studies.

KEYWORDS

da Vinci, endoscopic surgery, head and neck surgery, robotic surgery, Sistrunk procedure

1 | INTRODUCTION

Transoral robotic surgery (TORS) is a well-established treatment strategy for oropharyngeal cancers with excellent oncological and functional outcomes.[1–5] Further applications have been described for supraglottic,[6–9] partial,[10] and total laryngectomies[11–13] with encouraging initial results.

Although promising, the transoral robotic approaches to the larynx, hypopharynx, and sometimes the base-of-tongue are plagued with limitations of exposure.[14,15] This is on the one hand owed to the individual anatomy and position of the base-of-tongue and the hyoid bone, but often also the consequence of previous treatment with radiation therapy and/or surgery for previous HNC.[16] Often, patients with recurrent or secondary early T-stage of the base-of-tongue, larynx, or hypopharynx after previous radiation therapy and/or surgery must undergo extensive surgery including laryngectomies with significant functional detriment, since transoral resections are felt to be impossible due to inadequate exposure and concerns over meaningful functional recovery.[17,18]

To improve transoral exposure of the base-of-tongue, larynx, and hypopharynx, we proposed the creation of a single subplatysmal working space centered over the thyroid cartilage and hyoid bone just through the opening of the plane of the pretracheal fascia. This anatomical space is well known to head and neck surgeons, since it corresponds to the location of thyroglossal duct cysts and is thus commonly entered during the "Sistrunk" procedures.[19] A small median pharyngotomy after partial removal of the hyoid bone following the boundaries of the posthyoid space permits access to the pharynx and supraglottic larynx above the epiglottis. We have recently reported on the development of this surgical technique based on eight cadaver resections using at first the Xi and afterwards the SP da Vinci robot.[20–22]

In a prospective Phase II safety and feasibility study, we assessed the impact of the RESA approach by evaluating quality of exposure, surgical margins, and functional speech and swallowing recovery of six patients with cancers confined to the supraglottis, piriform sinus, postcricoid region, and base-of-tongue; three patients had previous radiation (RT) or chemoradiation (CRT) that were neither exposable for transoral laser (TLM) nor transoral robotic surgery (TORS).

2 | MATERIALS AND METHODS

Patients were enrolled in an institutional prospective robotic surgery register with appropriate ethics approval (CHUV_2020_019_RM); in accordance with institutional guidelines based on Swiss legislation and national recommendations. RESA was offered to those patients in whom optimum exposure could not be achieved for TORS or TLM but were deemed candidates for transoral surgery by the multidisciplinary team based on other patient and tumor characteristics.

2.1 | Operative technique

The da Vinci Xi robotic system (Intuitive, Sunnyvale, CA) was used for all surgical interventions. The patient is placed in supine position. The head is placed in slight atlanto-occipital extension. In all patients a tracheostomy is performed. A 7–8 cm submental incision is placed in the submental skin crease. A working space is then created in a subplatysmal plane to expose the hyoid bone; the muscular attachments of the hyoid body are released, and the central portion of the hyoid bone is removed. A Langenbeck retractor is then placed in the vallecula to guide a 3 cm median pharyngotomy. Following this, a self-retaining retractor with rotating modular blades (TrimLine Medtronic Sofamor Danek USA, Inc., Memphis, TN) is placed to obtain exposure of the tumor via the pharyngotomy. The robot is then docked in the usual way with two working channels and the telescope. The resection then follows recommended guidelines of achieving appropriate macroscopic margins. Closure is performed in three layers using 3.0 Vicryl sutures first closing the mucosa of the vallecula, then reapproximating the inner and outer layer of the supra- and infrahyoid musculature. A simple redon is then placed in the wound and the skin closed using staples or 5.0 Prolene.

Vessel control can be accomplished via the same incision. For supraglottic resections, control over the superior laryngeal vessels can be obtained by dissecting lateral to the superior cornu of the thyroid cartilage and lateral to the thyrohyoid muscle into the soft tissues. Vessels can be readily distinguished from branches of the superior laryngeal nerve, and ligated; the former structures are preserved to assist with swallowing recovery. For base-of-tongue resections the lingual artery on the side of the resection is identified in Lesser's triangle via the submental incision and selectively ligated.

2.2 | Rehabilitation and outcomes assessment

Swallowing and voice rehabilitation was delivered using analytic and functional exercises with a speech-and-language therapist. The first functional aim was the closure of the tracheostomy and optimizing upper airway protection. The speech therapist evaluated oral-lingual-facial motor and sensory function, efficiency of the cough, and secretion management. A teaspoon of thickened water was swallowed with guidance. Rehabilitation consisted of tongue strengthening, laryngeal lift improvement, increasing pharyngeal tone, and voice exercises. Vocal reinforcement was used to enhance glottic closure and improve vocal quality. Swallowing maneuvers were adapted to compensate for the structures lost following

surgical resection and to prevent aspiration. Flexible Endoscopic Evaluation of Swallowing (FEES) was performed with a flexible endoscope and recorded, with visual feedback on a screen. FEES evaluation was carried out in two sections: (a) examination of anatomical structures, amount of secretions, pharyngolaryngeal mobility and sensitivity, and efficacy of cough; (b) swallow examination and evaluation of the aspiration risk, scored according to the Penetration-Aspiration Scale (PAS).[23] The Functional Oral Intake Scale (FOIS) was used to assess oral intake for liquids and solids.[24] Preoperative FOIS was evaluated based on patient recollection during a postoperative visit. Voice quality was evaluated with GRBAS scale.[25] Based on the FEES findings and FOIS score, food textures were adapted for each patient. Thickened water was used for the first attempts, followed by smooth mixed texture and gradually solid food. Voice and swallowing rehabilitation were pursued on an outpatient basis with regular phoniatric follow-up.

3 | RESULTS

3.1 | Patient characteristics

A total of six patients underwent a tumor resection using the RESA technique. All patients had been tracheotomized. All patients were male and the mean age was 63.7 years (range 52–90). The cancer sites were supraglottic (2/6), postcricoid (2/6), base of tongue/vallecula (1/6), and piriform sinus (1/6). Patients 1, 2, and 5 had previously received radiotherapy-based treatment for other HNC and pulmonary cancers. Patient 1 received radiotherapy twice due to a regional recurrence. Only patients 4 and 6 had no previous oncological history (Table 1).

Histopathological analysis of the surgical specimen confirmed all patients to have had R0-resections. Patient 6 underwent a neck dissection concurrently and patient 3 had a neck dissection 2 weeks after the surgery for the primary lesion. The average hospital stay was 27 days.

3.2 | Feasibility, surgical margins, and complications of surgical procedures

Patients 1 and 2 had supraglottic lesions. In patient 1 transoral exposure was impossible because of severe trismus as a result of twice RT in the past (Table 1 and Figure S1, Supporting Information). Transhyoid exposure was readily achievable and allowed the resection of the lesion with a closest margin of 5 mm (Table 1 and Video S1). This patient had a postoperative bleeding on Day 18. He was taken to the operating theater and the mucosal edge of the right arytenoid was found to be the source, which was cauterized with the monopolar cautery (intermediate grade[26]). He developed a pneumonia on Day 20, which resolved upon antibiotics for 1 week. Patient 2 was transorally not exposable because of a hypertrophic base-of-tongue. Transhyoid resection was readily achievable and performed in the same manner as in patient 1. The closest surgical margin was 5 mm. There were no postoperative complications.

Patients 3 and 4 were treated for lesions of the postcricoid region. Patient 3 had RT to the neck in the past for a skin cancer and due to age limited reclination of the neck making transoral approaches impossible (Figure S2). Transhyoid resection was readily achievable with a 2-mm margin as the closest margin in the main specimen (Video S2). This patient developed a bleeding at Day 12 for which he was taken to the OR showing a light oozing from the mucosal margins of the wound bed that was cauterized (intermediate grade[26]). Patient 4 was treated for a lesion in the postcricoid region. Difficult exposure transorally was a consequence of a hypertrophic tongue base. Transhyoid resection was readily achievable and performed in the same manner as in patient 3. The closest surgical margin was 2 mm. This patient developed a pneumonia on Day 9 that resolved under antibiotic treatment 1 week later.

Patient 5 was treated for a right tongue base recurrence with extension up to the hyoid bone. Transoral exposure was limited due to previous RT. This patient was operated via a combined transoral (superior incision in the base-of-tongue) and transhyoid (main tumor resection) approach. The resection of the hyoid bone allowed to secure an adequate deep margin. A tumor resection with a 4 mm closest surgical margin was achieved (Videos S3a and S3b). This patient had a bleeding episode on Day 12 that resolved upon conservative measures (minor grade[26]).

Patient 6 was treated for a lesion of the piriform sinus. Transoral exposure was considered difficult during routine staging triple-endoscopy. Transhyoid resection was readily achievable (Video S4). This was the first RESA intervention and done without the Trim-Line retractor accounting for more difficulties to expose and resect the lesion. The closest surgical margin was the deep margin with 1 mm with the constrictor muscle free of infiltration. There were no postoperative complications.

3.3 | Functional recovery

All patients had preexisting oral food restrictions before surgery but were on a complete oral diet. Table 2 summarizes their functional characteristics. The preoperative FOIS level was 5 in four patients, 6 in one patient, and

TABLE 1 Patient characteristics with previous oncological history

Patient	Age	Localization	Clinical staging	Pathological staging	Closest margin (cm)	Hospital stay (days)	Complications related to surgery (surgical and medical)	Oncological history (site, staging, treatment)
1 Supraglottis	63	Supraglottis	cT1 cN0 cM0	pT2 cN0 cM0	0.5	29	Bleeding, D18 Pneumonia, D20	Left oropharyngeal SCC, pT2 ypN3b cM0 p16 negative • Left lateral pharyngectomy and left ND (ECE+), adjuvant RT with 66 Gy for the tumoral site, 59.4 Gy for the intermediate area, and 52.8 Gy for the ND area, 07/2016 • Regional recurrence, right radical ND, adjuvant CRT with Cisplatin, 66 Gy by tomotherapy and 52.8 Gy for the ND area, 06/2019
2 Supraglottis	54	Supraglottis	cT3 cN1 cM0	pT3 cN1 cM0	0.5	26	None	Adenocarcinoma, right superior lobe, cT3 cN2 cM1 • Stereotaxic RT with 20 and 33 Gy for cerebral metastasis, 06/2019, and 55 Gy for pulmonary metastasis, 03/2020 • Pembrolizumab since 07/2019
3 Postcricoid	90	Postcricoid	cT1 cN1 cM0	pT1 pN1 M0	0.2	42	Bleeding, D12	Right periauricular cutaneous SCC, pT2 pN3b (ECE+) • Tumor resection, superficial parotidectomy, radical ND with extracapsular extension, RT with 51.2 Gy for the tumoral site, 51.2 Gy for the lymph node, and 44.8 Gy for the ND area, 08/2020 • Without chemotherapy because of age Multiple cutaneous SCC and BCC: right pinna, nose root, right tempel, thorax • Tumor resection, 10/2017–01/2020
4 Postcricoid	55	Postcricoid	cT1 cN3b cM0	pT1 cN3b cM0	0.2	16	Pneumonia, D9	No oncological history
5 Base-of-tongue	68	Base of tongue	cT3 cN0 cM0	pT3 cN0 cM0	0.4	30	Bleeding, D12	Multiple synchronous SCCs: oral cavity cT2 (soft palate) and pTis (floor of the mouth), oropharynx cT4a, and pulmonary cT1, cN2c cM0: • Tumor resection of oral cavity cancers, Cetuximab and RT with 69.96 Gy for the oropharynx primary, and 66 Gy for the pulmonary lesion, 7/2020
6 Piriform sinus	52	Piriform Sinus	cT2 N3b cM0	pT2 pN3b cM0	0.1[a]	23		No oncological history

Abbreviations: BCC, basal cell carcinoma; CRT, radiochemotherapy; CT, chemotherapy; D, day postoperative; ECE+, lymph node with extracapsular extension; Gy, Gray; ND, neck dissection; RT, radiotherapy; SCC, squamous cell carcinoma.

[a]Corresponds to deep margin at M. constrictor inferior (R0).

TABLE 2 Swallowing outcome and aspiration/penetration

Patient and subsite	Preop. FOIS	Preop. voice	Postop. voice	Tube feeding (days)	Tracheotomy (days)	Ambulatory speech therapy sessions	FOISW1	FOIS W4	FOIS W8	FOIS W12	FOIS W16	PAS W1	PAS W4
1 Supraglottis	4	G1 R1 B0 A0 S1	G1 R1 B0 A0 S1	95	16	6	2	3	3	3	4	6	2
2 Supraglottis	6	G0	G0	26	20	9	2	7	7	RT	RT	4	1
3 Postcricoid	5	G1R1B0 A1 S0	G1R1B0 A1 S0	55	32	2	2	3	5	6	6	4	2
4 Postcricoid	5	G1 R1 B0 A0 S0	G1 R1 B0 A0 S0	15	11	2	3	5	RT	RT	RT	4	1
5 Base-of-tongue	5	G1 R1 B0 A0 S0	G1 R1 B0 A0 S0	43	88	4	1	2	2	3	5	3	1
6 Piriform sinus	6	G0	G0	50	15	0	5	7	7	RT	RT	3	1

Note: Gray color indicates previous RT.
Abbreviations: FOIS, Functional Oral Intake Scale; GRBAS, Grade; Roughness; Breathiness; Asthenia; Strain; PAS, Penetration and Aspiration Scale; RT, radiation therapy; W, weeks after surgery.

4 in one patient. Patient 1 had most severe restrictions with FOIS level 4, which means total oral diet with only one single consistency. Preoperative and postoperative voice quality remained similar, with a Grade 0 (normal voice) in two patients and a Grade 1 (slight dysphonia) in four patients. The average duration of tube feeding was 47.3 days and tracheostomy 30.3 days. The average number of ambulatory speech therapy sessions was 5. Postoperative FOIS was evaluated on Week 1, 4, 8, 12, and 16.

Based on FOIS score data all patients either recovered entirely their swallowing function prior surgery (Patients 1, 4, and 5) or improved (Patients 2, 3, and 6) at W16 or prior starting RT (Table 2). Regarding PAS scores at W4, four patients had no aspiration or penetration (PAS 1), and two patients had penetrations with clearing (PAS 2). No patient had signs of aspiration.

4 | DISCUSSION

This study reports the feasibility of the robotic extended "Sistrunk" approach (RESA), a new technique for robotic surgical access, in six patients in whom minimally invasive surgery would not have been otherwise possible. The outcomes of en bloc resections for cancers of the tongue base, supraglottic larynx, hypopharynx, and postcricoid region has been described in detail. Our results demonstrate that this novel approach allows for adequate exposure of these sites to perform en bloc resections with negative margins. It provides good vascular control, has a low complication rate even in patients who received previous radiation, and allows for excellent functional recovery with a postoperative swallowing function superior to the preoperative status in 50% of patients. In the salvage setting, the technique may support organ preservation.

Between 8 and 18% of patients with patients with oropharyngeal cancer are not suitable for minimally invasive transoral techniques owing to poor exposure.[27–29] This number is higher if resections are attempted in the supraglottic and hypopharyngeal region.[14,15] It is the distance between the tongue base and posterior pharyngeal wall, and the position of the hyoid bone that often prevent proper exposure of the supraglottic larynx and hypopharynx.[30] Also, previous radiation therapy has been demonstrated to be associated with poor exposure of the pharynx and supraglottic larynx for robotic surgery.[16] Single-port systems applied transorally will not help if a lesion cannot be exposed with the available instrumentation. The availability of flexible instrumentation will not solve the problem of tumors that cannot be adequately visualized with existing instrumentation. RESA solves this problem by circumventing the most critical anatomical region for transoral exposure located at the level of

the hyoid bone by a simple median pharyngotomy at the level of the vallecula after hyoid bone removal.

The margin status after supraglottic robotic resections has recently been reported by the GETTEC group in 122 patients. In this cohort 6.6% of patients had a positive margin and 41.8% a close margin. Patients were preoperatively screened for adequate exposure during triple-endoscopy.[6] The data demonstrate a potential weakness of transoral robotic surgery for supraglottic cancers which may be caused by the constrained working space in the supraglottic region upon transoral exposure, even if exposure seems adequate during endoscopy. An additional explanation for the rather high close margin rate may be the risk of a positive deep margin in the proximity of the hyoid bone during supraglottic resections. RESA appears to provide not only excellent access to the supraglottic region leading to negative surgical margins, but moreover helps to control the deep margin around the hyoid bone by its removal as being part of the procedure.

Adequate control over vascular structures during robotic surgery is of paramount importance. In order to avoid catastrophic bleeding after TORS often ligation of the external carotid artery is recommended,[31] which however in the radiated neck would require an additional transcervical procedure. RESA for radiated patients performed through a submental incision provides readily access to Lesser's triangle at the level of the hypoglossal nerve. As practiced in patient 5 the lingual artery can be selectively ligated through the same incision used for the tumor resection avoiding additional open transcervical approaches thus reducing morbidity. The superior laryngeal artery can be clipped lateral to the greater cornu of the thyroid cartilage.[22] In this area, it is easy to differentiate the superior laryngeal nerve from the artery, thus avoiding damage to the nerve and therefore helping with swallowing recovery. In this series of six patients, three patients had an episode of postoperative bleeding (two intermediate grade, one minor grade according to Mayo classification[26]). All these patients had received previous radiation with protracted wound healing, and in each case the source was identified to come from the mucosal edge of the resection.

The risk of fistula after RT with a pharyngotomy is significant and reported in a recent multicenter retrospective review to be as high as 43% in case of salvage laryngectomies with primary closures.[32] However, if this pharyngotomy is small and performed in an area of limited salivary stasis, it should be safely performed even in radiated patients. In our series three patients were radiated with one patient radiated twice. None developed fistulas suggesting that the trans-vallecular approach via a submental incision through a small pharyngotomy followed by a three-layer closure and then covered by a subplatysmal flap can likely prevent fistula formation. All patients in our series had been tracheotomized and this should be considered a disadvantage compared to transoral approaches. However, RESA is a technique for patients who are deemed unsuitable for transoral surgery, for whom the alternatives are open approaches, which usually require a covering tracheostomy.

This study demonstrates that using RESA leads to larynx preservation and may help to avoid open surgery in patients needing salvage resections. Considering large prospective randomized organ preservation trials, that is, RTOG 91-11, larynx preservation ranges between 64% and 82% at 10 years.[33] Recent data demonstrate that 80% of salvage laryngectomies are performed during the first 2 years for recurrent or persistent disease of which 55% are performed for early T-stage disease and 40% for supraglottic disease,[18] a patient population amenable to organ preservation surgery but with poor transoral access. RESA offers the option of organ preservation surgery in this patient group, thus improving the rate of organ preservation after CRT.

ACKNOWLEDGMENT

Open access funding provided by Universite de Lausanne.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Simon C, Beharry A, Paleri V, et al. The robotic-assisted extended "Sistrunk" approach for tumors of the upper aerodigestive tract with limited transoral access: First description of oncological and functional outcomes. *Head & Neck*. 2022;44(10):2335-2341. doi:10.1002/hed.27114