ORIGINAL ARTICLE

Robotic-Assisted Surgery for Primary or Recurrent Oropharyngeal Carcinoma

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Objective: To determine the feasibility of robotic-assisted salvage surgery for oropharyngeal cancer.

Design: Retrospective case-controlled study.

Setting: Academic, tertiary referral center.

Patients: Patients who underwent surgical resection for T1 and T2 oropharyngeal cancer between 2001 and 2008 were classified into the following 3 groups based on type of resection: (1) robotic-assisted surgery for primary neoplasms (robotic primary) (n=15), (2) robotic-assisted salvage surgery for recurrent disease (robotic salvage) (n=7), and (3) open salvage resection for recurrent disease (n=14).

Main Outcome Measures: Data regarding tumor subsite, stage, and prior treatment were evaluated as well as margin status, nodal disease, length of hospital stay, diet, and tracheotomy tube dependence.

Results: The median length of stay in the open salvage group was longer (8.2 days) than robotic salvage (5.0 days) ($P=.14$) and robotic primary (1.5 days) resection groups ($P<.001$). There was no difference in postoperative diet between robotic primary and robotic salvage surgery groups. However, a greater proportion of patients who underwent open salvage procedures were gastrostomy tube dependent 6 months following treatment (43%) compared with robotic salvage resection (0%) ($P=.06$). A greater proportion of patients who underwent open salvage procedures also remained tracheotomy tube dependent after 6 months (7%) compared with robotic salvage or robotic primary patients (0%) ($P=.48$). No complications were reported in the robotic salvage group. Two patients who underwent open salvage resection developed postoperative hematomas and 2 developed wound infections.

Conclusion: When feasible, robotic-assisted surgery is an acceptable procedure for resection of both primary and recurrent oropharyngeal tumors.

Trial Registration: clinicaltrials.gov Identifier: NCT00473564

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ROBOTIC-ASSISTED SURGERY has gained popularity in a wide variety of specialties over the last decade including cardiology, urology, gynecology, and most recently head and neck oncologic surgery. Procedures once associated with high morbidity are now performed with less blood loss and fewer complications than standard open techniques.[1-3] In addition, studies have shown that operative time, intensive care stays, and length of hospitalization can be reduced through the use of robotic assistance.[4]

Management of head and neck carcinoma has traditionally required extensive open resection to obtain access to the posterior oral cavity and oropharynx. These procedures result in considerable speech and swallowing dysfunction for many patients as well as poor cosmesis.[5,6] Robotic-assisted surgery allows for transoral resection of upper aerodigestive tract lesions and thereby provides a minimally invasive alternative to the treatment of advanced head and neck carcinoma. First described by Weinstein et al,[7] transoral robotic surgery has been proven safe and feasible in the clinical setting.[8,9] Oncologic resection of primary tonsillar, base of tongue, and supraglottic laryngeal carcinoma has been successfully performed with robotic assistance.[10-12] Transoral resection has previously been limited owing to restricted surgical access and the extensive nature of many neoplasms. With the excellent 3-dimensional visualization afforded by the surgical robot, lesions that would have classically

required an open approach can now be resected using robotic assistance. In the present study, we evaluated the potential role of robotic-assisted salvage resection and compared outcomes between robotic-assisted and open salvage surgery patients.

METHODS

A retrospective review of patients who presented with oropharyngeal cancer between 2001 and 2008 was performed at the University of Alabama at Birmingham following institutional review board approval. Patients who required surgical resection of primary or recurrent T1 and T2 carcinoma of the base of tongue, soft palate, tonsils, or pharyngeal wall were included in the study and underwent either open or robotic-assisted resection (n=36).

All patients who underwent robotic-assisted surgical resection (n=22) presented after March 2007, when institutional review board approval was obtained for a prospective clinical trial using the da Vinci Robot (Intuitive Surgical Inc, Sunnyvale, California). Following in-depth discussion of treatment preferences, patients requiring surgery or invasive treatment for upper aerodigestive tract lesions were given the option of robotic-assisted surgical resection. Patients unable to provide informed consent or without sufficient mouth opening for adequate exposure (defined as a maximal opening of <1.5 cm) were excluded, as well as those patients with tumor invading bone or when resection was predicted to result in a through-and-through defect necessitating free-tissue transfer.[13] Patients who underwent open salvage resection for T1 or T2 oropharyngeal lesions (n=14) presented prior to the robotic-assisted clinical trial.

The majority of robotic-assisted cases involve early-stage neoplasms of the upper aerodigestive tract, while open surgical resection is often reserved for advanced T category lesions and advanced disease. To allow for a side-by-side comparison of outcomes associated with each surgical technique, individuals with T3- or T4-stage disease were excluded from the study. Primary surgical margins were assessed by frozen section and confirmed on permanent pathologic examination. Selective or modified neck dissection was performed during the same operation or in a staged procedure, and all robotic-assisted surgery patients underwent healing by secondary intention.

After surgical resection, select patient cases were discussed at the multispecialty tumor board. Patients were treated with adjuvant radiation therapy when (1) more than 1 positive node was identified on neck dissection, (2) the patient had a T2 base of tongue lesion, or (3) if perineural or lymphovascular invasion was present. Concomitant chemoradiation therapy was administered (1) when positive margins (not reresectable) were identified on permanent pathologic examination and (2) in the presence of extracapsular nodal spread. Patients were followed up through their hospital stay and for 6 months postoperatively.

Demographic and clinical information consisted of patient age, sex, tumor subsite, stage, and prior treatment. Operative data included type of resection, histologic findings, margin status, and nodal disease. Postoperatively, complications, length of hospital stay, and diet were evaluated. Major outcome measures included tracheotomy or gastrostomy tube dependence at 6 months following surgery.

Descriptive variables are reported as mean (SD) and categorical variables as percentages. Descriptive statistics were compared by general linear models for normally distributed variables or the Kruskal-Wallis test when otherwise. The χ^2 test with exact option was used to compare categorical variables by group. $P<.05$ was considered statistically significant. Data analysis was performed using SAS version 9.1 software (SAS Institute Inc, Cary, North Carolina).

RESULTS

PATIENT POPULATION

There were 36 patients who underwent surgical resection for T1 or T2 oropharyngeal carcinoma between January 2001 and July 2008. Patients were divided into the following 3 groups: (1) those who underwent robotic-assisted surgery for a primary neoplasm (robotic primary) (n=15), (2) those who had robotic-assisted salvage (robotic salvage) surgery (n=7), and (3) those who required open salvage resection (n=14). Demographic data and tumor characteristics for each group are summarized in **Table 1**. Thirty-five patients were diagnosed as having squamous cell carcinoma and 1 patient was diagnosed as having recurrent mucoepidermoid carcinoma. A greater proportion of patients in the robotic primary and open salvage groups underwent resection for tonsillar carcinoma ($P=.04$) and had advanced-stage disease at the time of surgery ($P=.002$). There was no difference in T stage of disease between all 3 groups ($P=.25$). For patients who underwent salvage resection, previous head and neck cancer treatment consisted of chemotherapy and radiation, radiation alone, surgical resection, or combination therapy (**Table 2**).

OPERATIVE OUTCOMES

Excellent 3-dimensional visualization was afforded by the da Vinci Robot (**Figure 1**). A total of 7 patients underwent successful transoral robotic salvage resection (**Figure 2**), and negative margins were achieved in all 22 robotic-assisted patients (both primary and salvage). One patient from the robotic primary group required additional resection for a positive distal margin, which was negative following carbon dioxide laser excision. Negative margins were achieved in 12 patients (86%) who underwent open resection. In all cases, frozen section was used to confirm negative resection margins (at ≥4 mm). Neck dissection was performed immediately following transoral resection or during a staged operation (**Table 3**). Three robotic salvage patients and 1 open resection patient had prior neck dissections. All 4 had positive nodal metastasis at the time of initial operation.

POSTOPERATIVE OUTCOMES

Length of hospital stay was greater for patients who underwent open salvage resection (8.2 days) compared with robotic salvage (5.0 days) ($P=.14$) and robotic primary resection groups (1.5 days) ($P<.001$). Three patients (42%) who underwent robotic salvage surgery and 12 patients (80%) who underwent robotic primary surgery were tolerating oral nutrition prior to discharge. One patient required short-term nasal tube feedings, and 6 patients were gastrostomy tube dependent. There was no difference in postoperative diet between robotic primary and robotic salvage surgery groups ($P=.26$). All patients tol-

Table 1. Patient Characteristics

Characteristic	Patients, No. (%) Robotic Primary (n=15)	Robotic Salvage (n=7)	Open Salvage (n=14)	*P* Value
Age, mean (SD), y	56.1 (12)	67.7 (5)	59.0 (11)	.07
Sex				
Male	13 (87)	6 (86)	12 (86)	.99
Female	2 (13)	1 (14)	2 (14.3)	
Primary tumor subsite				
Base of tongue	4 (27)	5 (71)	5 (36)	.04
Tonsil	8 (53)	0	5 (36)	
Soft palate	0	1 (14)	4 (29)	
Pharyngeal wall	3 (20)	1 (14)	0	
T category				
T1	6 (40)	4 (57)	3 (21)	.25
T2	9 (60)	3 (43)	11 (79)	
Stage				
1	0	4 (57)	0	.002
2	6 (40)	2 (29)	8 (57)	
3	3 (20)	1 (14)	1 (7)	
4	6 (40)	0	5 (36)	

Abbreviations: Open Salvage, open salvage resection for recurrent disease; Robotic Primary, robotic-assisted surgery for primary neoplasms; Robotic Salvage, robotic-assisted salvage surgery for recurrent disease.

Table 2. Summary of Previous Head and Neck Therapy

Previous Treatment	Patients, No. (%) Robotic Salvage (n = 7)	Open Salvage (n = 14)
Surgery	0	1 (7)
Radiation	2 (29)	6 (43)
Chemoradiotherapy	2 (29)	4 (29)
Surgery + radiation	1 (14)	3 (21)
Surgery + chemoradiotherapy	2 (29)	0

Abbreviations: Open Salvage, open salvage resection for recurrent disease; Robotic Salvage, robotic-assisted salvage surgery for recurrent disease.

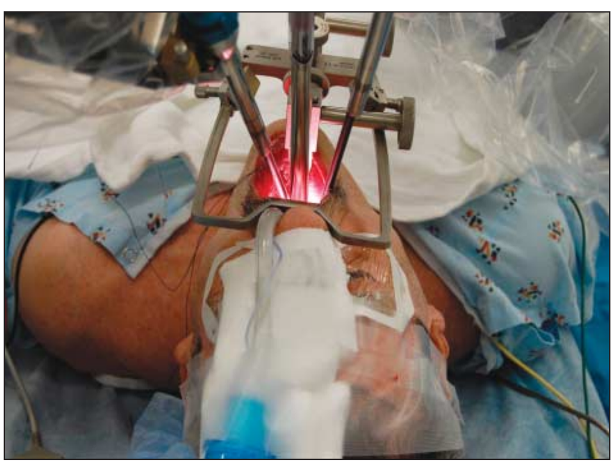

Figure 1. Intraoperative view of the 3 robotic arms inserted transorally.

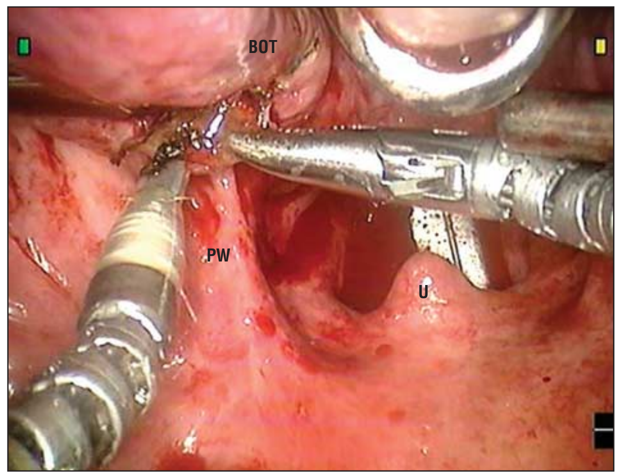

Figure 2. Robotic-assisted salvage surgery for a T2 base of tongue (BOT) lesion. The first mucosal incision has been made with excellent 3-dimensional visualization of the oropharynx including the uvula (U) and lateral pharyngeal wall (PW).

erated oral nutrition by 2 months postoperatively. Among the open resection patients, 35% tolerated oral nutrition at the time of hospital discharge, while the remaining patients required supplemental gastrostomy tube feedings. A greater proportion of open resection patients were gastrostomy tube dependent 6 months following treatment (43%) compared with robotic salvage (0%) or robotic primary resection patients (7%) ($P = .06$).

All patients who underwent open resection for oropharyngeal neoplasms required a tracheostomy. Tracheostomy was not performed at the time of surgery in patients who underwent robotic primary or robotic salvage surgery. One patient who underwent robotic primary surgery developed respiratory distress and pneumonia with prolonged ventilation and eventually required tracheotomy tube placement. The patient was decannulated prior to discharge. Six months following surgery, no patients from the robotic-assisted surgery groups and 1 patient (7%) from the open salvage surgery group remained tracheotomy tube dependent ($P = .48$).

No postoperative complications were reported in the robotic salvage group. Two patients who underwent robotic primary resection developed postoperative bleeding from the resection site. One patient was reintubated for 48 hours because of short-term airway edema, and 1 patient developed pneumonia, requiring prolonged ventilation and tracheostomy. Two patients who underwent open resection developed postoperative wound infections. One patient developed a neck abscess, which required incision and drainage. Despite further medical treatment, the patient experienced flap loss and required additional reconstructive surgery. In addition, 2 patients developed postoperative hematomas—one occurred at the donor site and was managed conservatively.

COMMENT

The treatment of head and neck squamous cell carcinoma has evolved over the years to include surgical, radiotherapeutic, chemotherapeutic, and combined therapy approaches. Despite surgical and medical advances, survival rates have remained unchanged and locoregional recurrence is a common concern. Primary surgical resection of oral cavity and oropharyngeal neoplasms results in locoregional control rates ranging from 60% to 85%.[14] Postoperative irradiation provides further disease control,[15] though a substantial number of patients still require salvage therapy. Aggressive surgical resection with mandibulotomy or pharyngectomy has typically been required to provide adequate excision of recurrent oropharyngeal tumors. These procedures result in significant speech and swallowing dysfunction as well as cosmetic deformity.[5,6]

The introduction of transoral endoscopic laser microsurgery reintroduced primary surgery as a means for the treatment of tongue base neoplasms[16] and has since also been applied to oropharyngeal salvage resection.[17] Although nonrobotic transoral techniques have been shown to reduce morbidity and mortality, this type of approach is limited by a smaller operative field and the need for line-of-sight manipulation. Transoral robotic-assisted surgery represents the latest minimally invasive alternative for the treatment of head and neck squamous cell carcinoma. Like endoscopic microsurgery, robotic assistance has been proven effective for the treatment of primary upper aerodigestive tract lesions[10-12] and provides several advantages including improved optics, 3-dimensional tumor visualization, and tremor filtration. In the present study, we demonstrate the safety and feasibility of robotic-assisted surgery and compare outcomes between robotic-assisted and open salvage techniques.

Robotic-assisted resection of recurrent oropharyngeal neoplasms was successful in all patients (n=7). Length of hospital stay (5.0 days) was reduced compared with open salvage resection (8.2 days) and all patients were able to tolerate oral nutrition by 2 months postoperatively. Previous studies have demonstrated an excellent ability to maintain oral nutrition following robotic primary surgery. In a study by Genden et al,[18] patients tolerated oral nutrition at an average of 1.4 days after surgery without clinical evidence of aspiration or velopharyngeal reflux. Eighty percent of robotic primary resection patients in this study tolerated oral nutrition at the time of discharge (1.5 days). Six months postoperatively, no robotic salvage patients were gastrostomy tube dependent. In comparison, nearly 43% of open salvage patients required supplemental tube feedings ($P=.06$). Open surgical procedures have a negative impact on swallowing and mastication, resulting in gastrostomy tube dependence. Transoral robotic resection improves functional outcomes in patients with both primary and recurrent oropharyngeal neoplasms compared with traditional surgical methods.

Table 3. Neck Dissection (ND) and Associated Nodal Metastasis

	Robotic Primary (n=15)	Robotic Salvage (n=7)	Open Salvage (n=14)
ND			
Concomitant	5	1	12
Staged	7	0	0
Previous	0	3	1
None	3	3	1
Total No. of NDs per group	12	4	13
Nodal metastasis (current or previous ND), No. (%)			
Yes	5 (42)	3 (75)	4 (31)
No	7 (58)	1 (25)	9 (69)

Abbreviations: Open Salvage, open salvage resection for recurrent disease; Robotic Primary, robotic-assisted surgery for primary neoplasms; Robotic Salvage, robotic-assisted salvage surgery for recurrent disease.

Previous studies have demonstrated that transoral robotic surgery can be performed safely without the need for tracheostomy.[11] In our study, nonrobotic-assisted surgery patients required tracheotomy tube placement at the time of surgery. In contrast, all open salvage patients required a tracheostomy. One patient from the robotic primary group developed short-term airway edema and was reintubated. As a result, patients who undergo robotic-assisted base of tongue resection remain intubated 24 to 48 hours postoperatively. Transoral robotic surgery has not been shown to increase airway edema, though there are reports of patients who remained intubated for an average of 2.7 days following radical tonsillectomy.[10] Transoral robotic surgery may require prolonged intubation in select patients.

The majority of patients who underwent open salvage surgery required composite resection and free flap reconstruction. These procedures are highly associated with morbidity and complications including flap failure and the need for additional surgery. Complications in the robotic primary group were consistent with transoral excision by any approach and included delayed postoperative bleeding and airway edema requiring reintubation. No complications were reported in the robotic salvage group. Of note, concomitant neck dissection was performed in 5 robotic primary patients and 1 robotic salvage patient. No orocervical fistula or increase in complications was noted.

This study is limited in that it is a retrospective review of outcomes associated with early-stage oropharyn-

geal carcinoma. Patients with T3 or T4 neoplasms were excluded from the investigation to allow for a side-by-side comparison of robotic and open procedures. Although T3 lesions of the larynx have been reportedly excised via transoral robotic surgery, the majority of robotic-assisted cases involve early-stage T1 and T2 lesions of the upper aerodigestive tract.[18] Conversely, open surgical resection is often required for large T-stage lesions and advanced disease. At the time of this study, 1 patient had undergone robotic salvage resection for a T3 lesion of the oropharynx. Resection proved to be more technically difficult but was successful with the patient experiencing an uncomplicated recovery.

Although robotic salvage therapy may not be reasonable for advanced T category disease, it appears to be safe and feasible for the treatment of select T1 and T2 oropharyngeal neoplasms as an alternative to open salvage resection. Further studies are required to identify long-term oncologic outcomes associated with robotic-assisted surgery and to compare those with outcomes achieved with other transoral techniques such as laser microsurgery.

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Author Contributions: Dr Magnuson had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Dean, Rosenthal, Carroll, and Magnuson. *Acquisition of data:* Dean, Kostrzewa, Jones, and Clemons. *Analysis and interpretation of data:* Dean and Desmond. *Drafting of the manuscript:* Dean, Kostrzewa, Jones, Desmond, and Clemons. *Critical revision of the manuscript for important intellectual content:* Dean, Rosenthal, Carroll, and Magnuson. *Statistical analysis:* Dean and Desmond. *Obtained funding:* Rosenthal. *Administrative, technical, and material support:* Dean, Clemons, and Magnuson. *Study supervision:* Rosenthal, Carroll, and Magnuson.
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