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Transoral endoscopy-assisted low-temperature plasma for the treatment of oropharyngeal malignant tumours: Preliminary Reports from a Single-Centre Retrospective Analysis

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Abstract

Objectives This study investigated the characteristics and clinical efficacy of transoral endoscopy-assisted low-temperature plasma surgery for the treatment of oropharyngeal malignant tumours.

Methods The clinical data of 14 patients who underwent transoral endoscopy-assisted low-temperature plasma resection of oropharyngeal malignant tumours in the Department of Otolaryngology-Head and Neck Surgery from January 2017 to October 2024 were retrospectively analysed. The general characteristics, clinical pathology results, surgical methods, operative time, volume of blood loss, length of hospitalization, and follow-up status of the patients were analysed.

Results The 14 patients included 13 males and 1 female, and the average age was 60 ± 9 years. Three patients received flaps for wound repair (1 forearm flap, 1 platysma myocutaneous flap, and 1 submental flap), 6 patients underwent unilateral neck lymph node dissection, 5 patients underwent bilateral neck lymph node dissection, and 1 patient underwent preventive tracheotomy. The average duration of the operations was 231 ± 114 min, and the average duration of tumour resection was 53 ± 15 min. The average volume of blood loss was 66 ± 55 ml, and the average duration of hospitalization was 10 ± 5 days. Postoperative pathology confirmed that 13 patients had squamous cell carcinoma, and 1 patient had mucoepidermoid carcinoma. The average duration of postoperative follow-up was 20 ± 14 months. One patient developed multisystem metastases, and one patient experienced tumour recurrence. all other patients survived well.

Conclusions Transoral surgery has become more common as a minimally invasive approach for treating oropharyngeal tumours. Transoral endoscopy-assisted low-temperature plasma-assisted resection of oropharyngeal malignant tumours may be used as a surgical approach.

Keywords Oropharyngeal malignant tumors, Endoscopy, Low-temperature plasma

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Introduction

Oropharyngeal malignant tumours are common malignant tumours that involve the upper respiratory tract and digestive tract [1, 2]. Smoking, alcohol consumption and human papillomavirus (HPV) infection are the main risk factors for these tumours, and they affect males more than females (male:female ratio ranging from 3:1 to 4:1). Among these tumours, HPV type 16 infection is the most common. At present, HPV-related oropharyngeal malignant tumours located in tonsils and tongue roots are considered unique diseases [3]. The main clinical manifestations include foreign body sensations in the pharynx, pharyngeal local pain, earache, and difficulty swallowing and breathing if the tumour grows rapidly [4, 5].

Studies have shown that radiotherapy (RT) is an effective method for treating oropharyngeal malignant tumours. In particular, definitive cisplatin-based chemoradiotherapy via the intensity-modulated technique is the standard of care for oropharyngeal malignant tumours, but this approach has drawbacks in terms of toxicity and subsequent patient quality of life (QoL) [6, 7]. For patients with early-stage disease (T1-T2), open surgery is the main treatment modality, and the purpose of surgical treatment is to reduce the postoperative tumour recurrence rate and incidence of complications [8]. Therefore, additional treatment methods are currently being explored for oropharyngeal malignant tumours [9, 10].

In recent years, surgeries for treating oropharyngeal malignant tumours have tended towards more transoral minimally invasive strategies, which have a lower complication rate than open surgeries. Minimally invasive techniques have improved patient outcomes. With the development of endoscopic surgical technology, endoscopy has gradually been used to treat oropharyngeal malignant tumours [11, 12].

Low-temperature plasma (LTP) has also been shown to effectively remove oropharyngeal lesions, as it can be used to perform low-temperature ablation, haemostasis, detachment and irrigation. Moreover, the use of LTP has been proven to be effective in tonsillectomy and adenoidectomy [13]. The plasma scalpel is composed of a conductive medium (sodium) and generates a high-concentration plasma consisting of highly ionized particles around the electrode. Because the current does not generate a large amount of heat through the tissues, the procedure does not risk burning the patient's tissues unnecessarily. Notably, unlike the mechanism by which common electric haemostasis devices stop bleeding, plasma haemostasis avoids injuring the patient and is becoming increasingly popular in surgical haemostasis and wound healing [13, 14]. Although LTP has advantages in haemostasis and thermal injury, it also has the disadvantages of high cost and great technical difficulty. It is necessary to evaluate the individual situation of patients and for operations to be performed by experienced doctors to reduce risks. Therefore, this study investigated the characteristics and clinical efficacy of transoral endoscopy-assisted low-temperature plasma surgery for the treatment of oropharyngeal malignant tumours.

Materials and Methods

The Ethics Review Committee of the Affiliated Hospital of Southwest Medical University approved this protocol (Approval Number: KY2024256). Owing to the retrospective nature of this study, the need for informed consent was waived by the Research Ethics Committee.

Patients and clinical evaluation

The following data were collected from patients who underwent transoral endoscopy-assisted LTP resection of oropharyngeal malignant tumours in our department from January 2017 to October 2024: age, sex, history of smoking, history of alcohol consumption, neck lymph node dissection and tracheotomy, volume of intraoperative bleeding, tumour-node-metastasis (TNM) stage, pathological type, any additional RT or chemotherapy after surgery, and postoperative follow-up data.

Surgical methods

All patients were placed under general anaesthesia through nasal tracheal intubation. With the patient in the supine position, the mouth was opened to the maximum extent possible with a Boyle–Davis mouth gag to expose the pharyngeal cavity. A mark was made 1 cm from the tumour boundary, along which the tumour was resected with plasma (MC401) under joint monitoring with a 4-mm diameter, 0° endoscope and a high-definition camera system (Karl Storz GmbH & Co. KG). After tumour resection, the surgical field was carefully examined under the endoscope to ensure the absence of residual tumour, while the tumour margin tissue was sent for intraoperative frozen tumour section analysis. A plasma surgical electrode was used to completely stop any bleeding. For patients with T1–T2–stage tumours and magnetic resonance imaging (MRI) data showing that the depth of tumour invasion was > 3 mm, those with T3–T4 tumours but no distant metastasis, and those with highly malignant mucoepidermoid carcinoma (MEC), neck lymph node dissection was performed concurrently with primary tumour resection. After surgery, the patient was routinely implanted with an indwelling gastric tube and was regularly followed up in the outpatient clinic.

Results

Clinical patient characteristics

All patients had oropharyngeal malignant tumours confirmed by pathology, including 3 patients with malignant tumours of the tongue root, 3 patients with malignant tumours of the soft palate, 2 patients with malignant tumours of the uvula, and 6 patients with malignant tumours of the tonsil. None of the included patients had a history of oropharyngeal lesions or tumours in other locations. The clinical characteristics of the 14 patients are shown in Table 1.

All 14 patients successfully underwent transoral endoscopy-assisted LTP resection of their oropharyngeal malignant tumours. The 14 patients included 13 males and 1 female, with an average age of 60 ± 9 years (median: 59 years; range: 47–76 years). Among them, 3 patients received flaps for wound repair (1 forearm flap, 1 platysma myocutaneous flap, and 1 submental flap); 11 patients underwent neck lymph node dissection due to preoperative suspicion of lymph node metastasis (6 patients underwent selective unilateral neck lymph node dissection, and 5 patients underwent bilateral neck lymph node dissection); 1 patient had MEC, but his family refused neck lymph node dissection, so he only underwent transoral tumour resection; and 1 patient underwent preventive tracheotomy. Notably, in this study, the operative time was divided into the transoral endoscopy-assisted LTP tumour resection time and the overall operative time, which included anaesthesia and intubation, tumour resection, neck lymph node dissection, tracheotomy, and microvascular anastomosis. Among them, the average time of transoral endoscopy-assisted LTP tumour resection was 53 ± 15 min (median: 53 min, range: 25–80 min), and the overall mean operative time was 231 ± 114 min (median: 235 min; range: 40–360 min). During the whole operation, the mean blood loss volume was 66 ± 55 ml (median: 45 ml; range: 20–150 ml).

In this study, a safe distance of at least 1 cm was reserved to remove the tumor. We confirmed that the surgical margins of all patients were negative via intraoperative frozen sections. Among the 14 patients, histopathology revealed that 13 had squamous cell carcinoma (SCC), and 1 had MEC. Immunohistochemistry revealed p16 positivity in 4 patients. According to the ranges of the tumour and the lymph node metastasis status after surgery and following multidisciplinary consultation and discussion, 9 patients received RT after surgery at a dose of 60 Gy/33 fractions. One of these patients also received concurrent chemotherapy for 4–6 cycles; 3 patients refused further adjuvant therapy after surgery; and 2 patients did not receive RT after surgery.

All patients received a routine indwelling gastric tube for 5 days after the operation. Because 3 patients underwent flap repair, the oral diet was delayed for 3 days, and the average time of the oral diet for all patients after the operation was 6 ± 1 days (median: 5 days; range: 5–8 days). The swallowing and pronunciation function recovered well after operation. Local postoperative complications included wound infection in 1 patient; no serious postoperative complications were observed in the other patients. All patients were discharged smoothly. The mean duration of hospitalization was 10 ± 5 days (median: 8 days; range: 5–20 days).

All patients were followed up regularly, with a mean duration of 20 ± 14 months (median: 16 months; range: 1–48 months). No tumour recurrence was observed in 12 patients; 1 patient with a uvula tumour who received RT died due to multisystem metastases 33 months after surgery; and 1 patient with a tonsil tumour who refused further adjuvant therapy experienced tumour recurrence 30 months after surgery.

Case presentation

A 71-year-old male patient was admitted to the hospital due to a sore throat without other clinical manifestations, a history of smoking for 40 years and a history of drinking for 50 years. Physical examination revealed cauliflower-like neoplasms on the left soft palate, tonsils, and left border of the tongue root. Preoperative contrast-enhanced MRI (CE-MRI) (Fig. 1A and B) and contrast-enhanced computed tomography (CE-CT) (Fig. 1C) of the neck revealed abnormal enhancement of the soft tissue on the left oropharyngeal wall and the left border of the tongue root, suggesting the presence of a neoplastic lesion. The patient underwent transoral endoscopy-assisted LTP extended resection for lesions in the soft palate, tonsils, and tongue root (Fig. 1G and H) and selective lymph node dissection in the left neck. Postoperative pathological examination suggested SCC, and no cancer metastasis was found in the neck lymph nodes. The immunohistochemistry results suggested that the patient was p16 (+). Postoperative RT was performed. CE-MRI (Fig. 1D and E), CE-CT (Fig. 1F) and laryngoscopy (F ig. 1I) of the neck at the 13th month of follow-up revealed no tumour recurrence.

Discussion

The incidence of oropharyngeal malignancies, the most common of which is oropharyngeal squamous cell carcinoma (OPSCC), has increased substantially in recent years. Worldwide, the pathogenesis of approximately 60% of oropharyngeal malignant tumours is associated with HPV infection, but in China, this value is notably lower, with only approximately 10–20% of all cases

Table 1 Clinical characteristics of patients

Patient number	Age	Sex	Tumour position	Smoking history	Drinking history	Hospital stay (day)	Surgical bleeding	Tumor resection / Total operation time (minutes)	Surgical margin	Tracheotomy	Neck dissection	Histological diagnosis	TNM	$_{P}$16	Adjuvant therapy	Follow-up time (month)
1	51	M	Tongue root	N	N	7	100	80/220	Negative	Y	Y	Squamous cell carcinoma	T2N1M0	–	Radiotherapy	48
2	60	M	Soft palate	Y	Y	6	60	65/240	Negative	N	Y	Squamous cell carcinoma	T1N0M0	–	/	36
3	73	M	Soft palate	Y	Y	19	150	60/360	Negative	N	Y	Squamous cell carcinoma	T3N0M0	–	R	35
4	50	M	Uvula	Y	Y	5	20	25/40	Negative	N	N	Squamous cell carcinoma	T1N0M0	–	Radiotherapy	33
5	50	M	Tonsil	Y	Y	15	200	65/420	Negative	N	Y	Squamous cell carcinoma	T2N1M0	+	R	30
6	56	M	Tonsil	Y	Y	9	40	50/150	Negative	N	Y	Squamous cell carcinoma	T4N2M0	–	Radiotherapy + Chemotherapy	23
7	47	M	Tonsil	N	N	5	20	40/60	Negative	N	N	Squamous cell carcinoma	T1N0M0	–	Radiotherapy	16
8	59	M	Soft palate	Y	Y	6	15	45/200	Negative	N	Y	Squamous cell carcinoma	T2N0M0	–	Radiotherapy	15
9	66	M	Uvula	Y	Y	8	30	35/230	Negative	N	Y	Squamous cell carcinoma	T1N0M0	–	/	13
10	58	M	Tonsil	Y	Y	10	50	45/340	Negative	N	Y	Squamous cell carcinoma	T2N2M0	–	Radiotherapy	12
11	76	M	Tongue root	N	N	20	30	70/100	Negative	N	R	Mucoepidermoid carcinoma	T3N0M0	–	R	12
12	71	M	Tongue root	Y	N	11	30	55/240	Negative	N	Y	Squamous cell carcinoma	T2N0M0	+	Radiotherapy	11

Table 1 (continued)

Patient number	Age	Sex	Tumour position	Smoking history	Drinking history	Hospital stay (day)	Surgical bleeding	Tumor resection / Total operation time (minutes)	Surgical margin	Tracheotomy	Neck dissection	Histological diagnosis	TNM	$_{P}$16	Adjuvant therapy	Follow-up time (month)
13	60	M	Tonsil	N	N	8	100	50/300	Negative	N	Y	Squamous cell carcinoma	T2N2M0	+	Radiotherapy	1
14	56	F	Tonsil	N	N	8	80	55/330	Negative	N	Y	Squamous cell carcinoma	T2N2M0	+	Radiotherapy	1

Abbreviations: F Female, *M* Male, *N* No, *Y* Yes, *R* Refuse

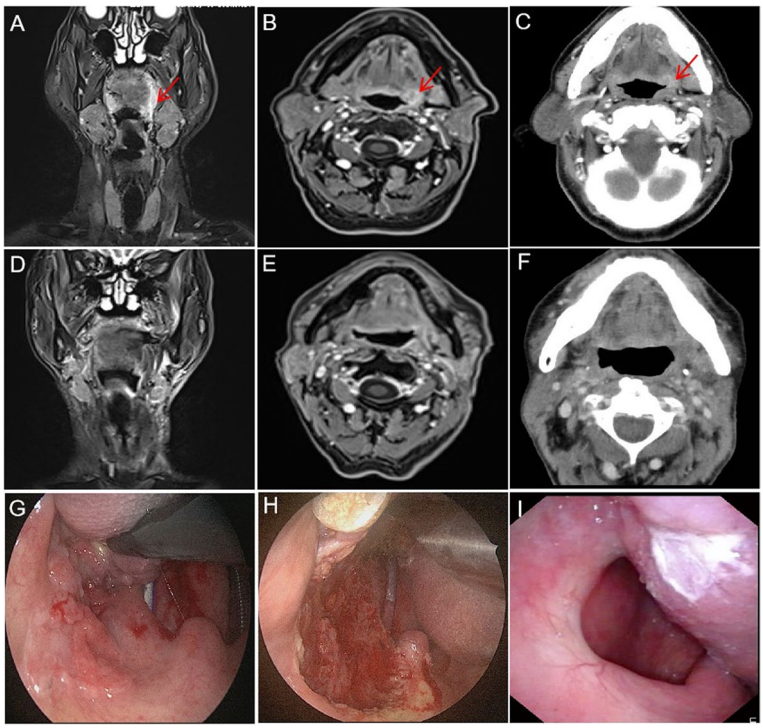

Fig. 1 Cervical imaging and surgical field of vision of patients with oropharyngeal malignant tumor: The coronal plane (**A**) and transverse position (**B**) of preoperative neck CE-MRI show that the tumor on the left side of oropharynx-the left edge of tongue root-the back of soft palate shows uneven enhancement with unclear boundary (red arrow). **C** Preoperative CE-CT of the neck showed uneven thickening of the mucosa from the left wall of oropharynx to the left tongue root, and the enhanced scanning was obviously enhanced (red arrow). **D**-**F** Postoperative follow-up showed that no tumor recurrence was found in neck CE-MRI and CE-CT. **G** Displaying the lesion range of oropharyngeal tumor through oral endoscope. **H** Display the wound surface after tumor resection through oral endoscope. **I** 15 months after operation, the follow-up laryngoscope showed no recurrence of the tumor

demonstrating positivity in the HPV test [15]. In the present study, 13 of the 14 patients had OPSCC, and the immunohistochemistry findings indicated p16 positivity in 4 patients.

The connection between HPV and OPSCC is well known, and HPV-16 is the most frequently involved subtype (85–90% of virus-related cases) [16]. Infection of the oropharyngeal squamous epithelium with HPV could result in a productive life cycle closely coupled with progressive differentiation of epithelial cells, culminating in virion generation and egress [17]. Patients with HPV-positive OPSCC have a favourable prognosis in comparison with those with HPV-negative OPSCC [16], and mutations associated with tumour suppressor genes such as p53 are relatively infrequent in the former [17].

Studies have reported that HPV-positive patients with oropharyngeal malignant tumours have similar overall survival rates between surgical treatment and RT alone; however, for HPV-negative patients with oropharyngeal malignant tumours, the overall survival rate following surgical treatment has been reported to be significantly better than that following RT alone. Since most patients with oropharyngeal malignant tumours in China are HPV negative, surgical treatment, including transoral endoscopy-assisted LTP surgery, should be considered when managing their lesions.

Given the different causes and pathogeneses of oropharyngeal malignant tumours, the preferred treatments are also changing and can currently be divided into open surgery and oral surgery [18]. Open surgeries include mandibular osteotomy and mandibular resection, but the limitations of this approach include a long operating time, a high degree of trauma, and a high incidence of treatment-related complications. Previous studies have indicated that in open surgery, the incidence of complications is approximately 50%, and the 5-year overall survival rate is approximately 20% [9]. Compared with open surgery, the emergence of endoscopy-assisted LTP technology has greatly reduced the difficulty of lesion resection and the need for flap repair, shortened the gastric tube indwelling time, caused less intraoperative trauma, and significantly improved the postoperative QoL of patients [12].

Given the improvements in the postoperative QoL of patients and reductions in the incidence of complications, transoral surgery has gradually become accepted by patients with tumours. When the lesions are superficial and easily removed, the range of invasion is limited, and there is no extensive or distant metastasis, the doctor can perform surgical resection under direct vision; however, for deep and posterior lesions and those that cannot be directly observed by the naked eye, endoscopy-assisted surgery can be used to remove them. Compared with traditional transoral surgical methods under direct vision, endoscopy-assisted LTP enables a clearer field of view with no blind angles or spots, while the plasma itself causes less intraoperative bleeding.

Transoral laser microsurgery (TLM), the main minimally invasive treatment for oropharyngeal malignant tumours, can also improve the QoL of patients. For oropharyngeal malignant tumours, TLM is superior to open surgery [19]. As a minimally invasive procedure, TLM is associated with minimal surgical trauma, a short hospital stay, and low hospitalization costs. However, TLM also has several drawbacks: 1) owing to the limited operating area of the microscope in the body, large tumours cannot be completely resected in one shot and must instead be removed in blocks [11]; 2) the surgical field of view is insufficient, which severely limits the operative range [20]; and 3) it is difficult for the TLM laser delivery system to enter the oropharynx, and the ablation produced by the laser beam may also affect the assessment of the surgical margins [21].

Transoral robotic surgery (TORS) is a relatively new technology that has been widely used in the minimally invasive surgical treatment of various tumours; some studies have shown that TORS is effective in treating oropharyngeal malignant tumours [22]. TORS overcomes one deficiency of the TLM, i.e., the limited surgical field, providing a more direct three-dimensional (3D) view and enabling the use of minimally invasive surgical methods to obtain optimal oncological results [23]. However, TORS also has its own deficiencies: 1) the most common adverse reaction is postoperative bleeding, with an incidence between 3 and 8% [24]; 2) other potential complications, such as aspiration pneumonia and difficulty swallowing; and 3) most importantly, the need for specific surgical equipment and personnel training, high initial costs, long operation times, and high equipment maintenance costs [25]. Therefore, TORS is not widely used at present. Compared with TORS, endoscopy-assisted LTP surgery does not require the purchase of expensive equipment; indeed, most hospitals already have endoscopic and plasma equipment and can perform endoscopy-assisted LTP surgery immediately.

As associated technology has continued to improve, transoral endoscopic surgery has gradually become widely used to treat oropharyngeal malignant tumours. Studies have shown that transoral endoscopic surgery can be used to remove deep tumours through the nasal, oral and other cavities and is a safe and effective technique for treating oropharyngeal malignant tumours [12]. Yamashita et al. [20] described the application of transoral endoscopic resection in patients with T1–T3–stage oropharyngeal malignant tumours and demonstrated the feasibility of this surgical approach.

Compared with TLM and TORS, transoral endoscopic surgery has many advantages: 1) it uses a 0° and 30° endoscope in combination with a high-definition camera monitoring system and provides sufficient lighting and a wide surgical field of view; 2) it does not require a specialized operating room or surgical equipment; 3) the surgeon does not need special training; 4) the surgical time is short, and the surgical and equipment maintenance costs are low; 5) the tumour boundary is better identified for complete tumour resection, allowing efficient and safe minimally invasive surgery; and 6) postoperative functional retention is high, and recovery is quick. Combined with related research, Compared with transoral endoscopy, the incidence of short-term complications (infection, Skin flap necrosis) and long-term complications (swallowing and pronunciation dysfunction) after open surgery is high; Short-term complications after laser and robot surgery (Scar stenosis, local tumor recurrence, bleeding and transient dyspnea) are obvious [12]. Transoral endoscopy-assisted low-temperature plasma is not only minimally invasive, but also has a good recovery of swallowing and pronunciation after operation.

Limitations

This study has several limitations. First, the small size of the cohort is the main weakness of this work; on the other hand, this study was only intended to present a preliminary case series. Second, this work only reported OPSCC patients treated using endoscopy-assisted LTP and lacked data concerning other surgical approaches. Third, the follow-up time was short, and more patients and longer durations are needed to verify the advantages and characteristics of transoral endoscopy-assisted LTP surgery.

Conclusion

According to the preliminary results, transoral endoscopy-assisted low-temperature plasma may also be a surgical method for the treatment of oropharyngeal malignant tumours. This method can provide a clear surgical field and sufficient working space to cover the whole oropharyngeal area to achieve safe and reliable whole resection of OPSCC.

Moreover, the study team plans to supplement the existing findings by increasing the number of cases and extending the follow-up time in the future.

Abbreviations

HPV	Human papillomavirus
LTP	Low-temperature plasma
QoL	Quality of life
TNM	Tumour-node-metastasis
RT	Radiotherapy
MEC	Mucoepidermoid carcinoma
OPSCC	Oropharyngeal squamous cell carcinoma
SCC	Squamous cell carcinoma
CE-MRI	Contrast-enhanced magnetic resonance imaging
CE-CT	Contrast-enhanced computed tomography
TLM	Transoral laser microsurgery
TORS	Transoral robotic surgery

Supplementary Information

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Supplementary Material 1.

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Statements and declarations
Not applicable.

Authors' contribution
G.Q. designed the study, performed surgeries, and made critical revisions to the manuscript. X.C., D.W., and H. F. collected and analysed the clinical data. X.C. and D.W. wrote the manuscript. S.X., W.Z., and F.L. performed the statistical analysis. All the authors have read and approved the final manuscript.

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Data availability
All the data generated or analysed during this study are included in this published article.

Declarations

Ethics approval and consent to participate
The Ethics Review Committee of the Affiliated Hospital of Southwest Medical University approved this protocol (Approval Number: KY2024256). Owing to the retrospective nature of this study, the need for informed consent was waived by the Research Ethics Committee.

Competing interests
The authors declare no competing interests.

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