Manubrial Resection and Anterior Mediastinal Tracheostomy: Friend or Foe?

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OBJECTIVES/HYPOTHESIS: To review our experience with manubrial resection and anterior mediastinal tracheostomy and formulate operative guidelines to improve the surgical outcome.

Study Design: Retrospective study.

Methods: Between January 1980 and June 2010, we performed 38 manubrial resections. The indications of the procedure, reconstructive methods, and operative outcomes were analyzed.

Results: Fourteen patients had tumors of the hypopharynx/cervical esophagus, eight had parastomal recurrences of laryngeal tumor, four had recurrent esophageal tumors, four had postirradiation sarcoma, four suffered from subglottic/upper tracheal tumors, three had thyroid malignancy, and the remaining patient had tumor recurrence at the previous tracheostomy site. The hospital mortality rate was 5.3% due to bleeding from major vessel erosion. The mean length of the tracheal stump was 5.4 cm, of which 81.6% required relocation inferior to the innominate artery for construction of the mediastinal tracheostomy. Among the different reconstructive methods for the pharyngoesophageal defects, the anastomotic leakage rate was 17.6%, the majority of which required exteriorization followed by second stage reconstruction. The long-term tracheostomy stenosis rate was 47.4%, the risk of which was significantly increased by anastomotic leakage and necrosis of distal trachea. The use of a pectoralis major flap was shown to protect against this complication. The overall survival was 80.6% at 1 year and 55.6% at 5 years after surgery.

Conclusions: With attention to operative details, manubrial resection and anterior mediastinal tracheostomy is a safe procedure with acceptable outcome. It should be performed when indicated to facilitate tumor resection in the cervicothoracic region.

Key Words: Manubrial resection, anterior mediastinal tracheostomy, innominate artery rupture, stenosis of tracheostomy.

Level of Evidence: 4

INTRODUCTION

When facing extensive tumors involving the cervicothoracic region, resection of the manubrium allows a wider resection and a better marginal control of both the cervical esophagus and the trachea, which is followed by the construction of an anterior mediastinal tracheostomy. Early series showed that the procedure was associated with significant morbidity and mortality. The purpose of our study is to review our experience of the approach over the last 3 decades.

MATERIALS AND METHODS

Between January 1980 and June 2010, at the Division of Head and Neck Surgery, Department of Surgery, The University of Hong Kong at Queen Mary Hospital, we carried out manubrial resection and anterior mediastinal tracheostomy for 38 patients presenting with tumors involving the cervicothoracic region.

All patients had a preoperative work-up for tumor staging. Endoscopic examination was performed to assess the local extent of disease and to rule out the presence of synchronous tumors. Magnetic resonance imaging provided detailed planning of the extent of resection, and also allowed better assessment of the extent of mediastinal lymph node involvement and the presence of great vessel invasion, the presence of which might signify unresectability. Preoperative nutritional build-up was mandatory in malnourished patients, and lung function test and assessment by a respiratory physician was required in smokers and patients with a history of pulmonary disease. All of our patients had removal of the manubrium so that resection of the underlying tumor could be performed. In addition to the usual transverse cervical or apron incision, a median vertical limb of the incision was made down to below the angle of Louis. Skin and subcutaneous fat was dissected from the underlying bone, exposing the bilateral sternoclavicular joints, the manubrium, and the medial ends of the first and second ribs. Care was taken to preserve the perforators arising from the internal mammary arteries, which supplied the deltopectoral flap. At the suprasternal notch, both the anterior jugular veins were ligated and divided, and the sternal heads of both sternocleidomastoid muscles were released. Afterward, a plane underneath the manubrial bone was developed by blunt dissection, separating the thymus and the surrounding great vessels and pleura from the undersurface of the bone to prevent inadvertent...
damage of these structure during osteotomy. Using the sternal saw with a guard, both medial ends of the clavicle together with the sternoclavicular joints, medial ends, and the costochondral junction of the first and second ribs and the manubrium were removed. Any bleeding from the cut edge of the bone were stopped by bone wax. The internal mammary arteries and the pleura were preserved. Surgical resection of the tumor was then carried out depending on the location and extent of the primary disease. Either laryngectomy, resection of the trachea, pharyngoesophagectomy, or a combination of the above was performed. Intraoperative frozen section examination of the resection margins was employed to ensure microscopic clearance of the tumor. After tracheal resection, if the remaining tracheal stump was too short, it was relocated below the innominate artery and brought out as an anterior mediastinal tracheostomy (Fig. 1). In case there was tension on wound closure, the pectoralis major (PM) flap was used for reconstruction (Fig. 2). Insertion of a chest drain was performed if the pleura was injured during the operation. A mediastinal drain was inserted in addition to the usual neck drains to avoid collection at the mediastinum. With the help of the anesthetist, an intraoperative Valsalva maneuver was performed to look out for possible lymphatic leakage secondary to injury of the lymphatic channels. If present, they were plicated with silk stitches.

Extubation was attempted after completion of the operation, and a tracheostomy tube was not required if extubation was successful. The patients were nursed in the general ward during the postoperative period. Humidification using the nebulizer and frequent sputum suctioning was performed to prevent drying of crust, especially around the tracheostomy, which might cause blockage and asphyxiation. Special attention was paid to complications such as pharyngocutaneous fistula and anastomotic leakage, which might require exteriorization with control pharyngostomy to avoid serious complications like mediastinitis and torrential bleeding from erosion of the great vessels. Depending on the result of the final pathological examination of the tumor, adjuvant chemoradiotherapy was given when indicated.

All the patients were followed up regularly with clinical and endoscopic examination to detect tumor recurrence and complications such as stenosis of the terminal tracheostomy. The data forming the basis of the current study were collected retrospectively. The demographic data of these patients, the number of different types of procedures performed, and the incidence of early and late complications were recorded. The statistical package SPSS version 17 (SPSS Inc., Chicago, IL) was used to analyze the data. A P value <.05 was regarded as statistically significant.
RESULTS
We treated 38 patients during the study period, among whom 30 were male and 8 were female. The age at presentation ranged from 20 to 72 years, with a median age of 62 years. The median follow-up period was 44 months. Fourteen (36.9%) patients had carcinoma of the hypopharynx involving the postcricoid region with invasion of the cervical esophagus inferiorly and posterior wall of the trachea anteriorly. The rest of the patients had parastomal recurrence after laryngectomy for carcinoma of the larynx (n = 8, 21.1%), recurrent carcinoma of the esophagus after previous transhiatal esophagectomy (n = 4, 10.5%), postirradiation sarcoma at the lower neck (n = 4, 10.5%), carcinoma of the subglottic and upper trachea (n = 4, 10.5%), carcinoma of the thyroid with invasion of the underlying larynx and upper trachea (n = 3, 7.9%), and recurrent tumor at the tracheostomy wound after glossectomy for carcinoma of the tongue (n = 1, 2.6%). Thirty-four (89.5%) patients required repair of the pharyngoesophageal region after tumor resection, including primary closure of the neopharynx (n = 8) and reconstruction using the free jejunal flap (n = 8), tubed PM flap (n = 6), and gastric pull-up (n = 12), respectively. In the remaining four patients with sarcoma of the lower neck, resection of the upper aerodigestive tract was not required. During the construction of the anterior mediastinal tracheostomy, the majority (81.6%) required repositioning of the trachea inferior to the innominate artery. The length of the remaining stump of the trachea, as measured from the transected end to the carina, ranged from 7.6 to 3.5 cm, with a mean of 5.4 cm. A majority (92.1%) of the patients had microscopically clear tracheal resection margins, whereas the remaining three cases showed dysplastic changes only. Fourteen patients required a pectoralis major flap in the construction of the mediastinal tracheostomy, as the remaining trachea was too short to allow suturing to the skin without tension.

Postoperative mechanical ventilation was required in six patients, and all of them were able to be extubated on day 1 after surgery. Early anastomotic leakage was detected in six patients (gastric pull-up: n = 3; tubed PM flap: n = 3), requiring exteriorization in two patients and takedown of the gastric conduit in another two patients. For the remaining two patients, the leakage was mild, and they were successfully managed by a

Fig. 2. (Above, left) Pharyngo-laryngo-esophagectomy with tracheal resection for carcinoma of the cervical esophagus with tracheal invasion, followed by reconstruction using a gastric conduit (arrow). (Above, right) Pectoralis major myocutaneous flap to reconstruct the posterior wall of the mediastinal tracheostomy. (Below, left) After passing through the subcutaneous tunnel, the skin paddle of the flap was used to bridge the posterior and lateral tracheal wall to the neck skin, minimizing the tension at the suture line. The muscle of the flap protected the underlying innominate artery and vein from pressure and infection. (Below, right) Upon the completion of surgery, check the color of the skin island of the flap to make sure that the flap was well perfused. Avoid extrinsic compression of the pedicle of the flap over the chest wall at the postoperative period to prevent vascular compromise of the flap. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]
conservative approach. Varying degrees of ischemia and partial necrosis of the terminal end of the trachea occurred in 11 (28.9%) patients, and all responded to conservative treatment. Two patients died from torrential bleeding, resulting in a hospital mortality of 5.3%. One patient from our early series bled from the innominate artery on day 12 after surgery, and the remaining one from the innominate vein on day 7 following the operation. Eighteen patients had been irradiated before the operation, whereas in 17 patients the radiotherapy was given postoperatively.

During follow-up, 18 (47.4%) patients were found to have stenosis of the stoma, requiring regular stenting using a tracheostomy tube. History of postoperative anastomotic leakage and necrosis of the distal end of the tracheal wall at the tracheostomy significantly increased the risk of long-term stenosis of the stoma ($P = .034$, $P = .026$, respectively). On the other hand, the use of the pectoralis major flap for the construction of the tracheostomy significantly reduced the risk of stenosis ($P = .028$). Twelve patients had persistent hypothyroidism and thyroxine replacement was needed. Sixteen patients had hypocalcaemia, and 10 of them required a Vitamin D supplement in addition to an oral calcium tablet.

Overall survival was 80.6% at 1 year and 55.6% at 5 years after surgery. Although three patients died of complications of adjuvant chemoradiotherapy, all other patients died of either locoregional recurrence of tumors or systemic metastasis.

**DISCUSSION**

Manubrial resection provides a spacious access for the resection of tumors involving the cervicothoracic region. By removing the manubrium together with the medial ends of the clavicles and first and second ribs down to the angle of Louis, the underlying retrosternal trachea and the cervical part of the esophagus is exposed. Moreover, it allows access to the pre- and para-tracheal and esophageal lymph nodes, permitting level VI lymphatic clearance if necessary. As a result, tumors involving the laryngo-tracheal complex and the cervical esophagus can be resected with a wider margin, thereby improving local tumor control. Properly performed, it is a valuable adjunct and allows the curative resection of tumors of the cervicothoracic region, which would otherwise be impossible.

Over the years, however, it has been considered as a major surgical undertaking. During the procedure, the underlying great vessels at the neck and mediastinum can be traumatized. In the early postoperative period, there is always a concern about the risk of innominate artery rupture. In fact, early series in the literature showed that the mortality rate attributable to arterial rupture ranged from 33% to 50%. Over the years, information regarding the procedure came from small case series only. Orringer probably reported the largest series in 1992. He presented his experience with 44 patients with anterior mediastinal tracheostomy. In-hospital mortality was 14%, and only one patient developed innominate artery erosion. He further updated his series in 1998 by adding 7 more patients, and he concluded that a 5-cm minimal length of trachea above the carina was optimal for construction of a mediastinal tracheostomy.

During the study period, we used this technique to resect a wide variety of different types of tumors in the region. The most common pathology was tumors at the hypopharynx/cervical esophagus, with invasion of the posterior tracheal wall followed by parastomal recurrence after total laryngectomy for laryngeal tumor, primary tumors of the upper trachea, thyroid malignancies with laryngeal and trachea invasion, and sarcoma in the central lower neck region. Removal of the manubrium allows better exposure of these locally advanced tumors at such difficult locations so that they can be resected with wider margins, leading to better oncological control and improved survival (80.6% at 1 year and 55.6% at 5 years after surgery in our series), which would be impossible to achieve with palliative chemoradiotherapy alone. In order to justify its routine clinical application, attention has to be paid during the resection of the manubrium and the construction of the mediastinal tracheostomy, aiming at minimizing the operative morbidity and mortality.

During the procedure, osteotomies are performed using a sternal saw with a guard in order to protect the integrity of the underlying structures, including the thymus gland, pleura, great vessels of the lower neck and mediastinum, namely the lower part of the carotid arteries and the internal jugular veins, innominate arteries and veins, and the bilateral internal mammary arteries. Perhaps the most important step for avoiding injury to these structures, however, is to develop a spacious plane underneath the bones to be resected before osteotomy is contemplated. This can be achieved by first dividing the anterior jugular veins and the sternal head of the sternocleidomastoid muscles on both sides, followed by blunt dissection, detaching all the soft tissue attachment to the undersurface of the bones. Normally, this is a bloodless plane, and in the majority of the patients this is easily achieved. Difficulties may be encountered, however, in cases of scarring of the area due to previous radiotherapy or tumor infiltration of the region.

All our patients required major resection of the upper trachea, necessitating the construction of the anterior mediastinal tracheostomy. In the past, the procedure was reported to be associated with significant mortality, mainly from innominate artery rupture. This catastrophe was attributed to the pressure necrosis of the arterial wall from the tracheal stump and skin suture line, as well as early postoperative anastomotic leakage and the resultant mediastinal sepsis. To avoid this dreadful complication, several points have to be remembered. First and perhaps the most important of all, the innominate artery should be free of compression from the surrounding structures. Some authors of early series recommended routine ligation of the artery in order to avoid pressure necrosis. It has become obsolete after the relocation of the tracheal stump inferior to the innominate artery has been described. Essentially,
this brings the trachea closer to the skin, thereby reducing the tension of the skin suture line, and at the same time avoiding direct compression on the artery. Attention has always been put on the artery. However, pressure necrosis of the innominate vein should not be overlooked. Erosion of the vein can also lead to torrential bleeding and death, as occurred in one of our patients. Should compression by the trachea be anticipated intraoperatively, the vein should be prophylactically ligated and divided. It is also noteworthy that, during relocation of the tracheal stump, it is advisable not to mobilize and skeletonize the trachea excessively from the surrounding soft tissue, as this will jeopardize the blood supply to the trachea, leading to necrosis of the distal end of the trachea, which occurred in 28.9% of our patients. Although they responded to conservative treatment, all of them subsequently developed problematic stenosis of the tracheostomy on long-term follow-up.

Second, the PM flap should be used with a low threshold.\textsuperscript{12–15} The interpositioning skin paddle of the flap reduces the suture line tension between the trachea and the neck skin, and the muscle separates the trachea from the innominate artery and protects the great vessels from infection secondary to anastomotic leakage. In addition to reducing the risk of innominate artery rupture, it also prevents stenosis of the stoma in the long run. Only 7.1% of our patients who have PM flap reconstruction of the posterior tracheal wall developed tracheostomy stenosis, possibly by deceasing the wound tension and hence reducing the necrosis of the distal trachea wall. The mean length of the tracheal stump in our series was 5.4 cm, with the shortest one being 3.5 cm. When an extremely short tracheal stump is encountered, in addition to relocation and the use of a PM flap, it is also possible to remove part of the upper edge of the sternum as well, so that the anterior wall of the trachea can be brought out and sutured without tension.

In patients who require resection of the hypopharynx and/or esophagus followed by reconstruction, it is important to monitor closely for the presence of anastomotic leakage during the early postoperative period, and if there are signs of infection the neck should be explored and the leak exteriorized early to avoid serious complications such as mediastinitis or major vessel blowout. A postoperative thyroid function test should be monitored and hypothyroidism should be corrected to avoid its adverse effect on wound healing.

Stenosis of the terminal tracheostomy causes long-term morbidity to patients, and is better prevented than revision when it develops. Eighteen (47.4%) patients in our series developed stenosis of the stoma, the risk of which is shown to increase substantially by the presence of anastomotic leakage and partial necrosis of the tracheostomy soon after the operation. On the other hand, the use of the PM flap in the construction of the tracheostomy significantly reduces the chance of subsequent stenosis, the mechanism of which was explained previously.

CONCLUSION

Manubrial resection with construction of anterior mediastinal tracheostomy is a useful adjunct that allows the resection of tumors at the cervicothoracic region with a better oncological control. Pectoralis major flap helps to reduce early complications such as innominate artery erosion, as well as late morbidities like stenosis of the tracheostomy. With attention to operative details, the procedure is safe with acceptable postoperative morbidity.

BIBLIOGRAPHY