Anterior Mediastinal Tracheostomy as Salvage Operation

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Background. This study aimed to assess early and long-term results after anterior mediastinal tracheostomy (AMT) as a salvage operation for recurrent neck malignancies.

Methods. Between October 2006 and February 2013, 12 patients (mean age, 57 years) underwent AMT. All patients had experienced stomal recurrence, with or without esophageal involvement, after laryngectomy. All patients had undergone previous radiotherapy (50.3 ± 6.2 [43–60] Gy) and previous surgical treatment: total laryngectomy (n = 11) and thyroidectomy (n = 2).

Results. The mean length of resected trachea was 3.7 ± 2.7 (2.5–6) cm. Resection was complete in 10 patients. All patients required relocation of the remaining trachea below the innominate artery and myocutaneous flap for coverage/stoma construction. AMT was associated with esophagectomy (n = 4) and supraaortic trunk resection (innominate artery, n = 2; carotid artery, n = 3). Seven patients required resection of the pharyngoesophageal region, and 4 patients underwent reconstruction, including primary closure of a pharyngeal remnant (n = 1) and gastric pull-up (n = 3). There was 1 operative death (8.3%) resulting from an infectious process leading to bypass fistulization. Major complications were partial tracheal necrosis (n = 3), pharyngeal fistula (n = 1), pneumonia (n = 4), and flap dehiscence (n = 2). Length of hospital stay was 30 ± 22.8 (13–66) days. Actuarial overall 5-year survival was 58.5%, and median estimated disease-free survival was 53 (31–75) months.

Conclusions. Our experience with AMT as salvage therapy has shown acceptable long-term results if complete resection is achieved. This procedure is not risk free, and very careful patient selection is required because of a tortuous postoperative course, especially in combined pharyngeal-esophageal and vascular reconstruction.

57 ± 13 (24–72), years underwent AMT as a salvage operation for recurrence of neck malignancy after previous operations and postoperative radiotherapy and were included in the present study. The hospital ethics committees approved the study, and informed consent was obtained from all participants.

Preoperative Evaluation
All patients underwent thorough preoperative functional and oncologic assessment. Neck tumor staging included clinical history, examination, standard blood tests, chest radiography, bronchoscopy, and cervicothoracic, abdominal, and cerebral computed tomography (CT), as well as 18F-fluorodeoxyglucose positron emission tomography (PET). Oncologic history included previous radiotherapy and cervicothoracic resections and related complications, along with atherosclerotic (n = 5) or radiotherapy-induced supraaortic trunk disease.

Fiberoptic examination of upper and lower airways was systematically performed, selectively followed by panendoscopy under general anesthesia. When cervicothoracic CT identified close contact of the tumor with the esophagus, potential involvement of esophageal layers was assessed by endoscopic ultrasonography.

All patients underwent noninvasive evaluation of patency or involvement of supraaortic trunks with combined cerebrovascular duplex ultrasonography, cervicothoracic CT angiography, and PET/CT analysis. If patients had a stomal recurrence after laryngectomy, pharyngeal and esophageal status (eg, previous fistulization after laryngectomy, tumor involvement) received special attention.

Resection and AMT were precluded in the following cases: (1) fiberoptic evidence of less than 5 cm macroscopic disease-free trachea up to the carina (Fig 1); (2) high suspicion of massive prevertebral fascia or aortic arch involvement on computed tomographic examination; (3) intraoperative macroscopic evidence of less than 1.5 cm of disease-free margins in tracheal and esophageal mucosa [9]; (4) systemic recurrence or a second primary intractable tumor during the same surgical stage; and (5) involvement of the supraaortic trunks with intractable cerebrovascular failure.

Operative Technique
Oncologic involvement of the trachea, availability of flaps, and digestive and vascular structures required slightly different modifications of our AMT technique (Figs 1, 2). The major modification, applied in 10 patients of our series, was systematic coverage of the anterior chest wall defect by a musculocutaneous flap—pectoralis major flap (PMF) or latissimus dorsi flap (LDF)—and establishment of the tracheostoma in the middle part of the skin island [2, 4, 10].

Tumor Resection: Esophageal and Vascular Reconstruction
Patients were placed supine. In the first patient, a doublevisor approach was performed, with a horizontal supraclavicular skin incision below the tracheostoma to dissect the previously irradiated structures belonging to the median thoracic outlet. A collar incision was used in other patients, resecting the previous stoma circumferentially with a skin island (1–3 cm) to achieve R0 margins. A nasogastric tube was routinely inserted, and ventilation was ensured by means of an armored cross-field tracheal tube. The tumor was assessed using the cervical approach; if resectable, a median incision was performed. The manubrium and clavicular heads were resected to achieve tumor dissection, division of the retrosternal trachea with free margin, and construction of the mediastinal stoma.

Tumor resection started with the more involved side [3] in the anterior border of the sternocleidomastoid muscle for carotid and jugular vein control. The thyroid gland was divided and removed for oncologic reasons if needed, with preservation of the parathyroid glands. When conservative management was indicated, careful and limited (anterior and lateral) esophageal dissection was performed to avoid postoperative digestive leaks. Reconstruction was indicated when more than one third of the esophageal circumference had been resected. After esophagectomy, reconstruction was deemed impossible.
in 3 patients (patients 1, 3, and 5) because of long-term esophageal diversion with no possibility of anastomosis or neoesophageal covering. In the other 9 cases, reconstruction was preferentially managed with gastric pull-up associated with routine jejunostomy feeding.

Distally, the trachea and any other suspect areas were checked by frozen section analysis to ensure R0 resection. Jugular-carotid and superior mediastinal lymph node dissection completed the tumor resection.

Systemic heparin sodium (5,000 units/h) was intravenously administered before any carotid, subclavian, or innominate artery clamping during dissection or resection. Involved supraaortic trunks were resected en bloc with tumor (n = 4) and reconstructed with anatomic or extraanatomic bypass using cryopreserved arterial allografts (patients 9 and 10) or saphenous vein (patients 11 and 12) (Fig 3). Shunting was routinely used in carotid resection.

Anterior Mediastinal Tracheostomy Construction

Chest wall resection was as limited as possible to minimize postoperative flail chest, but manubrium, clavicular heads, and anterior segments of first and second ribs of both sides were resected for proper neostomal construction. Innominate vein was either divided to create sufficient space for the mediastinal stoma, preventing tracheovascular complications, or preserved to avoid insufficient outflow when left PMF or LDF was scheduled. The trachea was routinely transposed inferior to the innominate artery and medial to the superior vena cava (Fig 1). A full release of mediastinal adherence was performed to reduce tension for the stomal constructions.

For coverage of mediastinal structures, a PMF was preferentially used (n = 10). The full-thickness chest wall defect was measured (skin island) and a thick musculocutaneous pedicled flap was harvested, large enough to cover the defect and extend into the mediastinum. A circular stoma was fashioned in the middle part of the skin island and across the flap, and the remnant trachea was guided through (Fig 4). The mediastinal stoma was created using interrupted polypropylene 3/0 or 4/0, stitching the tracheal stump to the skin [2]. The muscular layer of the flap achieved an interposition between the trachea and the innominate artery. In the case of definitive pharyngostomy (patients 1, 3, and 5), the risk of corrosive effects of saliva on vessels and airway sutures led us to systematically protect the mediastinal area by interposing a healthy 3-layer flap (skin, fat, and muscle).

To minimize anterior flail chest, the flap was anchored to the sternum and ribs laterally with nonabsorbable sutures. Finally, the mediastinal stoma was cannulated using a low-pressure tracheostomy tube.

Postoperative Care

After the operation, all patients were mechanically ventilated at least 12 to 24 hours in the intensive care unit. Gentle airway cleaning with fiberoptic bronchoscopy was performed daily to avoid blind suction of the tracheostoma and iatrogenic injury. A cuffed adjustable tracheostomy cannula (Portex, Smiths Medical, St. Paul, MN) was used until healing and changed as needed, using a guide until a silver cannula became adapted. Total parenteral nutrition was started on the first postoperative day and enteral nutrition several days after through the jejunostomy tube until oral feeding could be started. In the case of arterial reconstruction, patients received only postoperative low-molecular-weight heparin prophylaxis.

Any dehiscence in the tracheostoma was properly cleaned by removing scabs and cleaning the edges. Partial tracheal necrosis (1–2 rings) was treated conservatively by adding systemic antibiotics and removing ring...
necrosis after 2 to 3 weeks of underlayer healing. Stomal stitches were removed after 3 weeks if there were no complications. Flaps were carefully observed and dehiscence was treated using vacuum-assisted therapy (KCI International, Houten, Netherlands) until healing.

Survival, complications, tumor recurrence, and arterial bypass patency were assessed during hospitalization and follow-up. Thoracic contrast with multiplanar reconstruction, superior abdomen, and brain CT were scheduled every 3 months for 2 years and annually thereafter. Tumor resection was considered “curative” (R0) if all tumor margins were negative; R1–2 was considered palliative resection.

Statistics and Follow-Up
Results are expressed as means ± standard deviation. Survival from date of operation until death was calculated using the Kaplan-Meier method. Operative mortality was considered as occurring during hospitalization; overall survival and estimated median disease-free survival (months) was calculated from date of operation until any related oncologic event.

Results
Patient Characteristics
Previous surgical procedures, type of resection, and airway, vascular, and digestive reconstruction are listed for all 12 patients in Tables 1 and 2. Laryngeal squamous cell carcinoma involving the cervicothoracic junction or stoma recurred in 10 patients (78.5%), and papillary thyroid carcinoma with tracheal and esophageal transmural invasion recurred in 2 (14%). Most patients were symptomatic (71.4%), with mean symptom duration of 4.6 ± 3.1 (1–14) months; all presented with severe neck fibrosis related to previous irradiation (50.3 ± 6.2 [43–60] Gy).

Operative Treatment
Airway obstruction was cleared by neodymium–yttrium aluminum garnet laser in 3 symptomatic patients before AMT. Retrosternal division of the trachea was required in all patients and was associated with digestive tract reconstruction in 4 patients and supraaortic trunk resection in 4 patients.

Seven patients required, in this or previous procedures, pharyngoesophageal resection; 4 underwent reconstruction, including primary closure of a pharyngeal remnant necrosis after 2 to 3 weeks of underlayer healing. Stomal stitches were removed after 3 weeks if there were no complications. Flaps were carefully observed and dehiscence was treated using vacuum-assisted therapy (KCI International, Houten, Netherlands) until healing.
<table>
<thead>
<tr>
<th>Patient</th>
<th>Age/Sex</th>
<th>Malignancy</th>
<th>Symptom</th>
<th>Previous Radiotherapy</th>
<th>Previous Operations</th>
<th>Operative Flap</th>
<th>Digestive Tract Reconstruction</th>
<th>Supraaortic Trunk Disease/Reconstruction Complications</th>
<th>Type of Resection</th>
<th>Hospital Stay (d)</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24/F</td>
<td>LCR</td>
<td>Dyspnea</td>
<td>43 Gy</td>
<td>TL</td>
<td>AMT</td>
<td>Esophageal diversion(^a)</td>
<td>None/none  Partial tracheal necrosis (1 ring)</td>
<td>Curative</td>
<td>13</td>
<td>Alive, 81 mo</td>
</tr>
<tr>
<td>2</td>
<td>48/M</td>
<td>LCR</td>
<td>Asymptomatic</td>
<td>50 Gy</td>
<td>TL</td>
<td>AMT</td>
<td>Gastric pull-up</td>
<td>None/none  Pneumonia</td>
<td>Curative</td>
<td>22</td>
<td>Alive, 43 mo</td>
</tr>
<tr>
<td>3</td>
<td>60/M</td>
<td>LCR</td>
<td>Stomal recurrence</td>
<td>50 Gy</td>
<td>TL</td>
<td>AMT</td>
<td>Esophageal diversion(^a)</td>
<td>None/none  Partial tracheal necrosis (2 rings)</td>
<td>Palliative</td>
<td>21</td>
<td>Alive, 16 mo</td>
</tr>
<tr>
<td>4</td>
<td>59/M</td>
<td>LCR</td>
<td>Stomal recurrence</td>
<td>60 Gy</td>
<td>TL</td>
<td>AMT</td>
<td>. . .</td>
<td>None/none  None</td>
<td>Curative</td>
<td>16</td>
<td>Alive, 12 mo</td>
</tr>
<tr>
<td>5</td>
<td>72/M</td>
<td>LCR</td>
<td>Asymptomatic</td>
<td>60 Gy</td>
<td>TL</td>
<td>AMT</td>
<td>Right carotid and subclavian arteries atheromatous disease/none</td>
<td>None</td>
<td>Curative</td>
<td>24</td>
<td>Alive, 34 mo</td>
</tr>
<tr>
<td>6</td>
<td>67/M</td>
<td>LCR</td>
<td>Asymptomatic</td>
<td>50 Gy</td>
<td>TL</td>
<td>AMT</td>
<td>Right upper lobectomy, Right carotid endarterectomy</td>
<td>Left subclavian artery atheromatous disease/none</td>
<td>Flail chest, pneumonia, difficult weaning</td>
<td>Curative</td>
<td>27</td>
</tr>
<tr>
<td>7</td>
<td>49/M</td>
<td>TC</td>
<td>recurrence Dyspnea</td>
<td>54 Gy</td>
<td>Thyroidectomy</td>
<td>AMT</td>
<td>. . .</td>
<td>None/none  None</td>
<td>Curative</td>
<td>19</td>
<td>Alive, 27 mo</td>
</tr>
<tr>
<td>8</td>
<td>72/M</td>
<td>LCR</td>
<td>Stomal recurrence Dyspnea</td>
<td>43 Gy</td>
<td>TL</td>
<td>AMT</td>
<td>Pharyngeal partial resection</td>
<td>Carotid atheromatous disease/none</td>
<td>Pharyngeal fistula, pneumonia, difficult weaning</td>
<td>Curative</td>
<td>86</td>
</tr>
</tbody>
</table>

\(^a\) Patients considered to be without any possibility of digestive reconstruction (definitive laryngostomy, no tissues in the neck after radiotherapy or previous operation, neck coverture impossible.

AMT = anterior mediastinal tracheostomy;  LC = laryngeal cancer;  LCR = laryngeal cancer recurrence, not only of stoma;  LDF = latissimus dorsi flap;  PE = pulmonary embolism;  PMF = pectoralis major flap;  TC = thyroid cancer;  TEP = pulmonary embolism;  TL = total laryngectomy.
### Table 2. AMT With Supraaortic Trunk Reconstruction: Patient Characteristics and Outcomes

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age/Sex</th>
<th>Malignancy</th>
<th>Symptom</th>
<th>Previous Radiotherapy Dose</th>
<th>Previous Operation</th>
<th>Operative Flap</th>
<th>Digestive Tract Reconstruction</th>
<th>Supraaortic Trunk Disease/Reconstruction Complications</th>
<th>Type of Resection</th>
<th>Hospital Stay (d)</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>53/M</td>
<td>LCR</td>
<td>Stomal bleed/dyspnea</td>
<td>45 Gy</td>
<td>TL Clearance of obstruction by laser</td>
<td>AMT Omentum + LDF</td>
<td>. . .</td>
<td>None/innominate artery replacement</td>
<td>None</td>
<td>Curative</td>
<td>14</td>
</tr>
<tr>
<td>10</td>
<td>62/M</td>
<td>LCR</td>
<td>Asymptomatic</td>
<td>50 Gy</td>
<td>TL</td>
<td>AMT</td>
<td>. . .</td>
<td>Carotid atheromatous disease /innominate and right carotid artery replacement</td>
<td>Flap dehiscence</td>
<td>Curative</td>
<td>16</td>
</tr>
<tr>
<td>11</td>
<td>58/M</td>
<td>LCR</td>
<td>Stomal recurrence</td>
<td>60 Gy</td>
<td>TL Left carotid artery stenting</td>
<td>AMT PMF</td>
<td>Gastric pull-up</td>
<td>Atheromatous and radiotherapy-induced disease (previous stenting) /left carotid artery replacement</td>
<td>Partial tracheal necrosis (2 rings), flap dehiscence, pneumonia, difficult weaning, carotid bypass rupture</td>
<td>Curative</td>
<td>67</td>
</tr>
<tr>
<td>12</td>
<td>63/M</td>
<td>TC recurrence</td>
<td>Dyspnea/mass</td>
<td>54 Gy</td>
<td>Thyroidectomy/TL Clearance of obstruction by laser</td>
<td>AMT PMF</td>
<td>Gastric pull-up</td>
<td>None/left carotid artery replacement</td>
<td>Flail chest, tracheal malacia, pneumonia, difficult weaning</td>
<td>Palliative</td>
<td>35</td>
</tr>
</tbody>
</table>

AMT = anterior mediastinal tracheostomy; LCR = laryngeal cancer recurrence, not only stomal; LDF = latissimus dorsi flap; PMF = pectoralis major flap; TC = thyroid cancer; TL = total laryngectomy.
(n = 1) and gastric pull-up (n = 3). All patients required relocation of the remaining trachea inferior to the innominate artery. The mean length of resected trachea measured 3.7 ± 2.7 (2.5–6) cm. Tracheal resection with a free margin was achieved in all patients, but resection was incomplete in 2 (16.6%). Patient 12, with adenoid cystic carcinoma, had R1 margins because of extensive microscopic perineural and perivascular spread. Treatment of patient 3 was considered palliative because of submucosal esophageal invasion beyond the gastro-esophageal junction.

Complications and Follow-Up

Overall hospital mortality was 8.3% (1 operative death). Patient 11 died at day 67 because of left carotid bypass rupture resulting from partial tracheal necrosis, flap dehiscence, and mediastinal infection. Mean time of postoperative mechanical ventilation was 9.5 days and was prolonged to 17.2 ± 18.5 (8–67) days in 4 patients because of difficulty weaning related to paradoxical chest wall movements and pneumonia. Pharyngeal fistula in patient 8 was successfully treated conservatively. Two patients required local debridement of flap dehiscence and vacuum-assisted therapy. Partial necrosis of the remnant trachea occurred in 3 patients (21%); 2 of them were successfully treated by a conservative approach. Mean and median hospital stays were 30 ± 22.9 (13–86) days and 21.5 days, respectively.

No patients were lost to follow-up (median 34.5 ± 26.5 [4–81] months; 7 patients [58.3%] were followed more than 2 years). During follow-up, 2 patients experienced delayed recurrent stenosis of their stomas that required regular yearly dilatation using rigid bronchoscopy and balloon under general anesthesia.

Two patients experienced hormonal disorders, requiring thyroxine replacement in both patients and vitamin D and oral calcium in 1 patient. At 3 months postoperatively, all patients had relief of preoperative symptoms. However, 7 (58.3%) patients reported variable discomfort caused by insufficient anterior chest wall rigidity.

Actuarial overall 5-year survival was 58.3%, and median estimated disease-free survival was 53 months.

Comment

AMT is a challenging operation linked to postoperative vascular and respiratory morbidity and extensive long-term care because of tracheostomy adaptation and stenosis of the stoma. Our experience confirms the feasibility and excellent long-term survival in highly selected cases of salvage operations with resection extended to the esophagus or supraaortic trunks. Appropriate surgical palliation and respiratory symptom relief were also obtained.

In agreement with reported indications for AMT [1, 11], the majority of patients had a stomal or cervical recurrence after laryngectomy and radiotherapy for laryngeal squamous cell or adenoid cystic carcinoma. However, a recent report suggests that such tumors may respond to a combination of carboplatin/paclitaxel and radiation therapy, allowing an organ-sparing approach [12]. Another valuable indication is well-differentiated thyroid carcinoma with airway involvement, reaching a 10-year survival rate of 67.2% [13]. After tumor removal, cervical tracheostomy can be impossible because of insufficient tracheal length and AMT is indicated, requiring at least 4.5 to 5 cm of remnant trachea [1, 7, 10, 14], depending on tracheostoma proximity to the innominate artery and aortic arch [15].

Postoperative mortality in our series was caused by hemorrhage, the most common reported cause of death after ATM, which was generally attributed to primary and secondary rupture or fistulization of the innominate artery. This complication is linked to pressure necrosis of the innominate artery caused by tension on the tracheostoma resulting from a short remnant trachea, mediastinitis caused by stomal or flap dehiscence or pharyngoesophageal fistula [6, 9], and supraaortic trunk graft dehiscence. The proposed strategy to avoid primary rupture is systematic tracheal relocation below the innominate artery and medial to the superior vena cava [16] and construction of the mediastinal stoma in the middle part of the myocutaneous flap [17]. In contrast to a recent report [18], in which musculocutaneous flaps were not used in AMT construction, we consider the musculous part of the flap essential to obliterate dead space in the upper mediastinum around the trachea and great vessels. A slip of muscle may be separated from the flap and inserted around the pharyngogastric suture line or between the definitive pharyngostomy and tracheostoma. This strategy reduces vascular-related early mortality, as evidenced by recent 7.6% to 18% rates [1, 19] in comparison with earlier rates up to 50% [20].

For construction of the mediastinal stoma, we passed the stitches through the proximal ring and the skin after a perpendicular cut in the trachea through the interring spaces, without any oblique division of the trachea [3, 9]. To preserve the tracheal vasculature, we left the musculocutaneous flap as mobile as possible and depressed it to meet the remnant trachea in depth, avoiding excessive tension on the stoma. The tracheal dissection should be performed on the anterior and posterior face, because the last 2 cm of trachea is usually supplied from the flap pedicle after several weeks. Using this strategy, we achieved a low rate (21.4%) of partial necrosis of the first and second rings of the tracheal stump, without clinical relevance except possible stenosis requiring repeated dilation. Conversely, the rate of stomal revision was 36% in the series of Grillo and Mathieson [7], in which musculocutaneous flaps were not used. In most cases, a form-tailored silver cannula will offer an excellent quality of life. Manubrium, clavicular heads, and anterior segments of the first and second rib resections combined with flap mobilization may cause postoperative anterior flail chest [4]. Depending on preoperative status and the quality of the musculocutaneous flap, this side effect may cause pneumonia and tracheal infection, which are responsible for most postoperative morbidity. Moreover,
excess mobility of the tissues encompassing the mediastinal stoma may impair healing and lead to suture dehiscence. Limited chest wall resection if oncologically possible (by preserving a left side portion of sternum or first and second ribs and clavicular joints) could decrease this problem and avoid upper lobe herniation through the defect [4, 14, 21]. However, when a thick well-harvested myocutaneous flap is available, it is generally sufficient to fill the flail chest and fill the upper mediastinum defect [17].

Type III and type IV stomal recurrence [11] are usually considered to contraindicate resection related to supraaortic trunks or mediastinal involvement. Studies describing AMT [1–3, 7, 18, 22] report no associated vascular reconstruction. We did not consider local extension as a contraindication if radical resection was expected, and surgical intervention was only precluded in case of involvement of the aortic arch or supraaortic trunks that were impossible to replace (carotid unique or Willis polygon damaged). Of 4 patients with replacement of the supraaortic trunks, 1 died of postoperative hemorrhage, and another died of an unrelated cause at 4 months after palliative resection (both underwent combined esophageal resection), and the remaining 2 patients survived 60 and 67 months, respectively. Innominate artery rerouting or replacement with a nonbiological prosthesis linked to flap dehiscence or pharyngoesophageal cutaneous fistula will increase the rate of bleeding and artery or prosthesis rupture. The use of cryopreserved arterial allograft or saphenous vein may offer advantages, such as resistance to infection. We advocate setting vascular anastomoses distant from the mediastinal stoma and digestive suture lines and planning these complex reconstructions to implement a temporary shunt in case of the frequently associated atheromatous disease.

Reconstruction of the digestive tract using stomach pull-up, colon interposition, or free-pedicled jejunum with AMT construction significantly increases morbidity and mortality [1, 7, 9]. Pharyngeal or esophageal fistulas are very frequent in this highly irradiated field and in these patients who have undergone previous operations. All our patients had at least 3 risk factors for digestive fistulas (radiotherapy, previous tracheostomy or neck dissection, and malnutrition) [5].

In conclusion, our experience with AMT as a salvage operation has shown acceptable long-term results if complete resection is achieved. These procedures are not risk free, and candidate selection should be very careful because of the tortuous postoperative course, especially if both pharyngoesophageal and vascular reconstruction are involved.

We thank Professor Alain Wurtz for revision, comments, and friendship and Elaine M. Lilly for her contribution to the developmental editing of the manuscript.

References