European Journal of Cardio-Thoracic Surgery 51 (2017) 844–851
doi:10.1093/ejcts/ezw435 Advance Access publication 25 January 2017

ORIGINAL ARTICLE

Cite this article as: Rosskopfova P, Perentes JY, Schäfer M, Krueger T, Lovis A, Dorta G *et al.* Repair of challenging non-malignant tracheo- or broncho-oesophageal fistulas by extrathoracic muscle flaps. Eur J Cardiothorac Surg 2017;51:844–51.

Repair of challenging non-malignant tracheo- or broncho-oesophageal fistulas by extrathoracic muscle flaps

Petra Rosskopfova[a], Jean Yannis Perentes[a], Markus Schäfer[b], Thorsten Krueger[a], Alban Lovis[c], Gian Dorta[d], Moira Baeriswyl[e], Hans-Beat Ris[a,*] and Michel Gonzalez[a]

[a] Division of Thoracic Surgery, Centre Hospitalier Universitaire Vaudois, Lausanne, Switzerland
[b] Division of Visceral Surgery, Centre Hospitalier Universitaire Vaudois, Lausanne, Switzerland
[c] Division of Pulmonology, Centre Hospitalier Universitaire Vaudois, Lausanne, Switzerland
[d] Division of Gastoenterology, Centre Hospitalier Universitaire Vaudois, Lausanne, Switzerland
[e] Division of Anaesthesiology, Centre Hospitalier Universitaire Vaudois, Lausanne, Switzerland

* Corresponding author. Service de chirurgie thoracique, Centre Hospitalier Universitaire Vaudois, Rue du Bugnon 46, 1011 Lausanne, Switzerland. Tel: +41-21-3142408; fax: +41-21-3142538; e-mail: hans-beat.ris@chuv.ch (H.-B. Ris).

Received 31 August 2016; received in revised form 2 December 2016; accepted 17 December 2016

Abstract

OBJECTIVES: Evaluation of complex, acquired, non-malignant tracheo/broncho-oesophageal fistulas (TEF) repaired by extrathoracic pedicled muscle flaps that were, in addition to their interposition between the airways and the gastro-intestinal tract, patched into gastro-intestinal or airway defects if primary closure seemed risky.

METHODS: A single institution experience of patients treated between 2003 and 2015. Twenty-two patients required TEF repair following oesophageal surgery (18), Boerhaave syndrome (1), chemotherapy for mediastinal lymphoma (1), carinal resection and irradiation (1) and laryngectomy (1); 64% of them underwent prior radio- or chemotherapy and 50% prior airway or oesophageal stenting.

RESULTS: Airway defects were closed by muscle flap patch ($n = 12$), lobectomy ($n = 4$), airway resection/anastomosis ($n = 2$), pneumonectomy ($n = 1$), segmentectomy ($n = 2$) or primary suture ($n = 1$). Gastro-intestinal defects were repaired by oesophageal diversion ($n = 9$), muscle flap patch ($n = 8$) or primary suture ($n = 5$). A muscle flap patch was used to close airway and gastro-intestinal defects in 55% and 36% of cases, respectively. The 90-day postoperative mortality and TEF recurrence rates were 18% and 4.5%. Airway healing and breathing without tracheal appliance was obtained in 95% of patients and gastro-intestinal healing in 77% of those without oesophageal diversion. Five of nine patients with oesophageal diversion underwent intestinal restoration by retrosternal colon transplants.

CONCLUSIONS: Complex TEF arising after oesophageal surgery, radio-chemotherapy or failed stenting can be successfully closed using extrathoracic muscle flaps that can, in addition to their interposition between the airway and the gastro-intestinal tract, also be patched into gastro-oesophageal or airway defects if primary closure seems hazardous.

Keywords: Tracheo-oesophageal fistula • Tracheal surgery • Airway • Oesophageal surgery • Neoadjuvant induction therapy

INTRODUCTION

Acquired tracheo/broncho-oesophageal fistulas (TEF) are rare but life-threatening conditions. They cause a continuous spillage of gastric content into the tracheo-bronchial tree. This leads to recurrent pneumonia and lung destruction and may cause severe malnutrition, mediastinal sepsis, septic shock and death if left untreated. Acquired non-malignant TEF can be caused by trauma, local infection, prior laryngo-tracheal or oesophageal surgery, indwelling stents or complications of long-term mechanical ventilation. Several treatment strategies have been proposed [1–10] but controversy endures as to which is the optimal management approach. This controversy is fuelled by the variety of clinical presentations of TEF requiring different approaches. In some reports, the majority of TEF was related to postintubation injuries and was successfully managed by segmental tracheal resection combined to primary oesophageal closure through a cervical incision [1, 2, 5]. However, more recent literature reports that an important proportion of TEF occurs after oesophageal surgery [3, 4]. Therefore, patient characteristics, localization and size of TEF and degree of mediastinal sepsis are likely to vary between individuals and series. This suggests that an individualized approach for TEF management is required to fit the needs of each patient.

In this study, we retrospectively reviewed all repairs of acquired non-malignant TEF performed using extrathoracic muscle flaps. Most of these cases occurred after oesophageal surgery complications and were associated with intrathoracic leakage and mediastinal sepsis. We previously reported that large

Table 1: Patient characteristics and type of repair in 22 patients undergoing surgery for acquired non-malignant tracheo/broncho-oesophageal fistulas using pedicled muscle flaps

	Sex	Age	Cause	Flap	Repair Oesophagus	Airway
1	F	51	Laryngectomy	LD	Suture	Suture trachea
2	F	61	Oesophagectomy	LD	Exclusion	Muscle patch carina
3	M	49	Oesophagectomy	SA	Muscle patch	Muscle patch LMB
4	M	62	Oesophagectomy	LD	Suture	Muscle patch carina
5	F	52	CHT/lymphoma	LD	Exclusion	LMB resection
6	M	62	Oesophagectomy	PM	Exclusion	Muscle patch carina
7	M	59	Oesophagectomy	SA	Muscle patch	RUL lobectomy
8	M	39	ED repair	LD	Suture	LUL lobectomy
9	M	44	Oesophagectomy	SA	Muscle patch	RMB resection
10	M	62	Oesophagectomy	PM	Muscle patch	Muscle patch IB
11	M	70	Boerhaave	LD	Muscle patch	RLL lobectomy
12	M	56	Oesophagectomy	SA	Exclusion	Muscle patch carina
13	F	76	Oesophagectomy	PM	Exclusion	Muscle patch LMB
14	M	70	Oesophagectomy	LD	Exclusion	Muscle patch carina
15	M	63	Oesophagectomy	PM	Muscle patch	Sleeve RUL lobectomy
16	M	73	Oesophagectomy	LD	Muscle patch	RUL segmentectomy
17	F	29	Carinal resection	PM	Suture	RP/Muscle patch carina
18	F	7	EA repair	PM	Exclusion	Muscle patch RMB
19	F	14	EA repair	LD	Suture	Muscle patch RMB
20	M	51	Oesophagectomy	LD	Exclusion	Muscle patch carina
21	M	63	Oesophagectomy	DI	Muscle patch	RLL segmentectomy
22	M	59	Oesophagectomy	PM	Exclusion	Muscle patch RMB

CHT: chemotherapy; DI: diaphragm; EA: oesophageal atresia; ED: oesophageal diverticulum; IB: intermediate bronchus; LD: latissimus dorsi; LLL: left lower lobe; LMB: left main bronchus; LUL: left upper lobe; PM: pectoralis major; RLL: right lower lobe; RMB: right main bronchus; RP: right pneumonectomy; RUL: right upper lobe; SA: serratus anterior.

intrathoracic airway defects can be repaired with extrathoracic muscle flaps as airway substitutes in situations where a primary closure suture or an end-to-end reconstruction seems risky [11, 12]. The same holds true for the closure of oesophageal defects in the presence of mediastinal sepsis where extrathoracic muscle flaps were used to patch the defect to avoid primary closure suture [13]. In the present series, we explored extrathoracic pedicled muscle flaps for the closure of TEF. In addition to their interposition between the repaired airway and the gastro-intestinal tract, the muscle flaps were also used as airway or gastro-oesophageal wall substitute and patched into the defects if primary closure seemed hazardous.

MATERIALS AND METHODS

All patients undergoing surgical repair of acquired non-malignant TEF using an extrathoracic muscle flap in our institution between 2003 and 2015 were included. The data were collected from the Institution's database and analysed retrospectively. The study was approved by the Local Ethical Committee and individual consent was waived.

Patient's characteristics

The collective included 22 patients (15 men, 7 women) with an average age of 53 (7–76) years. Table 1 summarizes patients' characteristics, cause of fistulisation and repair technique selected for each patient. The underlying causes of fistulas were: complications after oesophageal surgery including leakage after oesophagectomy ($n = 15$) and after repair of oesophageal diverticulum ($n = 1$) or oesophageal atresia ($n = 2$); mediastinal lymphoma successfully treated by chemotherapy ($n = 1$); radio-necrosis after carinal resection and irradiation for adenoid cystic carcinoma of the carina ($n = 1$); laryngectomy for head and neck cancer ($n = 1$); delayed Boerhaave syndrome ($n = 1$). The size of the oesophageal defect varied between 1 and 8 cm. The airway defects were localized at the level of the trachea or carina ($n = 8$), the right ($n = 4$) and left ($n = 3$) main bronchus, the right ($n = 3$) and left ($n = 1$) upper lobe bronchus, the intermediate bronchus ($n = 1$) and the right ($n = 1$) and left ($n = 1$) lower bronchus. Their extent varied between 1 × 1 cm and 4 × 3 cm. In 91% of patients, TEF occurred after oesophageal or airway surgery and 64% of patients underwent radiotherapy or chemotherapy or both prior to TEF repair. Eleven patients (50%) had undergone prior oesophageal or airway stenting and five patients (23%) had undergone fistula repair while intubated or tracheotomized and mechanically ventilated.

Preoperative management

Preoperative preparation included control of broncho-aspiration, treatment of mediastinal sepsis and pleuro-pulmonary infections, daily bronchoscopies to clean the secretions, control of gastric reflux by nasogastric tubes and parenteral nutrition. The surgical approach was individualized and depended on clinical evaluation as well as on bronchoscopic and gastroscopic findings. Airway management during surgery depended on the size and location of the airway defect. Whenever possible, endotracheal intubation was performed with selective intubation of the non-affected

THORACIC

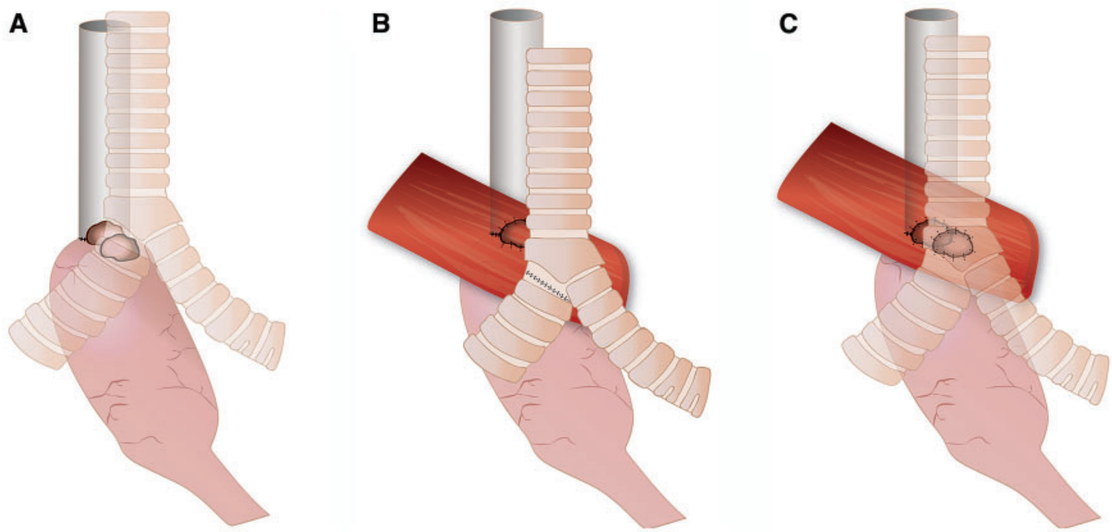

Figure 1: Schematic drawing of (**A**) a large TEF arising after oesophagectomy with intrathoracic oesophageo-gastric anastomosis; (**B**) repair of the oesophageal defect using a muscle patch derived from the pedicled extrathoracic muscle flap and of the carinal defect by an airway resection and end-to-end anastomosis; (**C**) airway and oesophago-gastric defects repaired by a muscle patch derived from the same pedicled extrathoracic muscle flap.

lung, either by a double lumen tube or a smaller-sized Univent® tube. TEF distal to the carina could then be safely managed by selective intubation of the controlateral lung. The same held true for more proximal tracheo-carinal defects since our technique of muscle airway repair relied on non-circumferential tracheo-carinal reconstructions. However, in situations with large tracheal defects, jet ventilation of the left lung was performed using an 11.0 Fr/83 cm Cook® airway exchange catheter during the muscle patch repair after withdrawal of the tube in the subglottic trachea.

Surgical repair

Incision. A right- or left-sided posterolateral thoracotomy was used in 19 patients. Two patients (patients #4 and #14) underwent a right-sided Paulson approach with resection of the posterior aspects of the first and second ribs to access the tracheal lesion at the level of the thoracic inlet. In one patient (patient #17), a clamshell incision was used for carinal repair with cardiopulmonary pulmonary bypass and central cannulation.

Muscle flap. In every case, a large, well-vascularized muscle flap was interposed between the gastrointestinal tract and the airway. In addition to its interposition, it was also patched into the debrided gastro-oesophageal or airway defects if a primary suture closure seemed unwise or technically hazardous [15]. The choice of the muscle flap depended on the availability of an intact and well-vascularized flap and the localization of the fistula (Table 1). The first choice was a latissimus dorsi muscle flap ($n = 10$), however, after a previous postero-lateral thoracotomy, a pedicled serratus anterior ($n = 4$) or pectoralis major muscle flap ($n = 7$) was used. The extrathoracic pedicled muscle flap was transposed into the chest cavity through the bed of a resected segment of the second rib as previously described [11–13]. One patient underwent distal TEF repair using a pedicled full thickness diaphragmatic flap. A muscle flap patch was used as substitute of airway or intestinal wall or both for the reconstruction of the defects in 55%, 36% and 9% of patients, respectively (Fig. 1).

Airway repair.Seven patients underwent pulmonary resection including pneumonectomy ($n = 1$), lobectomy ($n = 3$), sleeve lobectomy ($n = 1$) or segmentectomy ($n = 2$). All but one patient (# 17) requiring parenchyma resection presented with chronic, large-sized, mostly postsurgical oesophageal defects in combination with destruction of the adjacent lung. In these situations, the oesophageal defect was repaired by a muscle patch and lung resection was performed as economically as possible. One patient (#15) required a right upper sleeve lobectomy due to the extension of the airway defect from the right main stem bronchus into the upper lobe bronchus. One patient (#17) required right pneumonectomy due to extension of the airway destruction in the upper and lower lobe bronchus. In this patient, TEF occurred as a late complication after carinal resection and adjuvant radiotherapy (60 Gy). One patient had a direct suture closure of the trachea and two patients underwent main stem bronchus resection with end-to-end anastomosis. In 12 patients, the airway defect was reconstructed by a muscle patch of the transposed muscle flap, which was sutured tightly in the debrided airway defect to avoid circumferential airway resection and end-to-end anastomosis in inappropriate situations (Fig. 2A) [11]. This was of particular importance for TEF localized at the level of the trachea or carina in presence of mediastinal sepsis or dense desmoplastic reactions after prior surgery, radiation or chemotherapy (Fig. 3). In those situations, the muscle flap was sutured into the debrided airway defect with interrupted sutures under slight tension and bronchoscopic control to maintain stability of the airway and to prevent protrusion of the muscle into the lumen, as previously described (Fig. 2A) [11, 12] (Table 1).

Gastro-intestinal repair. The oesophagus or oesophago-gastric anastomosis was dissected away from the site of leakage, which was then gradually exposed and mobilized. Radical debridement of the oesophageal wall or anastomosis at the site of leakage was performed until healthy muscularis and mucosa layers were obtained. Five patients underwent primary suture closure of the debrided defect. In eight patients, the gastro-oesophageal defect was closed by a muscle patch deriving from the transposed muscle flap without attempting a primary suture. In seven patients, this was necessary for the reconstruction of a leaking anastomosis after oesophagectomy and in one patient for the repair of a delayed Boerhaave syndrome. In those situations, the

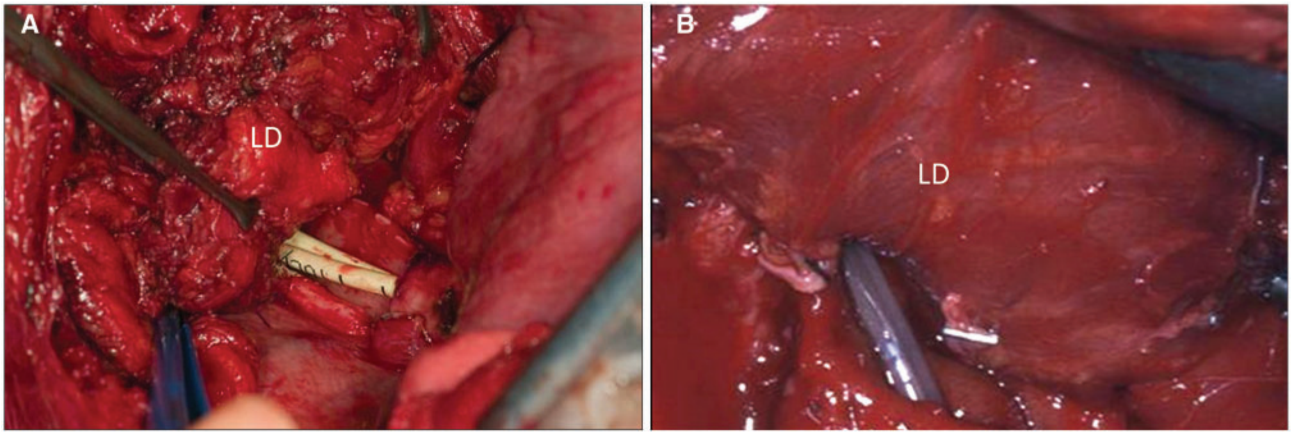

Figure 2: Intraoperative photo-documentation of the repair of (**A**) a tracheal defect (jet ventilation in place), and (**B**) an oesophageal defect (naso-gastric tube in place) by use of an intrathoracically transposed pedicled latissimus dorsi (LD) muscle flap.

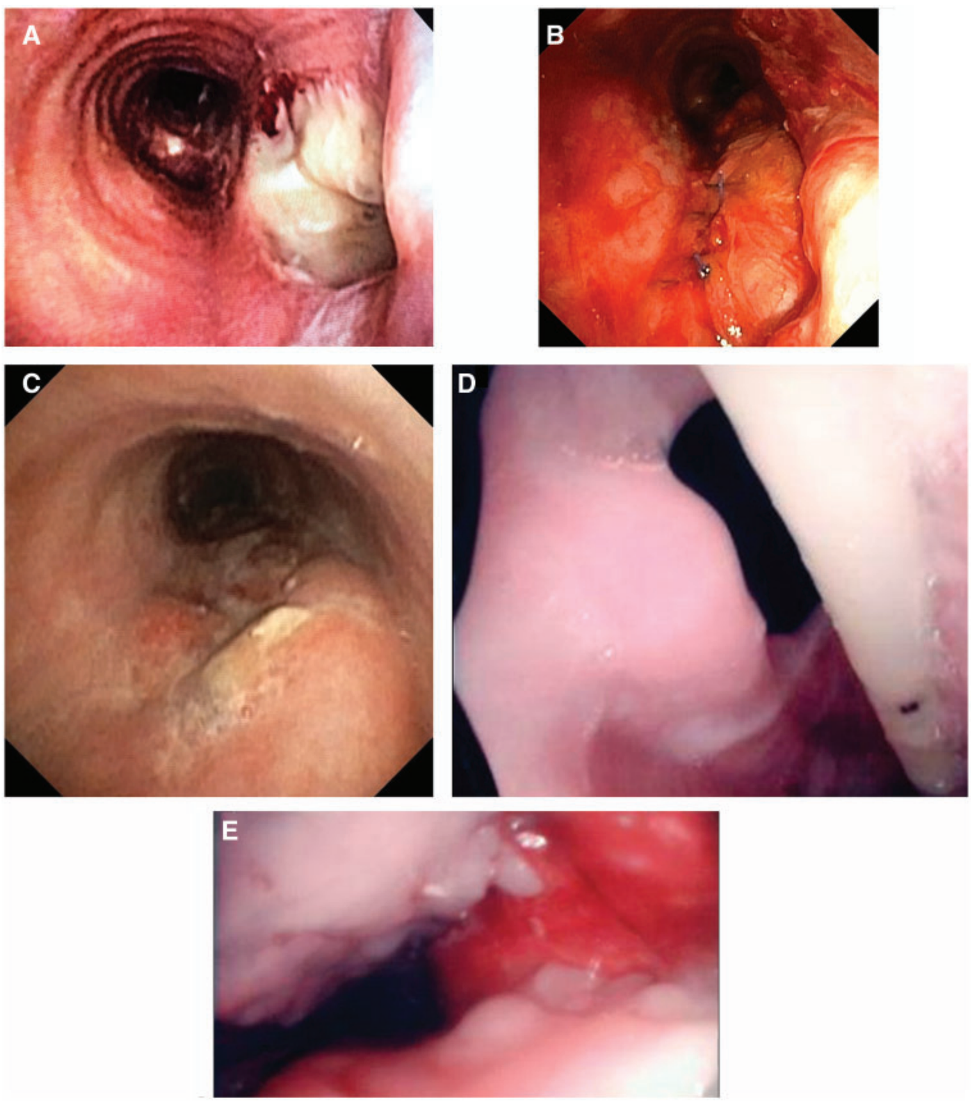

Figure 3: Repair of giant tracheo/broncho-oesophageal fistula by muscle patches derived from extrathoracic muscle flaps: endoscopic view of a giant tracheal defect (**A**) before, (**B**) immediately after repair and (**C**) 3 days after surgery; endoscopic view of a large oesophageal defect (**D**) before and (**E**) 10 days after repair.

pedicled muscle flap was used as a substitute for the oesophageal or gastric wall and was sutured as muscle patch into the debrided defect by interrupted 3–0 Prolene® sutures as previously described (Fig. 2B) [13]. The remnant flap was wrapped around the reconstruction and embedded into the debrided mediastinum. In nine patients, upfront oesophageal diversion was required due to the extent of anastomotic dehiscence and focal necrosis of the gastric pull up (Table 1).

Postoperative management

All patients were postoperatively managed in the intensive care unit. Postoperative extubation was performed as soon as possible in order to prevent injury of the repaired airway related to mechanical ventilation and positive airway pressure. Otherwise, a gradual weaning from the respirator was performed following usual ICU guidelines, if necessary by use of a temporary tracheostomy. Enteral feeding was used and applied by a surgically inserted feeding jejunostomy. Total parenteral nutrition was only used if enteral feeding did not cover caloric intake during the early postoperative phase. All patients underwent daily bronchoscopies to clean secretions and control the airway healing. In patients without oesophageal diversion, intestinal continuity was assessed by contrast imaging or gastroscopy between postoperative day 8 and 16.

Follow-up

For all patients, the 90-day postoperative mortality, reoperation and complication rates were recorded. All patients underwent routine control bronchoscopies until airway healing was documented. After their hospitalization, the patients were followed at regular intervals in an outpatient department. The mean follow-up time of the series was 18 months (range 3–132 months).

RESULTS

Postoperative mortality

Four patients (18%) died within 90-days after surgery (Table 2). Patient #11 required reoperation for a haemothorax and subsequently died of multi-organ failure with intact airway and oesophageal repair. Patient #12 died of persistent pneumonia and prolonged mechanical ventilation after therapeutic withdrawal with an excluded oesophagus and intact airway. Patient #15 died from aortal-oesophageal fistula due to persistent anastomotic leakage after TEF repair following oesophagectomy, with intact airway. He underwent unsuccessful leakage treatment by a covered stent. Patient #22 died from mesenteric ischaemia requiring multiple intestinal resections leading to treatment withdrawal but the repaired airway was intact.

Morbidity and re-operations

The main complications are summarized in Table 3. The 90-day reoperation rate was 27%. Two patients had reoperation for haemothorax. Two patients required reoperation for flap necrosis. In one patient, this was associated with a suture line dehiscence between the muscle patch and the carina. Both flaps (serratus anterior) were replaced by a pectoralis major muscle. In one case, it was sutured into the airway defect with subsequent uneventful airway healing. Two patients underwent reoperations for persistent oesophageal leakage after TEF repair following oesophagectomy with additional muscle flap transposition for space-obliteration in combination with covered oesophageal stents.

Airway healing

Twenty-one of 22 patients achieved airway healing (Table 2). Patient #17 presented recurrent TEF 24 months after repair of a TEF arising after carinal resection and adjuvant radiotherapy. Initial TEF repair was managed by right pneumonectomy, carinal reconstruction by muscle patch and oesophageal suture closure. The recurrent TEF was treated by oesophageal exclusion and carinal re-repair using a pectoralis muscle patch leading to the development of a malacic airway segment, which required stenting and bronchoscopy at regular intervals. Seventeen of 18 surviving patients revealed intact airways and breathed without tracheal appliance or endoscopic treatments during follow-up (Fig. 3A).

Gastro-intestinal healing

Nine patients underwent upfront oesophageal exclusion during TEF repair due to extensive anastomotic breakdown and gastric conduit necrosis after oesophagectomy (Table 2). Five of these patients underwent successful restoration of intestinal continuity after a delay of 6–9 months by retrosternal coloplasty with cervical oesophago-colonic anastomosis and colo-gastric anastomosis on the gastric remnant. A feeding jejunostomy was routinely placed during the reconstruction operation for 8–12 months but all patients resumed oral intake during follow-up and their jejunostomy was removed. Four patients did not undergo restoration of intestinal continuity, two (#12 and #22) died postoperatively and two are awaiting reconstruction.

Thirteen patients had oesophageal repair with preservation of gastrointestinal continuity (Table 2). Nine of these patients achieved uneventful oesophageal healing and resumed oral intake during follow-up (Fig. 3B). Four patients had recurrent leakage at the site of the oesophageal reconstruction, one patient (#17) after direct suture closure and three patients (#7, #9 and #15) after a muscle patch repair for anastomotic leakage following oesophagectomy. Three of the four patients had an intact airway but one patient (#17) revealed recurrent TEF 24 months after repair. In two patients with intact airway, the persistent oesophageal leak was treated by covered oesophageal stents in combination with repeat muscle flap transposition for oesophageal re-repair and space obliteration. In one of these patients (#9), the oesophageal leak healed after 11 months, the other patient (#7) died from oncological progression 12 months after surgery, with persistent oesophageal leakage. In one patient, the persisting oesophageal leak after TEF repair was treated by a covered oesophageal stent with subsequent development of an aortal-intestinal fistula (#15) and death. The patient with recurrent TEF (#17) underwent a two-staged procedure with oesophageal diversion and restoration of gastrointestinal continuity by retrosternal colon interposition 3 months later. Overall, 15 of 18 surviving patients resumed oral intake during follow-up and two are awaiting restrosternal intestinal restoration.

Table 2: Patient and tracheo/broncho-oesophageal fistula repair outcome in 22 patients undergoing surgery for acquired non-malignant tracheo/broncho-oesophageal fistulas using pedicled muscle flaps

#	Flap	Repair Oesophagus	Airway	Outcome Oesophagus	Airway	Mortality 90d
1	LD	Suture	Suture trachea	healed	healed	–
2	LD	Exclusion	Muscle patch carina	restored[a]	healed[b]	–
3	SA	Muscle patch	Muscle patch LMB	healed	healed	–
4	LD	Suture	Muscle patch carina	healed	healed	–
5	LD	Exclusion	LMB resection	restored[a]	healed	–
6	PM	Exclusion	Muscle patch carina	restored[a]	healed	–
7	SA	Muscle patch	RUL lobectomy	leakage	healed	–
8	LD	Suture	LUL lobectomy	healed	healed	–
9	SA	Muscle patch	RMB resection	healed[c]	healed	–
10	PM	Muscle patch	Muscle patch IB	healed	healed	–
11	LD	Muscle patch	LLL lobectomy	healed	healed	64d
12	SA	Exclusion	Muscle patch carina	excluded	healed	12d
13	PM	Exclusion	Muscle patch LMB	restored[a]	healed	–
14	LD	Exclusion	Muscle patch carina	restored[a]	healed	–
15	PM	Muscle patch	RUL sleeve lobectomy	leakage	healed	18d
16	LD	Muscle patch	RUL segmentectomy	healed	healed	–
17	PM	Suture	RP/muscle patch carina	TEF recurrence	TEF recurrence	–
18	PM	Exclusion	Muscle patch RMB	excluded	healed	–
19	LD	Suture	Muscle patch RMB	healed	healed	–
20	LD	Exclusion	Muscle patch carina	excluded	healed	–
21	DI	Muscle patch	RLL segmentectomy	healed	healed	–
22	PM	Exclusion	Muscle patch RMB	excluded	healed	53d

DI: diaphragm; LD: latissimus dorsi; SA: serratus anterior; PM: pectoralis major; RMB: right main bronchus; LMB: left main bronchus; RUL: right upper lobe; LUL: left upper lobe; LLL: left lower lobe; RP: right pneumonectomy.
[a]Retrosternal restoration of gastrointestinal continuity as two-staged procedure.
[b]Airway defect healed after repeat surgery with new muscle flap.
[c]Oesophageal healing after repeat surgery with new muscle flap and stenting.

Table 3: Major postoperative complications in 22 patients undergoing surgery for acquired non-malignant tracheo/broncho-oesophageal fistulas using pedicled muscle flaps

	n
Prolonged mechanical ventilation	10
Haemothorax/haematoma requiring drainage or surgery	4
Atrial fibrillation	4
Pneumonia	4
Pneumothorax requiring drainage	2
Sepsis	2
Acute renal insufficiency	2
Venous thrombosis	2
Clostridium enterocolitis	1
Empyema requiring surgery	1

DISCUSSION

Various techniques have been suggested for the treatment of non-malignant acquired TEF such as one-stage or two/multiple stage surgery [1–8] or a combined endoscopic and surgical approach with oesophageal or airway stenting [10, 11]. The variety of proposed strategies is the expression of the heterogeneity of TEF as a clinical entity and the need for an individual approach to achieve optimal results. As a consequence, this will strongly influence clinical and functional results, which renders the direct comparison of published series difficult.

It was previously reported that the division of the fistula and direct closure of the tracheal and oesophageal defects with soft tissue interposition (omentum, pericardial fat or intercostal muscle flaps) led to excellent functional results with low postoperative mortality and recurrence rates [6, 7]. We hypothesize that, in the majority of these cases, tracheal or oesophageal wall necrosis, mediastinal sepsis and desmoplastic reactions of surrounding tissues were minimal or absent. Mathisen *et al.* reported a single-stage procedure involving a two-layer closure of the oesophagus with circumferential tracheal resection and end-to end anastomosis via cervico-sternotomy [1]. In the vast majority of their patients, TEF was related to post-intubation tracheal injury. Their approach resulted in a low postoperative mortality (10.9%) and recurrence rate (7.9%), with excellent long-term functional results. Other groups obtained similar results for this type of TEF [2].

In more recent reports, the aetiology of TEF was more diverse and included complications of oesophageal surgery and oesophageal stent erosion. By way of consequence, this resulted in a wider distribution of distal tracheal or bronchial involvement as well as a non-negligible proportion of oesophageal leakage with mediastinal sepsis. Shen *et al.* reported on 35 patients with 11 TEF arising as a complication of oesophageal surgery [3]. Consequently, 20% of patients underwent a double- or multi-stage repair and 17% of patients necessitated oesophageal diversion. The majority of TEF was repaired through a thoracotomy, whereas segmental tracheal or bronchial resections/reconstructions were performed in only 9% of patients. Pedicled tissue flaps were interposed in 80% of patients. Four patients (11%) were ventilator-dependent at the time of repair. The individualized approach reported by these authors led to low postoperative mortality (5.7%) and recurrence (8.6%) rates. Oral feeding and breathing without appliance was obtained in 83% and 97% of patients, respectively, but in 11% of patients, intestinal continuity was never restored [3].

Muniappan *et al.* also reported shifting patterns in the aetiology and treatment of TEF with an increasing incidence of complex TEF after oesophagectomy and laryngectomy in their patients [4]. Several patients had a history of neoadjuvant chemo-radiotherapy and tracheal or oesophageal stenting prior to fistula repair. The postoperative mortality and recurrence rates were 3% and 11% and all recurrences occurred in fistulas arising after oesophagectomy or laryngectomy where the oesophageal defect was treated by direct suture closure or skin grafting. Oral intake and breathing without tracheal appliance was achieved in 83% and 71% of patients, respectively.

In the present study, the vast majority of patients had large, complex TEF arising after oesophagectomy that had been performed following neoadjuvant radio-chemotherapy for oesophageal cancer. Most patients presented with mediastinal sepsis and pleuro-pulmonary infections related to the oesophageal leakage, were in poor general condition and generally intubated and ventilated. Prompt surgical TEF repair was required to avoid continuous leakage and ongoing mediastinal sepsis. It seemed to us that a buttressed primary suture was not ideal for the management of these complex fistulas. In addition, in a non-negligible proportion of patients, the closure of the debrided oesophageal or airway defects required an important intestinal or airway substitute to restore intestinal and/or airway integrity. Pedicled extrathoracic muscle flaps transposed into the thorax have been used for many years to reinforce the mediastinum and to obliterate residual infected spaces. They are easy to dissect and have unique features with respect to their size, mechanical strength and versatility. This sustained their use for the closure of broncho-pleural fistulas and other intrathoracic airway defects of variable localisations and extents in cases where a direct suture or end-to-end reconstruction seemed risky. In these circumstances, the muscle flaps were found to efficiently replace airway defects with epithelialization over time [11, 12]. Likewise, intrathoracic oesophageal leaks with mediastinal sepsis were successfully managed using extrathoracic or diaphragmatic muscle flaps that were patched into the oesophageal defect in order to preserve intestinal continuity [13].

Based on these previous experiences, we explored this technique for the treatment of large and complex TEF. We found the use of large, well-vascularized extrathoracic pedicled muscle flaps an attractive strategy for TEF repair. As a matter of fact, in addition to their interposition between airway and intestine, they could also be patched into the debrided defects and function as airway and intestinal wall substitutes when necessary, allowing restoration of intestinal or airway continuity. In the present series, airway healing was achieved in 95% of the patients and the muscle patch technique was especially helpful for the repair of large tracheo-carinal defects above the carinal bifurcation. It also allowed for the successful reconstruction of gastro-oesophageal defects in a large number of patients where the only alternative strategy would have been oesophageal diversion. However, our results demonstrated that the muscle patch technique has its limitations for the anastomotic repair after oesophagectomy, especially in the context of extensive anastomotic breakdown above the carinal level and focal necrosis of the gastric conduit. Although primary oesophageal exclusion was deemed unavoidable to achieve TEF repair in a high proportion of our patients for these reasons, three patients with anastomotic muscle patch repair had recurrent intestinal leakage at the site of reconstruction and one died from aortal-intestinal fistula as a direct consequence of continuous leakage. Airway healing was achieved in virtually all patients by use of this muscle flap technique but not for anastomotic leakage after oesophagectomy: TEF with anastomotic defects arising after oesophagectomy and radio-chemotherapy may be successfully treated by a muscle flap patch but extensive anastomotic breakdown, gastric conduit necrosis or continuing leakage after repair should be treated by oesophageal exclusion in order to prevent fatal complications.

The mortality at 90 days' post-surgery in our series was 18% and was higher than previously reported. However, only one patient died from local complications arising from failing TEF repair. The other causes of death were likely to be attributed to the patients' poor general condition. Several reports suggest postponing surgical TEF repair until significant improvement and weaning from the ventilator were achieved [1, 4]. However, ongoing mediastinal sepsis from uncontrolled oesophageal leakage required surgery without delay in the majority of our patients.

Some studies have investigated the use of endoluminal stents for TEF repair, either for definitive treatment [9] or as initial temporary strategy in order to improve the patient's condition before surgery [14]. Oesophageal or airway stenting or both was performed in 50% of our patients before being referred to our institution. However, TEF healing was not achieved by stenting in any of them. Moreover, in some patients, stenting increased the TEF size which is particularly true for simultaneous stenting of both the airway and the oesophagus at the level of the trachea. This is probably related to stent-induced decubitus damage of the tracheal and oesophageal wall as previously reported [15]. For those reasons, we advocate prompt surgical repair of stented yet persisting TEF in order to avoid additional stent-induced tracheal and oesophageal injury. In these situations, we suggest to leave previously deployed stents in place until surgical repair can be performed and to remove them during surgery. Our experience was also disappointing with the use of stents for the treatment of persisting oesophageal leakage after surgery. Three patients of our series were treated by covered stents in this context; one died from aorto-oesophageal fistula and only one revealed TEF healing over time. Continuing oesophageal leakage after repair of complex TEF may be better managed by oesophageal exclusion and restoration of intestinal continuity by retrosternal colon interposition after several months.

Two-thirds of our patients underwent neoadjuvant radio-chemotherapy in the context of oesophageal cancer surgery. This proportion is significantly higher than in other series. This represents an emerging group of patients with challenging post-surgical TEF and an elevated risk of failing repair. Radio- and chemotherapy may both result in decreased tissue viability and wound healing capabilities [16]. In this context, closure of airways or anastomotic defects by extrathoracic muscle flap patches can alleviate tension on suture lines, bridge large defects with fresh, mechanically stable and well-vascularized tissue and serve as solid barrier interposed between repaired airways and the gastro-intestinal tract. However, caution is indicated in these situations since the extent of focal necrosis of the gastric conduit may be underestimated. This may lead to persistent intestinal leakage at the site of repair with fatal consequences if oesophageal exclusion is delayed.

In conclusion, closure of non-malignant TEF can be achieved in a high percentage of patients using extrathoracic muscle flaps patched into the gastrointestinal or airway defects if primary suture closure seems risky. This leads to airway healing in virtually all patients and to preservation of the intestinal continuity in a large number of cases.

Conflict of interest: none declared.

REFERENCES

[1] Mathisen DJ, Grillo HC, Wain JC, Hilgenberg AD. Management of acquired nonmalignant tracheoesophageal fistula. Ann Thorac Surg 1991;52:759–65.
[2] Macciarini P, Verhoye J-P, Chapelier A, Fadel E, Dartevelle P. Evaluation and outcome of different surgical techniques for postintubation tracheoesophageal fistula. J Thorac Cardiovasc Surg 2000;119:268–76.
[3] Shen KR, Allen MS, Cassivi SD, Nichols FC, Wiggle AD, Harmsen WS *et al*. Surgical management of acquired nonmalignat tracheoesophageal and bronchoesophageal fistulas. Ann Thorac Surg 2010;90:914–9.
[4] Muniappan A, Wain JC, Wright CD, Donahue DM, Gaissert H, Lanuti M *et al*. Surgical treatment of nonmalignant tracheoesophageal fistula: a thirty-five year experience. Ann Thorac Surg 2013;95:1141–6.
[5] Mangi AA, Gaissert HA, Wright CD, Allen JS, Wain JC, Grillo HC *et al*. Benign broncho-esophageal fistula in the adult. Ann Thorac Surg 2002;73:911–5.
[6] Baisi A, Bonavina L, Narne S, Perachia A. Benign tracheo-esophageal fistula: results of surgical therapy. Dis Esophagus 1999;12:209–11.
[7] Cherveniakov A, Tzekov C, Grigorov GE, Cherveniakov P. Acquired benign esophago-airway fistulas. Eur J Cardiothorac Surg 1996;10:713–6.
[8] Oliaro A, Rena O, Papalia P, Filosso PL, Ruffini E, Pischedda F *et al*. Surgical management of acquired non-malignant tracheo-esophageal fistulas. J Cardiovasc Surg (Torino) 2001;42:257–60.
[9] Blackmon SH, Santora R, Schwarz P, Barroso A, Dunkin BJ. Utility of removable esophageal covered self-expanding metal stents for leak and fistula management. Ann Thorac Surg 2010;89:931–6.
[10] Freire JP, Feijo SM, Miranda L, Santos F, Castelo HB. Tracheo-esophageal fistula: combined surgical and endoscopic approach. Dis Esophagus 2006;19:36–9.
[11] Meyer AJH, Krueger T, Lepori D, Dusmet M, Aubert JD, Pasche P *et al*. Closure of large intrathoracic airway defects using extrathoracic muscle flaps. Ann Thorac Surg 2004;77:397–405.
[12] Ris H-B, Krueger T, Cheng C, Pasche P, Monnier P, Magnusson L. Tracheo-carinal reconstructions using extrathoracic muscle flaps. Eur J Cardiothorac Surg 2008;33:276–83.
[13] Kotzampassakis N, Christodoulou M, Krueger T, Demartines N, Vuillemier H, Cheng C *et al*. Esophageal leaks repaired by a muscle onlay approach in the presence of mediastinal sepsis. Ann Thorac Surg 2009;88:966–72.
[14] Eleftheriadis E, Kotzampassi K. Temporary stenting of acquired benign tracheoesophageal fistulas in critically ill ventilated patients. Surg Endosc 2005;19:811–5.
[15] Han Y, Liu K, Li X, Wang X, Zhou Y, Gu Z *et al*. Repair of massive stent-induced tracheoesophageal fistula. J Thorac Cardiovasc Surg 2009;137:813–7.
[16] Mendelsohn FA, Divino CM, Reis ED, Kerstein MD. Wound care after radiation therapy. Adv Skin Wound Care 2002;15:216–24.