Interactive CardioVascular and Thoracic Surgery 26 (2018) 545–550
doi:10.1093/icvts/ivx364 Advance Access publication 22 November 2017

Cite this article as: Walgram T, Attigah N, Schwegler I, Weber M, Dzemali O, Berthold C *et al*. Off-label use of thoracic aortic endovascular stent grafts to simplify difficult resections and procedures in general thoracic surgery. Interact CardioVasc Thorac Surg 2018;26:545–50.

Off-label use of thoracic aortic endovascular stent grafts to simplify difficult resections and procedures in general thoracic surgery

Tanja Walgram[a], Nicolas Attigah[b], Igor Schwegler[b], Markus Weber[c], Omer Dzemali[d], Christian Berthold[e], Dirk Wagnetz[a] and Giovanni L. Carboni[a,*]

[a] Division of Thoracic Surgery, Department of Surgery, Triemli Hospital Zurich, Switzerland
[b] Division of Vascular Surgery, Department of Surgery, Triemli Hospital Zurich, Switzerland
[c] Division of Visceral Surgery, Department of Surgery, Triemli Hospital Zurich, Switzerland
[d] Division of Cardiac Surgery, Department of Surgery, Triemli Hospital Zurich, Switzerland
[e] Division of Interventional Radiology, Department of Radiology, Triemli Hospital Zurich, Switzerland

* Corresponding author. Division of Thoracic Surgery, Department of Surgery, Triemli Hospital, Birmensdorferstrasse 497, 8063 Zurich, Switzerland. Tel: + 41-44-4164306;
e-mail: giovanni.carboni@triemli.zuerich.ch (G.L. Carboni).

Received 14 June 2017; received in revised form 25 September 2017; accepted 17 October 2017

Abstract

OBJECTIVES: Tumour infiltration, or gross infectious involvement of the thoracic aortic wall, poses a significant intraoperative risk for fatal bleeding and therefore could compromise adequate resection or efficient surgical management of pleural infection in a considerable amount of cases. We present 3 successful cases of off-label thoracic aortic endografting to safeguard thoracic aortic wall integrity.

METHODS: After all patients received thoracic stent grafts through femoral access into the descending aorta, the first patient underwent a resection of a locally advanced squamous cell carcinoma of the left inferior lobe cT4cN0–1cM0 after neoadjuvant chemoradiation, which had infiltrated the descending aortic wall. The second case was video-assisted thoracoscopic bilateral pleural decortication for empyema with aortic ulcers of the distal thoracic aorta in a patient with pancreatic intrathoracic fistula in a necrotizing pancreatitis. The third patient was operated for a locally advanced squamous cell carcinoma of the left inferior lobe initial stage cT4 cN1–2 cM0 after neoadjuvant chemoradiation, which had broad contact to the descending aorta at the level of thoracic vertebrae 7 and 8 on a circumference of circa 180°. Regional ethics committee approval according the Swiss Federal Human Research Act was obtained according to regulations.

RESULTS: Preventive stent graft placement resulted in complication-free resection and significantly minimized the risk of fatal intraoperative bleeding. Patients were thus not exposed to complications associated with aortic cross-clamping, possible prosthetic replacement and extracorporeal circulation techniques.

CONCLUSIONS: In carefully selected patient populations, the resection of locally advanced tumours or infectious processes involving the aortic wall can be facilitated by thoracic endovascular aortic repair prior to resection.

Keywords: Thoracic aortic endovascular stent grafts • Tumour resection • Thoracic aorta • Thoracic aortic wall • Thoracic surgery • Lung cancer

INTRODUCTION

Surgery of tumours invading the aorta can result in positive resection margins. To avoid fatal bleeding during surgery, complete resection may require aortic cross-clamping, possible prosthetic replacement and extracorporeal circulation techniques. These methods are associated with serious complications such as paraplegia, stroke, cardiac events such as ischaemia and arrhythmia and respiratory and renal failure [1]. Since Parodi *et al.* [2] and Dake *et al.* [3] reported the first endovascular repair of abdominal and thoracic aneurysms in the early 1990s, only few surgeons described the prophylactic off-label use of aortic stent grafts to enable complete resection of tumours while at the same time minimizing the risk of bleeding [4–7]. The first case report of off-label use of endografts in an oncological setting has been published in 2008 by Marulli *et al.* [8]. Thoracic endograft placement in septic surgery of the pleura has not been described before.

Case reports

Case 1. A 60-year-old man was diagnosed with a squamous cell carcinoma originating from the superior lower lobe segment. Preoperative staging included computed tomography (CT) of the

cranium and thoraco-abdominal CT with a positron emission tomography. The initial clinical stage following the above-mentioned imaging was cT3cN3 (left supraclavicular) cM0. Mediastinal and cervical lymph node metastasis were excluded by invasive cervical and mediastinal staging through cervical lymph node excision and video mediastinoscopy. CT and subsequent operative exploration showed a locally advanced tumour with an infiltration of the descending aortic wall as well as the posterior chest wall over a distance of 5 cm (Fig. 1). After multidisciplinary assessment of these findings in the institutional tumour board, a neoadjuvant concomitant radiochemotherapy was recommended, which consisted of etoposide and cisplatin (following schema VP-16 INT-0139) with concurrent external beam radiation of 45 Gy (25 × 1.8 Gy). Restaging after radiochemotherapy was performed by thoracic and abdominal CT scans and showed a significant regression of tumour size with no evidence of distant metastases but persistent suspected invasion of the aortic wall and the posterior chest wall. Because of the still probable infiltration of the aortic wall, we decided to secure it with a thoracic endovascular graft (Fig. 2).

Tumour resection: Three weeks after thoracic endovascular aortic repair (TEVAR), the tumour was resected *en bloc* through a posterolateral thoracotomy. Left lower lobectomy with *en bloc* partial resection of Segment 2 was performed and, due to dorsolateral tumour extension, a partial chest wall resection including Costae 6 and 7 was performed. The adventitial layer of the aorta was resected semi-circumferentially on a distance of approximately 8 cm. Radical mediastinal lymphadenectomy completed the resection. No prosthetic reconstruction of the thoracic wall was needed, as the defect was well covered by musculature. Postoperative histological workup showed a stage ypT4ypN1 tumour with free resection margins.

Case 2. Patient 2 was a 51-year-old man who presented with an acute exacerbation of chronic relapsing pancreatitis with 2

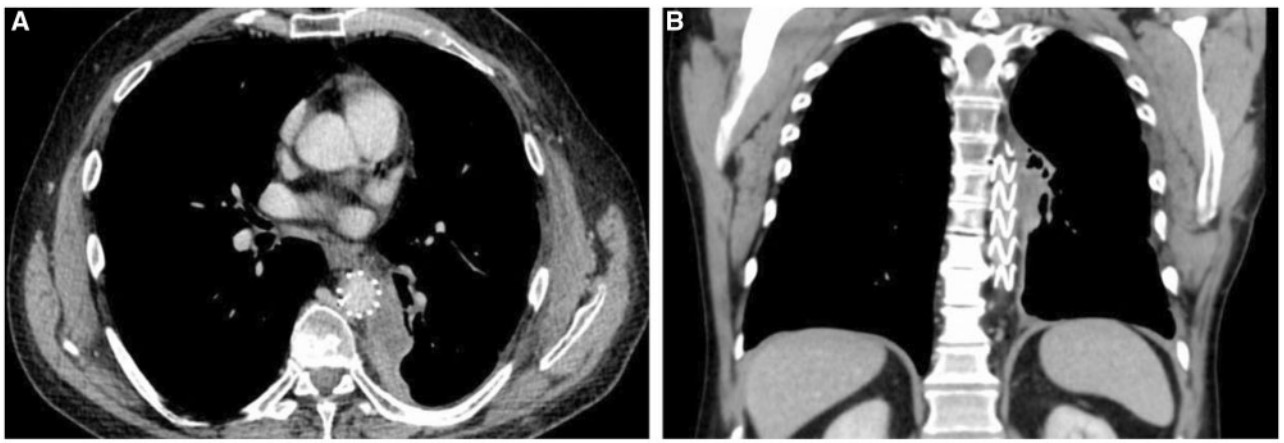

Figure 1: Computed tomography after induction chemoradiation and aortic endovascular graft placement shows a decrease of tumour size and a semi-circular broad-based contact to the thoracic aortic wall.

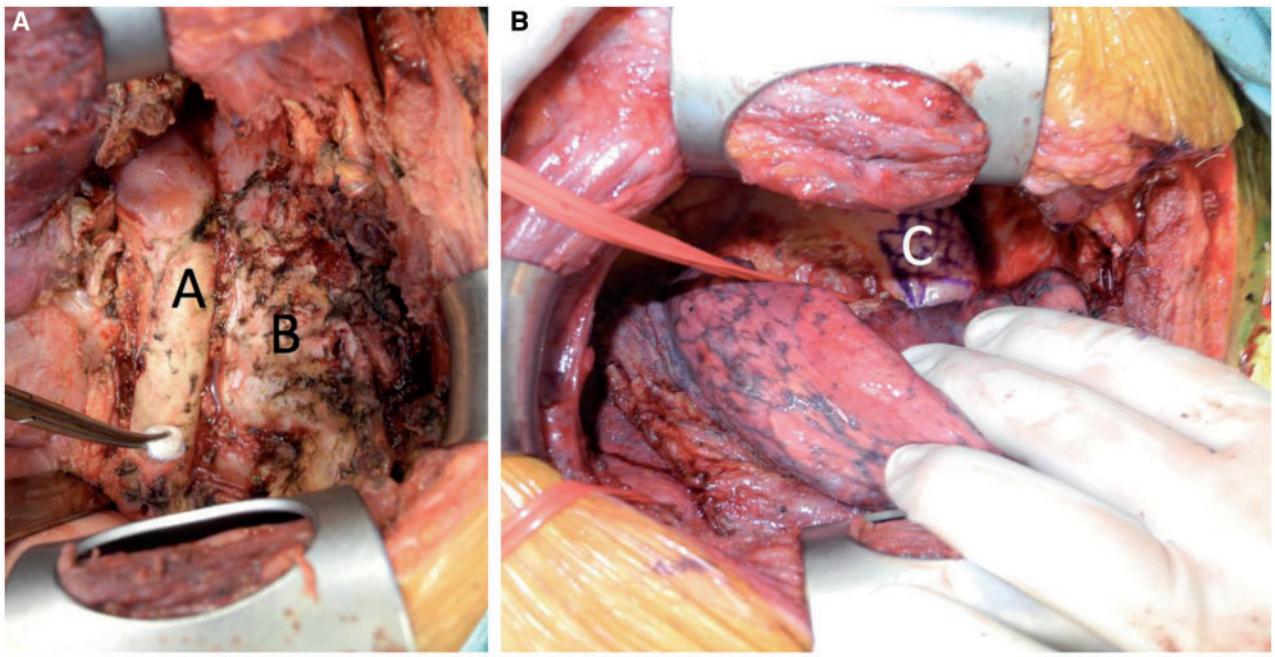

Figure 2: Intraoperative depiction of Patient 1. 'A' indicates area of aortic resection, 'B' is the nerve roots at the neuroforamina and 'C' is the landing zone of the stent in the proximal descending thoracic aorta.

pseudocysts and necrosis of the pancreatic corpus. Additionally, the patient had bilateral pleural effusions drained by chest drains. Due to the amylase-rich exsudate, intrathoracic pancreatic fistula was suspected. CT scan revealed 2 penetrating atherosclerotic ulcers of the distal descending aorta with a maximum diameter of 43.5 mm (Fig. 3). The patient had undergone endovascular aortic repair (EVAR) placement 2 years earlier because of an infrarenal aortic aneurysm. We performed thoracic aortic endografting before bilateral video-assisted thoracic surgery (VATS) decortication during the same anaesthesia (Fig. 4). No signs of vascular wall involvement of the aorta were seen during thoracoscopy. Complete decortication and bilateral pleural and mediastinal drainage were performed without intraoperative complications. Pleural effusions and pleural biopsy were sampled during decortication. Postoperative CT showed correct placement of the aortic endograft. Seven days later, the patient underwent a spleen preserving left pancreatectomy to resect the pancreaticopleural fistula and pseudocysts.

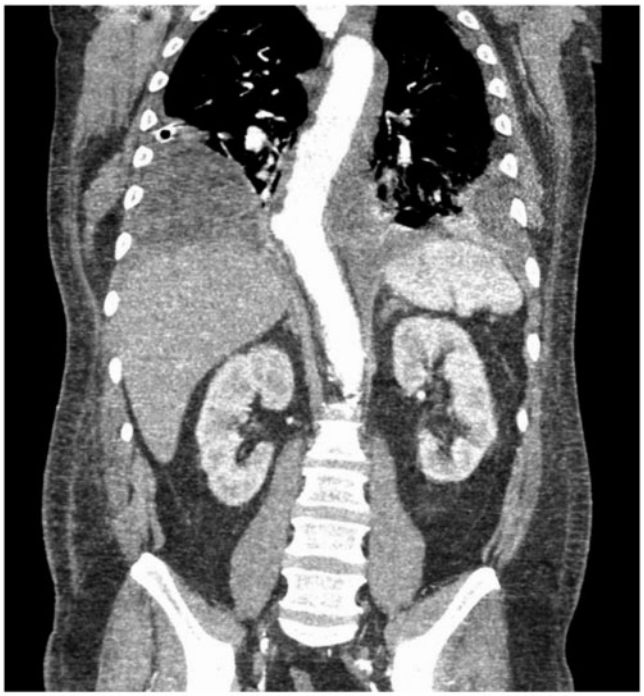

Figure 3: Computed tomography revealed 2 penetrating atherosclerotic ulcers or possible mycotic aneurysms of the distal aorta, one measuring 18 mm width and the second one 8 mm width. Periaortic pleural effusions surround the right-sided deviated distal thoracic aorta. Over a length of circa 9 cm, the descending aorta shows irregularities in calibre size.

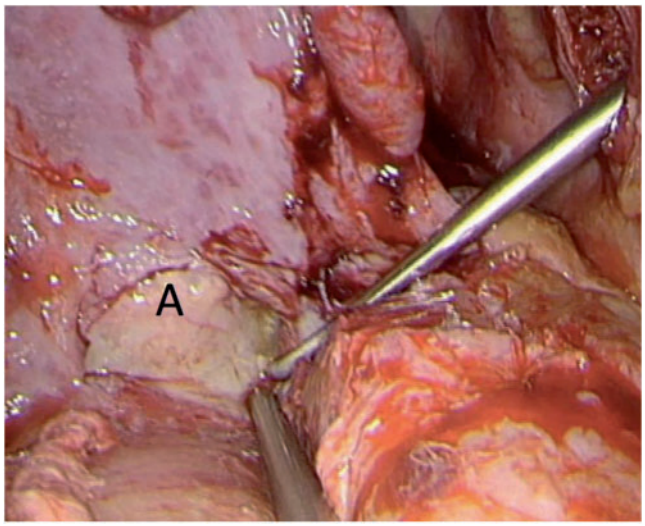

Figure 4: Intraoperative depiction of decortication in Patient 2. 'A' indicates pleural fibrosis.

Case 3. A 64-year-old patient was referred to surgery with a locally advanced squamous cell carcinoma originating from the left lower lobe. Preoperative examinations included thoracoabdominal CT and angio-CT, CT with a positron emission tomography, magnetic resonance imaging of the neurocranium and thorax, bronchoscopy with tissue sampling and histological as well as cytological examination. The initial tumour stage was cT4 (descending aorta) cN1 M0 stadium IIIA. CT results showed a locally advanced tumour with a coronal extension of 83 mm with immediate contact to the descending aorta at the level of thoracic vertebrae 7 and 8 on a circumference of circa 180° as well as infiltration of the left main bronchus, the mediastinum, paravertebral fatty tissue and direct contact to thoracic vertebrae 7 and 8 (Fig. 5). These findings were assessed at the multidisciplinary tumour board, and the patient was referred to neoadjuvant radiochemotherapy with docetaxel and Platinol as well as radiation of 45 Gy (25 × 1.8 Gy).

Because of the likely infiltration of the aortic wall, we decided to proceed with thoracic endovascular grafting.

Tumour resection: The tumour was successfully resected 4 weeks after TEVAR implantation through a posterolateral thoracotomy. Intrapericardial pneumonectomy without pericardial reconstruction due to small size of the excised pericardium was done. The dissection plane went through the adventitia semi-circumferentially, and at the level of thoracic vertebrae 6–8, the lateral aspect of the vertebral body was dissected (Fig. 6). A radical mediastinal lymphadenectomy was performed to complete the surgery. Staging after histological examination was ypT4 ypN1 with successful R0 resection.

Operative TEVAR technique for all patients: A Medtronic (Minneapolis, MN, USA) Valiant Captivia thoracic stent graft was advanced via femoral access into the descending aorta. An oversizing of 10–15% was judged necessary, as no aneurysmatic disease was present. The length of all grafts used was 150 mm. As in all cases, the treatment length was <200 mm; none of the patients underwent prior aortic surgery, and no preoperative cerebrospinal fluid drainage was established. Contralaterally, a 5-Fr angiography catheter was placed by direct puncture. A Roadrunner wire was used as the guiding wire and a Lunderquist wire was used as the support wire. The stent graft was deployed in respiratory arrest and with rapid pacing in the first patient, as the proximal landing zone was close to the left subclavian artery. In general, endovascular repair of aortic pathologies in landing zone <3, according to Mitchell *et al.* [9], were operated in functional cardiac arrest with rapid pacing. Femoral access was closed by suture, and the contralateral puncture site was closed with a femoral closure device (Starclose, Abbott, IL, USA).

Postoperative course

Case 1. The postoperative course was without any major complications. Hypokalaemia, hypomagnesaemia and hyponatraemia

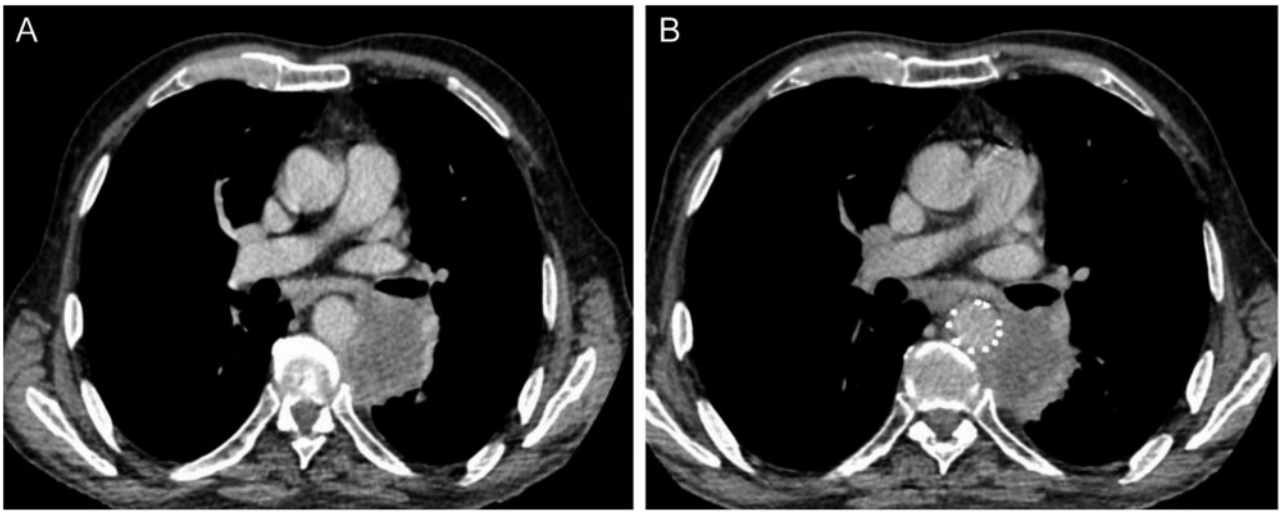

Figure 5: The tumour in Patient 3 shows immediate contact to the descending aorta at the level of thoracic vertebrae 7 and 8 on a circumference of circa 180°. Infiltration of the left main bronchus, the mediastinum, paravertebral fatty tissue and direct contact to thoracic vertebrae 7 and 8 was visible in computed tomography results. (**A**) Before stent graft placement. (**B**) After stent graft placement.

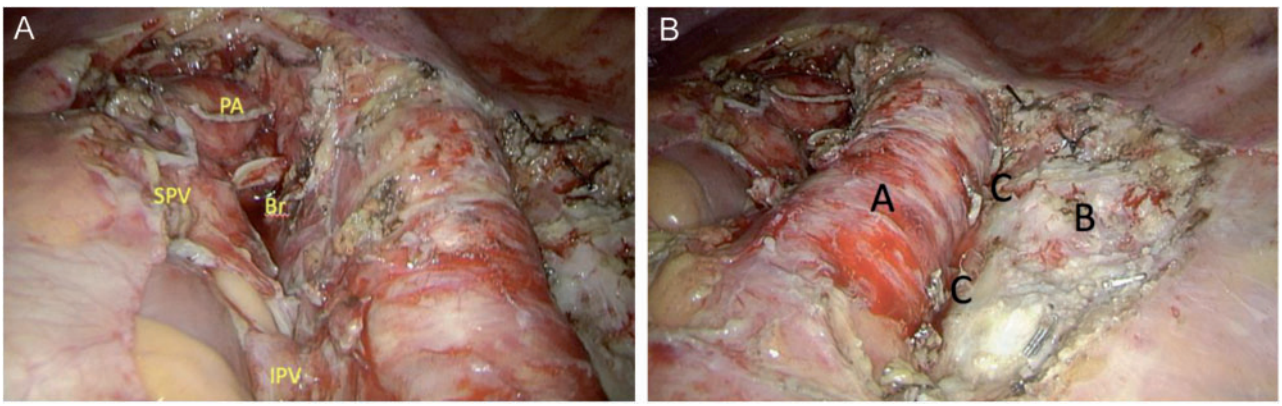

Figure 6: (**A** and **B**) Intraoperative depiction of tumour resection in Patient 3. Semi-circumferential dissection of the adventitia was performed. At the level of thoracic vertebrae 6–8, the lateral aspect of the vertebral body was dissected. 'A' denotes aortic adventitia, 'B' is vertebra 7, 'C' is intercostal arteries, 'PA' indicates pulmoary artery, 'Br' is bronchus, 'SPV' is superior pulmonary vein and 'IPV' is inferior pulmonary vein.

were substituted intravenously and orally. Closing pressures of the lower extremities were clinically unremarkable at all times. Oxygenation levels were sufficient, and no effusions were present. After each of the surgeries, the patient was haemodynamically monitored in the intensive care unit (ICU) for 1 day. A small proximal misalignment (bird's beak) was diagnosed in postoperative CT scan for TEVAR control due to gothic aortic arch configuration. This had no consequence for graft function. Otherwise there were no graft-related complications, such as stroke, dissection, graft migration or access site-related complications. The patient was discharged from hospital 3 days after TEVAR implantation and 6 days after tumour resection. Follow-up examinations were performed with CT every 6 months. So far, 2 years after treatment, the patient shows no tumour recurrence.

Case 2. The postoperative course was uneventful. The patient had 5 chest drains that were removed consecutively until the 12th and 14th postoperative days after decortication. The drain in the right groin was removed on the 2nd postoperative day after TEVAR, where later on a lymphatic fistula emerged, which was successfully managed by conservative measures. Abdominal drains after left pancreatectomy were left *in situ* for 2 weeks due to high amylase levels and were removed only after 14 days. After TEVAR implantation/VATS decortication and left pancreatectomy, the patient was transferred to the ICU and could be transferred back to the surgical ward on the 1st postoperative day each. An asymptomatic pericardial effusion of 9 mm width was diagnosed in a CT on the 13th postoperative day and appeared in remission until the patient was discharged from hospital. Pleural biopsy showed growth of *Propionibacterium acnes*. Postoperative complications included lymphatic fistula in the right groin, and no endograft-related complications occurred. The patient was discharged from the hospital on the 26th postoperative day after TEVAR.

Case 3. The patient was haemodynamically monitored in the ICU for 2 days after pneumectomy and was readmitted to the ICU on the 8th postoperative day with respiratory decompensation and decreased arterial saturation of 67%. Acute respiratory distress syndrome developed rapidly, and the patient had to be placed on non-invasive ventilation. No signs of bronchopleural fistula were seen on bronchoscopy. The patient received an

empirical antibiotic therapy with piperacillin and tazobactam for 19 days and clarithromycin for 12 days. The patient had non-invasive ventilation therapy, high-flow oxygenation supply and was treated with steroids. After clinical improvement, the patient was transferred to the surgical ward on the 21st postoperative day on nasal oxygen supply. The electrocardiography showed one episode of paroxysmal atrial fibrillation, which suspended after one-time administration of bisoprolol. On the 28th postoperative day, the patient was discharged from the hospital and transferred to a rehabilitation clinic. The definite histological results were presented once more at the institutional tumour board where it was decided that the patient should receive small volume additive radiation therapy to the area abutting the 7th vertebra, where resection margins were very close to the vital tumour.

DISCUSSION

Most of the authors concur that the scenario of a lung cancer or a pleural infectious problem involving the aortic wall is infrequent. Despite having units not considered to be large, we encountered 5 patients in the last 2 years initially considered for an endovascular thoracic aortic graft prior to thoracic surgery. Four patients had locally advanced lung cancer, and 1 patient had a pancreaticopleural fistula resulting in complicated empyema as described in this article. Two of the lung cancer patients were not referred to surgical treatment because of advanced nodal disease. Even if the aortic wall is eventually not involved, this scenario seems not that rare.

Estimation of the tumour infiltration depth into the aortic wall is difficult by relying solely on CT and/or magnetic resonance imaging, unless there is gross intravascular tumour protrusion. Scarring after induction treatment in cancer and inflammatory changes in infection additionally render the imaging of correct dissection planes more difficult. To determine difficult or impossible resection of tumours, indicators such as large surface of contact and extent of the aortic circumference enclosed by the tumour can be used. Incomplete resection or transmural vascular lesion can be expected if more than a third of the aortic circumference is enclosed by tumour over a distance of several centimetres as dissection of the tumour mass away from the aortic wall may pose a considerable surgical challenge. In the same way, resection away from the aortic wall is highly likely to be difficult if the tumour also invades the chest wall or part of the spine in cross-sectional imaging. Intravascular ultrasound techniques have been described as useful diagnostic tools in aortic wall diseases and aortic trauma evaluation. Although, to date, no published data exist regarding evaluation of the aortic wall integrity in oncological cases, it could be an option in the future.

We advocate the use of TEVAR in oncological cases without mediastinal nodal involvement and in the setting of a multimodal treatment including induction chemoradiation, where a T4 tumour is abutting a substantial part of the thoracic aorta and the possibility of complete resection is in doubt. Radiological signs that could indicate difficult dissection conditions were mentioned earlier and warrant the use of TEVAR prior to resection. Infectious situations, possible mycotic aneurysm with complex empyema such as intrathoracic pancreatic fistula or intrathoracic anastomotic leak after oesophagectomy could all represent good indications for prophylactic TEVAR even if the aortic wall integrity is later confirmed during surgery. This could potentially also represent an overtreatment; however, a catastrophic complication is avoided. In simple empyema or parapneumonic effusion, TEVAR would obviously be an overtreatment, as these situations do not justify the procedural risks of TEVAR.

The use of aortic endovascular grafts to facilitate the resection of locally advanced tumours requires similar preoperative planning and considerations regarding the choice of implant as in aneurysmatic disease. To date, there is no experimental data that would offer reliable advice on how much the covered stent area should measure at each end of the resection area. Most of the authors report a minimal length of 4 cm for the landing zone [5, 8]. We believe that a proximal and distal landing zone of at least 2 cm should be aimed for. Nevertheless, treatment length of the aortic segment should be kept as short as possible to cover as few intercostal arteries as possible. Perfusion of the subclavian artery should also be preserved whenever possible to maintain spinal perfusion. If coverage of the left subclavian artery is needed to extend the proximal landing zone and the treatment length is more than 20 cm or the infrarenal aorta has been operated before (EVAR or open repair), we would suggest prophylactic spinal cord drainage and the transposition of the left subclavian artery or alternatively a carotidosubclavian bypass prior to TEVAR [10, 11]. In case the tumour is close to the supra-aortic vessels, debranching procedures might be required. In such situations, an individual decision for each case must be taken on whether to have a shorter landing zone or to have a more complex and dangerous endovascular procedure.

Reported infection rates of EVAR/TEVAR are low between 0.2% and 5% in several smaller studies [12]. In one of our patients, an infectious involvement of the aorta could not be completely ruled out. In such cases, endovascular stent grafting must be seen as a potential bridging manoeuvre, and secondary conversion due to infection-related graft complications is not always necessary, but close surveillance is mandatory [13]. When more than the adventitial layer of the aorta is removed, the coverage of the aortic resection area is a possible way to lower the risk of infection. We also used endovascular stenting for a patient with possible mycotic aortic ulcer prior to VATS decortication to avoid intraoperative catastrophic bleeding. In the particular case of pancreaticopleural fistula, the preoperative extent of infectious involvement of the aortic wall is impossible to ascertain solely by CT imaging. Additionally, in this situation, prompt coverage of an exposed graft should be mandatory. Here, we suggest a xenopericardial patch. The possibility of stent graft infection should be kept in mind; however, an emergency aortic reconstruction in an infected pleural space would be a worse scenario. Consequently, we believe that the placement of an endovascular stent graft is the best option to facilitate decortication in these rare constellations. Because of the decreased risk of bleeding, the VATS approach could be adopted more generously resulting in lesser morbidity for the patient. In pleural infection with possible resulting graft infection, long-term suppressive antibiotic therapy is mandatory and must be selected according to resistance with good bioavailability in the pleura and in the biofilms. Therefore, beta-lactam antibiotics are usually not indicated for long-term therapy. Late complications due to infection are possible; therefore, therapy over several months at least should be aimed for. The choice of respective antibiotics has to be tailored individually. In our case, the only growth of bacteria in culture was clinically not relevant.

The main issue in the oncological setting is the tumour stage, as this influences long-term survival. Some authors suggest restricting prophylactic endografting to patients who have N0 or

N1 nodal involvement only [1, 14]. Surgical resection as part of a multimodal treatment concept in Stage IIIA and IIIB tumours with mediastinal nodal involvement is still controversial, and we also suggest limiting the selection to patients with N1 or no nodal disease. For all other patients, definitive radiochemotherapy is probably more suitable because of the comparable oncological outcome. Pneumonectomy after induction chemoradiation has a high morbidity and mortality even in experienced centres [15]. Therefore, patient selection should be conducted very carefully when pneumonectomy is expected. Full-thickness aortic wall resection is probably possible in up to a third of the circumference. Sasahara *et al.* [16] suggest a maximal circumferential resection extent of half the vascular wall based on a study conducted in dogs. Reconstruction of the defect by xenopericardial patch is advisable. Especially if full-thickness aortic wall is resected, reconstruction with a patch is mandatory, as bulging out of the stent graft might be an issue even with a safe landing zone of more than 4 cm. Chest wall and partial vertebral resection are feasible; however, they render the resection more difficult. One advantage of the described technique is that occlusion of the intercostal vessels through the stent graft minimizes bleeding during dissection of or through these structures. As the region is already devascularized from one side by stent placement and possibly through scarring due to radiation, resection of very large segments of the chest wall should be avoided to prevent perfusion damage to the spinal cord. Long-term complications after endovascular stent placement include endoleak, stent migration, infection, stroke, and misalignment [17–19].

Resection of T4 lung tumours with aortic involvement using cardiopulmonary bypass have been published with low mortality and morbidity by several groups [20–22]. The described technique has the advantage of avoiding related risks of bleeding and paraplegia and therefore is the preferable approach in most cases. The ideal interval between placement of the stent graft and tumour resection is not known. In this regard, we suggest not to be overly concerned about a too strong graft embedment due to remodelling after several weeks.

CONCLUSION

In selected cases, TEVAR can be useful to technically facilitate the resection of left-sided locally advanced tumours or infectious processes invading the aortic wall. This protective measure is safe, minimally invasive, does not compromise the thoracic access site and does not require aortic clamping.

Conflict of interest: none declared.

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