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Intentional Overstenting of the Celiac Trunk During Thoracic Endovascular Aortic Repair: Preoperative Role of Multislice CT Angiography

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Purpose: To report initial experience with intentional coverage of the celiac trunk to expand the distal landing zone in thoracic endovascular aortic repair (TEVAR) and to analyze preprocedural visualization of collateral blood flow by noninvasive computed tomographic angiography (CTA).
Methods: Between January 1997 and April 2008, 202 patients with thoracic aortic pathologies were treated by TEVAR. In 5 high-risk patients (3 women; mean age 73 years, range 62–88), intentional overstenting of the celiac trunk was performed when treating 2 ruptured aneurysms, 1 penetrating aortic ulcer, 1 type B dissection, and 1 distal type I endoleak. Multislice CTA (MSCTA) with multiplanar reconstruction was used to visualize the visceral collaterals; no angiography was performed.
Results: MSCTA was able to visualize the patent pancreaticoduodenal artery and other collaterals and to verify sufficient collateral blood flow. All celiac arteries were patent preoperatively; only 1 severe stenosis was demonstrated. After successful TEVAR in all cases, 1 of the 5 patients developed visceral malperfusion and died of multiorgan failure 1 day after TEVAR of a ruptured thoracic aneurysm. A second patient died 6 weeks postoperatively due to cardiopulmonary failure (non-procedure-related). There were no late complications or reinterventions.
Conclusion: Overstenting of the celiac trunk is feasible, with acceptable risk in emergency cases and high-risk patients if MSCTA documents collateral blood flow. Noninvasive MSCTA is sufficient and may obviate pre- and intraoperative selective angiography with or without a balloon occlusion test.

Key words: thoracic aortic pathology, thoracic endovascular aortic repair, overstenting, celiac trunk, aorta, stent-graft, multislice computed tomographic angiography

Thoracic endovascular aortic repair (TEVAR) is associated with reduced perioperative morbidity and mortality compared to open surgery (4.1% to 6% versus 15%).[1–3] These observations of reduced complications have also been seen with endovascular aneurysm repair in the infrarenal aorta,[4–6] as well as the exclusion of thoracic and thoracoabdominal lesions.[7–10] Therefore, endovascular repair has become the first line treatment in many

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vascular centers for selected patients and aortic pathologies.

Major exclusion criteria for TEVAR include the length and configuration of proximal and distal landing zones. To extend the proximal sealing zone, many investigators have described intentional coverage of the left subclavian artery (LSA).[11–14] Controversy continues as to whether or not primary revascularization of the LSA should be performed, since the recently published EUROSTAR results showed a significant risk for paraplegia (odds ratio 4, 95% confidence interval 1.17 to 13.3) after primary LSA coverage without revascularization.[15,16]

Treatment options of pathologies with short or diseased distal landing zones (<1 cm to the celiac trunk) consist of conventional open surgery, thoracoabdominal hybrid procedures,[17] branched endografts,[18,19] or endograft placement with coverage of the celiac trunk without prior revascularization.[20,21] Only small case series have been published regarding the feasibility of intentional celiac trunk coverage, either to treat celiac trunk and thoracic aortic aneurysm (TAA) or distal type I endoleak.[20–22]

The aim of this study was to analyze and report our preliminary experience with intentional overstenting of the celiac trunk in patients undergoing TEVAR. Instead of pre- or intraoperative invasive angiography, noninvasive multislice computed tomographic angiography (MSCTA) was analyzed for its ability to visualize mesenteric collateral blood flow.

METHODS

Between January 1997 and March 2008, 202 patients received a total of 315 thoracic stent-grafts, more than half (59%) under emergency conditions. Patient characteristics and procedural data were collected in a prospective database and retrospectively analyzed. Indications (>1 possible) included thoracic (n=52) or thoracoabdominal (n=37) aortic aneurysms (n=89), penetrating aortic ulcers (n=37), type A or type B dissections (n=56), acute traumatic aortic transections (n=15), aortobronchial fistulas (n=9), ruptured false aneurysms (n=6), and intramural hematoma (n=3).

In 5 (2.4%) of these patients (3 women; mean age 73 years, range 62–88), all treated after 2005, the celiac trunk was intentionally covered due to an inadequate distal landing zone (<20 mm by definition in TEVAR). Two patients suffered from contained rupture of TAA, 1 patient had an asymptomatic penetrating aortic ulcer, and 1 a subsequent chronic expanding Stanford type B dissection. The fifth patient needed distal stent-graft extension due to a secondary distal type I endoleak after elective TEVAR of a TAA. Three of 5 were elective procedures; the remaining 2 were emergencies due to aneurysm rupture. One emergency case was performed with local anesthesia; the remaining under general anesthesia. All patients had severe comorbidities represented by high ASA (American Society of Anesthesiologists) classifications (Table 1).

For diagnosis and procedure planning, MSCTA was performed preoperatively using a 16-slice CT scanner (Aquilion; Toshiba, Japan) operating on 120-kV tube voltage, with 1-mm reconstructed slice thickness, 0.8 increment, 0.94 pitch, gantry rotation 0.4 seconds, and a 240- to 400-mm field of view depending on patient size. A contrast medium with high iodine concentration (iomeprol, 400 mg I/mL) was injected intravenously (Injectron C2; Medron AG, Germany) through an 18-G needle at a high flow rate (5 mL/s) to achieve optimal vessel visualization using 90 to 110 mL of contrast. The scan volume was adjusted to include the complete aorta together with the beginning of the supra-aortic branches down to the hip joint. All 5 patients were imaged using the same CT protocol and scanner.

DICOM images were sent to a 3-dimensional (3D) workstation (Vitrea 2, version 3.9; Vital Images, Minnetonka, MN, USA) for image postprocessing.[23] Maximum intensity projection, oblique multiplanar reformations, and curved planar reformations where used for optimized visualization.[23] Patency of the celiac trunk and mesenteric and liver circulation between the superior mesenteric artery (SMA) and the celiac trunk via gastroduodenal artery collateral flow were assessed preoperatively in elective cases (Fig. 1). Using the centerline method, the length and diameter of the endografts were determined based on the distances between the distal end of the pathology and the celiac trunk and SMA.

TABLE 1
Patient Demographics, Treatment Indication, Status of the Celiac Trunk Pre/Post Endovascular Repair, and Follow-up Results

	Age, y	ASA Class	Indication	Diameter, mm	Celiac Artery Preop	Celiac Artery Postop	Endoleak	Device, mm	Follow-up
1	88	IV	TAA rupture	80	Patent	No imaging	No	TAG 31/150 28/150 28/100	Died of MOF at day 1
2	78	IV	TAA rupture	90	High-grade stenosis	Closed	No	Zenith 36/136 26/202	Died from CP failure at 6 weeks
3	69	II	PAU	48	Patent	Patent by collaterals	No	Valiant 34/100/34	Alive at 15 months
4	66	III	CEAD	65	Patent	Patent by collaterals	No	Valiant 24/112/24	Alive at 16 months
5	62	IV	Type I endoleak; TAA after TEVAR	60	Patent	Patent by collaterals	No	Zenith 32/124	Alive at 31 months

ASA: American Society of Anesthesiologists; TAA: thoracic aortic aneurysm, PAU: penetrating aortic ulcer, CP: cardiopulmonary, CEAD: chronic expanding aortic dissection, EL: endoleak, MOF: multiorgan failure, TEVAR: thoracic endovascular aortic repair.

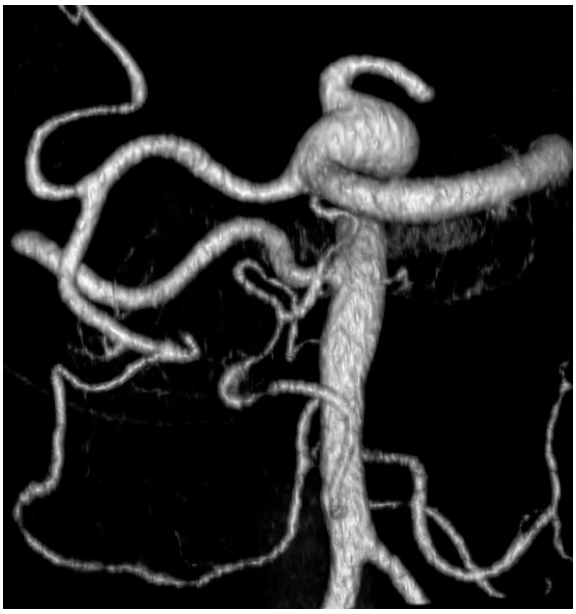

Figure 1 ◆ This 3D volume rendering of a preoperative MSCTA scan shows the collateral from the superior mesenteric artery to the celiac trunk. Note: the infrarenal aorta was segmented and visualized transparent for improved visualization of the collateral flow.

Invasive selective angiography was not performed, either pre- or intraoperatively.

Three different stent-grafts were implanted: 3 TAG (W.L. Gore & Associates, Flagstaff, AZ, USA), 2 Valiant (Medtronic Vascular, Santa Rosa, CA, USA), and 4 Zenith TX2 (Cook Inc., Bloomington, IN, USA). In most cases, the distal endograft had distal bare springs (Zenith or Valiant), which allows the SMA orifice to be covered but not occluded so as to extend the distal landing zone. This extra fixation also helps prevent the endograft from migrating distally, which would occlude the SMA and cause visceral ischemia. No additional embolic agents were used. The endovascular procedures were standard and have been published.[24]

Postoperative monitoring for visceral ischemia, hypertension, fever, pain, and laboratory values (liver transaminases, creatinine, urea, amylase, lipase, and blood count, as well as electrolytes) was performed in all 5 patients. The follow-up protocol included physical examination, ankle-brachial index (ABI) measurement, abdominal ultrasound, chest radiography, and MSCTA scan (Fig. 2). Serial images were analyzed to follow changes in the pathology and implanted devices, e.g., aneurysm sac shrinkage, retrograde collateral

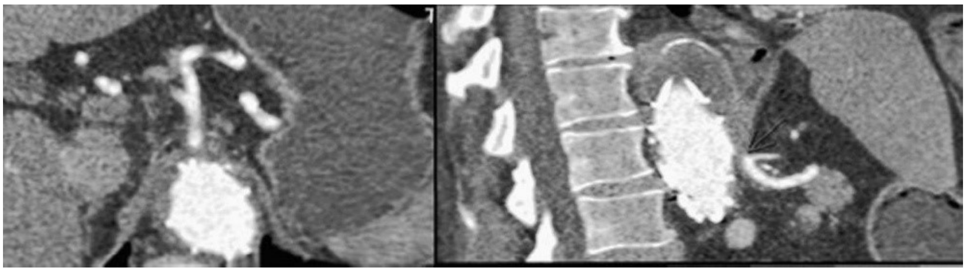

Figure 2 ◆ A multiplanar reformat of a postoperative MSCTA showing intraluminal coverage of the celiac trunk by an endograft with retro-collateral flow, but no type II endoleak.

filling of the celiac trunk, endoleaks, device migration, and material fatigue.

RESULTS

All celiac arteries were patent in the preprocedure CT scan, but 1 severe stenosis was demonstrated. Image postprocessing to identify collateral flow could not be performed prior to treatment in the 2 emergency cases. All 5 cases were completed successfully, with complete exclusion of the lesions, exact deployment covering the celiac trunk, no overstenting of the SMA, and no primary endoleak. Patient 1 (Table 1) died of multiorgan failure 1 day after successful emergent exclusion of a ruptured aneurysm (no collateral flow estimation preoperatively). The liver enzymes increased dramatically (up to 5635 U/L for aspartataminotransferase), and acute renal failure developed rapidly, with creatinine rising from 2.04 mg/dL before operation to 3.0 mg/dL. There where no signs of shock before or after the TEVAR procedure, and the hemoglobin levels were stable. The other 4 patients showed no clinical disorders or clinically relevant laboratory dysfunctions, although 1 patient had mild derangement in laboratory values (increases in amylase to 144 U/L, lipase to 335 U/L, and lactate dehydrogenase to 360 U/L) without any clinical relevance. There were no neurological complications or acute reinterventions.

During a follow-up ranging from 15 to 31 months (Table 1), patient 2 died from cardiopulmonary failure 6 weeks post endograft implantation without clinical signs of malperfusion or organ infarcts; there was minimal shrinkage of the aneurysm. None of the remaining 3 patients complained of abdominal claudication in follow-up. There was no late mortality related to the procedure or to the aortic pathology. No patient showed new peripheral claudication symptoms or changing ABI values. No false aneurysm of the femoral artery was observed. CTAs (Fig. 2) showed coverage of the celiac trunk without endograft migration; there was persistent collateral flow from the SMA, with adequate perfusion of the hepatic and splenic artery. No signs of material fatigue were evident. There were no reinterventions in follow-up.

DISCUSSION

The majority (90%) of thoracoabdominal pathologies are located in the aortic arch and the proximal descending aorta; only about 10% are in the visceral segment. In such rare cases, covering of the celiac trunk could be an option in TEVAR. This preliminary experience in a small series indicates that intentional overstenting of the celiac trunk is feasible in emergencies and selected patients at risk of visceral malperfusion. The extension of the distal landing zone without prior revascularization of the celiac trunk reduces time to successful exclusion of the aortic pathology, avoids laparotomy, and lowers procedure-related morbidity in high-risk patients. In case of ischemia, immediate bypass grafting is indicated.

Preprocedural imaging using high-resolution MSCTA with 3D reconstruction (1-mm slice thickness) allows visualization of mesenteric collateral circulation in a noninvasive fashion. In the future, MSCTA might be equivalent to a preoperative diagnostic angiogram with or without balloon occlusion of the visceral arteries as described by Libicher et al.[25]

TABLE 2
Visceral Ischemic Complications in Patients With Thoracoabdominal Pathologies Treated With Different Procedures

Study	Procedure	Number of Ischemic Bowel Complications
Böckler[17]	Hybrid procedures for thoracoabdominal aortic aneurysms and chronic aortic dissections	2/26 (7.7%)
Waldenberger[22]	Clinical outcome of endovascular therapeutic occlusion of the celiac artery	1/10 (10%)
Vaddineni[20]	Covered celiac trunk during endovascular thoracic aortic aneurysm repair	0/7 (0%)
Greenberg[18]	Branched endovascular graft for thoracoabdominal aneurysm	0/29 (0%)
Lawrence-Brown[26]	Hybrid open-endoluminal technique for repair of thoracoabdominal aneurysm	0/2 (0%)

and others.[21] With our CTA protocol, we were able to visualize collateral flow over the gastroduodenal artery as the most common collateral pathway.[22,23] Other collaterals are the left hepatic artery, the dorsal pancreatic artery, or the left and right gastroepiploic arteries,[22] which can also be detected in MSCTA.

A limitation of this approach is the inability of MSCTA to demonstrate the hemodynamic status of the collateral flow. Hypothetically, we could avoid this disadvantage using an electrocardiographically-triggered protocol, but this would increase radiation exposure, so it is not an alternative. The balloon technique (conventional angiography with balloon occlusion of the celiac trunk) described by Libicher et al.[25] can demonstrate direct blood inflow and the hemodynamic pattern of collateral blood flow. Nevertheless, the interpretation of these results remains speculative and highly subjective, as no quantifiable measurement is produced. The only objective method to prove sufficient collateral blood flow would be a direct artery flowmetry measurement, which requires an open surgical approach. Nevertheless, logic dictates that there is no reason why flowing blood should not use an open vessel as a collateral pathway. It is important to note that digital subtraction angiography is an invasive method, with known complications such as bleeding, false aneurysm, and local thrombosis. High-grade stenosis in collateral vessels can be demonstrated well with MSCT and if recognized, balloon dilation or another form of revascularization could be considered before covering the celiac trunk.

Bowel ischemia after intentional endovascular coverage of the celiac trunk seems to be a rare complication, with an incidence of 0% to 10% (Table 2).[20,21] Vaddineni et al.[20] reported no clinical evidence of malperfusion; none of their 7 patients showed clinically relevant laboratory dysfunctions or signs of abdominal claudication. Waldenberger et al.[22] described 1 of 10 patients with abdominal angina after sealing the celiac trunk.

In our series, 1 of 5 patients showed laboratory symptoms of visceral ischemia, with dramatically increasing liver enzymes and acute renal failure with fatal outcome. Only 1 other patient had mild and clinically irrelevant changes in liver enzymes; however, close (every 3 to 4 hours) postoperative laboratory and clinical examinations in the first days after the TEVAR are mandatory. In case of suspected visceral ischemia or reduced liver perfusion verified by clinical examination, laboratory testing, and imaging, explorative laparotomy with revascularization should be performed immediately, although this procedure is associated with a high perioperative mortality rate.

Because of the short distal landing zone and the retrograde perfusion of the celiac trunk, distal type I or type II endoleak is of special interest. In this small series, no endoleak could be detected on postoperative CTA. This is in line with the series reported by Vaddineni et al.,[20] who saw only a single type I endoleak after overstenting the celiac trunk.

Our approach to a persistent type II endoleak with increasing aneurysm size would be secondary embolization of the celiac trunk. This can be performed using a microcatheter placed between the endograft and the aortic wall or via the collateral vessel after canalization of the SMA. Routine open ligature of the celiac trunk with banding of the distal landing zone, as suggested by Lawrence-Brown et al.,[26] is, in our opinion, not indicated because it increases operation time and trauma in these highly comorbid patients.

Hybrid procedures for thoracoabdominal aortic aneurysms and chronic aortic dissections, which we reported recently,[17] include debranching of the visceral arteries followed by the endovascular procedure. In our experience, the visceral and renal graft occlusion rate was 11% at 30 days; bowel resection was necessary in 2 of 26 patients.

Besides open surgical repair and TEVAR with closure of the celiac trunk, branched endografts offer another treatment modality for these complex pathologies. The obvious advantage is preservation of antegrade visceral perfusion combined with a purely endovascular approach, but this technique is not feasible in emergencies. The short-term results using branched endografts or endografts combined with stents reflected a high rate of technical success from 89% to 95%.[18,19] Most procedures with branched endografts are done in the iliac region or with juxta- and suprarenal aneurysms. Only a few cases of branched endografting in thoracoabdominal aneurysm have been published so far.[18] Morbidity in thoracoabdominal or juxtarenal procedures is much higher compared to infrarenal procedures, with the risk of renal insufficiency ranging from 9.7% to 11% compared to the infrarenal procedure.[18,19] In our opinion, it is imperative that we initiate training programs to develop expertise in simple fenestrated graft implantation before using this method in thoracoabdominal pathologies. The handling and availability of branched endografts must be simplified to allow broader usage in routine or emergency cases. Nonetheless, the technique will probably remain limited to highly specialized centers with large endovascular experience.

We would like to point out that in our series we could not perform preoperative image postprocessing of the collateral flow in emergency patients. In an emergency, the main aim is to control bleeding of the ruptured aortic pathology. In some rare cases, this can be achieved only by covering the celiac trunk. Therefore, no imaging is needed. In stable patients, selective angiography with balloon occlusion as a test for collateral flow[25] could be performed, but this procedure prolongs operating time and risks dissection in the small arteries. Nevertheless, we think that intentional overstenting of the celiac trunk is justifiable in selected patients with thoracoabdominal pathologies as an alternative to open surgery, hybrid procedures, or branched endografts.

In our small series, we used 3 different types of endografts. The Gore TAG device has no distal bare stents, so this model needs a longer distal landing zone compared to the other 2 devices we used. On the other hand, the Gore TAG is the most flexible of the 3 and is thus well suited for kinked aortic morphologies. The Medtronic Valiant is available with a closed web or distal bare stents, which makes it is possible to cover the SMA orifice with bare stents and lengthen the sealing zone. The Cook Zenith device has an active fixation system using hooks to avoid stent migration, so it is frequently used in cases with short landing zones. A possible contraindication may be acute aortic dissections, as the hooks could cause intimal lesions and consequent rupture.

Conclusion

In this small series, intentional overstenting of the celiac trunk in TEVAR seems to be well tolerated and is associated with an acceptable risk of visceral ischemic complications. An optimized multislice CTA protocol followed by 3D reconstruction is feasible to demonstrate collateral visceral blood flow and might therefore be a replacement for preoperative angiography in the future.

REFERENCES

1. Schumacher H, Böckler D, von Tengg-Kobligk H, et al. Symptomatic plaque rupture and penetrating ulcer of the thoracoabdominal aorta. Who should be treated and which technique should be applied? [in German] *Gefässchirurgie*. 2005;10:38–50.
2. Dake MD, Miller DC, Semba CP, et al. Transluminal placement of endovascular stent-grafts for the treatment of descending thoracic aortic aneurysms. *N Engl J Med*. 1994;331:1729–1734.

3. Svensson LG, Crawford ES, Hess KR, et al. Variables predictive of outcome in 832 patients undergoing repairs of the descending thoracic aorta. *Chest*. 1993;104:1248–1253.
4. Greenberg RK, Chuter TA, Sternbergh WC, et al. Zenith AAA endovascular graft: intermediate-term results of the US multicenter trial. *J Vasc Surg*. 2004;39:1209–1218.
5. Matsumura JS, Brewster DC, Makaroun MS, et al. A multicenter controlled clinical trial of open versus endovascular treatment of abdominal aortic aneurysm. *J Vasc Surg*. 2003; 37:262–271.
6. Prinssen M, Verhoeven EL, Buth J, et al. A randomized trial comparing conventional and endovascular repair of abdominal aortic aneurysms. *N Engl J Med*. 2004;351:1607–1618.
7. Ellozy SH, Carroccio A, Minor M, et al. Challenges of endovascular tube graft repair of thoracic aortic aneurysm: midterm follow-up and lessons learned. *J Vasc Surg*. 2003;38:676–683.
8. Leurs LJ, Bell R, Degrieck Y, et al. Endovascular treatment of thoracic aortic diseases: combined experience from the EUROSTAR and United Kingdom Thoracic Endograft registries. *J Vasc Surg*. 2004;40:670–680.
9. Makaroun MS, Dillavou ED, Kee ST, et al. Endovascular treatment of thoracic aortic aneurysms: results of the phase II multicenter trial of the GORE TAG thoracic prosthesis. *J Vasc Surg*. 2005;41:1–9.
10. Orend KH, Scharrer-Pamler R, Kapfer X, et al. Endovascular treatment in diseases of the descending thoracic aorta: 6-year results of a single center. *J Vasc Surg*. 2003;37:91–99.
11. Peterson BG, Eskandari MK, Gleason TG, et al. Utility of left subclavian artery revascularization in association with endoluminal repair of acute and chronic thoracic aortic pathology. *J Vasc Surg*. 2006;43:433–439.
12. Görich J, Asquan Y, Seifarth H, et al. Initial experience with intentional stent-graft coverage of the subclavian artery during endovascular thoracic aortic repairs. *J Endovasc Ther*. 2002;9(suppl II):II39–II43.
13. Criado FJ, Barnatan MF, Rizk Y, et al. Technical strategies to expand stent-graft applicability in the aortic arch and proximal descending thoracic aorta. *J Endovasc Ther*. 2002;9(suppl II):II32–II38.
14. Riesenman PJ, Farber MA, Mendes RR, et al. Coverage of the left subclavian artery during thoracic endovascular aortic repair. *J Vasc Surg*. 2007;45:90–95.
15. Buth J, Harris PL, Hobo R, et al. Neurologic complications associated with endovascular repair of thoracic aortic pathology: incidence and risk factors. A study from the European Collaborators on Stent/Graft Techniques for Aortic Aneurysm Repair (EUROSTAR) Registry. *J Vasc Surg*. 2007;46:1103–1111.e2.
16. Kotelis D, Geisbüsch P, von Tengg-Kobligk H, et al. Paraplegia after endovascular repair of the thoracic and thoracoabdominal aorta. *Zentralbl Chir*. 2008;133:338–343.
17. Böckler D, Kotelis D, Geisbüsch P, et al. Hybrid procedures for thoracoabdominal aortic aneurysms and chronic aortic dissections – A single center experience in 28 patients. *J Vasc Surg*. 2008;47:724–732.
18. Greenberg RK, West K, Pfaff K, et al. Beyond the aortic bifurcation: branched endovascular grafts for thoracoabdominal and aortoiliac aneurysms. *J Vasc Surg*. 2006;43:879–887.
19. Verhoeven EL, Muhs BE, Zeebregts CJ, et al. Fenestrated and branched stent-grafting after previous surgery provides a good alternative to open redo surgery. *Eur J Vasc Endovasc Surg*. 2007;33:84–90.
20. Vaddineni SK, Taylor SM, Patterson MA, et al. Outcome after celiac artery coverage during endovascular thoracic aortic aneurysm repair: preliminary results. *J Vasc Surg*. 2007;45:467–471.
21. Saito N, Kimura T, Toma M, et al. Endovascular repair of a thoracoabdominal aortic aneurysm involving the celiac artery and the mesenteric artery. *Ann Vasc Surg*. 2006;20:659–663.
22. Waldenberger P, Bendix N, Petersen J, et al. Clinical outcome of endovascular therapeutic occlusion of the celiac artery. *J Vasc Surg*. 2007;46:655–661.
23. von Tengg-Kobligk H, Weber T, Rengier F, et al. Imaging modalities for the thoracic aorta. *J Cardiovasc Surg (Torino)*. 2008;49:429–447.
24. Böckler D, Schumacher H, Schwarzbach M, et al. Endoluminal stent-graft repair of aortobronchial fistulas: bridging or definitive long-term solution? *J Endovasc Ther*. 2004;11:41–48.
25. Libicher M, Reichert V, Aleksic M, et al. Balloon occlusion of the celiac artery: a test for evaluation of collateral circulation prior endovascular coverage. *Eur J Vasc Endovasc Surg*. 2008;36:303–305.
26. Lawrence-Brown M, Sieunarine K, van Schie G, et al. Hybrid open-endoluminal technique for repair of thoracoabdominal aneurysm involving the celiac axis. *J Endovasc Ther*. 2000;7:513–519.
27. Schumacher H, Böckler D, Bardenheuer H, et al. Endovascular aortic arch reconstruction with supra-aortic transposition for symptomatic contained rupture and dissection: early experience in 8 high-risk patients. *J Endovasc Ther*. 2003;10:1066–1074.