European Radiology (2018) 28:3221–3227
https://doi.org/10.1007/s00330-017-5288-8

VASCULAR-INTERVENTIONAL

Heparin-bonded stent graft treatment for major visceral arterial injury after upper abdominal surgery

Benedikt Michael Schaarschmidt[1] · Johannes Boos[1] · Christian Buchbender[1] · Patric Kröpil[1] · Feride Kröpil[2] · Rotem Shlomo Lanzman[1] · Guenter Fürst[1] · Wolfram Trudo Knoefel[2] · Gerald Antoch[1] · Christoph Thomas[1]

Received: 12 September 2017 / Revised: 13 December 2017 / Accepted: 22 December 2017 / Published online: 26 February 2018

Abstract

Purpose To analyse technical success, complications, and short- and intermediate-term outcomes after heparin-bonded stent graft implantation for the treatment of major abdominal vessel injury after upper abdominal surgery.

Methods This retrospective, IRB-approved analysis included 29 consecutive patients (female: $n = 6$, male: $n = 23$, mean age 65.9 ± 11.2 years). All patients underwent angiography and attempted heparin-bonded stent-graft implantation because of a major visceral arterial injury after upper abdominal surgery. Electronic clinical records, angiographic reports and imaging datasets were reviewed to assess technical success and complications. Telephone interviews were performed to obtain follow-up information and to estimate short- (> 30 days) and intermediate-term (> 90 days) outcomes.

Results Successful stent graft placement was achieved in 82.8% (24/29). Peri-interventional complications were observed in 20.7% (6/29) and delayed, angiography-associated complications were observed in 34.5% (10/29) of the patients. Symptomatic re-bleeding occurred in 24.1% (7/29). Short-term survival (> 30 days) was 72.4% (21/29). Intermediate survival (> 90 days) was 37.9% (11/29).

Conclusion Treatment of major vascular injuries with heparin-bonded stent grafts is feasible with a high technical success rate. However, survival depends on the underlying surgical condition, making interdisciplinary patient management mandatory.

Key Points

- *Stent graft implantation is challenging, but has a high technical success rate.*
- *Complications are frequent but surgical conversion is rarely necessary.*
- *Survival depends on the underlying surgical condition causing the vascular injury.*
- *Interdisciplinary management is crucial for the survival of these patients.*

Keywords Aneurysm · Haemorrhage · Stents · Abdomen · Arteries

Abbreviations

CT	Computed Tomography
HIT	Heparin-Induced Thrombocytopaenia
IRB	Institutional Review Board
rt-PA	Recombinant Tissue Plasminogen Activator
SIR	Society of Interventional Radiology

✉ Benedikt Michael Schaarschmidt
benedikt.schaarschmidt@med.uni-duesseldorf.de

[1] Department of Diagnostic and Interventional Radiology, University Dusseldorf, Medical Faculty, 40225 Dusseldorf, Germany

[2] Department of General, Viszeral and Pediatric Surgery, University Dusseldorf, Medical Faculty, 40225 Dusseldorf, Germany

Introduction

Delayed intra-abdominal haemorrhage is a rare but potentially lethal complication after upper abdominal surgery, most notably following partial pancreatic resection. Minor blood loss via surgical drains, also referred to as sentinel bleeding, is a frequent precursor of delayed intra-abdominal haemorrhage, which is associated with mortality rates of up to 50% [1]. While early intra-abdominal bleeding (< 24 h) is predominantly caused by incomplete intraoperative haemostasis, delayed intra-abdominal bleeding (> 24 h) is usually caused by intra-abdominal complications such as abscesses, pseudoaneurysms or erosion of the upper abdominal vessels due to leakage of pancreatic fluid, bile or closely located drains [2].

Surgical management of patients with delayed arterial haemorrhage is technically challenging, especially in the presence of leaking pancreatic anastomoses and associated inflamed tissue, leading to high perioperative mortality rates [3]. Thus, rescue operations such as the splenic artery switch operation have to be considered as second-line treatment options [4]. Effective interventional techniques in these critically affected patients may pose a possible alternative. Endovascular coil placement offers quick vessel occlusion but may cause infarction and necrosis of downstream organs such as the liver [5, 6]. Hence, for the treatment of lacerations of major intestinal vessels the use of stent grafts has been proposed to seal the bleeding site, reconstruct the diffusely eroded vessel and prevent necrosis [7]. Heparin-bonded, polytetrafluoroethylene-covered stents (Viabahn ®, W. L. Gore & Associates, Flagstaff, AZ, USA) are expected to improve patency rates in these vessels. However, only short-term results of small case series regarding this technique have been published until now [8–10]. Hence, we sought to investigate technical success, complications and clinical outcome after implantation of heparin-bonded stent grafts in patients with visceral arterial bleeding after upper abdominal surgery.

Material & Methods

Patients

This study was approved by the institutional review board. The institutional interventional radiology database was screened for patients who had undergone visceral artery stent graft implantation as a treatment for arterial haemorrhage after upper abdominal surgery between January 2007 and December 2016. Twenty-nine consecutive patients (female: $n = 6$, male: $n = 23$, mean age 65.9 ± 11.2 years) were included. Electronic clinical records, angiographic reports and imaging data sets including CT, MR and angiographic images were reviewed to assess technical success and complications. For the retrospective analysis of the available data, informed consent was waived by the IRB. Telephone interviews were performed to obtain follow-up information and to assess complications after discharge and related to the antithrombotic therapy. Verbal informed consent was obtained from patients before the telephone interview. There are no conflicts of interest to declare.

Procedure Details

Detection of major arterial vessel injury was performed using CT angiography. CT findings leading to emergency interventional angiography were active contrast extravasation, pseudoaneurysm formation and arterial vessel wall irregularities in conjunction with a sudden drop in haemoglobin levels. Angiography was subsequently performed following interdisciplinary consultation and informed patient consent in conscious patients. The access site (transbrachial versus transfemoral access) was selected by the interventional radiologist according to the bleeding location and the vascular anatomy of the patient. Especially in steep ramifications of the upper abdominal vessels, a transbrachial access at the crook of the arm was chosen. After placement of a 5-F sheath under local anesthesia, diagnostic angiography using a 5-F pigtail and/or selective catheter was performed to confirm vascular injury. If a relevant pathology of a major vessel (hepatic or mesenteric artery) and suitable anatomy were confirmed, graft sizing was performed according to the manufacturer's instructions for use. A long, flexible sheath (SuperArrow-Flex, Arrow Int., Reading, PA, USA) was introduced and its tip was placed in the proximal part of the target vessel. After crossing the lesion, a suitable stiff guidewire was introduced and a self-expanding, heparin-bonded, polytetrafluoroethylene-covered stent graft was placed across the lesion. As vasospasms are frequently encountered in bleeding vessels, the stent size was chosen according to the vessel size on preoperative CT imaging to avoid undersizing. In cases of insufficient treatment with a single stent graft, an overlapping second stent graft was placed. Additional angioplasty was performed if the implanted graft did not lead to spontaneous cessation of bleeding. Vascular access sites were closed either using a vascular closure device (Angio-Seal, Terumo, Japan) or manually using local compression (especially in cases of transbrachial access). For anticoagulation, heparin was started after technically successful stent graft placement and continued for 48 h. If absence of further bleeding was confirmed, double platelet inhibition using acetylsalicylic acid 100 mg and clopidogrel 75 mg was started.

Statistical Analysis

All statistical analyses were performed using SPSS 24.0™ (IBM, Armonk, NY, USA). Explorative data analysis of patient characteristics, procedural details, technical success, complications, short-term survival after 30 days, intermediate survival after 90 days and mean overall survival was performed according to the "Quality Improvement Guidelines for Percutaneous Transcatheter Embolization" by the Society of Interventional Radiology. Complications were assessed according to the "SIR Classification System for Complications by Outcome" [11].

Results

Patients

Twenty-nine consecutive patients were included in our analysis (female: $n = 6$, male: $n = 23$, mean age 65.9 ± 11.2 years). Surgery was performed because of suspected pancreatic

cancer in 51.7% (15/29) of the patients, cholangiocellular carcinoma in 13.4% (4/29), gastroesophageal cancer, neuroendocrine tumours or sarcoma in 6.9% (2/29), respectively, and duodenal cancer, recurrence of hepatocellular carcinoma, chronic pancreatitis and endoscopically unstoppable haemorrhage after papillotomy in 3.4% (1/29), respectively. In these patients, 70% (20/29) underwent pancreaticoduodenectomy, 17.2% (5/29) multivisceral resection, 10.4% (3/29) hepatic surgery and 3.4% (1/29) gastrectomy.

Angiography

Interventional angiography of the visceral arteries was performed 29 ± 14 days following surgery. Vessel pathology was located in the hepatic artery in 79.4% (23/29), in the superior mesenteric artery in 10.4% (3/29) and in the renal, splenic or coeliac arteries in 3.4% (1/29), respectively.

For stenting of the upper visceral arteries, a transbrachial access at the crook of the arm was necessary in 65.5% (19/29), using 6-F sheaths in 10.5% (2/19), 7-F sheaths in 73.7% (14/19) and 8-F sheaths in 15.8% (3/19). A transfemoral access was performed in 35.5% (10/29), using 6-F sheaths in 20% (2/10), 7-F and 8-F sheaths in 40% (4/10), respectively. Successful stent graft placement was achieved in 82.8% (24/29). A second overlapping stent graft was required to treat the bleeding in 20.7% (6/29), resulting in a total of 30 stent graft implantations. The following stent graft sizes were used: 5 × 25 mm: 33.3% (10/30); 5 × 50 mm: 13.4% (4/30); 6 × 25 mm: 10% (3/30); 6 × 50 mm: 20% (6/30); 7 × 25, 7 × 50 and 8 × 25 mm: 3.3% (1/30), respectively; 8 × 50 mm: 13.4% (4/30). In 17.2% (5/29), additional balloon angioplasty was necessary to achieve complete stent graft expansion, while an additional stenosis of the hepatic artery proximal to the stent graft had to be treated in 3.4% (1/29).

In 17.2% (5/29), stent graft placement was not possible. In 40% (2/5) of these patients, it was not possible to place the guidewire distal to the aneurysm; in 40% (2/5), the stent graft could not be placed at the exact anatomical localisation of the bleeding. In one patient stent graft placement was considered as unfavourable because of the close proximity of the bleeding to the segmental arteries supplying the fourth liver segment. In all five patients with failure of stent graft placement, aneurysm coiling was not considered possible because of diffuse vessel damage or the impossibility to safely place the microcatheter tip in the aneurysm. As complete vessel occlusion was considered unfavourable, the bleeding was treated surgically to maintain the blood supply of the downstream organs.

Complications

Successful stent graft placement without peri-interventional or delayed complications was observed in 37.5% (9/24).

During the intervention, a total of six complications occurred (minor complications: 83.3% (5/6), major complications: 16.7% (1/6); Table 1). Most complications could be effectively treated during the intervention: In 66.6% (4/6) of patients with complications, severe vasospasms were observed that could be treated successfully by the intra-arterial injection of nimodipine (Nimotop®, Bayer AG, Germany), and in one patient (1/6), a thrombotic occlusion of the stent successfully resolved after intra-arterial injection of rtPA. In one patient suffering from a type F complication, a bleeding pseudoaneurysm ruptured during stent graft placement because of perforation of the aneurysm wall caused by dislocation of the guidewire tip and subsequent massive haemorrhage. As it was not possible to place the guidewire distal to the bleeding site to perform emergency stent graft placement, the bleeding was sealed temporarily using an occlusion balloon in the proximal hepatic artery and the patient was transferred to the operating room for surgical conversion.

After the intervention, a total of seven recurrent abdominal haemorrhages and ten delayed complications associated with the angiographic treatment were observed (minor complications: none, major complications: 100% (10/10); Table 1).

Access-related complications were observed in three patients, all of whom had undergone transbrachial stent graft placement. While occlusion of the brachial artery was observed in two patients, one patient developed a pseudoaneurysm at the puncture site. Surgical treatment was performed in all three cases.

A total of seven stent graft occlusions were observed in all 24 patients with technically successful stent graft implantation (29.2%, 7/24).

Five early stent graft occlusions were found in 20.8% of the treated patients (5/24) 12 ± 13 days (range 0 to 41) after the intervention. In this specific subgroup, all patients eventually deceased during their stay at our hospital. Of special interest is a case of a 60-year-old male patient requiring multiple interventions because of recurrent stent occlusions after treating a bleeding of the hepatic artery haemorrhage using a heparin-bonded stent graft. The reason for these occlusions turned out to be development of heparin-induced thrombocytopaenia type II (HIT II) induced by stent graft implantation and/or heparinisation. To restore vessel patency, the patient was treated with stenting of an additional stenosis of the hepatic artery as well as intra-arterial thrombolysis and thrombectomy. However, sustained stent graft patency could not be achieved and the patient died 6 days after stent graft placement because of liver failure (Fig. 1).

Delayed stent graft occlusion was observed in one asymptomatic patient 140 days after the intervention on oncological follow-up CT. In a second patient, an intentional stent graft occlusion using cyanoacrylate was performed because of recurrent and otherwise unstoppable bleeding 53 days following the initial heparin-bonded stent graft placement. In these two

Table 1 Complications after stent graft treatment for major visceral arterial injury after upper abdominal surgery according to the "SIR Classification System for Complications by Outcome" [11]

SIR classification of complications by outcome			Acute complications (n = 6)		Delayed complications (n = 10)	
Minor complications	A	No therapy, no consequence	0	0	0	0
	B	Nominal therapy, no consequence	5	83.3%	0	0
Major complications	C	Require therapy, minor hospitalisation (< 48 h)	0	0	0	0
	D	Require major therapy, prolonged hospitalisation (> 48 h)	0	0	8	80.0%
	E	Permanent adverse sequelae	0	0	0	0
	F	Death	1	16.7%	2	20.0%

patients, survival after the intervention was 538 and 75 days, respectively. In a mean follow-up period of 164 days, no stent occlusion was observed in the other 50% of all successfully treated patients (12/24). In 20.8% (5/24), no follow-up imaging was available.

Symptomatic re-bleeding occurred in 24.1% (7/29). Three patients were treated by additional stent graft placement (Fig. 2). CT-guided injection of haemostatic agents and simultaneous coil occlusion of the hepatic artery were performed in one patient and cyanoacrylate embolisation of the right hepatic artery in another patient (as mentioned above). Surgical conversion, however, was only necessary in two patients.

Outcome

Overall survival at the time point of the analysis was 17.2% (5/29). Mean follow-up for all surviving patients was 1183 ± 621.6 days. Mean survival after the intervention was 287 ± 337 days, ranging from 1 to 2672 days. Short-term survival (> 30 days) was 72.4% (21/29). Here, 2/8 patients died from multiorgan failure, 2/8 patients died from diffuse and untreatable intra-abdominal bleeding, three patients from necrosis of the small intestine (2/8) or the liver (1/8) after stent occlusion and 1/8 patient from cardiogenic shock. Intermediate survival (> 90 days) was 37.9% (11/29). In the additional ten patients, 9/10 patients died from multiorgan failure, most often caused by septic complications, and 1/10 patient died from unstoppable bleeding located at an intestinal anastomosis.

Survival was especially poor in all five patients suffering from early stent occlusion. Here, short-term survival (> 30 days) was 40.0% (2/5) in this subgroup, and none of these patient survived more than 90 days.

Discussion

Major vessel injury after upper abdominal surgery is a rare, potentially lethal complication. Especially after pancreatic surgery, intra-abdominal infections, closely located drains and intra-abdominal fluid collections containing bile or pancreatic fluid can lead to erosion of the upper abdominal

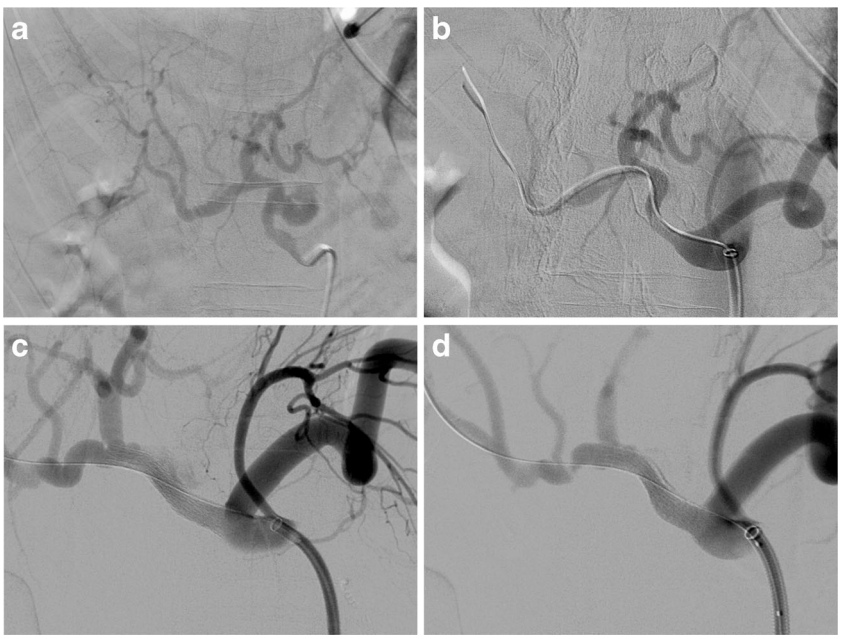

Fig. 1 A 30-year-old male patient after pancreaticoduodenectomy experienced rectal bleeding after discharge. In the abdominal CT examination, a hepatic pseudoaneurysm was detected in CT and confirmed by angiography (**A**). The vessel was successfully reconstructed using a stent graft (**B**). Before discharge, another pseudoaneurysm distal to the stent graft was detected. After overlapping stent graft implantation, contrast media extravasations could be still observed (**C**). Complete sealing of the bleeding could be achieved by additional balloon dilatation of the stent graft (**D**)

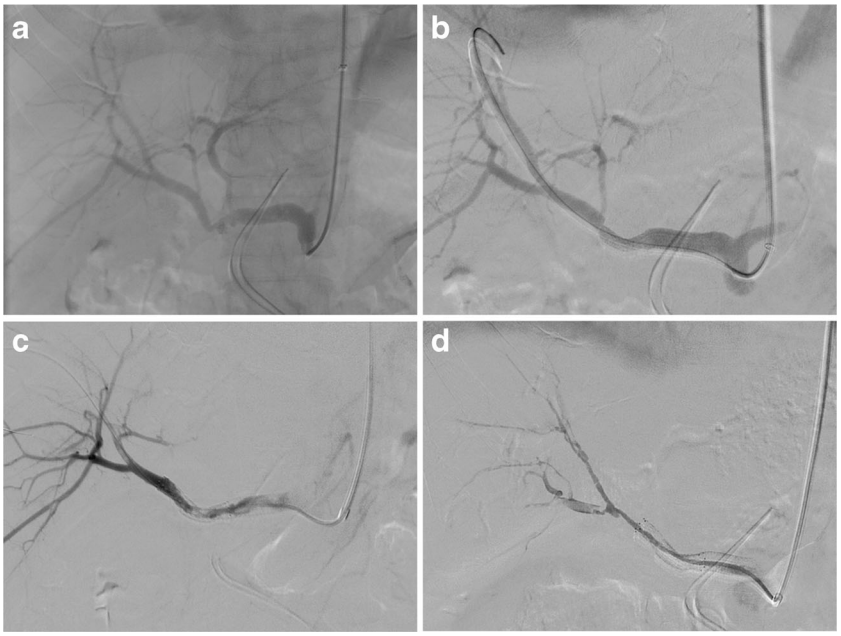

Fig. 2 Sentinel bleeding via the drains was observed in a 60-year-old male patient after pancreaticoduodenectomy. In angiography, a pseudoaneurysm of the hepatic artery was found (**A**) and successfully treated using a heparin-bonded stent graft (**B**). However, stent graft occlusion was observed 2 days after the intervention. Despite successful thrombectomy and treatment of a stenosis at the distal stent graft using a bare metal stent (**C**), recurrent thromboses were observed, which turned out to be caused by a heparin-induced thrombocytopaenia type II. Despite multiple interventions and prolonged continuous intra-arterial thrombolytic therapy, stent patency could not be achieved (**D**) and the patient died 6 days after stent graft implantation

vessels. So-called "sentinel" bleedings via the drains or pseudoaneurysm formation often precede a massive intra-abdominal haemorrhage, which is associated with a high mortality. Hence, immediate treatment of these vascular pathologies is necessary. In this study, most bleedings originated from the hepatic artery and could be successfully treated in 82.8% (24/29). Peri-interventional complications were observed in 20.7% (6/29) and delayed angiography-associated complications were observed in 34.5% (10/29) of the patients. While short-term survival (> 30 days) was 72.4% (21/29), intermediate survival (> 90 days) was 37.9% (11/29). While reasons for short-time mortality were quite diverse, most patients died from septic complications in the further course. Therefore, stent graft placement has to be considered an emergency procedure to gain time to treat the underlying surgical problem. Survival, however, depends on the underlying surgical condition causing the vascular injury as well as stent graft patency, stressing the importance of interdisciplinary management in these patients.

In the interventional treatment of haemorrhage, vessel embolisation using coils provides a high success rate. In the major abdominal arteries, however, proximal vessel occlusion frequently leads to infarction of downstream organs. In a recently published analysis, Hasegawa et al. showed that coil embolisation of the hepatic artery leads to hepatic failure and/or hepatic abscesses in 32% of patients [12]. Hence, it is desirable to maintain vessel patency and seal the bleeding by using stent grafts [13].

Albeit more challenging than coiling, technical success rates for stent graft placement range from 66 to 100%, which are comparable to the results in our study [8–10, 13, 14].

Re-bleeding was a common occurrence in our study. Like in our cohort, the observed incidence in the literature after successful treatment ranges from 8 to 31% and is slightly higher in comparison to coiling [9, 13, 14]. However, most re-bleedings occur at a novel site because of continuing vessel erosion caused by persisting pancreatic fluid or inflammation and are rarely associated with insufficient stent graft placement [13]. Thus, parallel to vascular injury repair, local inflammation should be minimised by either surgical repair of leaking anastomoses or interventional draining.

Another possible complication is early stent occlusion, which can occur in up to 25% [15]. Early stent occlusion had a negative impact on the overall clinical outcome, a phenomenon also described by Lim et al. In their study, two patients with immediate stent graft occlusion died shortly after the intervention because of extensive liver necrosis [15]. In our study, we observed early stent graft occlusions in five patients. A potential problem might be the small diameter of the upper abdominal arteries and the cautious use of antithrombotic or anti-platelet drugs normally administered after stent graft placement in these patients. Therefore, heparin-bonded stent grafts are considered to provide better patency rates. However, previously published results included only small numbers of implanted stent grafts from different vendors, making a literature based recommendation of a specific

type of stent graft impossible. Further studies are necessary to investigate if this coating has an effect on stent patency compared to regular stent grafts in the upper abdominal arteries.

Heparin-induced thrombocytopaenia is observed in less than 1% of all intensive care patients necessitating heparin therapy and can lead to thrombocytopaenia as well as recurrent thrombosis [16]. Induced by stent graft implantation and/or heparinisation, it can lead to life-threatening situations after heparin-bonded stent graft implantation because of stent occlusions. The only solution to treat these patients is stent graft explantation, which might be impossible because of the bad overall clinical status [17]. Unfortunately, the available antibody testings are associated with many false-positive findings, making a reliable antibody screening prior to the implantation of heparin-bonded stent grafts impossible [18]. However, preexisting HIT is a contraindication for implantation of heparin-bonded stent grafts.

A major complication is vessel rupture, which occurred in one patient in our study. This rare complication has also been described in other case series and is most commonly caused by perforation of the vessel wall by the guidewire tip [10]. Here, immediate sealing of the artery is necessary to avoid lethal blood loss. If emergency stent graft placement cannot be performed, temporary balloon occlusion of the visceral arteries is a possible emergency technique to bridge the timespan till definite surgical treatment [19].

Despite the possibility of the above-mentioned complications, this intervention has to be considered as an essential emergency technique. As perioperative mortality in patients with upper abdominal bleeding is high, interventional treatment should be preferred [1, 3].

Concerning outcome, a stark contrast can be observed between the initial technical success and the clinical results. Especially long-term outcome depends on the underlying surgical problem. Therefore, it is not surprising that most patients in our study died from multiorgan failure or septic complications but not from vessel-related complications. As described in the literature, stent graft-associated mortality due to necrosis of downstream organs was comparably low. However, especially early stent graft occlusion is associated with a high mortality, in accordance with previous studies [15].

The limitation of this study is its retrospective character. Hence, no control group treated using coil embolisation or non-coated stent grafts was available. As previous publications included a variety of stent graft types, it is also difficult to compare our data with results provided in the literature. However, a prospective, randomised study approach using heparin-coated and non-coated stent grafts will not be able to recruit a sufficient number of patients in a reasonable timespan. Therefore, it would be desirable to agree on a multi-centre reporting system to gain further insight in this topic.

In conclusion, treatment of postoperative upper abdominal haemorrhage with heparin-bonded stent grafts is a feasible emergency technique with a high technical success rate. As complications are possible, an experienced interventional team is necessary to perform these interventions. Long-term survival depends on the treatment of the underlying surgical condition. Therefore, an effective interdisciplinary management taking into account not only the bleeding but also its surgical cause is crucial for the survival of these patients.

Funding The authors state that this work has not received any funding.

Compliance with ethical standards

Guarantor The scientific guarantor of this publication is Christoph Thomas.

Conflict of interest The authors of this manuscript declare no relationships with any companies, whose products or services may be related to the subject matter of the article.

Statistics and biometry No complex statistical methods were necessary for this paper.

Informed consent Written informed consent was waived by the Institutional Review Board.

Ethical approval Institutional Review Board approval was obtained.

Methodology
- retrospective
- case-control study
- performed at one institution

References

1. van Berge Henegouwen MI, Allema JH, van Gulik TM, Verbeek PCM, Obertop H, Gouma DJ (1995) Delayed massive haemorrhage after pancreatic and biliary surgery. Br J Surg. 82:1527–1531
2. Wente MN, Veit JA, Bassi C et al (2007) Postpancreatectomy hemorrhage (PPH)–An International Study Group of Pancreatic Surgery (ISGPS) definition. Surgery 142:20–25
3. Yekebas EF, Wolfram L, Cataldegirmen G et al (2007) Postpancreatectomy hemorrhage: diagnosis and treatment. Ann Surg 246:269–280
4. Kröpil F, Schauer M, Krausch M et al (2013) Splenic artery switch for revascularization of the liver: a salvage procedure for inflammatory arterial hemorrhage. World J Surg 37:591–596
5. Lee HG (2010) Management of bleeding from pseudoaneurysms following pancreaticoduodenectomy. World J Gastroenterol 16: 1239
6. Hur S, Yoon CJ, Kang S-G et al (2011) Transcatheter arterial embolization of gastroduodenal artery stump pseudoaneurysms after pancreaticoduodenectomy: safety and efficacy of two embolization techniques. J Vasc Interv Radiol 22:294–301
7. Puppala S, Patel J, McPherson S, Nicholson A, Kessel D (2011) Hemorrhagic complications After Whipple Surgery: imaging and radiologic intervention. Am J Roentgenol 196:192–197
8. Lü P-H, Zhang X-C, Wang L-F, Chen Z-L, Shi H-B (2013) Stent graft in the treatment of pseudoaneurysms of the hepatic arteries. Vasc Endovasc Surg 47:551–554

9. Bellemann N, Sommer C-M, Mokry T et al (2014) Hepatic artery stent-grafts for the emergency treatment of acute bleeding. Eur J Radiol 83:1799–1803
10. Pedersoli F, Isfort P, Keil S et al (2016) Stentgraft implantation for the treatment of postoperative hepatic artery pseudoaneurysm. Cardiovasc Intervent Radiol 39:575–581
11. Angle JF, Siddiqi NH, Wallace MJ et al (2010) Quality improvement guidelines for percutaneous transcatheter embolization. J Vasc Interv Radiol 21:1479–1486
12. Hasegawa T, Ota H, Matsuura T et al (2017) Endovascular treatment of hepatic artery pseudoaneurysm after pancreaticoduodenectomy: risk factors associated with mortality and complications. J Vasc Interv Radiol 28:50–59.e5
13. Ching KC, Santos E, McCluskey KM et al (2016) Covered stents and coil embolization for treatment of postpancreatectomy arterial hemorrhage. J Vasc Interv Radiol 27:73–79
14. Gaudon C, Soussan J, Louis G, Moutardier V, Gregoire E, Vidal V (2016) Late postpancreatectomy hemorrhage: predictive factors of morbidity and mortality after percutaneous endovascular treatment. Diagn Interv Imaging 97:1071–1077
15. Lim SJ, Park KB, Hyun DH et al (2014) Stent graft placement for postsurgical hemorrhage from the hepatic artery: clinical outcome and CT findings. J Vasc Interv Radiol 25:1539–1548
16. Verma AK, Levine M, Shalansky SJ, Carter CJ, Kelton JG (2003) Frequency of heparin-induced thrombocytopenia in critical care patients. Pharmacother J Hum Pharmacol Drug Ther 23:745–753
17. Blas J-VV, Carsten CG, Gray BH (2016) Heparin-Induced thrombocytopenia associated with a heparin-bonded stent graft. Ann Vasc Surg 33:227.e1–227.e4
18. Farley S, Cummings C, Heuser W, et al. Prevalence and overtesting of true heparin-induced thrombocytopenia in a 591-bed tertiary care, teaching hospital. J Intensive Care Med 2017;0885066617722707.
19. Wang M-Q, Guo L-P, Lin H-Y, Duan F, Liu F-Y, Wang Z-J (2011) Management of life-threatening celiac-hepatic arterial hemorrhage after pancreaticoduodenectomy: usefulness of temporary balloon occlusion. Chin Med J 124:4115–4118