Fenestrated and branched stent-grafts for treatment of complex aortoiliac aneurysms

SUMMARY

This thesis investigates the technical challenges, outcomes, and risks of endovascular treatment of complex aortoiliac aneurysm. It suggests that hybrid operating rooms may assist in achieving satisfying results in complex FEVAR. However, complex FEVAR might unnecessarily expose the patients to higher risk of complications in the treatment of juxtarenal AAA, which are suitable for renal FEVAR. We have shown that renal FEVAR is a safe and effective treatment option with fewer intraoperative complications and similar mid-term outcomes compared with complex FEVAR. In the last decade a trend has evolved towards more complex FEVAR. The systematic review revealed that renal FEVAR remains a safe and effective treatment option in the borders of instruction of use with no higher risk on type Ia endoleak or reinterventions during follow-up compared to complex F/BEVAR. The indications for endovascular interventions increase due to the less invasive character and getting more applicable even in the elderly high-risk population. This thesis showed that age itself is not a reason to withhold FEVAR in the elderly, and choice of treatment should be based on the patient's comorbidities and preferences. Furthermore, the thesis support FEVAR as a feasible option for the repair of juxtarenal AAA after prior failed EVAR, but it is associated with increased technical challenges due to the previous placed stent-graft.

Chapter 2 evaluates the benefits of a hybrid operating room (group 2) compared with a mobile C-arm (group 1) in the treatment of AAA with FEVAR. We analysed 96 patients, of whom 46 patients were treated with a mobile C-arm and 50 patients in a hybrid operating room. In our hospital the hybrid operating room was active from December 2012, and we had the possibility to use CBCT and 3-D image fusion. The technical success and intraoperative complications were not significantly different (respectively, 91.3% group 1 vs. 94% group 2, p = .72 and 17% group 1 vs. 12% group 2, p = .46). In group 2 significantly less contrast was utilized compared to group 1 (group 1 median 150ml vs group 2 median 100mL, p< .001). Fluoroscopy- and intervention time were not significantly different. The 30-day mortality in group 1 was 9% and 2% in group 2 (p = .14), and 1-year survival was also not significantly different between both groups. Target vessel patency was significantly higher in group 1 (87.6% vs. 85.5% [p = .006] and 83.8% vs. 78.3% [p = .03]) at 6 and 12 months, respectively). However, this could be explained due to the significant (p< .001) more complex FEVAR (including SMA or/and celiac trunc) that were performed in group 2 compared to group 1. Regarding the primary patency in the renal arteries there was no significant

difference between the two groups. Freedom from reintervention during the 1-year follow-up was 91.3% in group 1 and 88% in group 2 (p = .60). This study showed satisfactory clinical and technical results using mobile C-arm or hybrid operating room in FEVAR interventions. In terms of mortality (30-day and 1-year), technical success, perioperative complications, reinterventions, and perioperative complications were similar between both groups, despite the significantly higher number of more complex FEVAR and secondary revisions of previously placed EVAR in group 2. The similar results in both groups could be explained due to better image quality and the use of advanced imaging applications in the hybrid operating room.

The impact of stent-graft configurations in FEVAR on clinical outcome has been investigated in **Chapter 3**. The aim of this study was to compare mid-term outcomes of fenestrated stent-grafts with only renal fenestration (renal FEVAR group) with stent-grafts including the SMA and celiac trunk (complex FEVAR group). We studied 154 patients (54 renal FEVAR vs. 100 complex FEVAR), who underwent FEVAR for the treatment of AAA. Median follow-up was 25 months (IQR 7-45). We revealed no significant differences in technical success and perioperative mortality. Intraoperative complications (4% vs. 18%, p = .001), operative time (145 min vs. 191 min, p = .001), radiation dose (119372 mGy*cm^2 vs. 159573 mGy*cm^2, p = .004) and fluoroscopy time (39 min vs. 54 min, p = .007) were significantly lower in the renal FEVAR group. During follow-up target vessel instability, endoleaks and reinterventions (renal FEVAR 24% vs. complex FEVAR 16%) were not significantly different between the two groups. The study showed that renal FEVAR is a safe and effective treatment for juxtarenal AAA. When we compared the renal FEVAR group to the complex FEVAR we describe fewer intraoperative complications with similar mid-term outcomes. We advise to choose for renal FEVAR stent-graft configuration if the anatomy is suitable for it. The renal FEVAR group had a significantly lower total effective seal zone and total used seal zone compared with the complex FEVAR group. However, during follow-up no late type Ia endoleaks in the renal FEVAR group was detected, which shows a secure proximal sealing zone.

The aim of **Chapter 4** is to demonstrate if there is a relationship between increased stent-graft complexity and clinical outcomes. After screening 7149 articles, 11 matched the inclusion criteria with a total of 2167 patients. Patients of any race, sex and age who presented with a PAA or TAAA (only Crawford type IV) and underwent elective endovascular repair were eligible for inclusion. Studies that compared renal (double) with complex (triple or quadruple) fenestrated

(FEVAR) and/or branched endovascular aneurysm repair (BEVAR) were eligible for inclusion. The systematic review showed no significant difference in technical success and all-cause mortality rate during hospital stay or within 30 days, however the latter was twice as high for the complex group. No significant difference was revealed between the two groups regarding reinterventions or the other secondary outcomes. In conclusion juxtarenal aneurysms renal FEVAR remains a safe and effective treatment option depending on the anatomy of the aneurysm and staying within the instruction of use. No significant higher risk on type Ia endoleak was reported in the renal FEVAR group, suggesting that whenever the anatomy is indicated for two fenestrations and a scallop for the SMA you can choose for this configuration, without elevated risk for reinterventions in the proximal sealing zone. However, complex FEVAR in this study showed no increase significant risk for target vessel occlusion, perioperative complications, mortality or reinterventions compared to renal FEVAR, so a liberal approach of complex FEVAR might be justified. On the other hand, we should be prudent with interpreting the data, as the large portion of the complex FEVAR was performed in the last period of several studies with accumulated experience and some of the studies were performed by high volume centres with extensive experience in FEVAR.

In **Chapter 5** we evaluate the mid-term results of FEVAR in octogenarians from two tertiary referral centers. We investigated 272 patients, which were divided in group 1 octogenarians (n 42) and group 2 non-octogenarians. The median age was respectively, 82 years and 72 years old. In our study there was no statistically significant difference in technical success, survival, and reintervention of FEVAR between the two groups. Moreover, no difference was seen between groups for the estimated cumulative target vessel patency. In conclusion, age itself should not be a reason to refuse FEVAR in the treatment of complex AAA. The choice of treatment in octogenarians should be weighed by patients' preference and comorbidities.

In **Chapter 6** we present results of one of the endovascular solutions after failed previous EVAR for the treatment of AAA. A total of 26 patients were treated with FEVAR (25 had a type Ia endoleak and one patient with endotension after EVAR). Twenty-three patients were treated with a fenestrated cuff and 3 patients with a bifurcated fenestrated stent-graft. The previous EVARs were from various manufacturers, but the fenestrated stent-grafts were all customized based on the Cook Zenith system (William A. Cook Australia, Ltd., Brisbane, Australia). Technical success was 92.3% and there was no postoperative mortality. Two

major complications occurred: one patient needed an open conversion because of impossibility to retrieve the top cap as a result of twist of the ipsilateral limb and another patient required permanent dialysis due to loss of the right kidney. In the patients who underwent a successful FEVAR interventions, target vessel patency was 100%. Our results suggest that FEVAR after EVAR is technical feasible, and that the outcome is related to the initial technical success. It is advantageous in terms of mortality and less morbid than open surgery but is associated with increased technical challenges because of the previously placed stent-graft.

Chapter 7 focusses on the use of an iliac branch device in the treatment of aortoiliac aneurysms and assesses the compatibility of the combination of two stent-grafts (EVAR Medtronic® (Vascular, Inc, Minneapolis, Minnesota, USA) and E-liac stent-graft System (Artivion® GmbH, Hechingen, Germany)) from different manufacturers. The study included 38 patients with a total of 50 hypogastric arteries which were treated with an IBD. Only balloon expandable stents (94% E-Ventus BX stent, 6% Advanta V12) were used as extension in the hypogastric artery. The aneurysm was successfully excluded in 94.7%. During follow-up, type Ib or type III endoleak wasn't detected and all stented hypogastric arteries remained patent. We conclude that the combination of these stent-grafts (EVAR+IBD) from different manufacturers are an effective and safe procedure for the treatment of aortoiliac aneurysms. Moreover, we confirm the high hypogastric artery patency rate using IBD.

Chapter 8 describes the mid-term outcomes of the E-liac stent-graft in the treatment of aortoiliac aneurysms. The clinical data regarding the E-liac stent-graft from Artivion®, however, are scarce. We included sixty-three patients (60 male, median age 70 years (IQR 66-;76) in our study, who were treated with 82 E-liac stent-grafts with a median follow-up of 38 months (IQR 22-51). This study showed a technical success rate of 95% and the internal iliac artery stayed patent during follow-up in 97.6%. No patients died or needed reinterventions within 30-days. During follow-up, we revealed in one patient an endoleak type Ib of both hypogastric arteries, however the patient refused additional interventions. One other patient had a contained rupture due to a type II endoleak. The patient had severe comorbidities and based on these findings the patient was rejected of any interventional treatment. Furthermore, only one (1.6%) IBD-related reintervention was needed with relining of the stent-graft. The primary patency of the hypogastric branch was 95.1% and the mortality was 25.4% during follow-up. In conclusion our study showed a high technical success rate for the E-liac stent-graft, with corresponding good mid-term outcomes. The E-liac stent-graft is a feasible, safe

and effective stent-graft in the treatment of aortoiliac aneurysms.

Chapter 9 reports our first experience with inner-branched stent-grafts (iBEVAR) for the treatment of pararenal AAA. Twenty-three patients were treated with a mean follow-up of 15 months. Technical success was achieved in 96% of procedures, incorporating 87 inner branches. Two (8.3%) intraoperative complications (target vessel dissection) were reported, without additional reinterventions needed. Two (8.3%) patients died within 30 days after initial procedure. One due to respiratory failure and the other from an ischemic stroke. During follow-up, two patients (8.7%) required reintervention. The first patient had a type IIIc endoleak at the left renal artery that was treated by religning the bridging stent with another balloon expandable covered stent-graft after 12 months. The second patient needed an IBD intervention that was not successful during the initial iBEVAR procedure. Primary target vessel patency and freedom from reintervention during follow-up was respectively 98.9% and 87%. We detected no aneurysm-related mortality during follow-up. Overall survival was 69.6%. This study showed that iBEVAR was a safe and effective intervention achieving high technical success rate in the treatment of pararenal AAA.

In conclusion, this thesis describes the results of endovascular treatment of aortoiliac aneurysms. It provides evidence on the impact of stent-graft configurations (renal FEVAR, complex FEVAR, BEVAR) and compatibility of different manufactured stent-grafts for the management of aortoiliac aneurysms. Moreover, the high technical success and patency of IBDs was reconfirmed. Furthermore, it showed that after previous failed EVAR, endovascular solution with FEVAR is in terms of mortality and morbidity less than in open surgery. These complex interventions should not be abstained from octogenarians and should be performed with high sophisticated intra operative imaging. Further research on endovascular solutions for the treatment of aortoiliac aneurysms are crucial, as failed treatment leads to rupture and death of these patients.