Complications of endo-vascular aortic repair for abdominal aortic aneurysm: A retrospective single-centre experience

Nabil A. Al-zoubi *, Zuhair Al-shawwa

Department of Surgery, Department of Vascular, Jordan University of Science and Technology, Irbid, Jordan

**ARTICLE INFO**

**Keywords:** AAA, EVAR, OAR

**ABSTRACT**

**Background:** Endovascular aortic repair (EVAR) is obviously less invasive than open aortic repair (OAR) for the treatment of infra-renal abdominal aortic aneurysm (AAA). However, it is not free of complications which can potentially result in severe morbidity or even mortality. The purpose of this study was to share our single-center experience with stent-graft related and systemic complications associated with EVAR.

**Methods:** Patients with infra-renal AAA treated by elective and emergency EVAR between March 2014 and November 2020 were retrospectively identified. Demographic data, risk factors, American Society of Anesthesiologists (ASA) score, systemic complications, stent-graft related complications, surgical site complications, 30-day mortality, late EVAR related mortality, estimated blood loss, intensive care unit (ICU) length of stay (LOS), hospital LOS and follow-up durations were collected and analyzed.

**Results:** A total of 43 patients underwent EVAR during the period of study. There were 42 males (97.7%) and 1 female (2.3%). The mean age was 68.8 ± 6.2 years. Elective EVAR was performed in 36 (83.7%) and emergency EVAR in 7 (16.3%). Technical success was achieved in 42 patients (100%) with no conversion to OAR. Stent-graft related complications were (21.0%) endoleaks, (2.3%) graft limb occlusion, (0%) graft infection, and (2.3%) rupture-EVAR. Systemic complications were (2.3%) myocardial infarction (MI), (2.3%) stroke, (2.3%) spinal cord injury (SCI), (2.3%) respiratory failure, (19.0%) wound complications, and (2.3%) acute lower limb ischemia (ALI). The 30-day mortality was (2.3%) due to perioperative MI and the late graft related mortality was (2.3%) due to rupture-EVAR.

**Conclusion:** EVAR showed a high technical success rate with no conversion to OAR. The most common complications were type II and type I endoleaks followed by graft limb occlusion. The 30-day mortality was 2.3% due to perioperative MI. Only one late stent-graft related mortality was registered due to rupture-EVAR.

1. Background

AAA is a common disease that constitutes a serious health problem [1,2]. It particularly affects men older than 60 years with a prevalence that ranges from 2% to 7% [1,2]. In 1991, Parodi, Palmaz, and Barone reported the first EVAR for AAA [3]. This approach has steadily increased in prevalence among vascular specialists who treat this pathology until it has become the first-choice treatment for anatomically-suitable AAAs [3–5]. Randomized trials have demonstrated significant perioperative benefits of EVAR versus OAR, including increased survival, reduced morbidity, significantly better clinical utility outcomes, and faster time to recovery [3]. Although it is obviously less invasive than OAR, it is not free of complications which can potentially result in severe morbidity or even mortality [6]. The principal technical complications affecting EVAR are the development of endoleaks, stent-graft infections, migration and occlusion of the limb-graft [4]. The purpose of this study was to share our single-center experience with stent-graft related complications together with systemic complications associated with EVAR.

2. Methods

This is a retrospective single-center study in which all consecutive patients presented to King Abdullah University Hospital (KAUH) with AAAs who underwent elective and emergency EVAR between March 2014 and November 2020 were enrolled. Demographic data, risk factors, ASA score, systemic complications, stent-graft related complications, surgical site complications, 30-day mortality, late EVAR related...
mortality, estimated blood loss, ICU LOS, and hospital LOS were recorded, and follow-up durations were collected and analyzed. The primary and secondary endpoints were to report EVAR device-related complications and systemic complications respectively.

All procedures were performed in the Cath lab by vascular surgeons and vascular interventional radiologists. They were performed under general anesthesia. All of the procedures were within the stent graft’s instructions for use (IFU). Bilateral access to the common femoral artery (CFA) is obtained via femoral artery cut-down. Bilateral cannulation by 6F introducer sheaths. Flush catheter advancement over the wire to the supra-renal aorta. Angiogram to the aorta and bilateral iliac arteries to evaluate the proximal neck, angulations, and access arteries. All pre-operative CT-Angiogram (CTA) measurements were re-discussed. Giving intra-venous (IV) heparinization according to the patient weight.

Exchange to a super-stiff wires. Introduction of the ipsilateral main body just inferior to the lowest renal artery. A repetition of angiogram before proximal deployment was performed if necessary. Cannulation of the contralateral limb of the main body. Another super-stiff wire was used. Advancement of the contralateral iliac tube graft. A completion angiogram was performed to confirm complete exclusion of the aneurysm and maintain perfusion to the lower extremity. In case of contralateral limb cannulation failure, the brachial artery approach or cross-over technique were the next steps. Once necessary internal iliac artery (IIA) embolization is performed before endograft deployment. Patients with access arteries stenosis and occlusions were treated in advanced or at the same EVAR procedure. Follow-up protocol was CTA angiography at 1 month, 6 months, and yearly thereafter. This study was approved by the Ethics Institutional Review Board (IRB) of Jordan University of Science and Technology (JUST) and KAUH and reported in line with the STROCSS criteria [7]. Patient informed consent was waived because of the respective nature of the study and due to absence of breach of patients’ confidentiality. IBM SPSS Statistics for Windows, version 22 (IBM Corp.) was used for data analysis. Research Registry registration unique identifying number (UIN) ID is researchregistry6504 (https://www.researchregistry.com/browse-the-registry#home/)

3. Results

A total of 43 patients underwent EVAR during the period of study. There were 42 males (97.7%) and 1 female (2.3%). The mean age was 68.8 ± 6.2 years. Of them, 27 patients (62.8%) had hypertension (HTN), 11 patients (25.6%) diabetes mellitus (DM), 10 patients (23.2%) chronic obstructive pulmonary disease (COPD), 16 patients (37.1%) coronary artery disease (CAD), 1 patient (2.3%) cerebrovascular disease (CVD), 7 patients (16.2%) hyperlipidemia. The mean body mass index (BMI) was 25.1 ± 3.3. The majority, 35 patients (81.4%) were smokers. Three patients (7.0%) had renal insufficiency (RI) and underwent CO2-EVAR. Thirty-one (72.1%) had ASA risk score-3 while 12 (27.9%) had ASA risk score-4. All AAs were located infra-renal. The average aortic aneurysms diameter was from 4.8 cm to 9.1 cm. Elective EVAR was performed in 36 (83.7%) and emergency EVAR in 7 (16.3%) (Table-1). Technical success was achieved in 42 patients (100%) with no conversion to OAR. Only 7 patients (16.7%) received blood transfusions with average of 2.1 units (Table-2).

The reported complications were; 1 (2.3%) myocardial infarction (MI), 1 (2.3%) stroke, 1 (2.3%) spinal cord injury (SCI), 1 (2.3%) respiratory failure. Eight complications (19.0%) related to access site were recorded; 3 (7.0%) hematoma, 2 (4.7%) lymphocele, and 3 (7.0%) infection). Acute lower limb ischemia occurred in 1 patient (2.3%). Endoleak was occurred in 9 cases (21.0%). Endoleak type II was in 6 cases (14.0%), followed by type 1 in 3 cases (7.0%); type Ib in 1 case (2.3%) and type IIb in 2 cases (4.7%). No cases of type III and IV endoleaks were reported. One case (2.3%) had graft limb occlusion. No stent graft infections were reported (Table-3). The average LOS in the ICU and in the hospital were 2.8 days and 8.4 days respectively. The 30-days mortality was (2.3%) due to one case of MI. The mean follow-up was 22.3 ± 3.1 months. Eleven patients (25.6%) had no documented follow up data. One patient came after 4 years (without follow-up) and died due to ruptured EVAR.

4. Discussion

EVAR offers an undisputed operative benefit in operative mortality over OAR, although this early gain has not been translated into a long-term survival advantage and the early benefit has been completely lost in the long-term, even leading to a slightly higher aneurysm-related mortality at 4 years after EVAR [8]. Common complications include both those related to the endograft device and systemic complications. Device-related complications include endoleaks, endograft migration or collapse, kinking and/or stenosis of an endograft limb and graft infection. Post-procedural systemic complications include end-organ ischemia, cerebrovascular and cardiovascular events [9].

Since introduced in 2010 at KAUH, EVAR constituted 81.4% of AAA compared to only 18.6% of the OAR. The indications for EVAR were infra-renal AAAs with suitable anatomy according to stent-graft IFU. OARs were performed only for unstable patients with ruptured or in unsuitable anatomy for EVAR.

| Table 1 | Patients demographics and characteristics. |
| --- | --- |
| Variables | All patients (43) |
| Age, years, mean ± SD | 68.8 ± 6.2 |
| Gender | |
| Male | 42 (97.7%) |
| Female | 1 (2.3%) |
| EVAR | |
| Elective | 36 (83.7%) |
| Emergency | 7 (16.3%) |
| Location | |
| Infra-renal | 43 (100%) |
| Supra-renal | 0 |
| Associated Diseases | |
| HTN | 27 (62.8%) |
| DM | 11 (25.6%) |
| COPD | 10 (23.2%) |
| CAD | 16 (37.1%) |
| CVD | 1 (2.3%) |
| Hyperlipidemia | 7 (16.2%) |
| Smoking | 35 (81.4%) |
| BMI, mean ± SD | 25.1 ± 3.3 |
| Renal Insufficiency | 3 (7.0%) |
| ASA risk score | |
| 1 | 0 (0.0%) |
| 2 | 0 (0.0%) |
| 3 | 31 (72.1%) |
| 4 | 12 (27.9%) |

| Table 2 | Procedure-related variables. |
| --- | --- |
| Variables | EVAR (n = 43) |
| LOS, days | |
| ICU | 2.8 |
| Hospital | 8.4 |
| Contrast Used | |
| Iodinated | 40 (93.0%) |
| CO2 | 3 (7.0%) |
| Technical success | 43 (100%) |
| Conversion to OR | 0 (0.0%) |
| Blood Transfusion | |
| Patients need transfusion | 7 (16.7%) |
| Average units | 2.1 |
| Follow-up | |
| Follow-up, months, mean ± SD | 22.3 ± 3.1 |
| No documented follow up | 11 (25.6%) |
3 cases (4.70%) of late type Ib which were discovered after one year by follow up CTA. One of the type Ib endoleak was treated successfully by tube graft extension to the iliac artery, while in the second case the patient refused the treatment and lost follow-up. No type III, IV and V endoleaks have been occurred during early and late follow up.

4.2. Graft limb occlusion

Cochennec F et al. studied 460 patients treated by EVAR with a median follow-up of 23.4 months and concluded that the rate of graft limb occlusion after EVAR was 7.2% and mostly occur during the first 9.5 months after implantation of the stent-graft due to type of device, the presence of a kink and underlying stenotic disease [12]. Patients may present with acute limb ischemia, while most patients presented with less severe symptoms or asymptomatic [12]. Only one case (2.3%) of graft limb occlusion was found in this study which occurred within the first month after EVAR. It was diagnosed by CTA when the patient started to complain of intermittent claudication without rest pain or tissue loss. He was treated conservatively because of the poor functional status of the due to congestive heart failure.

4.3. Graft infection

Aortic endograft infection is a rare complication after EVAR [13]. Cernohorsky P et al. performed a retrospective cohort study in 1431 patients and found that the incidence is below 1%, with a mortality rate of 25% [14]. Surgical treatments with complete explantation of the infected endograft seems to be the optimal management in selected patients [12]. In this study, no aortic endograft infection has been reported.

4.4. Rupture-EVAR

Schlosser FJV et al. in large cohort studies have reported rupture rates between 0.5 and 1.2% per patient per year after EVAR [15]. It occurred within the first 2–3 years of follow-up. Endoleaks were by far the most frequent cause of AAA rupture and graft migration the second most frequent cause [15]. Our data showed that only one case (2.3%) presented with AAA rupture after 4 years of EVAR due aneurysmal sac enlargement most likely because of endoleak which resulted in patient death.

4.5. Mortality

Patel R. et al. showed that the total and the aneurysm-related mortality are lower in patients who received EVAR in the first 6 months compared to OAR. However, after 8 years of follow-up, both the total and the aneurysm-related mortality are significantly higher in the EVAR than in the OAR [1]. In our study, the 30-days mortality was 2.3% due to MI and the long term aneurysm related mortality was 2.3% due to rupture-EVAR.

4.6. Wound complications

The risk of wound complications following open femoral exposure for EVAR in practice is unclear and usually associated with prolonged hospital LOS and higher resource utilization [16]. In this study, 19.0% of patients developed wound complications following EVAR.

4.7. Systemic complications

According to the European Society of Cardiology (ESC)/European Society of Anesthesiology (ESA) guidelines, EVAR is an intermediate cardiac risk procedure, with a 1%–5% incidence of cardiac events (MI or cardiac death) [2]. In our study, all patients had ASA risk score ≥3 (31 patients (72.1%) had ASA-3 and 12 patients (27.9%) ASA-4). MI was the

---

**Table 3**

Complications and mortality.

| Complications                  | EVAR (n = 43) |
|-------------------------------|--------------|
| **NONE-GRAFT-RELATED COMPLICATIONS** |             |
| MI                            | 1 (2.3%)     |
| Stroke/TIA                    | 1 (2.3%)     |
| SCI                           | 1 (2.3%)     |
| Bowel ischemia                | 0            |
| Renal insufficiency           | 0            |
| Respiratory complications     | 1 (2.3%)     |
| **Wound complication**        |              |
| Hematoma                      | 3 (7.0%)     |
| Lymphocele                    | 2 (4.7%)     |
| Infection                     | 3 (7.0%)     |
| Pseudoaneurysm                | 0            |
| Acute lower limb ischemia     | 1 (2.3%)     |
| Death                         |              |
| **30-days mortality**         | 1 (2.3%)     |
| **Overall mortality**         |              |
| **GRAFT-RELATED COMPLICATIONS** |             |
| Endoleak                      |              |
| Type Ia                       | 1 (2.3%)     |
| Type Ib                       | 0            |
| Type II                      | 6 (14.0%)    |
| Type III                     | 0            |
| Type IV                      | 0            |
| Type V                       | 0            |
| **Total**                     | 9 (21.0%)    |
| **Graft Limb Occlusion**      | 1 (2.3%)     |
| **Graft infection**           | 0            |
| **Ruptured EVAR**             | 1 (2.3%)     |

4.1. Endoleak

The term endoleak was first coined and classified by May et al. and refers to continued blood flow outside the lumen of the graft but within the aneurysm sac [4]. It is one of the most common complications and remains the most important weakness of EVAR which may progress to aneurysm rupture [10]. It is classified into four types. In type I endoleak, there is poor apposition between one of the attachment sites of the stent-graft and the native aortic or iliac artery wall, and blood can leak through this defect into the aneurysm sac. Type I endoleaks are further sub-classified into type Ia endoleaks which occur at the proximal aortic attachment site, and type Ib endoleaks which occur at one of the distal iliac artery attachment sites [10]. In type II endoleaks, there is retrograde flow of blood into the aneurysm sac via an excluded aortic branch, most commonly the inferior mesenteric artery or a lumbar artery. In type III endoleaks, there is leakage of blood through the body of a stent-graft. In type IV endoleaks, there is leakage with no origin (graft porosity). Finally, in type V endoleaks, there is expansion of the aneurysm with no leakage (endotension) [10,11]. Although some endoleaks are observed to resolve spontaneously, persistent leaks can lead to expansion of the aneurysm sac and subsequently cause aneurysm rupture [4]. In general, high-pressure lesions (types I and III) require urgent management because of the relatively high short-term risk of sac rupture. Low-pressure lesions (types II and V) are considered less urgent but may warrant eventual endovascular evaluation if there is continued growth of the aneurysm sac or if the patient presents with progressive symptoms [9].

Kassem TW found in a cohort study which involved 37 patients for one year of follow-up that 37.8% had positive endoleaks. Type I endoleak was diagnosed in 10.8% and type II endoleaks was diagnosed in 27% [11]. In our study, endoleaks were the most common graft-related complications. The most common type of endoleaks was type II which represented 66.7% of all endoleaks and occurs in 14% of EVAR. No type II endoleaks were associated with aneurysmal sac expansions and they were treated conservatively with no need for re-interventions. Type I endoleak occurred in three cases (7.0%); 1 case (2.30%) of type Ia which was immediately treated by aortic cufi without complications and 2

---

- Kassem TW found in a cohort study which involved 37 patients for one year of follow-up that 37.8% had positive endoleaks. Type I endoleak was diagnosed in 10.8% and type II endoleaks was diagnosed in 27% [11]. In our study, endoleaks were the most common graft-related complications. The most common type of endoleaks was type II which represented 66.7% of all endoleaks and occurs in 14% of EVAR. No type II endoleaks were associated with aneurysmal sac expansions and they were treated conservatively with no need for re-interventions. Type I endoleak occurred in three cases (7.0%); 1 case (2.30%) of type Ia which was immediately treated by aortic cufi without complications and 2

---

- Kassem TW found in a cohort study which involved 37 patients for one year of follow-up that 37.8% had positive endoleaks. Type I endoleak was diagnosed in 10.8% and type II endoleaks was diagnosed in 27% [11]. In our study, endoleaks were the most common graft-related complications. The most common type of endoleaks was type II which represented 66.7% of all endoleaks and occurs in 14% of EVAR. No type II endoleaks were associated with aneurysmal sac expansions and they were treated conservatively with no need for re-interventions. Type I endoleak occurred in three cases (7.0%); 1 case (2.30%) of type Ia which was immediately treated by aortic cufi without complications and 2
cause of death in one patient (2.3%). The incidence of acute kidney injury after elective EVAR is 18.8% which is independently associated with higher morbidity, prolonged length of hospital stay, cost, and short-term mortality [17]. None of our patients developed renal impairment during the early post-operative period that required dialysis. Stroke can be a devastating complication after complex endovascular treatment for AAA, resulting in mortality, permanent disability and significant decline in quality of life. Although cerebrovascular events are multifactorial in etiology, upper extremity access is a recognized factor because catheter manipulations in the aortic arch and supra-aortic trunks can be associated with embolic events [18]. Among our patients, left brachial artery approach was used in two patients for contralateral graft limb cannulation. One of them developed embolic cerebrovascular complications with no clinical consequences. SCI is a rare, but devastating complication following EVAR [19]. One of our patients developed SCI and was successfully treated by conservative management which was reported in literature as a rare case report [19].

EVAR continues to be burdened with the same ischemic complications seen with OAR. ALI after aortic reconstructions, often referred to as “trash foot” is a well-recognized result of atheroemboli, and occurs in 1%-5% of patients [20]. In the present study, ALI occurred in one patient due to embolic occlusion of the distal popliteal artery which was managed by immediate embolectomy.

There are several limitations of this study. The major limitation was the small number of patients, which is related to absence of national screening program for AAA in Jordan. In addition, the retrospective nature of data collection. Finally, the impact of different cardiovascular risk factors on complication rate and mortality rate was difficult to assess due to low volume of patients treated with EVAR. Those limitations can be overcome by performing a prospective study and increasing the sample size.

5. Conclusion

EVAR showed a high technical success rate with no conversion to OAR. The most common complications were type II and type I endoleaks followed by graft limb occlusion. The 30-day mortality was 2.3% due to perioperative MI. Only one late stent-graft related mortality was registered due to rupture-EVAR.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Funding

No source of funding.

Ethical approval

No ethical approval was required.

Consent

No consents were required as there were no break in patients’ privacy. It is a retrospective study.

Author contribution

The first author and the co-author had contributed in the study concept, data collection, data analysis, and writing the paper.

Registration of Research Studies

Name of the registry: Research Registry.
Unique Identifying number or registration ID: researchregistry6504.

Hyperlunk to your specific registration (must be publicly accessible and will be checked): https://www.researchregistry.com/browse-the-registry#home/.

Guarantor

Dr. Nabil A. Al-zoubi
Associate Professor.
Consultant Vascular Surgery and Endovascular Therapy.
Department of Surgery.
Faculty of Medicine - Jordan University of Science and Technology (JUST).
Chief Medical Officer - King Abdullah University Hospital (KAUH).
Irbid, 22110, Jordan.
Mobile: 00962(0)795774637.
Email: nazoubi@just.edu.jo, dr_nabeil_z3bi@yahoo.com.

Declaration of competing interest

No Conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jamsu.2021.102219.

Funding

No source of funding.

References

[1] R. Patel, M.J. Sweeting, J.T. Powell, R.M. Greenhalgh, Endovascular versus open repair of abdominal aortic aneurysm in 15-years’ follow-up of the UK endovascular aneurysm repair trial 1 (EVAR trial 1): a randomized controlled trial, Lancet 388 (2016) 2366–2374.
[2] P.V. Reis, M. Morgado, I. Valdoleiros, M.D. Neto, J. Mourao, Complications of endovascular aneurysm repair: mortality, myocardial infarction and acute kidney injury, Turk J Anaesth Reanim. 46 (2018) 222–228.
[3] D. Ratheil, Endovascular aortic aneurysm repair: association between anatomical fixation and outcomes using the Powerlink device, Interv Cardiol. 3 (2) (2011) 149–159.
[4] H.S. Flora, E.J. Chaloner, A. Sweeney, J. Brookes, J.M. Raphael, M. Adireshiah, Secondary intervention following endovascular repair of abdominal aortic aneurysm: a single centre experience, Eur. J. Vasc. Endovasc. Surg. 26 (2003) 287–292.
[5] M. Yalcin, O. Tiryakioglu, Single-center study comparing short and mid-term results of EVAR in old and young populations, Braz. J. Cardiovasc. Surg. 34 (3) (2019) 279–284.
[6] G. Maleux, M. Koolen, S. Heye, Complications after endovascular aneurysm repair, Semin. Intervent. Radiol. 26 (2009) 3–9.
[7] R. Agha, A. Abdali-Ranak, E. Crouseley, N. Dowlut, C. Josifidis, G. Mathew, for the STROCSS Group, The STROCSS 2019 guideline: strengthening the reporting of cohort studies in surgery, Int. J. Surg. 72 (2019) 156–165.
[8] G. Kouvelos, A. Koutsoumpelis, A. Lazaris, M. Matsagkas, Late open conversion after endovascular abdominal aortic aneurysm repair, J. Vasc. Surg. 61 (2015) 1350–1356.
[9] D. Davy, T.G. Walker, Complications of endovascular aneurysm repair of the thoracic and abdominal aorta: evaluation and management, Cardiovasc. Diagn. Ther. 8 (1) (2018) 138–156.
[10] M.R. Bashir, H. Ferral, C. Jacobs, W. McCarthy, M. Goldin, Endoleaks after endovascular abdominal aortic aneurysm repair: management strategies according to CT findings, AJR 192 (2009) 178–186.
[11] T.W. Kazem, Follow up CT angiography post EVAR: endoleaks detection, classification and management planning, Egypt. J. Radiol. Nucl. Med. 48 (2017) 621–626.
[12] F. Cochennee, J.P. Becquemin, P. Desgranges, E. Allaire, H. Kobeiter, F. Roudot-Thoraval, Limb graft occlusion following EVAR: clinical pattern, outcomes and predictive factors of occurrence, Eur. J. Vasc. Endovasc. Surg. 34 (2007) 59–65.
[13] C. Argirious, G.S. Georgiadis, M.K. Lazarides, E. Georgarakos, G.A. Antoniou, Endograft infection after endovascular abdominal aortic aneurysm repair: a systematic Review and meta-analysis, J. Endovasc. Ther. 24 (5) (2017) 688–697.
[14] P. Cernohorsky, M.M.P.J. Reijnen, I.F.J. Tielliu, et al., The relevance of aortic thoracic and abdominal aorta: evaluation and management, Cardiovasc. Diagn. Ther. 8 (1) (2018) 138–156.
[15] F.J.V. Schlosser, R.J. Gusberg, A. Dardik, Aneurysm rupture after EVAR: can the ultimate failure be predicted? Eur. J. Vasc. Endovasc. Surg. 37 (2009) 15–22.
[16] B. Trinidad, D. Rybin, G. Doros, M. Eslami, T.W. Tan, Factors associated with wound complications after open femoral artery exposure for elective endovascular abdominal aortic aneurysm repair, Int. J. Angiol. 28 (2019) 124–129.

[17] A. Saratzis, N. Melas, A. Mahmood, P. Sarafidis, Incidence of acute kidney injury (AKI) after endovascular abdominal aortic aneurysm repair (EVAR) and impact on outcome, Eur. J. Vasc. Endovasc. Surg. 49 (2015) 534–540.

[18] M.M. Meertens, C.C. Lemmens, G.S. Oderich, G.W.H. Schurink, B.M.E. Mees, Cerebrovascular complications after upper extremity access for complex aortic interventions: a systematic Review and meta-analysis, Cardiovasc. Intervent. Radiol. 43 (2020) 186–195.

[19] Q. Aljarrah, M.H. Al-Omari, M. Elbeis, M. Al-Jarrah, A. Jamal, A. Alzoubi, Successful reversal of isolated delayed spinal cord ischemia following endovascular abdominal aneurysm repair, Vasc. Health Risk Manag. 15 (2019) 81–87.

[20] T.S. Maldonado, C.B. Rockman, E. Riles, Ischemic complications after endovascular abdominal aortic aneurysm repair, J. Vasc. Surg. 40 (2004) 703–710.