Endovascular aneurysm repair (EVAR)– and transcatheter aortic valve replacement (TAVR)–associated acute kidney injury

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Acute kidney injury (AKI) after surgery or intervention is an important complication that may impact mortality, morbidity, and health care costs. Endovascular procedures are now performed routinely for a variety of pathologies that were traditionally treated with open surgery because randomized trials comparing endovascular and open surgery have shown at least equally good results and reduced complication and hospitalization rates with endovascular techniques. However, endovascular procedures have been associated with an increased risk for postoperative AKI, predominantly owing to contrast nephrotoxicity. Over the years, endovascular techniques have progressively been applied for the treatment of complex cardiovascular pathologies, and in recent years, nephrologists have increasingly encountered patients who developed AKI after endovascular aneurysm repair or transcatheter aortic valve replacement. These 2 procedures typically involve high-risk patients who have several established AKI risk factors prior to intervention. Several studies have investigated the incidence, risk factors, and natural course of AKI after endovascular aneurysm repair and transcatheter aortic valve replacement. This review summarizes current data on incidence, risk factors, pathophysiology, prognostic implications, and treatment of AKI associated with endovascular aneurysm replacement and transcatheter aortic valve replacement.

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The term acute kidney injury (AKI) has been proposed to encompass the entire spectrum of a syndrome that ranges from minor changes in markers of renal function to the requirement for renal replacement therapy.[1,2] It represents an acute and usually reversible decrease in renal function and is defined by stringent criteria, based on fluctuations in serum creatinine (SCr) levels and urine output. AKI of various etiologies is an important public health issue worldwide.[3] Based on various epidemiologic studies, 20% of individuals undergoing elective cardiovascular (CV) surgery or intervention may develop AKI.[4,5] Postoperative AKI has important implications relating to subsequent mortality, morbidity, and cost.[4,6–8]

Endovascular techniques have greatly evolved since their conception and are now widely applied for the correction of atheromatous and nonatheromatous lesions in various vascular beds. Recently, technological evolutions have allowed the treatment of more complex pathologies using such techniques. Endovascular aneurysm repair (EVAR) for abdominal aortic aneurysm (AAA) is now routinely performed, both as an elective and emergency procedure; randomized controlled trials (RCTs) have shown equally good or better results with endovascular surgery than with open surgery over the short and medium term.[9–12] Similarly, transcatheter aortic valve replacement (TAVR) for severe aortic stenosis has been recently introduced, with promising results in RCTs involving intermediate and high-risk patients.[13,14] However, such endovascular procedures have been traditionally associated with a significant risk for AKI development, mainly attributed to the use of contrast media, among other risk factors.[6,15] Important research efforts have been undertaken to establish appropriate preventive measures for this complication.[16–18] Given that EVAR and more recently, TAVR are used ever more often worldwide, AKI after such procedures has become a more common occurrence facing nephrologists, and several aspects of AKI related to these procedures have been the object of research studies. This review aims to provide an up-to-date overview of the incidence, risk factors, pathophysiology, prognostic implications, and treatment of AKI associated with EVAR and TAVR.

Acute kidney injury after endovascular abdominal aortic aneurysm repair

AAA constitutes an important health problem and is a common cause of CV-related death in the western world, with prevalence rates ranging from 1.3% to 4%.[19–21] EVAR, a minimally invasive alternative to traditional open repair, was introduced approximately 25 years ago and is now a first-line treatment, predominantly in the elective setting.[22] EVAR involves the deployment of a stent graft in the abdominal aorta to exclude the aneurysmal segment from the circulation and to prevent rupture. Access is usually gained through the femoral arteries, either percutaneously or after surgical exposure, and the devices are subsequently advanced and deployed using fluoroscopic control and a contrast medium, which is necessary to visualize the relevant anatomy.[23] An iodine-based nonionic contrast medium is typically used in modern practice. The stent grafts, in case of an infrarenal AAA, are fixated below the renal orifices and may employ suprarenal fixation modalities such as hooks, bare stents, or barbs, which attach the device to the healthy suprarenal aortic wall, while allowing blood flow into the renal arteries.[24] Early and medium-term outcomes of EVAR have been proven similar or superior to those of open repair in several RCTs.[12] However, patients undergoing EVAR are at a risk for certain technical and device-related complications, such as endoleak, stent graft migration, and endograft limb occlusions; they are also at a serious risk for developing AKI. Similar to other endovascular procedures, accumulating evidence suggests that AKI after EVAR impacts subsequent mortality, CV morbidity, long-term renal function, length of hospital stay, and associated costs.[4–6,25]

Incidence. The reported AKI incidence after elective EVAR widely ranges from 3% to 19%; the main reason for that is the wide variability in AKI definition criteria that were, until recently, used in the literature.[26–30] Several investigators did not include postoperative urine output while defining AKI. Furthermore, most studies used only SCr level changes as a marker of immediate (24–48 hours) postoperative renal dysfunction, which was reported as AKI. Other measures previously used include a decrease in Cr clearance or estimated glomerular filtration rate (eGFR).[31] RCTs in the field of EVAR also did not report AKI incidence using acceptable contemporary definitions. Overall, immediate postoperative renal injury, using an absolute SCr decrease within 48 hours, has a lower incidence after EVAR than after open repair in most historical series,[32] whereas at least 3 studies (2 defining AKI as an SCr increase of >50% and 1 defining AKI as an increase of >30% compared with baseline) have shown a higher incidence after EVAR (estimated at approximately 18%) than after open repair (ranging from 5% to 15%).[4,6,28,33–35]

The introduction and evolution of contemporary criteria for AKI (risk, injury, failure, loss, end-stage [RIFLE]; Acute Kidney Injury Network [AKIN]; and Kidney Disease Improving Global Outcomes [KDIGO])[36] have provided a uniform basis for research efforts in the field and have led to several relevant studies being conducted. Table 1 summarizes the findings of studies that report AKI incidence after elective EVAR using contemporary AKI reporting criteria. Using the AKIN and KDIGO criteria, including urine output measurements that are usually not included in similar literature, we reported regarding 149 patients undergoing EVAR and observed a postoperative AKI incidence of 18.8%.[4] This was verified in a subsequent study of 947 elective EVARs; using the AKIN and KDIGO criteria,[5] AKI incidence was 18%. The vast majority of patients undergoing elective EVAR who develop AKI are typically classified as stage 1 in these series, and a requirement for dialysis is rare (<1%). Using the AKIN and RIFLE criteria, 2 previous studies that included 87 and 207 elective EVARs, respectively, showed an AKI incidence of 17%.[37,38] Another prior retrospective series, including 47 EVARs, revealed an AKI incidence of 14% using the AKIN criteria.[39]

Fenestrated and branched EVAR (fEVAR and bEVAR, respectively) were introduced during the last decade, enabling the treatment of a wider range of aneurysmal disease of the abdominal aorta using endovascular procedures.[40–44] These techniques involve the cannulation and stenting of aortic branches, such as the renal arteries, during EVAR to treat juxtarenal or suprarenal AAAs. Such aneurysms could not otherwise have been treated using endovascular procedures, which are more complex and require more contrast than standard infrarenal EVAR. Furthermore, the renal arteries are at a far higher risk for occlusion or stenosis, given that covered stents are deployed in the actual renal vasculature. In the largest series of fEVAR and bEVAR reported to date (449 patients), the rate of renal artery occlusion was 2.3% for fEVAR and 9.6% for bEVAR.[45] We recently used the AKIN

Table 1 | Incidence of acute kidney injury in elective infrarenal endovascular aneurysm repair using standardized acute kidney injury reporting criteria

Reference	Type	Date	EVAR (n)	AKI criterion	AKI incidence	AKI (n)	AKI stage > 2 (n)	Dialysis	Urine output available
Pirgakis *et al.*[37]	Retrospective	2014	87	AKIN	17%	15	None	1	No
Ueta *et al.*[39]	Prospective	2014	47	AKIN	14%	6	Stage 2: 1	None	No
Pisimisis *et al.*[38]	Retrospective	2013	208	RIFLE	17%	36	NA	NA	No
Saratzis *et al.*[4]	Prospective	2015	149	AKIN & KDIGO	19%	28	Stage 2: 3	None	Yes
Saratzis *et al.*[49]	Retrospective	2015	484	AKIN	12%	58	NA	None	No
Saratzis *et al.*[5]	Retrospective	2015	947	KDIGO	18%	167	Stage 2: 12; Stage 3: 2	None	No
Castagno *et al.*[130]	Retrospective	2016	146	Aneurysm Score	5.5%	8	NA	None	No
Obata *et al.*[131]	Prospective	2016	95	AKIN	9.4%	9	Stage 2: 1	None	No

AKI, acute kidney injury; AKIN, Acute Kidney Injury Network Criteria; EVAR, endovascular aneurysm repair; KDIGO, Kidney Disease Improving Global Outcomes; NA, not available; RIFLE, risk, injury, failure, loss, end-stage renal disease.