Incidence and risk factors of renal dysfunction after thoracic endovascular aortic repair

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Objectives: The risk of renal failure after thoracic endovascular aortic repair is not widely established. The aim of this study was to assess the incidence and risk factors of renal failure.

Methods: Between 1998 and 2008, 175 consecutive patients underwent 210 procedures at 2 tertiary academic institutions. Similar nephroprotective protocols and intravascular ultrasound were used. Retrospective analysis was performed. Generalized linear model was used to identify factors associated with change in postoperative estimated glomerular filtration rate.

Results: Underlying aortic diseases included 103 aneurysms, 72 dissections, 21 transections, and 14 penetrating ulcers. Median preoperative estimated glomerular filtration rate was 65 mL $\cdot$ min^{-1} $\cdot$ 1.73 m^{-2}. Contrast media averaged 108.7 $\pm$ 69.8 mL. Median estimated glomerular filtration rates within 48 hours and 30 days were 69 and 67 mL $\cdot$ min^{-1} $\cdot$ 1.73 m^{-2}, respectively. Rates of acute renal dysfunction risk (>25% estimated glomerular filtration rate decrease), acute kidney injury (>50% estimated glomerular filtration rate decrease), acute kidney function failure (>75% estimated glomerular filtration rate decrease), and hemodialysis were 9.8% (19/193), 1.6% (3/193), 0% (0/193), and 0.5% (1/193), respectively. Rates of renal dysfunction at 1 month and 6 months were 13.3% (10/75) and 17.7% (6/34), respectively. Risk factors for acute renal dysfunction were intraoperative hypotension, stroke, sepsis, lengthy procedures, and number of stents; at 1 and 6 months they were increased age, male gender, African American race, diabetes mellitus, chronic pulmonary disease, smoking, and zone 0 to 1 graft deployment. Obesity was nephroprotective.

Conclusions: Thoracic aortic endograft has a significant rate of renal dysfunction; however, it is lower in this cohort than in previous smaller series. Routine use of intravascular ultrasound and reduced contrast may have contributed to lower rates of renal insufficiency. (J Thorac Cardiovasc Surg 2010;140:S161-7)

Thoracic endovascular aortic repair (TEVAR) has been increasingly applied for various aortic diseases as a promising alternative to the open surgical approach. Proposed advantages of TEVAR include shorter operative time, less blood loss, decreased need for general anesthesia, and shorter hospital stays.[1,2] TEVAR avoids morbid thoracotomy and thoracoabdominal incisions, cardiopulmonary bypass, aortic crossclamping, and in some cases hypothermic circulatory arrest. Although TEVAR has a series of complications that are unique to the endovascular procedures, there are morbidities such as renal dysfunction that are subject to both open and endovascular interventions. The risk of renal dysfunction after TEVAR has not been well studied. There is controversy in literature regarding the incidence of renal dysfunction after TEVAR of thoracic aortic diseases ranging from 1.5% to 34%.[3,4] The goal of this study is to determine the incidence of acute and chronic renal failure after TEVAR and to identify associated risk factors.

METHODS

Patient Population

From October 1998 to May 2008, 175 consecutive patients underwent 210 TEVAR procedures for descending thoracic aortic aneurysms, descending thoracic aortic dissections (Stanford type B), penetrating thoracic ulcers, and traumatic aortic transection at 2 tertiary academic institutions (Harbor–UCLA Medical Center and University of Nebraska Medical Center). Fifty-seven of the 210 procedures involved patients who had previously undergone TEVAR and were analyzed further as a subgroup. All patients signed consent forms for the use of these investigational devices and agreed to participate in the surveillance protocols after deployment of the devices.

Inclusion and Exclusion Criteria

The study included patients with symptomatic aneurysms of the descending thoracic aorta, asymptomatic aneurysms of the descending thoracic aorta with at least twice the size of the proximal normal aorta,

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Abbreviations and Acronyms

ARF = acute renal failure
CKD = chronic kidney disease
CT = computed tomography
eGFR = estimated glomerular filtration rate
IQR = interquartile range
IVUS = intravascular ultrasound
RIFLE = Risk of acute renal dysfunction, Injury to the kidney, Failure of kidney function, Loss of kidney function, End-stage kidney disease
TEVAR = thoracic endovascular aortic repair

complicated acute Stanford type B aortic dissections, aneurysmal degeneration of chronic Stanford type B aortic dissections, symptomatic penetrating aortic ulcers, and traumatic aortic transections. Other inclusion criteria were signing the informed consent and agreeing to be followed up in the institutional surveillance program. Furthermore, the patient's arterial anatomy must have met device-specific requirements to be a candidate for TEVAR. Adequate proximal and distal landing zone and adequate-sized access vessels were evaluated before TEVAR was offered to the patients.

Exclusion criteria were applied to patients with diseases of the ascending aorta, connective tissue disorders, pregnancy, age below 18 years, systemic infection, and hypercoagulable state. Patients were also excluded if stent-graft placement was technically unsuccessful (n = 3), if they died in the operating room but before procedure initiation (n = 2), or if they were already undergoing dialysis before the procedure (n = 6).

Definitions

Aortic ulceration is defined an ulcer penetrating the elastic lamina into the tunica media associated with hematoma within the aortic wall. Acute aortic dissection is considered an acute event if it occurred within the first 14 days from onset of symptoms and as chronic if it occurred after 14 days Aortic transection typically involves the intima and media, is nearly always transverse to the axis of the vessel, and may be complete or incomplete. The term ''complicated dissection'' was defined as persistent/unrelenting back pain despite maximal medical therapy, uncontrollable hypertension, aortic enlargement more than 5 mm per year, malperfusion syndromes, or (imminent) rupture.[5] The patient's clinical health status was evaluated according to the classification of the American Society of Anesthesiologists.[6] Baseline glomerular filtration rate was calculated with the abbreviated Modification of Diet in Renal Disease formula[7] (estimated glomerular filtration rate [eGFR] [mL · min^{-1} · 1.73 m^{-2}] = 186 × [serum creatinine]$^{-1.154}$ × [age]$^{-0.203}$ × [0.742 if female] × [1.210 if African American]). Chronic kidney disease (CKD) was defined as a baseline eGFR of 60 mL · min^{-1} · 1.73 m^{-2} or less, and chronic renal failure was defined as eGFR of 30 mL · min^{-1} · 1.73 m^{-2} or less (stage III vs IV and V according to the Kidney Disease Outcome Quality Initiative)[8] (Table 1). The most recent proposal for a consensus definition for acute renal failure (ARF) stems from the Acute Dialysis Quality Initiative group,[9] which suggested criteria for 3 grades of increasing severity—risk of acute renal dysfunction (R), injury to the kidney (I), failure of kidney function (F)—and 2 outcome classes—loss of kidney function (L) and end-stage kidney disease (E) (Table 2). The RIFLE classification, based on eGFR and serum creatinine, was applied to postoperative diagnosis of acute renal dysfunction. Postprocedure RIFLE class R was defined accordingly as eGFR decline of more than 25% or serum creatinine increase ×1.5 compared with baseline, RIFLE class I as eGFR decline of more than 50% or serum creatinine increase ×2 compared with baseline, and RIFLE class F as eGFR decline of more than 75% or serum creatinine increase ×3 compared with baseline or acute serum creatinine greater than 4 mg/dL, all based on nadir eGFR/peak creatinine values within 48 hours after the procedure. The patients' renal function was monitored postoperatively as an outpatient at 1 month and 6 months.

TABLE 1. National Kidney Foundation classification of stages for CKD

Stage	Description	GFR
1	Kidney damage with normal or ↑ GFR	>90 (with CKD risk factors)
2	Kidney damage with mild or ↓ GFR	60–89
3	Moderate ↓ GFR	30–59
4	Severe ↓ GFR	15–29
5	Kidney failure	<15 (or dialysis)

CKD, Chronic kidney disease; *GFR,* glomerular filtration rate.

Imaging Protocol

The patients underwent computed tomographic (CT) scans using a 64-slice scanner with 3-mm collimation and 3:5 pitch. All patients except 6 underwent CT scans with electrocardiographic gating. Images were reconstructed using 50% overlap. All patients received Omnipaque (General Electric, Fairfield, Conn); 150 mL was injected at a rate of 3 mL/s using a power injector, and the scan was initiated 30 seconds after the start of the contrast injection. No trailing saline bolus was used. Approximately 20% of patients had CT scans performed at outside institutions, using similar protocols.

The intraoperative imaging included pulsed and regular fluoroscopy, as well as intravascular ultrasound (IVUS) (Volcano Therapeutics, Inc, Laguna Hills, Calif). The procedure was started with open exposure of prescreened femoral artery, placement of a 9F sheath, and IVUS interrogation: the IVUS measures diameter of the ipsilateral (and if necessary contralateral) external and common femoral arteries. This is important to assure that the access vessel will accommodate the selected stent graft. Amount of calcification, intramural abnormalities, and tortuosity is also accurately assessed by IVUS. Next, the IVUS is advanced to the area of interest, where proximal and distal landing zones are evaluated for any thrombus or calcium. Next, by use of the IVUS, the diameters of the proximal and distal landing zones are measured, and the aortic branch vessels are marked on the fluoroscopic screen. Furthermore, the treatment length (distance between proximal and distal landing zones as well as any stent-graft overlap) is measured with IVUS by the pull-back method. With the information above, the appropriate stent grafts are chosen and introduced to the area of interest. A pre-deployment angiogram may be performed to reconfirm the location of the branch vessels (but this is not necessary). Subsequent to stent-graft deployment, the apposition of the graft and potential endoleaks are assessed by IVUS and treated with ballooning or

TABLE 2. RIFLE criteria for the classification of acute kidney injury

Class	GFR criteria
Risk	Plasma creatinine increase 1.5 × baseline or GFR decline > 25%
Injury	Plasma creatinine increase 2 × baseline or GFR decline > 50%
Failure	Plasma creatinine increase 3 × baseline or GFR decline > 75% or acute plasma creatinine > 4 mg/dL
Loss	Persistent ARF = complete loss of kidney function requiring dialysis for > 4 weeks but < 3 months
End stage	End-stage kidney disease requiring dialysis for > 3 months

RIFLE, Risk, Injury, Failure, Loss, End-stage kidney disease; *GFR,* glomerular filtration rate; *ARF,* acute renal failure.