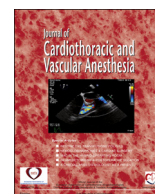




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Original Article

## Acute Kidney Injury After Total Arch Replacement Combined With Frozen Elephant Trunk Implantation: Incidence, Risk Factors, and Outcome

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**Objectives:** Acute kidney injury (AKI) is common after thoracic aortic surgery and is a significant predictor of morbidity and mortality. Total arch replacement (TAR) combined with frozen elephant trunk (FET) implantation has been reported to produce satisfactory clinical outcomes, whereas several features of the surgical procedure may induce postoperative AKI. The authors aimed to clarify the incidence of and risk factors for postoperative AKI and the association of AKI with short-term outcomes.

**Design:** This study was a retrospective analysis of a prospectively collected cohort. A multivariate logistic regression model was used to identify predictors of postoperative AKI.

**Setting:** Single center.

**Participants:** Clinical data were analyzed for 553 consecutive patients who underwent TAR combined with FET implantation between 2013 and 2016.

**Interventions:** None

**Measurements and Main Results:** Postoperative AKI was defined using the Kidney Disease Improving Global Outcomes criteria. Postoperative AKI occurred in 77.6% of the whole cohort. Patients in stage 3 AKI were associated with a higher incidence of major adverse events and in-hospital and 90-day mortality ( $p < 0.001$ ,  $p < 0.05$ ,  $p < 0.01$ , respectively). In the multivariate analysis, male sex (odds ratio [OR] 1.94; 95% confidence interval [95% CI] 1.22-3.18;  $p = 0.005$ ); older age (per 10 years) (OR 1.37; 95% CI 1.14-1.67;  $p = 0.001$ ); elevated body mass index (per 5 kg/m<sup>2</sup>) (OR 1.41; 95% CI 1.08-1.87;  $p = 0.01$ ); and prolonged cardiopulmonary bypass duration (per 30 minutes) (OR 1.17; 95% CI 1.01-1.37;  $p = 0.03$ ) were identified as independent predictors of postoperative AKI.

**Conclusion:** TAR combined with FET implantation carries a high-risk for postoperative AKI compared with other types of thoracic aortic surgeries. Cardiopulmonary bypass duration was identified as the only modifiable predictor of AKI, and patients may benefit from moderate hypothermic circulatory arrest instead of deep hypothermic circulatory arrest.

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**Key Words:** acute kidney injury; risk factors; total arch replacement; aortic dissection

RECENT STUDIES HAVE shown that total arch replacement (TAR) combined with the frozen elephant trunk (FET) technique produces favorable clinical outcomes worldwide.<sup>1-3</sup> The technique therefore has gained wide acceptance as an option to treat extensive aortic dissection or aneurysms involving the ascending aorta, aortic arch, and descending aorta.<sup>4</sup> Improved clinical outcomes with this thoracic aortic surgery are believed to be related to reliable techniques for organ protection.

Recent studies suggest that acute kidney injury (AKI) after thoracic aortic surgery is a significant predictor of mortality and major adverse cardiovascular and cerebrovascular events.<sup>5-7</sup> The reported incidence of AKI after thoracic aortic surgery ranges from 18% to 67%, according to different definitions of AKI and confounding patient selection.<sup>5,8-13</sup> Among all types of thoracic aortic surgeries, TAR combined with the FET technique features a longer surgical time, extended hypothermic circulatory arrest time, and greater technical complexity. All these features may be associated with postoperative AKI. Nevertheless, in previous studies<sup>13,14</sup> reporting renal outcomes in cohorts of patients undergoing TAR combined with FET, there was no sufficient sample size or well-recognized definition to demonstrate the incidence of and risk factors for postoperative AKI.

The authors' institute, a world-class center for thoracic aortic surgery, has performed a high volume of TAR combined with the FET technique. Therefore the authors possess a large cohort of cases for clinical research. For this study, the authors hypothesized that the incidence of AKI after TAR combined with FET was greater than the incidence with other types of thoracic aortic surgeries. To test this hypothesis, the incidence of AKI, defined using the Kidney Disease Improving Global Outcomes (KDIGO) criteria, which are the most up-to-date and widely recognized diagnostic criteria, was calculated. The authors also aimed to explore potential risk factors to identify patients at risk for AKI and to clarify the association of AKI with short-term outcomes.

## Methods

### Study Population

After approval by the Ethics Committees of Fuwai Hospital in Beijing, the authors conducted this retrospective observational study on consecutive patients who underwent TAR with modified FET implantation from January 2013 to March 2016. From this group of 558 patients, patients who died within 48 hours after the surgery were excluded because of the lack of postoperative serum creatinine to define AKI ( $n = 3$ ). Patients with missing preoperative or postoperative serum creatinine (SCr) values ( $n = 2$ ) also were excluded, leading to a final study population of 553 patients.

### Surgical Technique

All study participants underwent TAR combined with modified FET implantation. The surgical technique has been described previously in detail.<sup>15</sup> This procedure integrates total arch replacement using a trifurcated graft with implantation of a special stented graft in the descending aorta as a treatment option for extensive dissections or aneurysms involving the ascending aorta, the aortic arch, and the descending aorta. This procedure sometimes is called Sun's procedure and is viewed as a standard therapy for type A dissection involving repair of the aortic arch.<sup>4,15</sup> Deep hypothermic circulatory arrest (DHCA) or moderate hypothermic circulatory arrest (MHCA) and selective cerebral perfusion were performed routinely in this procedure. Deep hypothermia was defined as nasopharyngeal temperature between 14.1°C and 20°C, whereas moderate hypothermia was defined as nasopharyngeal temperature between 20.1°C and 28°C.<sup>16</sup>

### Data Definition

AKI was ascertained and categorized according to the KDIGO criteria, with slight modifications.<sup>17</sup> The postoperative AKI was defined when the postoperative SCr increased more than 50% of the baseline in the first 7 days or if there was an increase of 0.3 mg/dL within 48 hours postoperatively. Preoperative SCr values that were the nearest to the time of surgery were used as baseline SCr levels. Urine output was not taken into consideration because of its inaccuracy when collected retrospectively. Also, urine output after cardiac surgery is a reflection of many confounders apart from renal function (eg, diuretic or vasopressor use, presence of hypotension, fluid balance). AKI was staged for severity according to the criteria presented in Table 1.

Major postoperative adverse events were defined as a composite of in-hospital death, prolonged ventilation (intubation time for more than 5 d), stroke, redo surgery, deep sternal wound infection, and paraplegia. The Society of Thoracic Surgeons composite endpoint of postoperative complications was used, with the exception of renal outcome because it had been analyzed as a single outcome and the addition of paraplegia because it is an outcome unique to distal aortic surgery.<sup>18</sup>

Table 1  
Description of Staging of Acute Kidney Injury Using KDIGO Criteria.

Stage	Serum Creatinine Increase
1	1.5~1.9 times baseline or $\geq 0.3$ mg/dL (26.5 $\mu\text{mol/L}$ ) increase
2	2.0~2.9 times baseline
3	$\geq 3.0$ times baseline or increase in serum creatinine to $\geq 4.0$ mg/dL (353.6 $\mu\text{mol/L}$ ) or initiation of renal replacement therapy

Abbreviation: KDIGO, Kidney Disease Improving Global Outcomes.

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