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definition in large trauma registries at a rate of 0.2–0.5%.

Victims are usually males in their fourth and fifth decades of life.

Motor vehicle collision (MVC) is the most commonly reported cause of injury. Other causes of injury include falls from height, pedestrians versus vehicles, and motorcycle accidents.
Exsanguination secondary to aortic injuries is the second most common cause of death in trauma after traumatic brain injuries.\(^9,10\) One of the earliest reports reported 90% mortality within six hours of injury.\(^11\) Subsequent reports emphasized the high mortality associated with blunt traumatic aortic injuries (BTAs)\(^7,12–16\). BTAs are classified into four grades: I) intimal tears, II) intramural hematoma, III) pseudoaneurysm, and IV) complete transection.\(^17\) The aortic isthmus is the most commonly injured area.\(^11,15\) Mortality is potentially attributed to associated severe injuries to the head, chest, abdomen, and orthopedic injuries\(^7,8,11,16,18\) or presence of aortic transection (i.e., grade IV BTAI).\(^7,19\)

The use of thoracic endovascular aortic repair (TEVAR) in the management of BTAI has surpassed open surgical repair in numbers over the past two decades.\(^20\) It is a safer procedure associated with less risk of death, permanent disability, and other morbidities [Figure 1].\(^17,18,20,21\)

**METHODS**

We conducted a retrospective analysis of a prospective multi-center registry that included 40 consecutive blunt trauma patients presenting with an image-proven diagnosis of BTAI between January 2012 and July 2017.

Ethical approval was obtained from Sultan Qaboos University Hospital, a tertiary care teaching hospital, Royal Hospital, a tertiary care hospital, and Khoula Hospital, the capital’s main trauma center. Forty consecutive patients were identified out of which four were excluded for incomplete data. The remaining 36 patients were divided based on the timing of repair into early (< 7 days) or delayed (≥ 7 days) repair. Patient’s electronic records were reviewed to obtain their demographic information, date of injury, mechanism of injury, and injury severity score (ISS). Specific aortic injury details recorded were injury grade, native aorta diameter, and distance from injury to left subclavian artery (LSA). During admission, the need for blood products transfusion, use of anti-impulse medications, anticoagulation, intensive care unit (ICU) stay, and total hospital stay were also noted. Operative details such as LSA coverage status, degree of stent graft oversizing, device access site, and technical success were also recorded. Reported complications during admission and follow-up were categorized into aorta-related and non-aorta-related (i.e., respiratory, renal, cerebrovascular, paraplegia, thromboembolic, gastrointestinal, access site-related, and others). Total follow-up time and the need for reintervention were also included in the data collection sheet. Primary endpoints included in-hospital mortality, aortic-related morbidity, non-aortic-related morbidity, and the need for reintervention.

Patients with an incidental diagnosis of BTAI beyond index trauma admission and those with incomplete data were excluded.

Data were summarized using mean, standard deviation, median, frequency, and percentage. Independent samples t-test and Mann-Whitney U-test were used to analyze parametric and non-parametric continuous variables, respectively.

![Figure 1](image-url): (a) Angiogram showing blunt traumatic aortic injury before thoracic endovascular aortic repair. (b) Completion angiogram post-thoracic endovascular aortic repair.
Chi-square test and Fisher’s exact test were used to analyze categorical variables. A $p$-value $\leq 0.050$ was considered statistically significant. All analysis was carried out using SPSS Statistics (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.).

### RESULTS

Our study subjects were young with a mean age of $33.5\pm14.8$ and $29.9\pm11.0$ years in the early repair and delayed repair cohorts, respectively ($p = 0.447$). MVC accounted for the majority of cases ($82.6\%$ and $76.9\%$ in early and delayed repair groups, respectively, $p = 0.893$). Half of our patients were transferred from another facility for TEVAR ($60.9\%$ in the early repair group and $38.5\%$ in the delayed group ($p = 0.299$)). The delayed repair group had a higher but not statistically significant ISS ($39.4\pm17.8$ vs. $34.9\pm12.3$, $p = 0.425$). Complete demographic data is available in Table 1.

Thoracic injuries including pneumothorax, hemothorax, and lung injuries were the most commonly associated injuries in both early and delayed repair groups [Table 2]. Compared to early repair, patients who had undergone delayed repair had a higher incidence of exploratory laparotomies, but the difference was not statistically significant [Table 2].

There were four cerebrovascular accidents (CVAs) post-TEVAR. There were two symptomatic ischemic CVAs manifesting with paresis in one patient 21 days post-TEVAR and dysphasia in the other patient five days post-TEVAR, and one patient...
with symptomatic hemorrhagic CVA manifesting with paresis. The fourth patient presented with delirium 17 days post-TEVAR and was found to have a proximal stent migration causing non-occlusive thrombosis of major vessels [Figure 2]. Computed tomography (CT) of the head showed bilateral basal ganglia stroke [Figure 3]. He underwent aortic debranching with bilateral aortic-carotid bypass and was discharged 14 days later in good condition. Proximal stent migration was associated with a higher incidence of asymptomatic CVAs \( (p = 0.050) \). Total and partial LSA coverage was necessary for six and three patients, respectively. There was no statistically significant correlation between coverage and incidence of CVA \( (p = 0.220) \), type 1 endoleak \( (p = 0.466) \), or type 2 endoleak \( (p = 0.102) \).

Furthermore, neither the mean native aortic diameter (i.e., diameter proximal to the area of injury) nor the distance from injury to LSA affected the incidence of type 1 and 2 endoleaks \( (p = 0.501 \) and \( p = 0.483 \), respectively). There was no statistically significant difference in the incidence of aorta-related or non-aorta-related complications between our two cohorts. Our data showed that the early repair cohort had a longer but not statistically significant ICU stay \( (7.8 \pm 6.8 \) vs. \( 5.3 \pm 10.7, p = 0.386) \). Prolonged ICU stay was associated with greater likelihood to require blood transfusion \( (p < 0.001) \), incidence of respiratory complications \( (p = 0.010) \), and gastrointestinal complications \( (p = 0.026) \).

There was one recorded in-hospital mortality in our population overall in the early repair cohort. The

| Variables            | Injury to intervention interval | Early (< 7 days) n (%) | Delayed (≥ 7 days) n (%) | p-value |
|----------------------|---------------------------------|------------------------|--------------------------|---------|
| Head                 |                                 | 7 (30.4)               | 5 (38.5)                 | 0.720   |
| Lungs                |                                 | 19 (82.6)              | 12 (92.3)                | 0.634   |
| Ribs                 |                                 | 14 (60.9)              | 9 (69.2)                 | 0.727   |
| Other thoracic       |                                 | 21 (91.3)              | 8 (61.5)                 | 0.073   |
| Liver                |                                 | 4 (17.4)               | 4 (30.8)                 | 0.422   |
| Spleen               |                                 | 9 (39.1)               | 4 (30.8)                 | 0.727   |
| Other abdominal      |                                 | 9 (39.1)               | 5 (38.5)                 | 1.000   |
| Spinal               |                                 | 7 (30.4)               | 4 (30.8)                 | 1.000   |
| Musculoskeletal      |                                 | 15 (65.2)              | 9 (69.2)                 | 1.000   |
| Laparotomy           |                                 | 2 (8.7)                | 4 (30.8)                 | 0.161   |
| Mediastinal hematoma |                                 | 15 (65.2)              | 8 (61.5)                 | 1.000   |

Table 2: Associated injuries in patients undergoing thoracic endovascular aortic repair.

Figure 2: Computed tomography-angiogram showing (a) proximal stent graft migration and brachiocephalic thrombosis and (b) left common carotid and left subclavian thrombosis.

Figure 3: Brain computed tomography showing bilateral basal ganglia infarct.
reintervention rate was 4.3% vs. 7.7% in the early and delayed repair cohorts, respectively ($p = 1.000$).

**DISCUSSION**

We have taken an interest in the 'trauma epidemic' in Oman, specifically MVC-related mortalities and morbidities due to the large burden it poses on the population. According to the 2013 World Health Organization global report on road safety, there were 30.4 recorded MVC-related mortality per 100 000 population in Oman in comparison to 11.4 and 6.8 per 100 000 in the US and Canada, respectively. Of all MVC victims, 1.4% survive with permanent disability. This study represents Oman’s experience with TEVAR for BTAI since its introduction to trauma care with the first repair taking place in January 2012. Our study population was comparable to previous reports in terms of young age and male predominance.

In our study, native aortic diameter proximal to site of injury was significantly narrower than previously reported in other studies, which compounded with the young age at the time of TEVAR poses a serious question on stent graft durability.

The concept of delaying management of hemodynamically normal BTAI for other immediately life-threatening injuries to be managed is evident in the literature. In 2014, the Eastern Association for the Surgery of Trauma advocated for delayed repair citing lower incidences of paraplegia and mortality. The 2011 Society of Vascular Surgery also offered similar recommendations in favor of prioritizing management of other life-threatening injuries and performing TEVAR before patient discharge. Moreover, multiple institutions cited similar results with a clear reduction in mortality.

In our study, we elected to divide patients into early (< 7 days since injury) and delayed (≥ 7 days) repair cohorts.

Multiple factors contributed to the delay between injury and intervention in our population. As much as two-thirds of the early repair and more than one-third of the delayed repair patients required transfer from another hospital after diagnosis. Many of these patients had significant associated injuries as clearly indicated by a high mean ISS score of $34.9 ± 12.3$ and $39.4 ± 17.8$ in early and delayed repair groups, respectively. Previous studies have emphasized the impact of an initial high ISS on BTAI grade and potential survival. Moreover, thoracic aortic stent grafts are not always available off the shelf in our centers.

Anti-impulse therapy was prevalent in our population ($77.8\%, n = 28$) overall as a bridge to TEVAR while associated injuries were being managed. Despite the positive impact of blood pressure control in lowering complications with low grade injuries (i.e., grade I intimal tears), a variable success rate is reported in preventing injury progression and exsanguination for higher grade injuries, such as pseudoaneurysms and transections (grade III and IV), which comprised 97.2% ($n = 35$) of our subjects.

The last two decades have seen a significant paradigm shift in BTAI management from traditional open repair to TEVAR. Endovascular management is a less morbid option. In our experience, there was no recorded paraplegia post-TEVAR. This is comparable to larger BTAI experiences which report a less than 1% risk. There was no statistically significant difference in the incidence of aortic or non-aortic complications between the early and delayed cohorts. Aorta-related complications were encountered in six patients (16.7%). One patient had a type 1 endoleak immediately post-TEVAR, which was managed with balloon angioplasty. A repeat CT-angiogram, on day three post-TEVAR, showed no endoleak. The second patient had both type 1 and type 2 endoleaks post-TEVAR. He underwent an unsuccessful angioembolization on post-deployment day two followed by a successful embolization on post-deployment day six. At 38 days post-deployment, a repeat CT-angiogram showed no evidence of endoleak. Two patients had type 2 endoleak. One patient had no evidence at three days post-deployment on CT angiography (CTA) while the other patient was lost to follow-up.

Furthermore, two patients had documented proximal stent graft migration on follow-up CTA. The first patient presented on post-TEVAR day 17 with headache and dizziness but no paresis. A brain CT with thoracic CTA showed bilateral parietal hypodensities and non-occlusive thrombosis of all three major vessels. He was noted to have a bovine aortic arch at deployment with LSA coverage. He subsequently underwent bilateral aortic-carotid bypass one day later and was discharged with no
neurological deficits 14 days later. The second patient had CTA evidence of proximal stent graft migration and non-opacification of the LSA four months post-TEVAR but no symptoms. In a large experience published by the American Association for the Surgery of Trauma, endograft-related complications were reported in up to 20% of cases, possibly due to lack of appropriate devices for BTAI. Our study 

Our study recorded four CVA (three in early repair and one in delayed repair, \( p = 1.000 \)). Previous studies report stroke rates at 2–5% compared to our CVA rate of 11.1%. We could not find a statistically significant correlation between the incidence of CVA and injury distance from the LSA, LSA coverage, or proximal stent graft migration.

The only recorded mortality in our series was attributed to severe acute respiratory distress syndrome (ARDS) post-TEVAR. This patient underwent TEVAR the day after trauma (i.e., early repair cohort). In the ICU, he developed severe ARDS with no clear etiology eventually passing away 13 days post-TEVAR. There were no recorded aorta-related mortalities.

**CONCLUSION**

The short-term outcomes for TEVAR of BTAI continue to show its feasibility in managing BTAI in severely injured patients. There was no clear statistical significance in mortality and morbidity comparing early repair versus delayed repair. However, our experience is based on a small sample size and short median follow-up but provides a good platform for further analysis.

**Disclosure**

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