ORIGINAL ARTICLE

Five-year experience with the peri-operative goal directed management for surgical repair of traumatic aortic injury in the eastern province, Saudi Arabia

Haytham Z. Al-Gameel,
Mohamed R. El-Tahan,
Mohammed A. Shafi,
Hany A. Mowafi,
Abdulmohsin A. Al-Ghamdi

Department of Anesthesia, Faculty of Medicine, University of Dammam, Dammam, Saudi Arabia

Address for correspondence:
Dr. Mohamed R. El-Tahan, Department of Anesthesia, King Fahd Hospital of the University of Dammam, P. O. 40289, Dammam, Al Khubar 31952, Saudi Arabia.
E-mail: mohamedrefaateltahan@yahoo.com.

ABSTRACT

Context: Traumatic aortic injury (TAI) accounts for 1/3 of all trauma victims. **Aim:** We aimed to investigate the efficacy of the adopted standardized immediate pre-operative and intra-operative hemodynamic goal directed control, anesthetic technique and organs protection on the morbidity and mortality in patients presented with TAI. **Settings and Design:** An observational retrospective study at a single university teaching hospital. **Materials and Methods:** Following ethical approval, we recruited the data of 44 patients admitted to the King Fahd Hospital of the University, Al Khobar, Saudi Arabia, with formal confirmation of diagnosis of blunt TAI during a 5-year period from February 2008 to April 2013 from the hospital medical records. **Statistical Analysis:** descriptive analysis. **Results:** A total of 44 victims (41 men, median (range) age 29 (22-34) years) with TAI who underwent surgical repair were recruited. Median (range) post-operative chest tube output was 700 (200-1100) ml necessitated transfusion in 5 (11.4%) of cases. Post-operative complications included transient renal failure (13.6%), pneumonia (6.8%), acute lung injury/distress syndrome (20.5%), sepsis (4.5%), wound infection (47.7%) and air leak (6.8%). No patient developed end stage renal failure or spinal cord injury. Median intensive care unit stay was 6 (4-30) days and in-hospital mortality was 9.1%. **Conclusion:** We found that the implementation of a standardized early goal directed hemodynamic control for the peri-operative management of patients with TAI reduces the post-operative morbidity and mortality after surgical repair.

Key words: *Anesthesia, goal directed therapy, hemodynamic, surgery, traumatic aortic injury*

INTRODUCTION

Blunt aortic trauma accounts for 30% of all trauma admissions (mean age 41 ± 20 years), with overall mortality of 55%.[1] Although any portion of the aorta is at risk most blunt aortic injuries occur in the descending aorta at the level of the ligamentum arteriosum, a point of fixation of the vessel, where the relatively mobile aortic arch can move against the fixed descending aorta.[2] Despite major advances in pre-hospital life support, nearly 40-90% of patients presenting with traumatic rupture of the thoracic aorta die at the scene, whereas 10-60% survive to the emergency department (ED) with an aortic isthmus injury and an in-hospital mortality of 31.4-66% respectively.[3-5] Survivors to the ED usually have lacerations of part or all of the aortic circumference with the pseudo-aneurysm formation in 60% of cases.[6]

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The priorities in management for those unique patients who sustained a deceleration or acceleration injury with potential aortic injury are to rapidly stabilize the cardiopulmonary status, proper trauma imaging, identify those with associated injuries to chest, liver and spine[3] and early or delayed prompt open surgical versus endovascular repair.[7] Vigilant hemodynamic and neurological monitoring, proper interventions in response to the changes in hemodynamics during the different stages of surgery and intensive post-operative care can improve the survival and reduce the incidence of post-operative complications.[8]

The aim of the present retrospective report was to investigate the efficacy of the implemented standardized King Fahd Hospital of the University (KFHU) peri-operative management protocol on the morbidity and mortality in the patients presented with traumatic aortic injury (TAI).

MATERIALS AND METHODS

Setting

This study was carried out at the KFHU, Al Khobar, Saudi Arabia, with about 233,196 annual admissions to the ED.

We adopted a standardized systematic approach for the peri-operative care of the victims of TAI.

First aid in the ED

A multidisciplinary trauma team was activated in the ED.

Immediately a primary survey was performed by assessing and managing the patient's airway, with cervical spine stabilization, breathing and circulation. All patients were assumed to have an injured spine and spinal immobilization was maintained until spine injury was cleared. Patient monitoring included electrocardiograph, non-invasive blood pressure (BP), pulse oximetry, core temperature and urine output.

If breathing was inadequate, after exclusion of pneumothorax, hemothorax, or fracture ribs, positive pressure ventilation was considered.

After the establishment of two large gauge intravenous (IV) accesses, a fluid bolus of 20 ml/kg of normal saline or lactated Ringer's solution was administered, if circulation was inadequate, tamponade was used to control any continuing external hemorrhage. If the circulation continued to be unstable, repeated fluid boluses using normal saline, lactated Ringer's, Voluven 6% (hydroxyethyl starch 130/0.4) or 5% plasma protein fraction solution were administered. A central venous and peripheral arterial access were obtained, a vasopressor with or without inotrope was infused, blood bank was notified and packed red blood cells (O negative, group-specific or cross-matched, as available) was transfused [Figure 1].

All patients were screened according to our standardized stepwise imaging protocol included chest X-ray and contrast-enhanced multi-slices computed tomography (CT), transesophageal echocardiography and angiography. The secondary survey for the associated injuries composed of history (if applicable), head to toe evaluation, X-ray for suspected fractures, abdominal ultrasonography, brain and abdominal CT scanning and direct peritoneal lavage if needed. CT angiography was often confirmative and diagnostic for the wide spectrum of aortic lesions that range from intimal tears to free ruptures. Based on imaging, TAI is classified into Grade Ia: Intimal tear, Grade Ib: Intramural hematoma; Grade II: Intimal injury with periaortic hematoma; Grade IIIa: Aortic transection with pseudoaneurysm, Grade IIIb: Multiple aortic injuries; and Grade IV: Free rupture.[9]

Pre-operative preparation

Two wide bore peripheral IV cannulae were inserted for rapid volume expansion. Insertion of central venous lines for monitoring of central venous pressure (CVP) was delayed in the stable patients to the operating theatre. Other preparations included emergency medications, fluid warmers, fluids, cell salvage system (Cell Saver 5, Hemonetics Corp., USA), blood products and pumps. In addition, the facility of perfusion techniques using left heart bypass was on standby in the operating room.

Sedation was omitted in most of our patients. Invasive arterial (from both the right radial and one of the femoral arteries) and central venous and/or pulmonary arterial BPs were monitored if they were not initiated in the ED. Other monitors included a train-of-four stimulation of the ulnar nerve, depth of anesthesia using state entropy (SE) and response entropy (RE) or bispectral index (BIS) (GE Healthcare, Helsinki, Finland).

Anesthesia induction

Anesthetic technique was standardized in all patients. For hemodynamically stable patient IV propofol 1-2.5 mg/kg in combination with fentanyl (2-3 μg/kg) or sufentanil (0.2-0.3 μg/kg) were administered. Etomidate (0.2-0.3 mg/kg) provided a good alternative in unstable patients due to its favorable cardiovascular profile. However, the combination of Ketamine (0.5-1 mg/kg) with midazolam (0.02 mg/kg) alternated the lack of etomidate in some situations. The doses used in anesthetic induction varied according to hemodynamic response.

Lung isolation was considered in all patients to avoid injury of the left lung during the surgical manipulations. The proper position of the lung isolation tool was confirmed with the use of a fiber optic bronchoscope.

Anesthesia maintenance

In stable patients, anesthesia maintenance was left to the discretion of the anesthesiologist, sevoflurane 0.7-1.5 minimum alveolar concentration or propofol in oxygen/air mixtures and rocuronium, in combination with fentanyl, sufentanil or remifentanil infusions guided by changes in the heart rate, BP and SE and RE or BIS to avoid awareness during the procedure [Figure 2]. In unstable patients, anesthesia was maintained with midazolam, ketamine, rocuronium and fentanyl or sufentanil.

Two-lung ventilation was performed according to the discretion of anesthesiologist using either pressure-controlled or volume controlled ventilation mode using tidal volume (VT) of 8 ml/kg, with or without positive end expiratory pressure (PEEP) of 5 cm H_2O and frequency adjusted to maintain $PaCO_2$ at 35-45 mmHg.

All surgeries were done by the same surgeons. Surgical approach was carried out through a standard left posterolateral thoracotomy. After pleurotomy, one-lung ventilation was initiated using VT of 6-8 ml/kg with or without PEEP of 5 cm H_2O according to the preference of the anesthesiologist.

Figure 2 shows our adopted algorithm for the intra-operative management of hemodynamics and organ perfusion before, during aortic cross-clamping and after aortic declamping.

Aortic cross-clamping

The main target during the period of cross-clamping was to maintain hemodynamic stability and to lessen the unwanted proximal hypertension, myocardial work and the risk of myocardial. This was achieved by maintenance of an adequate anesthetic depth, the use of vasoactive medications and varying fentanyl/sufentanil infusions. Esmolol, selective β-blockers, was considered to treat persistent tachycardia despite optimum anesthetic depth and analgesia [Figure 2].

Spinal cord and renal protection during aortic cross-clamping

The limitation of the aortic cross-clamping time to less than 45 min together with maintenance of adequate distal perfusion ≥40 mmHg through monitoring of the mean arterial pressure obtained from the femoral artery catheter were the cornerstone for organ protection.

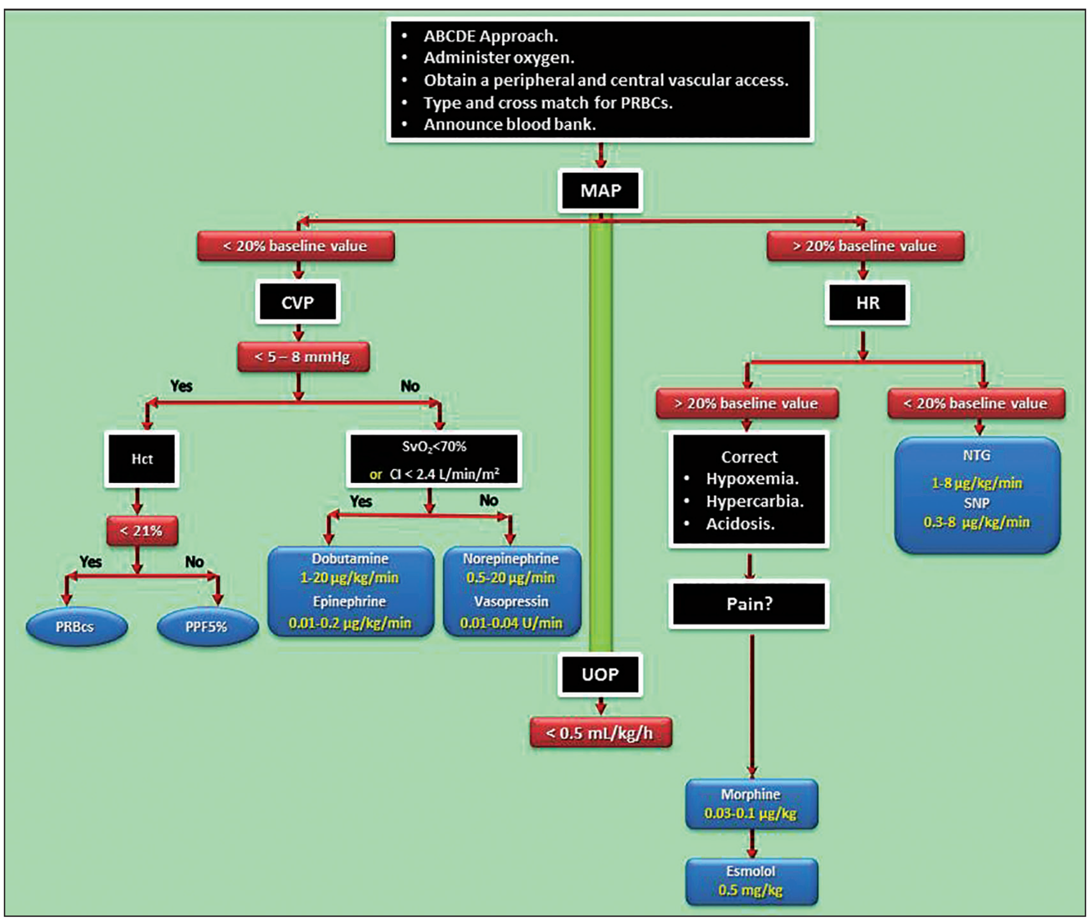

Figure 1: Pre-operative King Fahd Hospital of the University algorithm for resuscitation of patients with traumatic aortic injury. MAP: Mean arterial pressure; CVP: Central venous pressure; Hct: Hematocrit; PPF: Plasma protein fraction 5%; RBCs: Packed red blood cells; SvO_2: Mixed-venous oxygen saturation; CI: Cardiac index; UOP: Urine output; HR: Heart rate; NTG: Nitroglycerine; SNP: Sodium nitroprusside

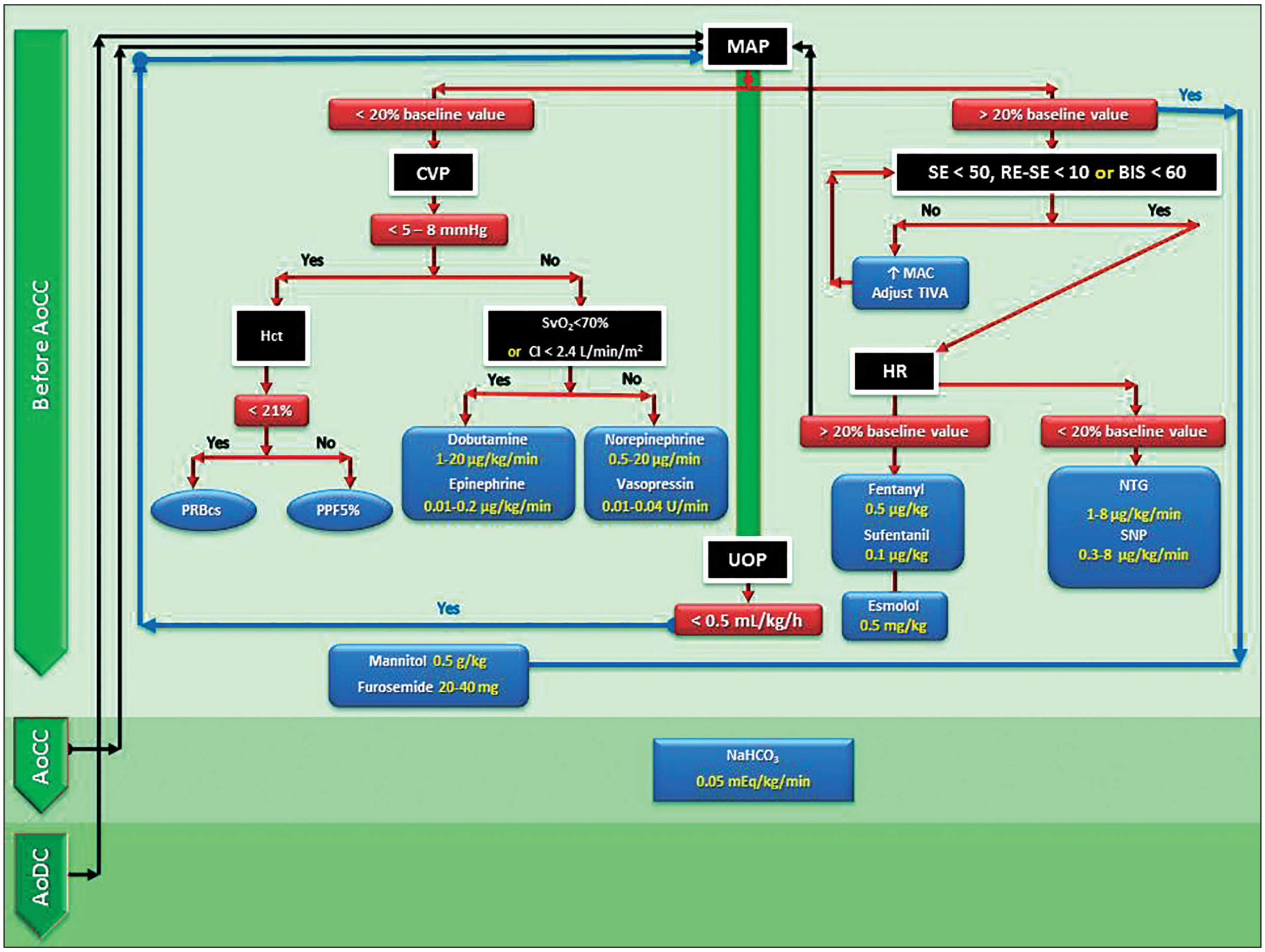

Figure 2: Intra-operative King Fahd Hospital of the University algorithm for hemodynamic management and organ protection during repair of traumatic aortic injury. AoCC: Aortic cross-clamping; AoDC: Aortic de-clamping; MAP: Mean arterial pressure; CVP: Central venous pressure; Hct: Hematocrit; PPF: Plasma protein fraction; RBCs: Packed red blood cells; SvO_2: Mixed-venous oxygen saturation; CI: Cardiac index; UOP: Urine output; HR: Heart rate; BIS: Bispectral index; SE and RE: State and response entropy; MAC: Minimum alveolar concentration; TIVA: Total intravenous anesthetics; NTG: Nitroglycerine; SNP: Sodium nitroprusside; $NaHCO_3$: Sodium bicarbonate

Sodium bicarbonate ($NaHCO_3$) was infused at a rate of 0.05 mEq/kg/min from the onset of aortic cross-clamping to declamping of the aorta to avoid metabolic acidosis.

No trial was done to warm up the patient until declamping of the aorta and the patient's temperature was left to drop to 35-36.0°C to protect against the spinal cord ischemia. The use of cooling measures as IV cold saline, cold fluids, thermal blankets and ice packs were reserved in case of expected long aortic cross-clamping time.

Adequate renal perfusion was ensured throughout by maintaining of the CVP >8-15 mmHg, $NaHCO_3$ infusion, furosemide (20-40 mg IV boluses), mannitol (0.25-0.5 g/kg) and relative hypothermia.

Aortic de-clamping

Many measures were taken to avoid, correct and minimize the predicted hemodynamic instability after aortic de-clamping. Metabolic acidosis was corrected with further boluses of $NaHCO_3$. Ionized hypocalcemia was corrected with administrating of IV 1 g of 10% calcium chloride or 2 g of 10% calcium gluconate. Decreasing the depth of anesthesia in parallel with administering fluid boluses and infusions of vasopressor without or with inotropes was considered to maintain hemodynamic stability. The gradual release of the aortic clamp and/or rapid aortic re-clamping was considered as the top measure of choice for correction of profound hypotension after aortic de-clamping. Frequent arterial blood gases and lactate analysis were considered during this critical period [Figure 2].

Intra-operative oliguria, blood loss, need for inotropic/vasopressor infusions and blood transfusions are shown in Table 1.

Post-operative management

All of those critical patients were transferred to the surgical intensive care unit (ICU) intubated, sedated and mechanically ventilated. Post-operative sedoanalgesia was accomplished with infusions of dexmedetomidine or midazolam in combination with fentanyl or remifentanil and IV paracetamol. Gradual discontinuation of ventilator support was initiated 24 h after admission to the surgical ICU. Attention was paid to blood pressure control within the period of post-operative ICU stay, maintaining systolic blood pressure <130 mmHg, to avoid possible leakage from the aortic anastomosis lines, using medications such as labetalol, esmolol, nitroglycerine and sodium nitroprusside. A restrictive fluid policy (24 hourly negative fluid balance > −0.3-0.5 l) was adopted.

Data collection

The study was performed according to the local legality concerning retrospective in concordance with the Ethics Committee of the KFHU. During a 5-year period (February 2008-April 2013), all reported cases of traumatic rupture of the thoracic aorta presented to the KFHU, were retrieved from the hospital medical records by three independent investigators. The records of all subjects were reviewed for formal confirmation of diagnosis of blunt TAI applying several search criteria including traumatic rupture of the thoracic aorta, TAI, traumatic aortic laceration, traumatic aortic lesion and blunt aortic rupture. Patients' characteristics, associated injuries, admission and operative data, post-operative outcome data and complications, mortality and length of stays were collected.

Data analysis

Descriptive analysis for the collected data was performed using STATISTICA software for Windows (version 8; Statsoft, Inc., Tulsa, USA). Data are presented as mean ± standard deviation, median (range) and number (percent).

Exclusion criteria

Patients who presented with unwitnessed cardiac arrest were excluded from the analysis.

RESULTS

Patients

Table 2 shows the demographic characteristics of the patients.

First aid management in the ED

A multidisciplinary trauma team was activated in response to out-of-hospital calls in 5 (11.4%) patients and after admission to the ED in the remaining 88.6% patients.

In some patients (15 [37.5%]), there was a substantial delay between the primary and secondary survey because either immediate resuscitation or a lifesaving surgery was indicated.

Table 1: Outcome data

Variables	
Mean ICU stay (days)	6 (4-30)
Post-operative chest tube output (ml)	700 (200-1100)
Patients needed post-operative transfusion (*n*)	5/44
Patients needed post-operative inotropic/vasopressor infusions (*n*)	8/44
Mean post-operative ventilation (days)	4 (0.7-13)
Post-operative complications (*n*)	
Renal failure/impairment	6/44
Pneumonia	3/44
ALI/ARDS	9/44
Sepsis	2/44
Wound infection	21/44
Air leak	3/44
Mortality (*n*)	4/44

Data are presented as median (minimum-maximum) and number; ALI: Acute lung injury; ARDS: Acute respiratory distress syndrome; ICU: Intensive care unit

Table 2: Demographic data and operative characteristics

Variables	
Age (years)	29 (22-34)
Gender (m/f) (*n*)	41/3
Weight (kg)	72 (60-85)
Type of trauma (*n*)	
Motor vehicle accident	41/44
Falling from height	3/44
Patients presented with shock needed inotropic/vasopressor support (*n*)	4/44
Time of surgical intervention (*n*)	
Immediate	36/44
Delayed	8/44
Surgical intervention (*n*)	
End-to-end anastomosis	41/44
Interposition graft	3/44
Direct aortic clamp and sew technique (*n*)	44/44
Mean aortic cross clamp time (min)	35 (20-43)
Intra-operative oliguria (*n*)	6/44
Patients needed intraoperative inotropic/vasopressor infusions (*n*)	12/44
Intra-operative blood loss (ml)	1100 (500-1800)
Patients needed intraoperative transfusion (*n*)	24/44

Data are presented as median (minimum-maximum) and number

Abnormalities seen on chest X-ray and CT scan included; widened mediastinum (29 [65.4%]), left hemothorax or hemopneumothorax (42 [95.4%]), pulmonary contusions (39 [88.6%]), rib fractures (40 [90.9%]) and tracheal deviation (9 [20.5%]).

The surgical repair was immediate in 36 cases while it was delayed in 8 stable cases referred from other hospitals in the Eastern Province of the Kingdom of Saudi Arabia for a period from 1 to 4 days.

Pre-operative preparation

Patients were transferred to the operating room from the ED (81.8%) or the surgical ICU (18.2%) with continuation of bedside monitoring.

Only five out of 44 patients received sedation with midazolam (0.02 mg/kg). A pulmonary artery catheter was floated to the right pulmonary artery in 23 cases (52.7%).

Anesthetics and intra-operative management

In all non-intubated patients (88.6%), a rapid sequence induction was considered using succinylcholine to facilitate the placement of either a double-lumen endobronchial tube (81.8%) or a tracheal tube for Fuji or Arndt's endobronchial blockers (18.2%). Five patients were intubated before arrival to the operating theatre and endobronchial blockers were placed to separate the left lung.

The time of aortic cross-clamping was limited to an average of 35 min (range: 20-43).

None of our patients needed distal shunt, left heart bypass technique or re-implantation of the intercostal arteries to maintain the spinal cord perfusion.

Lumbar drainage of cerebrospinal fluid was not used for any of our patients. The urgency of the surgical intervention, associated spinal injury (35 [79.5%]), expected short aortic clamping time and the hemodynamic instability of some patients precluded the use of this technique for spinal cord protection.

In the last 12 patients, near-infrared spectroscopy probes were placed on the midline back on the T10-L2 posterior flank (somatic) for measuring the somatic regional O_2 saturation (rSO_2). The probes were monitored by a dual-detector device (Somanetics INVOS 5100, Troy, MI) and trended at 1-min intervals. We aimed to maintain the somatic rSO_2 >40% of the baseline during aortic cross-clamping.

Patients' outcome

The median ICU stay was 6 days (range: 4-30 days). The chest drains output, post-operative blood transfusion and infusions of inotropes and vasopressors, days free of ventilation and prevalence of complications are shown in Table 1. Six patients developed post-operative acute lung injury (ALI).

A continuous renal replacement therapy was initiated during the 1st post-operative day in 3 (6.8%) patients to treat a transient acute oliguric renal failure, despite the optimization of the filling pressures and perfusion and use of diuretics [Table 1]. No patient developed end stage renal failure or spinal cord injury.

Mortality in our cohort was 9%. Four out of our reported 44 cases died. One patient died during surgery due to exsanguination. The other three patients died because of acute respiratory distress syndrome (ARDS). One of these patients died on the 7th post-operative day. The other two patients developed severe sepsis caused by pseudomonas aeruginosa and methicillin-resistant *Staphylococcus aureus* infections complicated with pneumonia and ARDS.

DISCUSSION

In the current document, we retrospectively describe our standardized protocol for the peri-operative management of patients with TAI and it possible effect on the reduction of the incidence of post-operative complications and in-hospital mortality.

Intra-operative hemodynamic management is pivotal to the outcome and success of surgical repair of TAI. Empirical formula and invasive monitoring have been traditionally used to guide intra-operative fluid, inotropic and vasoactive management and assess the volume and cardiac output status to optimize oxygen delivery especially in those high-risk patients. Our standardized protocol was created based on the goal-directed hemodynamic resuscitation of Surviving Sepsis Campaign released in 2008.[10]

During the 5-year observation period, a total of 44 patients (93.2% men and 6.8% women) with TAI presented to the KFHU giving a rate of 1.6 cases/100,000 admissions to the ED per year. In contrast, a recent retrospective study[3] of the TAI in the greater area of Zurich, Switzerland during a 14-year period, reported lower population-based annual rate of TAI (0.6 cases/100,000 persons, with a mean age of 46.8 ± 18.8 years), observed mainly in the men (82.4%) rather than in the women (17.6%). The lower incidence in Switzerland may be linked to the strict introduction of seat belt law in Switzerland since 1981. On the contrary, the lower incidence in Saudi women may reflect the fact that women are not allowed to drive in Saudi Arabia.

Our study shows that the risk of TAI is more prevalent among the victims of motor vehicle crashes (93.2%) than in other studies (49.4-57%).[3,4,11,12] In similar to others,[3] we found drivers to be affected twenty-fold as much as non-drivers. The associated injuries were present in 39 patients (88.6%) including left hemopneumothorax (95.4%), pulmonary contusions (88.6%), rib fractures (90.9%), traumatic brain injury (20.5%), splenic injury (6.8%), hepatic injury (9.1%) and spinal injury (79.5%) respectively. These associated injuries would worsen the outcome after surgical repair of TAI. Delayed surgical repair of TAI was reserved to 18.2% hemodynamically stable patients who were referred from other hospitals in the Eastern Province. This had no significant impact on the outcome in our study. Only 6.8% of patients needed interposition graft.

Although, we adopted a restrictive fluid and protective ventilation strategies, 20.5% of the survivors developed ALI and ARDS, which may be related to the high prevalence of pulmonary contusions.

The absence of end-stage renal failure or neurological sequelae in our patients may be related to our adopted stepwise algorithm. A study by Miyaji *et al.*,[13] found a significant inverse correlation between somatic rSO_2 and the increase of lactate concentration ($r = -0.795$, $P < 0.0001$) during aortic arch reconstruction. This indicated that the reduction of vascular resistance of collateral vessels increased somatic blood flow, resulting in improved tissue oxygen delivery. However, there was no significant correlation between somatic rSO_2 and post-operative urine output, creatinine, or blood urea nitrogen. Thus, monitoring of somatic rSO_2 was used in the last 12 cases to provide early detection of any significant harmful decreases in spinal cord perfusion and hence oxygen delivery.

The longer ICU stay was predictive of morbidity and mortality and it was related to higher chest drains output, higher needs for post-operative blood transfusion and infusions of inotropes and vasopressors, fewer days free of ventilation and occurrence of complications such as renal dysfunction, pneumonia, ALI, ARDS, sepsis, wound infection and air leak.

In contrast to previous studies,[3-5] the implementation of our standardized early peri-operative hemodynamic management protocol was associated with significantly reduced in-hospital mortality after TAI from 31.4-66% to 9.1% respectively. Sepsis and ARDS were the leading causes of death in our cases.

The present study had several limitations. First, the nature of the retrospective design and the fewer number of patients might pose bias. Second, the safety belt users versus non-users, the side impact versus frontal collision, the transfer times between ambulance stations to the scene of accident and from there to the KFHU and pre-hospital mortality were not investigated in the present study.[3] Third, the thoracic endovascular aortic repair which may result in improved outcome, was not performed in any of the reported cases.

Further multi-center studies are needed to address the clinical importance of the application of our adopted KFHU protocol for improving the outcome after surgical repair of TAI.

CONCLUSION

The authors found that, the implementation of a standardized early goal directed hemodynamic control for the peri-operative management of patients with TAI may have a good impact on the post-operative morbidity and mortality after surgical repair. Furthermore, prevention of such fatal injuries needs to be the highest priority in future national efforts.

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