European Journal of Trauma and Emergency Surgery (2019) 45:959–964
https://doi.org/10.1007/s00068-019-01123-3

ORIGINAL ARTICLE

Efficacy and safety of TEVAR with debranching technique for blunt traumatic aortic injury in patients with severe multiple trauma

Kenichiro Uchida[1] · Tetsuro Nishimura[1] · Hiromasa Yamamoto[1] · Yasumitsu Mizobata[1]

Received: 23 January 2019 / Accepted: 28 March 2019 / Published online: 3 April 2019

Abstract

Background Blunt traumatic aortic injury (BTAI) patients are severely ill, with high mortality and morbidity. As 60% of BTAIs occur in the distal arch, left subclavian artery (LSCA) management is determined without knowing posterior cerebral or left arm circulation in emergent cases. Because we perform thoracic endovascular aortic repair (TEVAR) + debranching technique for thoracic BTAI, we assessed efficacy and safety of debranching TEVAR in BTAI patients.

Methods We retrospectively reviewed vital signs on arrival, injury mechanism, characteristics, clinical time-series, concomitant injuries, injury description, operative procedures, and results from patient records. We excluded patients in cardiopulmonary arrest on arrival.

Results From April 2014 to December 2018, nine of 25 patients admitted with BTAI underwent TEVAR. Median Injury Severity Score was 34 (29–34) and probability of survival was 0.82 (0.16–0.94). Society for Vascular Surgery BTAI injury grade was III or IV in all patients. Three patients underwent simple TEVAR and six underwent debranching TEVAR (LSCA occlusion + left common carotid artery to LSCA bypass). Median operation time was 108 (75–157) min for simple TEVAR and 177 (112–218) min for debranching TEVAR. Concomitant injuries included intracranial hemorrhage ($N=1$), intra-abdominal injuries ($N=3$), pneumo- or hemothoraxes ($N=4$) and pelvic/extremities fractures ($N=7$). Only one complication of left-hand claudication occurred postoperatively in a patient with simple TEVAR with LSCA occlusion.

Conclusion Despite debranching TEVAR taking approximately 60 min longer than simple TEVAR, short-term results indicated it to be acceptable for BTAI in multiple trauma patients to avoid LSCA complications unless we fail to stop bleeding first.

Keywords Blunt traumatic aortic injury · Debranching thoracic endovascular aortic repair (TEVAR) · Left subclavian artery · Left common carotid artery · Severe multiple trauma

Abbreviations

BTAI	Blunt traumatic aortic injury
CT	Computed tomography
ISS	Injury severity score
LCCA	Left common carotid artery
LSCA	Left subclavian artery
SVS	Society for vascular surgery
TEVAR	Thoracic endovascular aortic repair

✉ Kenichiro Uchida
cvs.uchida@gmail.com

Tetsuro Nishimura
tetusayo2004@mail.goo.ne.jp

Hiromasa Yamamoto
hyamamoto@med.osaka-cu.ac.jp

Yasumitsu Mizobata
giulietta534@me.com

[1] Department of Traumatology and Critical Care Medicine, Osaka City University Graduate School of Medicine, Osaka, Japan

Background

Multiple trauma patients with blunt traumatic aortic injury (BTAI) tend to be severely ill and have high rates of mortality and morbidity [1, 2]. Recently, as acceptable moderate- to long-term outcomes of thoracic endovascular aortic repair (TEVAR) have been published [3, 4], the indications for and frequency of performance of TEVAR to treat BTAI have increased.

As approximately 60% of BTAIs are reported to occur in the distal arch [5], TEVAR is indicated in many of these trauma cases instead of open surgery. However, management

of the left subclavian artery (LSCA) must be done without detailed knowledge of the posterior cerebral or left arm circulation in emergent cases.

If the injured site requires zone 2 TEVAR, debranching techniques are recommended especially in patients with left vertebral artery dominance, the presence of a left internal mammary artery graft to a coronary artery, a left vertebral artery directly branching from the aorta and left-hand dominance [6]. However, many reports have shown that these indications are not adequate in preventing complications associated with LSCA occlusion.

In 2015, the Eastern Association Society for Trauma published the practice management guideline for BTAI [7], but there is still no strong consensus on the treatment strategies for BTAI. After experiencing one case of arm claudication induced by LSCA ischemia, we now strive to perform TEVAR + debranching technique for thoracic BTAI.

The objective of this study was to assess the efficacy and safety of TEVAR with debranching technique in severe multiple trauma patients.

Methods

This single-center retrospective review assessed patients admitted to the Trauma and Critical Care Center of Osaka City University Hospital, a level 1 urban area trauma center in the third largest city by population in Japan. We sought to enroll all patients aged over 16 years who were diagnosed as having blunt aortic injury from April 2014 to December 2018. We defined patients with severe multiple trauma as those with an Injury Severity Score (ISS) of 16 or higher and the presence of two or more separate regions of injury defined according to an Abbreviated Injury Score ≥ 3.

The records of the BTAI patients with severe multiple trauma injuries were reviewed for the mechanism of injury, patient characteristics, vital signs on arrival, clinical time flow, concomitant injuries, injury description, operative details, other performed procedures, and outcomes with complications. Those patients in cardiopulmonary arrest on hospital arrival were excluded.

Grading of BTAI based on CT angiographic imaging

All patients included in this study underwent enhanced computed tomography (CT) scan with CT angiography on admission; none underwent conventional angiography for diagnostic purposes. Based on CT angiographic imaging, the aortic injury was classified into one of four categories defined by the guidelines of the Society for Vascular Surgery (SVS) [8, 9]: Grade I, intimal tear; Grade II, intramural hematoma; Grade III, aortic pseudoaneurysm; and grade IV, free rupture.

Our strategy for BTAI

We perform TEVAR for BTAI in patients with an SVS injury grade of ≥ II within 48 h after injury. In 2016, we experienced one patient with postoperative left arm claudication in whom zone 2 TEVAR with LSCA occlusion was performed because we detected retrograde left vertebral arterial flow intra-operatively. However, after the surgery the patient complained of slight left-hand claudication, and the left arm blood pressure was approximately 40 mmHg lower than the right arm pressure (Fig. 1).

After this experience, if the thoracic aortic injury site is located where zone 2 TEVAR is required, we attempt TEVAR with debranching technique. We basically perform zone 2 TEVAR with a left common carotid artery (LCCA) to LSCA bypass to minimize the risk of stroke or left arm ischemia (Fig. 2).

The quality of the LCCA and cerebral perfusion are evaluated with a CT scan, intra-operative aortography and direct exposure. Prior to TEVAR, we bypass the LCCA to the LSCA with a side-to-side anastomosis using an artificial vascular graft.

For intra-operative cerebral perfusion monitoring, we routinely use the bispectral index and near-infrared spectroscopy to monitor regional oxygen saturation and administer intravenous steroid to prevent intra-operative cerebral edema.

If the patients have other active bleeding sites such as in the abdomen, retroperitoneum or some other body cavity, we perform abdominal exploration, pelvic packing or trans-arterial embolization first prior to TEVAR according to the patient's vital signs.

Although we do not maintain an in-hospital stock of stent grafts for TEVAR, because our hospital is in a highly urban area, the devices are available within half an hour after being sized and ordered for delivery.

Statistical methods

Because this was a pilot study with small sample size and the data were not normally distributed, data of the continuous variables are presented as the median (25–75% interquartile range), and the categorical variables are presented as number (%). Data were analyzed using IBM SPSS Statistics, version 22 (SPSS Inc., Chicago, IL, USA).

Results

From April 2014 to December 2018, 25 patients were diagnosed as having BTAI and admitted to Osaka City University Hospital. Emergency medical service transported 21

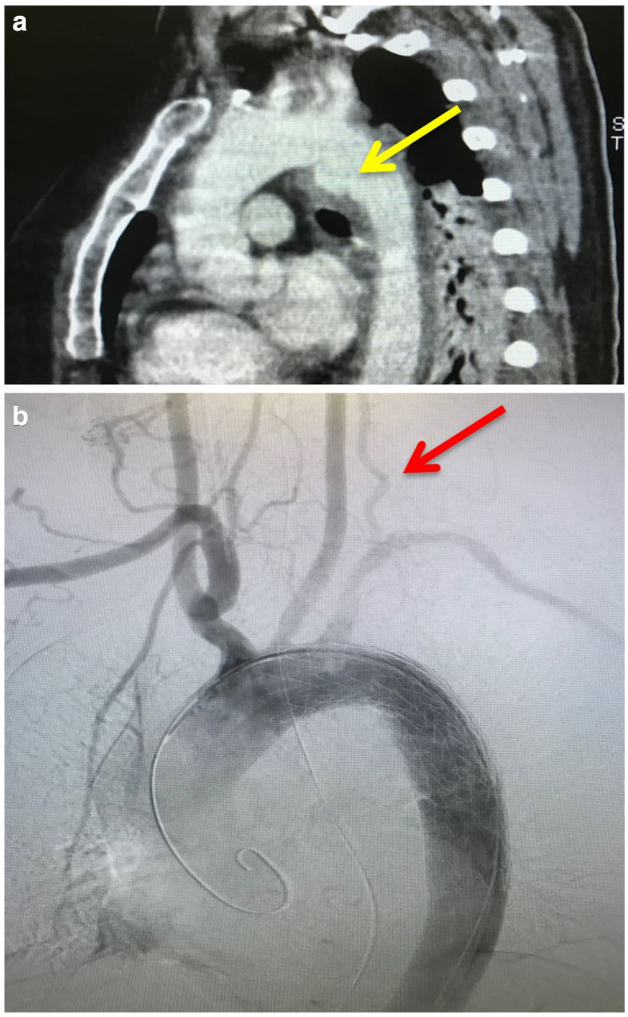

Fig. 1 **a** The sagittal CECT scan of distal arch BTAI with pseudoaneurysm (yellow arrow). **b** We performed zone 2 TEVAR with left subclavian artery occlusion because we detected retrograde left vertebral arterial flow intra-operatively (red arrow). After the surgery, however, the patient complained of slight left-hand claudication. The left arm blood pressure was approximately 40 mmHg lower than that of the right arm. *CECT* contrast enhanced computed tomography, *BTAI* blunt traumatic aortic injury, *TEVAR* thoracic endovascular aortic repair

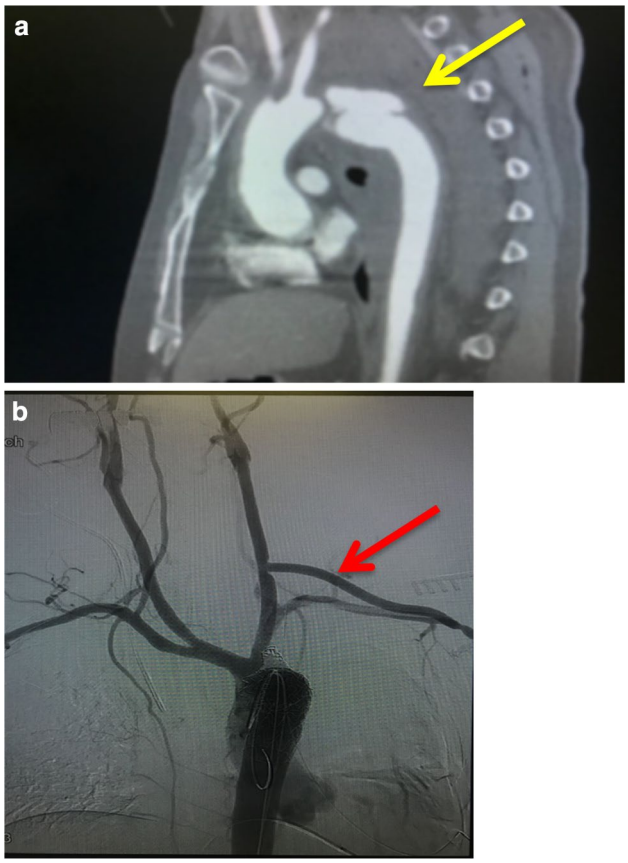

Fig. 2 **a** The sagittal CECT scan of distal arch BTAI with pseudoaneurysm (yellow arrow). **b** We underwent TEVAR with LCCA to LSCA bypass to minimize the risk of stroke or left arm ischemia (red arrow). *CECT* contrast enhanced computed tomography, *BTAI* blunt traumatic aortic injury, *TEVAR* thoracic endovascular aortic repair, *LCCA* left common carotid artery, *LSCA* left subclavian artery

patients directly to our hospital, and the other 4 patients were transferred from different hospitals because BTAI was detected. All of these BTAI patients had multiple severe traumatic injuries as defined above. Nine patients arrived in cardiopulmonary arrest and had a ruptured isthmus or descending open aortic injury as diagnosed during emergency resuscitative thoracotomy. Seven patients had grade I intimal tearing or quite small grade II intramural hematoma injuries according to the SVS guideline and were safely treated by conservative therapy with blood pressure control. The remaining nine patients treated with TEVAR were included in the present study (Fig. 3).

Table 1 shows the patients' characteristics. One patient was hemodynamically unstable on arrival because of hemorrhagic shock induced by concomitant pelvic fracture. Bleeding was controlled by trans-catheter arterial embolization of the internal iliac artery prior to TEVAR. The median patient vital signs on arrival were as follows: heart rate: 114 (107–119) beats/min, systolic blood pressure: 104 (91–112) mmHg, Glasgow Coma Scale score: 11 (7–14), and respiratory rate: 30 (25–30) breaths/min.

Table 2 shows the concomitant injuries, the emergent interventions that were performed prior to TEVAR, and the other emergent interventions performed within 24 h after TEVAR. The median ISS was 34 (29–34) and probability of survival was 0.82 (0.16–0.94). As Table 3 shows, the overall survival rate was 100% in both groups.

Table 4 lists the outcomes of the operation. The indications for debranching were four patients with left vertebral artery dominance, two patients with left vertebral artery

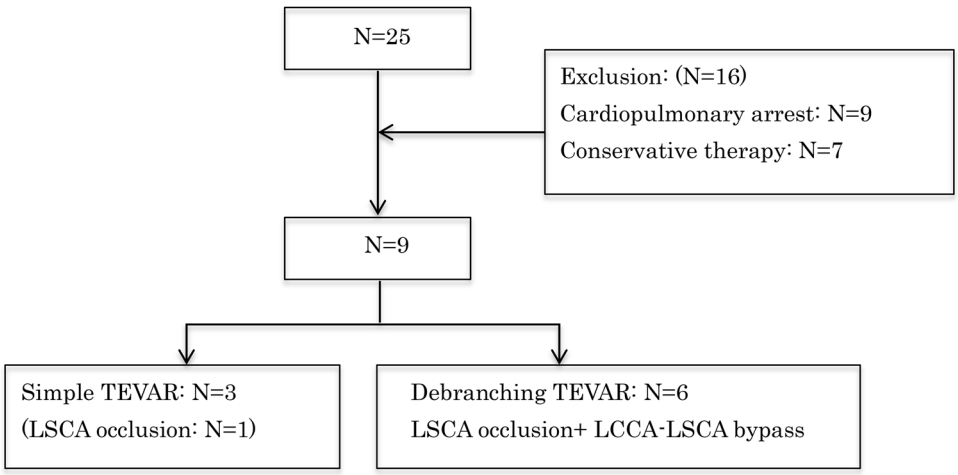

Fig. 3 Patient selection. *TEVAR* thoracic endovascular aortic repair, *LSCA* left subclavian artery, *LCCA* left common carotid artery

Table 1 Patient characteristics

	N = 9
Sex, male/female	5/4 M: 66.7%
Age, years	44 (28–57)
Mechanism of injury	
Fall from height	5 (55.6%)
Pedestrian hit by car	4 (44.4%)
SVS injury grade (I/II/III/IV)	
Zone 0–1	0
Zone 2	7 (0/0/6/1)
Zones 3–4	2 (0/0/1/1)

SVS Society for Vascular Surgery

directly branching from the aorta. The time from admission to operation was 296 (187–358) min in the simple TEVAR group and 312 (172–365) min in the debranching TEVAR patients. And the operation time for simple TEVAR was approximately 60 min less than that of debranching TEVAR. There seemed no significant difference in the number of units of blood transfused between the two groups.

Table 3 Injury Severity Scores

	Simple TEVAR	Debranching TEVAR
ISS	34 (34–34)	34 (29–34)
Probability of survival	0.82 (0.45–0.85)	0.845 (0.35–0.95)
Survival	100%	100%

TEVAR thoracic endovascular aortic repair, *ISS* Injury Severity Score

Despite the 60-min longer operation time in the debranching TEVAR group, no unexpected hemodynamic or respiratory instabilities occurred during the surgeries. All patients were operated on under general anesthesia, and two patients were treated without heparinization because of the evidence of intracranial hemorrhage and concomitant intra-abdominal bleeding.

Three patients underwent simple TEVAR (LSCA occlusion: 1) and six underwent debranching TEVAR (LSCA occlusion + LCCA to LSCA bypass). The only postoperative complication to occur in either group was left arm claudication in one patient in the simple TEVAR group. There

Table 2 Concomitant injuries

	Simple TEVAR	Debranching TEVAR
Intracranial hemorrhage	1 → ICP catheter insertion[a]	0
Hemothorax/pneumothorax	2 → 2: TT[a]	2 → 2: TT[a]
Liver injury	1	2
Kidney injury	0	1 → 1: TAE[a]
Pelvic fracture	2	1 → 1: TAE[a] & EF[b]
Extremities fracture	2 → 2: Traction[b]	2 → 1: Traction[b]

TEVAR thoracic endovascular aortic repair, *ICP* intracranial pressure, *TT* tube thoracostomy, *TAE* transcatheter arterial embolization, *EF* external fixation

[a]Performed prior to TEVAR

[b]Performed concurrently or after TEVAR

Table 4 Operative results

	Simple TEVAR	Debranching TEVAR
Time from admission to first aortography (min)	296 (187–358)	312 (172–365)
Operation time (min)	108 (75–157)	177 (112–218)
No heparinization	1	1
Blood transfusion (units)	6 (2–12)	8 (4–10)
Complications		
Stroke	0	0
Spinal cord ischemia	0	0
Arm claudication	1	0
Surgical conversion	0	0
Intra-operative death	0	0

TEVAR thoracic endovascular aortic repair

were no surgical conversions and no hospital deaths in either group. Ultimately, 33.4% of the patients were discharged home and the other 66.7% were transferred to rehabilitation hospitals.

Discussion

Although the incidence of BTAI is low, it is a life-threatening trauma and is the second most common cause of death [1, 2]. More than 80% of BTAI patients are estimated to die at the scene, and even in those who arrive at the hospital alive, the mortality related to BTAI is reported to be approximately 30% [5, 10]. Because of developments in aortic endovascular therapy such as stent grafts in recent decades, the strategies for BTAI have also changed dramatically.

There are many reports describing the advantages of TEVAR compared to open surgery even in trauma patients [10–12]. However, to our knowledge, there are still no reports or any consensus on how to manage the LSCA in multiple trauma patients requiring a zone 2 TEVAR. Although some reports support the option of simple LSCA coverage in elective aortic surgical cases because of no increased risk of complications [11, 13], there is no doubt about the 3–10% risk of LSCA occlusion or ischemia of the left arm, spinal cord or vertebral artery even after evaluation of the circulation [9, 14]; hence, the SVS practice guidelines also recommend some type of bypass for the LSCA [15].

We performed debranching TEVAR for multiple trauma in six patients and experienced no short-term mortality or morbidity. One disadvantage of debranching TEVAR is the approximately 60-min longer operation time required during the acute phase of multiple trauma. This waste of time can sometimes be critical for the patient if some other life-threatening injuries have been missed, uncontrolled bleeding sites still exist or intracranial pressure is progressively increasing. However, there were no unexpected changes in vital indicators, and no unexpected interventions were required during the surgeries in the present study patients. We surmise that there are two important reasons for this safe perioperative management. First is how we prioritize interventions for each organ injury. If the patients have other bleeding sites such as in the abdomen, retroperitoneum or some other body cavity, we perform abdominal exploration, pelvic packing or trans-arterial embolization first prior to TEVAR. A good monitoring system is also vital during the surgery. If there are suspicions or risks of increasing intracranial pressure, an ICP monitoring sensor is inserted prior to surgery. Second is the timing of endovascular therapy. Recently, several previous studies reported that delaying surgery by almost 24 h or more after injury was associated with a reduction in mortality [16–22]. We also believe this conclusion is reasonable because it allows more time for the evaluation of the circulation of the posterior cerebral circle or vertebral flow and also for confirmation of the status of the other injuries or bleeding sites. Clamping of the LCCA and TEVAR itself are reported to carry risks of cerebral infarction of 3–8%, especially in elderly patients with an aneurysm in a shaggy aorta [23, 24], but we suppose that these data are not applicable to young trauma patients with no degeneration of the aorta. Thus, taking all of these risks and benefits into consideration, the approximately 60-min longer operation time required for the LSCA bypass is thought not to be a disadvantage even in patients with multiple trauma.

Limitations

The present single-center study is a small preliminary report, and further multi-institutional, prospective, randomized trials will be planned on the basis of this study to assess the need for LSCA bypass for zone 2 TEVAR and the appropriate timing of TEVAR for BTAI.

Conclusion

The short-term results of TEVAR with debranching technique for BTAI in patients with multiple trauma were acceptable and no complications or critical delays in intervention for other injuries occurred in these patients. We thus conclude that the short-term results indicated that TEVAR with debranching technique for BTAI in patients with multiple trauma is acceptable to avoid LSCA complications unless we fail to stop bleeding first.

Author contributions KU organized and coordinated the study design and wrote the initial draft of this manuscript. KU and TN contributed to data cleaning and interpretation of the data. HY and YM reviewed and modified the manuscript. All authors read and approved the final manuscript.

Funding All the authors report no sources of funding.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

Informed consent Written informed consent of the clinical details and clinical images for publication was obtained from all of the patients.

References

1. Baker CC, Oppenheimer L, Stephens B, Lewis FR, Trunkey DD. Epidemiology of trauma deaths. Am J Surg. 1980;140:144–50.
2. Mattox KL. Approaches to trauma involving the major vessels of the thorax. Surg Clin N Am. 1989;69:7–87.
3. Brenner M, Teeter W, Hadud M, Hoehn M, O'Connor J, Stein D, et al. Long-term outcomes of thoracic endovascular aortic repair: a single institution's 11-year experience. J Trauma Acute Care Surg. 2017;82:687–93.
4. Azizzadeh A, Ray HM, Dubose JJ, Charlton-Ouw KM, Miller CC, Coogan SM, et al. Outcomes of endovascular repair for patients with blunt traumatic aortic injury. J Trauma Acute Care Surg. 2014;76:510–6.
5. Wall MJ Jr, Tsai P, Mattox KL. Heart and thoracic vascular injury. In: Moore EE, Feliciano DV, Mattox KL, editors. Trauma. 7th ed. New York: McGraw-Hill; 2013.
6. Feezor RJ, Hess PJ Jr, Martin TD, Klodell CT, Beaver TM, Lottenberg L, et al. Endovascular treatment of traumatic thoracic aortic injuries. J Am Coll Surg. 2009;208:510–6.
7. Fox N, Schwartz D, Salazar JH, Haut ER, Dahm P, Black JH, et al. Evaluation and management of blunt traumatic aortic injury: a practice management guideline from the Eastern Association for the Surgery of Trauma. J Trauma Acute Care Surg. 2015;78:136–46.
8. Azizzadeh A, Keyhani K, Miller CC, Coogan SM, Safi HJ, Estrera AL. Blunt traumatic aortic injury: initial experience with endovascular repair. J Vasc Surg. 2009;49:1403–8.
9. Lee WA, Matsumura JS, Mitchell RS, Farber MA, Greenberg RK, Azizzadeh A, et al. Endovascular repair of traumatic thoracic aortic injury: clinical practice guidelines of the Society for Vascular Surgery. J Vasc Surg. 2011;53:187–92.
10. Demetriades D. Blunt thoracic aortic injuries: crossing the Rubicon. J Am Coll Surg. 2011;214:247–59.
11. Murad MH, Rizvi AZ, Malgor R, Carey J, Alkatib AA, Erwin PJ, et al. Comparative effectiveness of the treatments for thoracic aortic transection [corrected]. J Vasc Surg. 2011;53:193–9.
12. Takagi H, Manabe H, Kawai N, Goto SN, Umemoto T. Endovascular versus open repair for blunt thoracic aortic injury. Ann Thorac Surg. 2009;87:349–50.
13. Hajibandeh S, Hajibandeh S, Antoniou SA, Torella F, Antoniou GA. Meta-analysis of left subclavian artery coverage with and without revascularization in thoracic endovascular aortic repair. J Endovasc Ther. 2016;23:634–41.
14. Bradshaw RJ, Ahanchi SS, Powell O, Larion S, Brandt C, Soult MC, et al. Left subclavian artery revascularization in zone 2 thoracic endovascular aortic repair is associated with lower stroke risk across all aortic diseases. J Vasc Surg. 2017;65:1270–9.
15. Matsumura JS, Lee WA, Mitchell RS, Farber MA, Murad MH, Lumsden AB, et al. The Society for Vascular Surgery Practice Guidelines: management of the left subclavian artery with thoracic endovascular aortic repair. J Vasc Surg. 2009;50:1155–8.
16. Demetriades D, Velmahos GC, Scalea TM, Jurkovich GJ, Karmy-Jones R, Teixeira PG, et al. Blunt traumatic thoracic aortic injuries: early or delayed repair–results of an American Association for the Surgery of Trauma prospective study. J Trauma. 2009;66:967–73.
17. Pate JW, Gavant ML, Weiman DS, Fabian TC. Traumatic rupture of the aortic isthmus: program of selective management. World J Surg. 1999;23:59–63.
18. Pate JW, Fabian TC, Walker W. Traumatic rupture of the aortic isthmus: an emergency? World J Surg. 1995;19:119–25.
19. Pacini D, Angeli E, Fattori R, Lovato L, Rocchi G, Di Marco L, et al. Traumatic rupture of the thoracic aorta: ten years of delayed management. J Thorac Cardiovasc Surg. 2005;129:880–4.
20. Pierangeli A, Turinetto B, Galli R, Caldarera L, Fattori R, Gavelli G. Delayed treatment of isthmic aortic rupture. Cardiovasc Surg. 2000;8:280–3.
21. Kipfer B, Leupi F, Schuepbach P, Friedli D, Althaus U. Acute traumatic rupture of the thoracic aorta: immediate or delayed surgical repair? Eur J Cardiothorac Surg. 1994;8:30–3.
22. Maggisano R, Nathens A, Alexandrova NA, Cina C, Boulanger B, McKenzie R, et al. Traumatic rupture of the thoracic aorta: should one always operate immediately? Ann Vasc Surg. 1995;9:44–52.
23. Milewski RK, Szeto WY, Pochettino A, Moser GW, Moeller P, Bavaria JE. Have hybrid procedures replaced open aortic arch reconstruction in high-risk patients? A comparative study of elective open arch debranching with endovascular stent graft placement and conventional elective open total and distal aortic arch reconstruction. J Thorac Cardiovasc Surg. 2010;140:590–7.
24. Koullias GJ, Wheatley GH 3rd. State-of-the-art of hybrid procedures for the aortic arch: a meta-analysis. Ann Thorac Surg. 2010;90:689–97.