Chapter 33
In Patients with Cervico-Thoracic Vascular Injuries Is Endovascular Repair Superior in Long-Term Durability When Compared to Open Repair?

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Abstract Trauma to the great vessels, descending thoracic aorta, and the cervical carotid and vertebral arteries is uncommon but management can be very challenging. Endovascular therapy has changed surgeons' approach to these injuries. While short term results have been promising, especially in the treatment of subclavian artery injuries, long term results are lacking; long-term outcomes are of paramount importance in a group of relatively young patients that would be expected to have a long life expectancy after recovery from their trauma. We will review current data regarding short- and long-term outcomes after endovascular management of blunt and penetrating injuries to the cervicothoracic vessels, provide examples of successful treatment, and make recommendations for current management strategies and areas of future research.

Keywords Vascular trauma • Endovascular management • Carotid artery injury • Subclavian artery injury • Thoracic aortic injury

Introduction

Trauma to the great vessels, descending thoracic aorta, and the cervical carotid and vertebral arteries is uncommon but management can be very challenging. Over the last several years, paralleling the development of these techniques in other arenas, there has been an explosion in reports of treatment of both blunt and penetrating

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Table 33.1 PICO table

P (Patients)	I (Intervention)	C (Comparator)	O (Outcomes)
Patients with cervicothoracic vascular injury	Endovascular repair	Open repair	Technical success, durability

arterial injuries in these distributions by endovascular means. While short term results have been promising, especially in the treatment of subclavian artery injuries, long term results are lacking; long-term outcomes are of paramount importance in a group of relatively young patients that would be expected to have a long life expectancy after recovery from their trauma.

Selecting which injuries may be appropriate for endovascular management is a particular challenge. A perception exists among many surgeons that patients with acute arterial injuries, especially hemodynamically unstable patients with ongoing hemorrhage, are inappropriate for endovascular management, despite data showing improved outcomes in unstable patients with ruptured aortic aneurysms managed with an "endo-first" approach. An increasing percentage of both blunt and penetrating vascular injuries in the US are being managed by vascular surgeons with endovascular techniques [1–3] and it is of significant importance that all surgeons have an understanding of the situations in which endovascular therapy may be a viable and readily applied alternative to major open vascular reconstruction in severely injured patients. We will review current data regarding short- and long-term outcomes after endovascular management of blunt and penetrating injuries to the cervicothoracic vessels, provide examples of successful treatment, and make recommendations for current management strategies and areas of future research. Given the large volume of data available on endovascular repair of the thoracic aorta for trauma, we will examine this separately from other cervicothoracic vascular injuries.

Search Strategy

We reviewed the English-language literature from the OVID and PubMed databases from 2005 to 2015 to identify published data on surgical approaches to patients with cerviothoracic vascular injury (PICO Table 33.1). We elected to include only literature starting in 2005 in an attempt to only include patients treated with modern endovascular devices and techniques. Search terms used were "trauma", AND("verterbral" OR "carotid" OR "subclavian" OR "innominate"), AND "endovascular repair"; Case reports and small case series were excluded from analysis, as they contained only descriptions of procedures but no information regarding intermediate- and long-term outcomes. No randomized trial data were found. Relevant studies meeting our inclusion criteria are included in Table 33.2.

Table 33.2 Summary of literature review

Study	Patients (#)	Follow-up duration (median)	Vessels involved	Procedures	Outcomes	Quality
Desai et al. (2014) [9]	10	13 months	Common carotid (1) Internal carotid (2) Subclavian (7)	Stent graft	Patent grafts at follow-up; no complications reported	Low
Maughan et al. (2013) [4]	17	22.2 months	Vertebral (iatrogenic)	Observation, stenting or coil embolization	76 % no change in neurological status 2 patients with neurological decline	Low
Seth et al. (2013) [10]	47 (53 injuries, 47 blunt, 6 penetrating)	Up to 7 years	Cervical internal carotid	Stent graft, coil emoblization	Technical success 100 % 1 stent occlusion, 1 stent-related false aneurysm, 3 transient ischemic attacks	Moderate
Rocha et al. (2013) [11]	8	17 months	Subclavian/axillary (5) Carotid (3)	Stent graft	2 subclavian grafts occluded within one year; no other complications	Low
Dubose et al. (2012) [15]	160 (literature review)	Up to 70 months	Axillary/subclavian	Stent graft	84.4 % durable patency 6.3 % repeat intervention 3.1 % open conversion	Moderate

(continued)

Table 33.2 (continued)

Study	Patients (#)	Follow-up duration (median)	Vessels involved	Procedures	Outcomes	Quality
Shalhub et al. (2011) [17]	34 (16 open, 12 endo, 3 converted to open)	235 days (open) 411 days (endo)	Innominate (11) Subclavian (16) Axillary (7)	Stent graft	3 immediate conversions 100 % patent at 1 year follow-up both open and endo Endo times and blood loss significantly less than open	Low
duTroit et al. (2008) [16]	57	48 months	Subclavian/axillary (penetrating)	Stent graft	3/57 early graft occlusion 2 died within 30 days 5 short-term stenosis	Moderate
DuBose et al. (2008) [12]	113	2 weeks-2 years	Internal carotid	Unclear (literature review)	9.7 % occlusion rate, 94 % alive with no neurologic sequelae at follow-up	Low
Maras et al. (2006) [13]	20	Up to 2 years	Internal carotid (20)	Stent graft or bare-metal stents	3 long-term occlusions Study performed prior to availability of current endografts	Low
Cothren et al. (2005) [14]	46 (23 stented, 23 medical management)	2–35 months	Internal carotid (23)	Bare-metal stent	21 % complication rate, 45 % occlusion rate for stenting; 5 % complication rate for medical management	Moderate

Results

While increasing numbers of endovascular repairs are being performed for vascular trauma [1, 2] no randomized trials were identified comparing endovascular to open repair. Similarly, very few data were available regarding long-term outcomes of endovascular repair.

Vertebral Artery

Maughan and colleagues [4] examined vertebral artery injuries occurring in the setting of neck surgery, providing some of the only available data regarding endovascular treatment of these lesions for trauma. Seventeen vertebral artery injuries were identified out of 8213 patients undergoing neck or skull-base surgery over a 15 year period. Nine of the 17 patients underwent endovascular repair of their injuries with either coil embolization or endovascular stenting, and at a median follow-up of 22 months, none of the treated patients had significant neurological sequelae. However, numerous authors [5–8] have noted that management of vertebral artery injuries is controversial, with medical management (antiplatelet agents and/or anticoagulation) often superior to surgical or endovascular management. Anticoagulation and antiplatelet therapies have not been compared head-to-head for medical management purposes. No clear conclusions can be drawn from the literature to recommend routine endovascular management of vertebral artery injuries, regardless of grade, in the absence of ongoing hemorrhage or neurological deterioration.

Carotid Artery

More data exist with regard to endovascular management of carotid artery injuries. Desai and coworkers [9] recently reviewed the charts of 28 patients with arterial injuries in Houston. Of these injuries, only 10 were to the carotid (7) and subclavian (3) arteries. All endovascular repairs were completed with covered endografts. While all repairs were patent at a median follow-up of 13 months, longer-term outcomes were not assessed. No complications were reported during the follow-up period in the ten relevant patients. Similarly, Seth and colleagues [10] retrospectively reviewed 50 cervical internal carotid interventions in 47 patients that were treated with endovascular stenting, coil embolization, or both; only one patient suffered stent occlusion, and three patients suffered transient ischemic attacks. Outcomes at up to 7 years were excellent. While similar results have been reported by other authors [11–13], there was an initial negative experience with carotid stenting for trauma reported by Cothren and coworkers in 2005; they demonstrated a stent occlusion rate of 45 % in 23 patients treated for trauma [14]. However, more recent experience has demonstrated safety, excellent technical success, and good

short-term outcomes for these procedures in carotid trauma. Long-term outcomes are lacking, and multi-center prospective trials are needed. At this time, moderate-quality evidence exists to support endovascular repair of carotid artery injuries with ongoing bleeding, neurological changes or false aneurysms; we recommend endovascular repair for patients that are hemodynamically unstable, and that have difficult to access injuries (i.e. distal internal carotid artery, proximal common carotid artery, strength of recommendation: weak).

Subclavian and Innominate Arteries

Subclavian and innominate artery injuries can be notoriously difficult to control, and are often well situated for endovascular repair. DuBose and coworkers [15] reviewed the English-language literature regarding endovascular management of subclavian/axillary artery trauma. A total of 160 injuries (150 subclavian, 10 axillary) were well-described, culled from 31 separate reports. 84.4 % were patent for duration of follow-up, with 18 patients requiring delayed repeat intervention. duToit and coworkers [16] published the largest single series reviewing endovascular management of these injuries, including 57 patients. There were four short-term complications (one femoral artery injury, three acute endograft occlusions), and five patients required repeat intervention for stenosis. Technical success for the initial endovascular repair was 100 %. Similar results were reported by Shalhub and colleagues [17], examining innominate, subclavian and axillary artery injuries. Long-term results of prospective studies do not exist for these procedures, and again multicenter trials are needed. Subclavian/innominate injuries should be managed endovascular means when feasible (grade of evidence: moderate, strength of recommendation: strong).

A Personal View of the Data

There is a common misperception that endovascular repair of arterial injuries should not be employed in patients with hemodynamic instability. We have taken the converse approach; patients with hemodynamic instability are often very well suited to endovascular repair by a vascular surgeon, who has the unique ability to quickly convert between open, endovascular, and hybrid techniques in the appropriate settings with a high-quality hybrid endovascular suite. As an example, Fig. 33.1 demonstrates a patient that sustained a trans-cervical gunshot wound, with one wound at the angle of the mandible on each side of the neck, and exsanguinating hemorrhage from the left neck on arrival. Successful endovascular treatment of the internal carotid artery with a covered endograft was achieved. Figure 33.2 demonstrates an example of successful treatment of a subclavian injury.

Our institution was a participant in the RESCUE trial [18], and we have consistently adopted an “endo-first” approach to all descending thoracic aortic injuries. Every descending thoracic aortic injury is immediately evaluated by our multidisciplinary

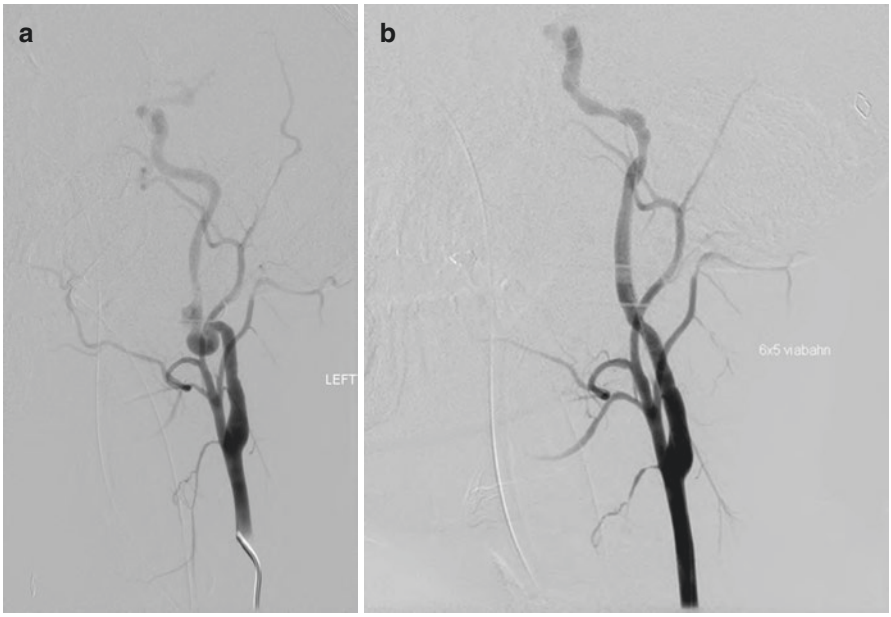

Fig. 33.1 (**a**) Transcervical gunshot wound, internal carotid artery injury, initial arteriogram, showing distal internal carotid artery false aneurysm. (**b**) Final arteriogram showing successful exclusion of false aneurysm with endograft (Gore Viabahn, Flagstaff, AZ)

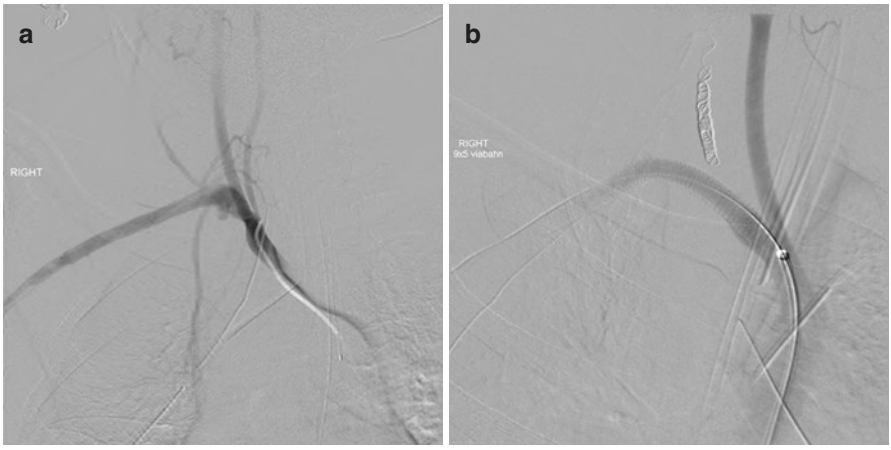

Fig. 33.2 (**a**) Proximal right subclavian artery disruption. (**b**) Completion arteriogram, after vertebral embolization and placement of endograft (Gore Viabahn, Flagastaff, AZ)

team of cardiothoracic surgeons, vascular surgeons, and interventional radiologists; all services are immediately activated for every injury, with endovascular repairs being performed by a collaborative team from vascular surgery and interventional radiology. We have not had as much success adopting the endo-first approach with peripheral and cervico-thoracic injuries as we have with thoracic aortic injuries. This has been due to

resistance from other providers, who believe that an endovascular approach to these injuries is slower than open surgical treatment despite data to the contrary.

We propose that endovascular treatment and open surgical treatment of cervicothoracic arterial injuries are complementary approaches, and that sometimes a hybrid approach is the best; this can be done only by vascular surgeons in a well-equipped hybrid endovascular surgical suite, with the ability to switch between modalities based on the clinical situation. Ongoing research will need to center on both the optimal initial approach to these injuries, as well as the long-term outcomes in this relatively young group of patients.

Recommendations

1. Vertebral artery injuries should be managed medically in the absence of active hemorrhage or neurological deterioration (**grade of evidence: poor, strength of recommendation: weak**).
2. Carotid artery injuries should be managed by endovascular techniques for difficult-to-access injuries (distal internal carotid, proximal common carotid), active hemorrhage, and false aneurysms (**grade of evidence: low quality, strength of recommendation: weak**).
3. Subclavian/innominate artery injuries should be managed by endovascular techniques when anatomically suitable (**grade of evidence: moderate, strength of recommendation: strong**).
4. There are no data to support routine endovascular therapy of aortic arch/great vessel origin injuries, and these should be considered open surgical cases until new data are available (**grade of evidence: weak, strength of recommendation: strong**).

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