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Original Article

Treatment strategy for traumatic innominate arterial injury

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ABSTRACT

Purpose: To discuss and share the experience of treatment of traumatic innominate arterial injury.
Methods: A retrospective analysis was performed on patients with innominate arterial injuries admitted from January 2016 to July 2018 at the department of vascular surgery, Beijing Jishuitan Hospital, China. All the arterial injuries were confirmed by arteriography. Clinical data including mechanism of injury, type of injury, demographics, concomitant injuries, time interval from trauma to blood flow reconstruction, and operation methods were collected. Follow-up program included outpatient visit and duplex-ultrasonography. SPSS version 23.0 was adopted for data analysis. Categorical variables are presented as number and/or frequency and continuous variables as mean ± standard deviation.
Result: Altogether 7 patients were included and 6 (85.7%) were male. The mean age of patients was (29.43 ± 7.98) years, range 19-43 years. Six patients had isolated innominate arterial injuries and the rest 1 combined innominate arterial and vein injuries. The injury causes were road accidents in 3 patients, stab wound in 2, gunshot wound in 1, and crush injury in 1. All the 7 patients presented hemorrhagic shock at admission, which was timely and effectively corrected. No perioperative death or technical complications occurred. Intimal injury ($n = 2$) and partial transaction ($n = 2$) of the innominate artery were treated with covered stents. Two patients with complete transection of artery received vascular reconstruction by artificial grafts. One patient with partial transaction received balloon dilation and open surgical repair (hybrid operation). The mean time interval from trauma to blood flow reconstruction was (4.27 ± 0.18) h, range 4.0–4.5 h; while the operation time was (48.57 ± 19.94) min, range 25–75 min. Cerebral infarction occurred in one patient with brain injury due to anticoagulation contraindication. The average follow-up was (13.29 ± 5.65) months, range 6–24 months. No severe stenosis, occlusion, and thrombosis of covered stents or artificial vessels were found by color Doppler ultrasound.
Conclusion: Urgent control of hemorrhage and restoration of blood supply are critical for the treatment of traumatic innominate arterial injury. Endovascular therapy is a feasible and effective method with short operation time and less trauma.

Introduction

Traumatic injury to the innominate artery is rare, and the actual incidence is unknown because the majority of patients die before treatment.[1] It is reported that 71% of patients with innominate arterial injuries die before arriving at a hospital.[2] These patients are mostly the victims of motor vehicle collisions and approximately 85% of injuries occur in the proximal segment of the artery, while the rest occur in the middle or distal segments.[3] Once injury to the innominate arterial has been diagnosed, immediate surgical treatment should be conducted. The mortality rate in patients undergoing surgical treatment has decreased from 50% in the 1960s to 10% in 1980s.[4] This may be related to the advances in transport, diagnosis, and surgical techniques.

Most patients with innominate arterial injuries undergo surgical repair, as reported in the literature and stated by Hirose and Gill.[5] Endovascular treatment offers an alternative to conventional surgical repair.[6] The purpose of the present retrospective study is to describe our experience of handling traumatic innominate arterial injuries.

Methods

Clinical materials of all patients with innominate arterial injuries and treated from January 2016 to July 2018 were retrospectively analyzed. Mechanism of injury, type of injury, demographics,

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concomitant injuries, type of lesion, time interval from trauma to blood flow reconstruction, operation methods, and follow-up were reviewed. Ethical approval for the study was obtained from the ethics committee of the hospital.

Endovascular procedures

Successful endovascular repair was defined as the restoration of blood flow on arteriography at the end of the procedure. Endovascular procedures were performed by digital subtraction angiography.

The patients were placed supine under local anesthesia with 0.5% lidocaine (5 mL) at the vascular access site. The femoral artery was punctured using the Seldinger technique. The location and severity of arterial injury were confirmed by arteriography. An appropriate covered stent was implanted to manage the injured innominate arteries. The length of the stent was required to be able to cover the lesion. The diameter of the stent was measured by arteriography with approximately 10% oversize. Stenosed segments of the stent were dilated by using an appropriate balloon. Finally, arteriography was conducted to confirm the patency of the covered stents.

Surgical repair

Surgical repair was performed according to standard arterial exposure and repair procedures. Patients were positioned supine, and the injured artery was exposed through a medial approach. Proximal and distal control of the injured artery was obtained. Unfractionated heparin was used for anticoagulation before vascular repair. Fogarty catheter embolectomy was performed if necessary to ensure inflow and unobstructed distal flow. The artery repair was achieved with the use of polytetrafluoroethylene (PTFE) vascular grafts (ACUSEAL; W. L. Gore & Associates Inc., Flagstaff, Ariz).

Hybrid surgery

Patients received endovascular treatment by digital subtraction angiography. They were positioned supine under general anesthesia. The Seldinger technique was adopted to puncture the ipsilateral femoral artery. The severity, location, and type of arterial injury were confirmed by arteriography. If repeat attempt of passing the guide wire through the injured site failed, open surgery needs to be taken. But intraoperative hemorrhage must be controlled firstly. An appropriate balloon catheter was advanced to the innominate artery, starting at the origin of the artery. The balloon was inflated at a proper pressure in case of blood loss. Surgical exposure of the innominate artery was performed. Fogarty catheter embolectomy was performed if necessary to ensure inflow and outflow. PTFE vascular grafts were adopted for arterial repair (ACUSEAL; W. L. Gore and Associates, Flagstaff, Ariz). The patency of the injured artery was confirmed by arteriography.

Statistical analysis

All data were analyzed using SPSS version 23.0 (IBM Corp, Armonk, NY, USA). Categorical variables are presented as number and/or frequency, while continuous variables presented as mean ± standard deviation (SD).

Results

From January 2016 to July 2018, 7 patients who matched the selective criteria received treatment for innominate arterial injuries in our department. Of them, 6 (85.7%) were male. The mean age was (29.43 ± 7.98) years, range 19–43 years. Six patients had isolated innominate arterial injuries. One patient had innominate arterial and vein injuries. All the 7 patients presented hemorrhagic shock on arrival. Road accident claimed the injury causes in 3 patients, followed by stab wound in 2 (Fig. 1), gunshot wound in 1 (Fig. 2), and crush injury in the rest patient.

Fig. 1. A patient with a stab wound: the incision is about 2 cm long.

One patient had a sternal fracture and other concomitant injuries are shown in Table 1. Rib fractures were present in 5 patients. The clinical and demographic data for all the 7 patients are presented in Table 1.

All patients received arteriography to confirm the diagnosis of innominate arterial injuries. Hemorrhagic shock was timely and effectively corrected. The mean time interval from trauma to blood flow reconstruction was (4.27 ± 0.18) h, range 4.0–4.5 h. Four patients with intimal injury ($n = 2$) or partial transaction ($n = 2$) were treated with covered stents (Figs. 3 and 4). Two patients with complete transection underwent vascular reconstruction by PTFE vascular grafts. Hybrid surgery was conducted in Case 3 with partial transaction (Fig. 5). Balloon dilation was applied in the proximal

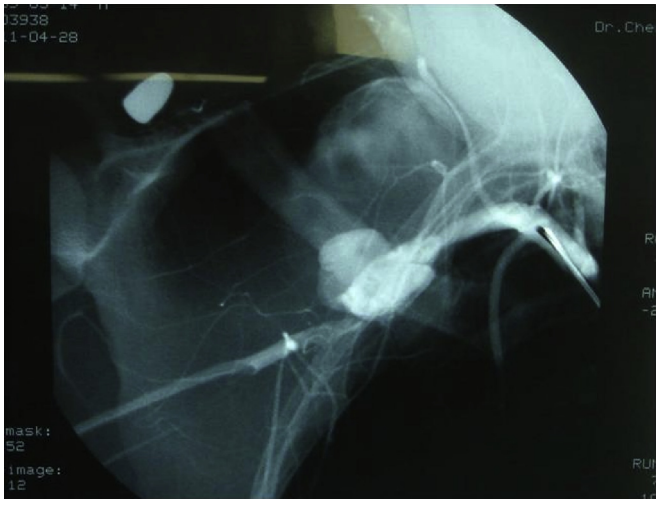

Fig. 2. Arteriography shows rupture of the innominate artery in a patient with a gunshot wound.

Table 1
Demographic and clinical data of 7 patients with innominate artery injury.

Case	Sex/Age(years)	Mechanism of injury	Concomitant injuries	Time of operation procedures (min)	Time interval from trauma to blood flow restoration (h)	Type of lesion	Operation methods	Instrument utilized	Follow-up (month)
1	M/19	Road accident	Rib fracture	65	4.4	Complete transection	Surgical repair	PTFE vascular grafts	6
2	M/25	Gunshot wound	Rib fracture	60	4.4	Complete transection	Surgical repair	PTFE vascular grafts	9
3	M/28	Stab wound	Mediastinal contusion and rib fracture	75	4.5	Partial transection	Hybrid operation	PTFE vascular grafts and balloon	13
4	M/35	Road accident	Sternal fracture	25	4.0	Intimal injury	Endovascular surgery	Covered stent and balloon	15
5*	M/43	Crush injury	Rib fracture and craniocerebral injury	55	4.3	Partial transection	Endovascular surgery	Covered stent and balloon	12
6	F/24	Road accident	Rib and clavicular fracture	30	4.1	Intimal injury	Endovascular surgery	Covered stent and balloon	24
7	M/32	Stab wound	-	30	4.2	Partial transection	Endovascular surgery	Covered stent and balloon	14

*: the 5th patient had both innominate artery injury and vein injury; " - ": no concomitant injuries. PTFE: polytetrafluoroethylene.

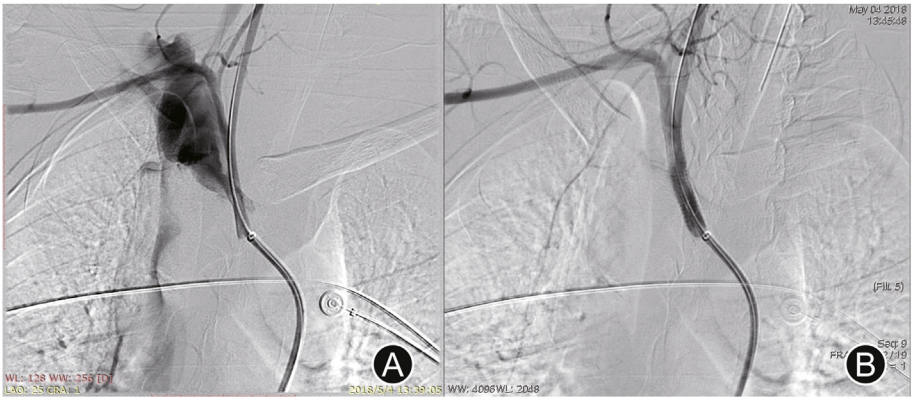

Fig. 3. Arteriography shows rupture of the innominate artery (A) in a patient with road accident, which was treated by covered stent placement (B).

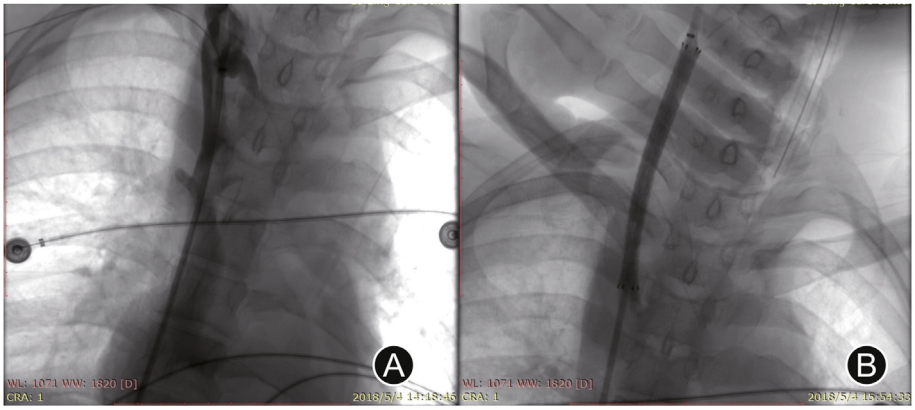

Fig. 4. Venography shows covered stent placement for rupture of the innominate vein (A and B) in a patient with crush injury.

innominate injury to prevent massive blood loss. The patient received open surgical repair by PTFE vascular grafts.

All the patients were successfully treated with a mean operation time of (48.57 ± 19.94) min, range 25–75 min. No perioperative death or technical complication occurred. Cerebral infarction occurred in 1 patient with brain injury due to anticoagulation contraindication.

The average follow-up was (13.29 ± 5.65) months, range 6–24 months. No severe stenosis, occlusion, and thrombosis of stents or artificial vessels were found by color Doppler ultrasound.

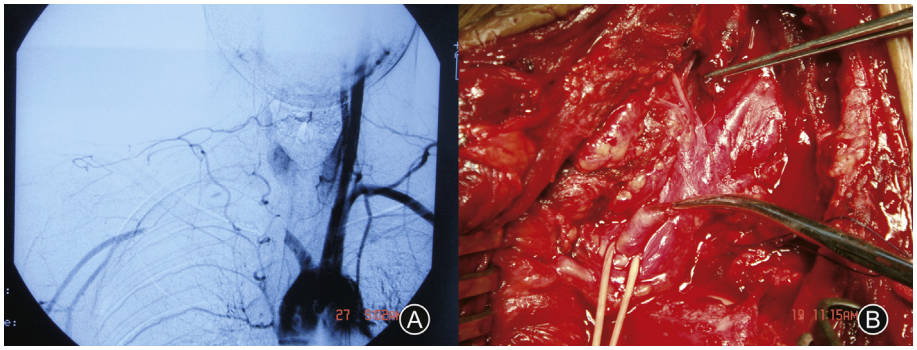

Fig. 5. Partial transection of the innominate artery (A) in a patient with a stab wound, for which vascular reconstruction is conducted by a polytetrafluoroethylene artificial graft (B).

Discussion

Injury to the thoracic aorta and supra-aortic trunk has a high mortality: about 38% in patients who successfully reached the hospital.[7] It is estimated that approximately 3/4 of patients with these injuries die before arriving at a hospital.[4] Rupture of the innominate artery from blunt or penetrating trauma is an infrequent but life-threatening injury. Speedy diagnosis and treatment are critical for such patients.

For the management of innominate arterial injury, to control the massive bleeding is challenging, which results in a higher mortality rate. The leading types of trauma are blunt and penetrating injuries. Anatomically the innominate arteries are protected by the thoracic and other bony structures and are generally hard to damage. When the strength of external force exceeds the tolerance capability of the bone structure, thoracic fracture will occur. At this time, the probability of injury to the brachial artery is significantly increased. For patients with penetrating injuries, the sharp instrument damages the innominate artery by penetrating the mediastinum along the bony interstitial space.

Bullet wounds are rare in China. Tunnel effect occurs when the bullet enters soft tissues, that is, the skin injury is minimal, but the tissue injury around the trajectory is severe. This kind of mild superficial damage but serious inner damage should be taken seriously.

If a patient had blood vessel damage caused by a knife stab, it is often a vascular intimal injury and partial transection. In this condition, the injured artery cannot be elastically retracted to reduce bleeding. And the thrombus cannot be effectively formed because of the large vessel flow, so the bleeding is rapid, patient is dangerous and the mortality rate is high.

Conventional treatment for innominate artery rupture is the urgent surgical repair of the injury.[4,8,9] The advantages of surgical repair are open surgical field vision, accurate bleeding control, and satisfactory vascular repair. It is preferred for various types of vascular injuries. However, there are bony structures outside the innominate artery. Once damage occurs, the bones that originally protect the artery turn as an obstacle for the exposure of blood vessels during surgery. Besides, the innominate artery is the largest branch of the aortic arch, which has a high arterial pressure and fast blood flow. Its injury leads to rapid deterioration of patient's condition and consequently quick hemorrhagic shock. After the time of transportation to hospital, patients often lose the opportunity for open surgery. In this study, 3 patients survived because of open surgery. The main reason is that although the fracture has damaged the blood vessel, the broken end of the fracture is embedded in the vascular lesion, which plays a temporary blocking role. And our team is able to conduct open surgical repair after a definite diagnosis. Therefore, surgeons must be alert to innominate artery injury in patients with severe chest trauma, especially those presented with progressive hemorrhagic shock. Thoracic or clavicular fractures should not be repositioned immediately. Instead they should be treated after severe vascular damage.

Endovascular treatment is a new and promising option of vascular repair.[10] Compared with open surgical repair, it is more time-saving, less invasive and has less systemic effects. For patients with incomplete vascular rupture, we can use this technique for vascular reconstruction. At the time of definite diagnosis, covered stents can be introduced to repair the damaged blood vessels.

However, the endovascular procedure also has certain limitations. For example, if the blood vessel is completely broken or thrombosis occurs during angiography and the distal blood vessel is not well developed, it will be very difficult for the guide wire to pass through the lesion and may even cause secondary bleeding. If a poor development of the distal vascular is found during arteriography, repeated attempts to open the lumen should be conducted in case of any delay of the treatment opportunity. In case 3 of the study, innominate artery injury was discovered during angiography, but the distal subclavian artery and carotid artery were poorly developed, and the blood vessel was broken entirely. As a result, hybrid surgery was adopted. A balloon was used to block in the proximal vessel of the lesion and then open surgery was adopted, and the patient successfully survived.

In summary, for patients with rapid bleeding and high mortality following innominate arterial injury, vigilant early diagnosis and timely treatment are critical. Endovascular treatment has the advantages of short operation time, minimal trauma, and satisfactory therapeutic effect. It is suitable for patients with incomplete vessel transection that has been confirmed by angiography. However, when the endovascular technique cannot be performed smoothly, alternative open surgery should be immediately conducted to repair the blood vessels and save patient's life. In short, speedy hemorrhage control and blood supply restoration are critical for the treatment of traumatic innominate arterial injury. Endovascular therapy is a feasible and effective method with short operative time and less trauma.

Funding

Nil.

Ethical Statement

Ethical approval for the study was obtained from the ethics committee of the hospital.

Declaration of Competing Interest

The authors declare no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cjtee.2019.11.004.

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