Full realization of internal mammary artery injury after blunt chest trauma

Künt göğüs travması sonrası iç meme arteri yaralanmasının tam olarak farkına varılması

Chen Jinming, Yang Guanggen, Shen Zhong, Wang Liang

Institution where the research was done:
Department of Surgery, The Third People’s Hospital of Hangzhou, Zhejiang, China

Author Affiliations:
1Department of Surgery, The Third People’s Hospital of Hangzhou, Zhejiang, China
2Department of Thoracic Surgery, Zhejiang University, Zhejiang, China

ABSTRACT
Due to the substantial and continual increase in the number of motorized vehicles globally, clinicians are faced with an enormous population at risk for suffering internal mammary artery injuries after blunt chest trauma. Nevertheless, very little attention has been paid to this issue by relevant health practitioners. In addition, there is a scarcity of extant research data, as well as societal guidelines, regarding internal mammary artery injury. In cases with undetected internal mammary artery injury, however, the outcome may be catastrophic or fatal. Thus, investigating and reviewing the anatomy, etiology, diagnostic approaches, and treatment strategies for patients with internal mammary artery injury are urgently needed.

Keywords: Blunt chest trauma; diagnosis; internal mammary artery injury; treatment.

ANATOMY
Internal mammary artery arises from the concavity of the first part of the subclavian artery and immediately passes downwards, forwards and medially. In addition, it lies on the pleura in the upper intercostal spaces up to the third costal cartilage. It then continues anterior to the transversus thoracis muscle to end in the sixth intercostal space by dividing into the superior epigastric and musculophrenic arteries. The left subclavian artery directly derives from the aortic arch, and the right springs from the brachiocephalic trunk. Left IMA diameter has been measured at the second (2.56±0.39 mm), third (2.46±0.38 mm), fourth...
(2.39±0.38 mm) and fifth (2.35±0.38 mm) rib level, respectively.[6] In addition, the right IMA and vein are larger than the left in all intercostal spaces.[6] It is a rare occurrence when a left IMA originates from the distal subclavian artery.[7] The IMA and its accessory branches, in addition to perfusing the chest wall structures, also contribute to supplying the thymus, diaphragm, pericardium, bronchia, female breast and superior abdominal wall, as well as the liver in special circumstances.[8]

**ETIOLOGY**

Most IMA injuries after blunt chest trauma are caused by a severe impact, such as from a motorcycle or automobile accident, or from participating in a physically dangerous athletic activity, such as American football.[9] Rare causes of IMA injury include falling or jumping from a height, pounding the chest, being struck by a heavy object, suffering from an explosive injury, and performing chest compressions.[10-14] Possible mechanisms of IMA injury include fracture of an adjacent bony structure, such as a rib, clavicle or sternum, or shearing forces acting on the IMA during periods of extreme acceleration or deceleration.[15]

**CLINICAL PRESENTATIONS**

Both males and females can injure their IMA. The right, left, and bilateral IMAs can be injured by an external force. There is a predominant incidence of IMA injury in males and on the left side.[2] The leading causes of IMA injuries are motorcycle and automobile accidents.[2] Compared to females, more males ride motorcycles and participate in physically strenuous athletic activities, such as American football, rugby, and soccer. In traumatic aortic injuries, the site of rupture is in the region of the isthmus, just distal to the left subclavian artery.[16] A total of 85% of injured branch vessels directly originate from the aortic arch after blunt thoracic trauma.[17] Therefore, a greater incidence of left IMA injury may be correlated with the different anatomical structure connected with the aortic arch.[2]

Patients’ only complaint with IMA injury is anterior chest pain and chest tightness.[9] A secondary survey of IMA injury showed breast contusion or abrasion, a small area of subcutaneous emphysema, crepitus in the chest wall, and decreased breathing sounds. Additionally, midsternal tenderness to palpation exists, as well as multiple areas of ecchymosis and prominent swelling in the upper chest.[10,18-20] For patients with traumatic arteriovenous fistula of the IMA, a pulsating mass along the parasternal area where a loud bruit is audible is often present.[21]

Some IMA patients are admitted to the hospital with severe shock. Other vital signs, however, are stable on an initial survey of these patients. After a brief period, these patients often suddenly experience shock symptoms. In addition, the average IMA blood flow is 150 mL/minute, which can result in a life-threatening hemorrhage within a few minutes.[22] Although IMA transection can sometimes retract and achieve temporary hemostasis during periods of hypotension and arterial spasm, renewed bleeding may occur once the patient is resuscitated.[23]

Internal mammary arteries have anterior intercostal, sternal, and perforating branches.[24] Therefore, the different branches of the IMA can be injured by blunt chest trauma. If undiagnosed, IMA injuries may result in persistent bleeding. Portable supine chest radiographs often show a markedly widened mediastinum and obscuration of the aortic knob.[25]

Color-coded duplex sonography uses standard ultrasound methods to produce images of blood vessels. In addition, a computer converts Doppler sounds into colors that represent the speed and direction of blood flow through the vessel. In the course of preoperative diagnosis and postoperative follow-up, portable color-coded duplex sonography is routinely utilized to provide quick assessments of blood vessels for use by clinicians.[26]

Contrast enhanced computed tomography (CT) or computed tomography angiography (CTA), when performed urgently, plays a fundamental role in identifying the presence of active bleeding, defining its origin, and thus directing efficacious management of the patient. Meanwhile, multidetector CTA provides a time-efficient method for patients with acute bleeding, leads to faster selective catheterization of bleeding vessels, and thereby facilitates embolization.[27]

Magnetic resonance angiography (MRA) is also utilized to generate images of arteries. With recent advancements in hardware and software techniques, MRA provides dramatically improved functionality. For example, rapid whole chest contrast-enhanced MRA using parallel imaging enables scan time to be significantly reduced to only 16 seconds.[28] Moreover, the use of novel intravascular contrast agents substantially increases image windows and decreases contrast dose.[29] The lower risk and cost of non-contrast enhanced MRA has attracted renewed interest in this technique. However, non-contrast enhanced MRA methods still require longer scan times than contrast-enhanced MRA.[28,30]
Invasive catheter digital subtraction angiography (DSA) has been historically used to image the peripheral artery system, and still remains the optimal choice. However, newer developments in axial imaging, including CTA and MRA, have in large part supplanted DSA for imaging the peripheral artery system in clinical practice. Although CTA screening is more cost effective than DSA, DSA can be applied to achieve not only quick diagnosis, but also prompt treatment. Currently, neither CTA nor MRA constitutes an adequate substitute for DSA.

The aorta is the most common major thoracic artery injured by blunt trauma. Injury to supra-aortic trunks is much less common than injury to the aorta. With the increasing use of thoracic CT to assess blunt chest trauma, this vascular injury is more indirectly detected because of associated bleeding. For IMA injury, the diagnostic findings are anterior mediastinal hematoma (AMH), hemothorax, pseudoaneurysm, extra-pleural hematoma, and arteriovenous fistula. Different parts and the extent of IMA injury, adjacent vein injury, as well as the integrity of the pleura, determine differences in bleeding modality. According to anatomical characteristics, IMA injury is relatively easy to form an AMH from its origin to the third costal cartilage, and an extra-pleural hematoma after the third costal cartilage.

Other diagnostic findings regarding IMA injury include pneumothorax, hemopneumothorax, pulmonary contusion, laceration and consolidation, as well as fractures of the rib, clavicle and sternum, and cardiac tamponade.

A rich potential collateral network exists in the mediastinum and pericardium, which renders injury to the IMA prone to producing mediastinal hematoma, pericardial effusion/tamponade, and hemothorax. In addition, AMH associated with cardiac tamponade is focal, rather than a global compression. Internal mammary artery injury, as well as injury to adjacent veins, such as the left subclavian and innominate veins, internal mammary vein, pulmonary vein and chest wall vein, often lead to an arteriovenous fistula. Thus, transthoracic echocardiography reveals the presence of a dilated vessel with abnormal continuous blood flow in the intercostal space.

**TREATMENT**

Traumatic injury to the IMA constitutes a major challenge for clinicians. It is quite difficult to diagnose, and different treatment options exist from which to choose. Thoracotomy was once regarded as the optimal treatment for IMA injury, particularly for those patients presenting with profound shock. Patients with unilateral IMA injury were placed in a contralateral decubitus position at 45°. In general, an anterolateral emergent thoracotomy incision is taken. When a chest exploration is requisite, this incision can be extended to the posterolateral side. The length of the incision is mainly based on whether it is desirable to merge other visceral injuries in the thoracic cavity. Active bleeding of IMA injury was found, and controlled with proximal and distal suture ligation. If the patients present with bilateral IMA injuries as well, or the unilateral IMA injury leads to AMH associated with cardiac tamponade, a median sternotomy explorative incision should be selected. In addition, injury to the IMA with massive tension hemothorax requires immediate resuscitative thoracotomy. However, surgical treatment is often regarded as an invasive technique. The first reported case of embolotherapy of an IMA injury is believed to have been in 1982. Selective transcatheter arterial embolization (TAE) of the bilateral IMA did not find tissue necrosis in thoracic trauma patients. Chen et al. reviewed articles describing IMA injury after blunt chest trauma in 49 patients. Of the 49 patients studied, 20 underwent embolization, 22 underwent surgical operation, four were managed by clinical observation, and three received undescribed treatment. As complete reports, Chen et al. further analyzed 29 cases of IMA injury in 49 patients. Thirteen (45%) of the 29 patients presented with symptoms of shock. Of the 13 patients with shock, six underwent an operation, and seven underwent embolization. Nineteen patients (65.5%) presented with AMH, and nine patients (31%) presented with shock and AMH. Anterior mediastinal hematoma combined with cardiac tamponade was reported in six patients (21%). Of the six patients studied, four underwent an operation, and two were managed by embolization. Four of these patients also had shock, and two did not. In addition, one of the patients died. Moreover, three (10.3%) of the 29 patients died as a result of blunt chest trauma, one had a large AMH, one had coexistence of a severely extensive intracranial injury, and one had a left cerebellar hemorrhage.

The success rates for patients with IMA injury in the embolization group and surgically managed group were 91.6% and 66.0%, respectively. Although embolotherapy offers an effective, efficient, and safe alternative for IMA injury, approximately half of the patients were previously managed by the conventional surgical method. With the extensive development of interventional techniques and materials, transcatheter endovascular techniques are currently regarded as the first choice for IMA injury. As soon as bleeding
arteries are identified, emergency embolization is performed using gelatin sponge, polyvinyl alcohol particles, and coils. Because of the diversified angiographic presentation of acute hemorrhage, proper selection of the embolic agent constitutes the key to successful hemostasis. The advantages of gelfoam are its availability, low cost, and ease and speed of delivery. However, delayed recanalization is one of its disadvantages. At present, gelfoam is the only commercially available biodegradable embolic material used to treat blunt trauma. However, a novel biodegradable macromolecule material with thrombin-loaded alginate-calcium microspheres was prepared using electrostatic droplet techniques, and a special method was developed for hemostatic embolization. Guglielmi detachable coil (DC) (Boston Scientific, Natick, MA, USA) occlusion proved to be a safe and effective therapeutic alternative to surgery in patients with ruptured or unruptured basilar tip aneurysms. The convenience of the Guglielmi DC is that it can be recaptured if it is not suitable for the location of the lesion. Electrolytically, DC offers some advantages over conventional coils because of its controlled deployment, repositioning, and removal. However, DCs are expensive, and endovascular treatment using DCs has low cost-efficacy. To achieve the trapping of arteries, fiber-coated platinum coils are generally preferred over DCs because of the convenience of using thrombogenic characteristics. Moreover, the cost of fiber-coated coils is less than 10% of that of Guglielmi DCs. A MicroNester coil (Cook Medical, Bloomington, IN, USA) was developed from the Nester coil with a 0.018-inch microcatheter. The most specific feature of the MicroNester coil is its extended length of 14 cm. Recently, SMART coils (Penumbra Inc., Alameda, CA, USA) have been developed, which transitions into softness along the length of their coils.

Temporary arterial balloon occlusion constitutes an effective and safe alternative for controlling hemorrhages in emergent situations. Despite its benefits, balloon occlusion also presents risks, such as endothelial damage, thrombus formation, tissue ischemia and catheter dislocation, as well as vessel dissection or rupture. Intermittent deflation of the occluded balloon is sometimes required to reduce the risk of tissue ischemia. This technique has also been successfully used perioperatively to reduce intraoperative blood loss and transfusion requirement.

Urgent endovascular stent-graft placement proved to be safe and effective in restoring the arterial lumen and patency, excluding pseudoaneurysms and controlling bleeding caused by arterial lacerations. The endovascular approach limits the risk of operative damage to surrounding structures and the potential for blood loss. The coated endovascular stent has a smoother inner wall than other endovascular stents, which reduces the incidence of intimal thickening, stenosis, and embolism. The IMA is located in the proximal segment of the subclavian artery, where the vertebral artery, thyrocervical trunk, and costocervical trunk are located. It is necessary to cover the IMA ostium with a coated endovascular stent in order to consider the potential compromise with collateral branches, particularly the vertebral artery. It is essential to evaluate the rest of the supra-aortic trunks and the cerebral primary collateral circulation, and well as to perform a balloon occlusion test of the affected vertebral artery. However, patients who cannot tolerate the vertebral artery sacrifice will not be eligible for covering its ostium. A “chimney” procedure has been performed, which involved placement of a Viabahn stent (W.L. Gore, Flagstaff, AZ, USA) in the vertebral artery alongside the subclavian arterial endograft.

The technical success rate for chimney stents was 94.3%, and the patency rate was 92%. This procedure provides a viable alternative for emergency patients who are poor candidates for complex open surgical repair. Therefore, chimney graft use is becoming widely accepted as a particularly useful technique in emergent settings. Accessing site arterial injury, endoleaks, graft migration, stent thrombosis, stent infection, intimal thickening, stenosis, and embolism are common complications following endovascular stent placement. The risks of placing a stent-graft in the proximal subclavian artery still include ischemia and necrosis of the upper limb, neurolysis, brachial plexus injury, subclavian steal syndrome, and cerebral neurologic complications. A study with a larger sample size and a longer follow-up period should be performed to further evaluate long-term outcomes.

In brief, for patients with IMA injury, selective TAE or selective TAE combined with temporary endovascular balloon-assisted occlusion has become the optimal treatment choice. In anticipation of an immediate conversion to surgery, surgeons and an operating room should be on continual standby during the TAE. At any stage of the procedure, a simultaneous occlusive balloon can be placed at the proximal subclavian artery to achieve rapid and complete bleeding control, if necessary. For emergency patients with severe shock who cannot tolerate complex open surgery, a chimney graft with concurrent balloon-assisted occlusion will be effective.
If hospitals do not have an adequate endovascular service, however, conventional open surgery must be immediately implemented. Clinical observation is limited to only a small, unenlarged and well-circumscribed extra-pleural hematoma with longer history. Even if endovascular intervention or surgical treatment is successful and clinical observation is uneventful, strict monitoring is essential to check for the recurrence of acute blood loss.\(^{[10,12,18]}\)

A detailed rescue flow chart should be created by a multidisciplinary team. In the case of IMA injury, action should be initiated immediately, according to the flow chart. Close coordination of multidisciplinary teams is also necessary.

In conclusion, blunt chest trauma to the internal mammary artery constitutes an under-recognized entity that is associated with a significant risk of morbidity and mortality. Despite its prevalence and serious consequences, it has not been well-described in the extant literature, and remains a highly challenging problem. It is also difficult to diagnose, and different diagnoses and treatment options are available. Knowledge of potential dangers and indicators is critical to select the optimal and highest-yield modality. Once rapid and early diagnosis is confirmed, immediate treatment according to an emergency response preplan is required to avoid severe hemorrhagic shock and acute cardiac tamponade. In the absence of randomized trials or societal guidelines, rapid and definitive diagnosis and immediate endovascular bleeding control are essential for the successful treatment of patients with internal mammary artery injury after blunt chest trauma. In addition, skilled application of endovascular techniques, aggressive resuscitation, close monitoring, a multidisciplinary team, and a detailed preplan are also highly recommended.

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