Hindawi
Disease Markers
Volume 2023, Article ID 9807872, 1 page
https://doi.org/10.1155/2023/9807872

Retraction

Retracted: Early Diagnosis and Treatment of Nine Patients with Severe Multiple Injuries Accompanied by Traumatic Aortic Dissection during Emergency Treatment

Disease Markers

Received 11 July 2023; Accepted 11 July 2023; Published 12 July 2023

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

In addition, our investigation has also shown that one or more of the following human-subject reporting requirements has not been met in this article: ethical approval by an Institutional Review Board (IRB) committee or equivalent, patient/participant consent to participate, and/or agreement to publish patient/participant details (where relevant).

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] J. Zhang, J. Xu, Y. Zhang et al., "Early Diagnosis and Treatment of Nine Patients with Severe Multiple Injuries Accompanied by Traumatic Aortic Dissection during Emergency Treatment," *Disease Markers*, vol. 2022, Article ID 8241405, 9 pages, 2022.

Hindawi
Disease Markers
Volume 2022, Article ID 8241405, 9 pages
https://doi.org/10.1155/2022/8241405

Research Article

Early Diagnosis and Treatment of Nine Patients with Severe Multiple Injuries Accompanied by Traumatic Aortic Dissection during Emergency Treatment

Jiaming Zhang,[1] Jinyu Xu,[1] Yun Zhang,[1] Xiaoqing Zang,[1] Dongdong Ji,[1] Yu Luo,[1] Guorong Huang,[1] Jiangfeng Li,[1] Hui Liu,[2] Huijun Lu,[2] and Xiaodong Cao[3]

[1]*Department of Emergency, Wuxi People's Hospital Affiliated to Nanjing Medical University, Wuxi, China 214023*
[2]*Department of Vascular Surgery, Wuxi People's Hospital Affiliated to Nanjing Medical University, Wuxi, China 214023*
[3]*Department of Nursing, Wuxi People's Hospital Affiliated to Nanjing Medical University, Wuxi, China 214023*

Correspondence should be addressed to Xiaodong Cao; dongdonger99@163.com

Received 27 October 2021; Accepted 27 January 2022; Published 8 March 2022

Academic Editor: Yuzhen Xu

Objective. This study is aimed at investigating the early diagnosis and efficacy of emergency treatments of nine patients with severe multiple injuries accompanied by traumatic aortic dissection (TAD). *Methods*. Patients who sustained severe multiple injuries accompanied by TAD following a car accident ($n = 6$) and falls from a height ($n = 3$) were treated in the emergency department of our hospital from October 2017 to July 2021. Data of these patients, including seven men and two women (average age, 53 ± 15.2 years; range, 18–83 years) were analysed retrospectively. Upon hospital arrival, the multidisciplinary treatment (MDT) trauma team, composed of doctors and nurses, immediately performed resuscitation following the *Green Channel Consultation and Treatment Process for Severe Multiple Injuries*. Life-threatening injuries were managed urgently. Blood tests and blood preparation and bedside B-scan ultrasonography and CT were performed. Aortic computed tomography angiography (CTA) was conducted decisively in patients suspected of TAD so that endovascular graft exclusion (EVGE) with the aortic covered stent can be performed promptly, followed by emergency management, second-stage surgery, and intensive care according to the injury control strategy. *Results*. This study included nine patients suffering from severe multiple injuries accompanied by Stanford type B TAD, with injury severity scores ranging from 35 to 43 points. Six patients underwent EVGE while receiving emergency treatment, whereas two patients who also had intracranial haemorrhage underwent selective EVGE. One case of TAD missed in the emergency department was detected 13 days after hospitalisation; therefore, the patient promptly underwent EVGE. Emergency procedures performed included exploratory laparotomy and splenectomy ($n = 2$), thoracic closed drainage ($n = 5$), haemothoracotomy ($n = 3$), second-stage fracture surgery ($n = 4$), and tracheotomy ($n = 1$). Postinjury complications included haemorrhagic shock, coagulation disorders, hyoxaemia, pulmonary infection, renal insufficiency, and hypoproteinaemia; however, all patients recovered after intensive care treatment. Aortic CTA after EVGE revealed the disappearance of the dissection and the resorption of the intermural haematoma. However, varying degrees of stenosis or occlusion were observed in the left subclavian artery. Nine patients with severe multiple injuries were treated satisfactorily by the MDT, without fatalities, and all patients were discharged for rehabilitation. *Conclusion*. In this study, procedures including resuscitation, urgent aortic CTA for definitive diagnosis, prompt EVGE, emergency injury control surgery, second-stage definitive surgery, intensive care treatment, and rehabilitation were rationally performed by the emergency MDT trauma team. Overall, this continuous and seamless process is a key factor for the successful treatment of patients with severe multiple injuries accompanied by TAD.

1. Introduction

Traumatic aortic dissection (TAD) is a serious condition caused by a tear in the intima of the aorta, which mostly occurs on the lesser curvature side and distal aortic turn of the left subclavian artery. It is a result of external shear forces and sudden increases in high-velocity blood flow following high-energy injuries such as car accidents, falls, and thoracoabdominal compression. In the case of TAD, blood enters the aortic mesentery from the injured intimal tear, detaching the mesentery and thereby forming a haematoma. If prompt and effective interventions are not taken after the injury, the enlarging haematoma may lead to further dissection separation, rupture, and haemorrhage; untreated TAD has a high rate of disability and mortality [1–3]. In recent years, continuous improvement in the treatment of severe multiple injuries in our department and the breakthrough advances in vascular interventional medical technology at our hospital have led to an increasing in-depth understanding of the pathophysiological features of aortic dissection. In patients with severe multiple injuries and suspected of TAD, aortic computed tomography angiography (CTA) is decisively performed in conjunction with routine plain head, neck, chest, and abdominal CT. Once TAD is diagnosed, analgesics, sedatives, and vasoactive drugs are immediately administered to control blood pressure. In our hospital, endovascular graft exclusion (EVGE) is performed as early as possible to prevent the risk of dissection rupture due to body position changes and blood pressure fluctuations during resuscitation. Subsequent management of other injuries and intensive care unit (ICU) treatment is implemented according to the injury control strategy [4, 5], leading to satisfactory treatment outcomes. Overall, this study describes the early diagnosis and intensive care protocols of nine patients with severe multiple injuries accompanied by TAD to provide a reference for clinical treatment.

2. Information and Methodology

2.1. General Information. Nine patients who sustained severe multiple injuries accompanied by TAD after a car accident ($n = 6$) and falling from a height ($n = 3$) were treated in the emergency department (ED) of our hospital from October 2017 to July 2021. Data of these patients, including seven men and two women (average age, 53 ± 17.7 years; range, 18–83 years), were analysed retrospectively. Six patients with severe multiple injuries and critical conditions were transferred to our hospital after undergoing cephalothoracic and abdominal plain CT in external hospitals. TAD was confirmed based on aortic CTA in one case, whereas it was diagnosed based on emergency aortic CTA in the remaining five cases after arrival. The other three patients were brought to our hospital by ambulance after the injury. TAD was confirmed in two cases based on CT of the head, neck, chest, and abdomen and aortic CTA, and one case of TAD was subsequently identified based on follow-up CTA during the disease course. The severity of injuries was assessed using the Injury Severity Score, with total and mean scores of 35–43 and 38.39 points, respectively. Two patients had a history of hypertension. Details of patients with severe multiple injuries are presented in Table 1.

2.2. Diagnostic and Treatment Process. Upon arrival to our hospital, the multidisciplinary treatment (MDT) trauma team, composed of medical and nursing staff, was activated according to the trauma centre's procedure for treating severe multiple injuries. Specifically, the nursing team immediately monitored the vital signs, administered oxygen, established intravenous access, drew blood for tests, and performed blood dispensing. A physician made an initial assessment of the condition and diagnosis according to the ABCDEF principle based on the causes of injury, signs and symptoms, CRASH PLAN sequential examination, and external CT findings. Haemostatic drugs such as tranexamic acid were administered for the urgent treatment of life-threatening injuries, followed by blood transfusion and administration of vasoactive drugs to correct haemorrhagic shock. Hypotensive resuscitation was performed before surgery to control active bleeding. In cases of possible TAD, urgent and decisive CT scans of the head, neck, chest, and abdomen and aortic CTA were performed.

In this study, all nine patients suffered from severe multiple injuries accompanied by Stanford B type TAD. Three of these patients had varying degrees of aortic dissection rupture. Six patients with multiple rib fractures had hydropneumothorax, three had craniocerebral trauma, three had vertebral fractures, three had limb fractures, five had pelvic fractures, and three had a ruptured spleen. In view of the poor prognosis owing to the aggravated rupture or haemorrhage caused by TAD, as diagnosed by MDT, and the avoidance of factors causing rupture induced by other surgical extracorporeal procedures and open thoracoabdominal surgery, six patients underwent EVGE under general anaesthesia to close the intimal rupture of the aorta. Subsequently, other multiple injuries were treated according to injury control strategies. Two patients underwent splenectomy, five underwent thoracic closed drainage, and three underwent thoracotomy haemostasis. Two other patients who also had intracranial haemorrhage underwent EVGE after intracranial stabilisation to avoid severe intracranial haemorrhage caused by heparin administration during endovascular interventions. One patient who also had TAD detected based on CTA 12 days after hospital admission underwent EVGE the day after the detection. Complications such as haemorrhagic shock, hypoxaemia, infection, and renal insufficiency were treated in the ICU. Neurological function was closely monitored to rule out cerebral and spinal cord ischaemia and mesenteric and lower limb ischaemia after EVGE. Once the condition was relatively stable, surgical treatment with definitive internal fixation of fractures (Table 1) and rehabilitation were performed subsequently.

The endovascular intervention with a thoracic aortic covered stent is described below. In view of the multiple injuries and bleeding sites, low-dose heparinisation was implemented to reduce the bleeding risk. The right femoral artery was punctured, the suture position was reserved, and aortography was performed to clarify the site of the intimal rupture. This was performed in four cases each of rupture

Table 1: General information and treatment of patients.

Cases	Sex	Age	Injury method	Time from injury to CTA	Location of aortic dissection	Time from injury to operation	Hospital stay (days)	History of hypertension	Other trauma	Other surgery
1	Male	53	CA	10 h	5 cm distal to SLA	ES	6	Deny	I	Conservative treatment
2	Female	83	CA	1 d	SBS	9 d later	17	Deny	II	Conservative treatment
3	Male	51	FFt	1 h	SBS + 1 cm distal to SLA	ES	34	Yes	III	Thoracic haemostasis under thoracoscopy, splenectomy and tracheotomy
4	Male	46	CA	1 h	SBS	ES	30	Deny	IV	Open reduction with internal fixation for left intertrochanteric fractures
5	Male	46	CA	4 h	2 cm distal to SLA	ES	32	Deny	V	Internal fixation for sternum fractures, internal fixation for rib fractures, thoracoplasty
6	Female	63	CA	36 h	SBS	23 d later	44	Yes	VI	Conservative treatment
7	Male	18	CA	2 h	1 cm distal to SLA	ES	24	Deny	VII	Splenectomy, ankle fracture incision, and internal fixation
8	Female	66	CA	10 h	SBS	ES	7	Deny	VIII	Haemothorax
9	Male	51	FFH	12d	1 cm distal to SLA	13 d later	23	Deny	IX	Conservative treatment

LCS: lesser curvature side; CA: car accident; FFH: fall from a height; ES: emergency surgery.

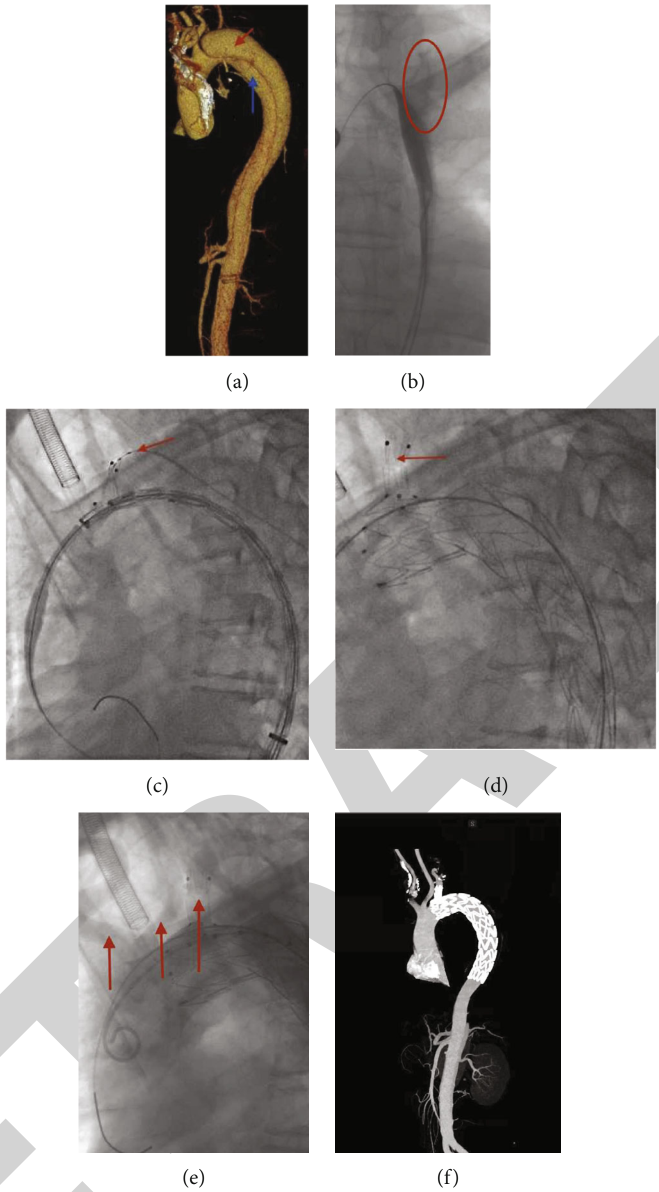
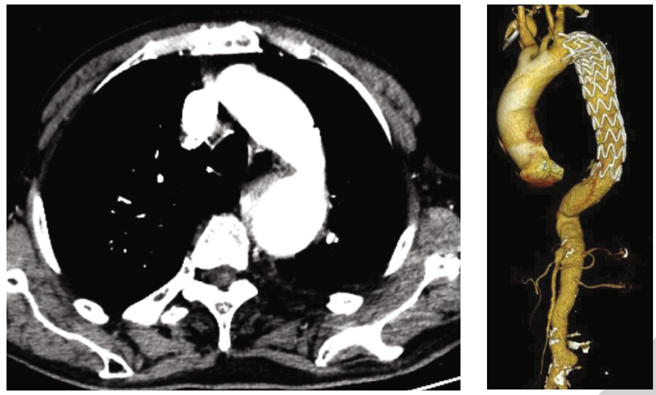


Figure 1: Aortic CTA (a) 12 days after injury suggests separation of the dissection to the entire thoracoabdominal aorta, true luminal stenosis and involvement of the left subclavian, mesenteric, and left common iliac arteries. Intraoperative aortogram. (a) An intimal rupture in the aorta located 1 cm distal to the subclavian artery. (c) Placement of a thoracic aortic covered stent (with left subclavian artery branch) under dual guide-wire guidance in the subclavian artery and aorta. (d) Complete opening of the stent. (e) Good patency of the subclavian artery with a closed endothelial rupture and no extravasation of contrast. (f) 100 days after aortic covered stenting suggests intermural haematoma resorption, no extravasation of contrast, and good visualisation of the subclavian artery. CTA: computed tomography angiography.

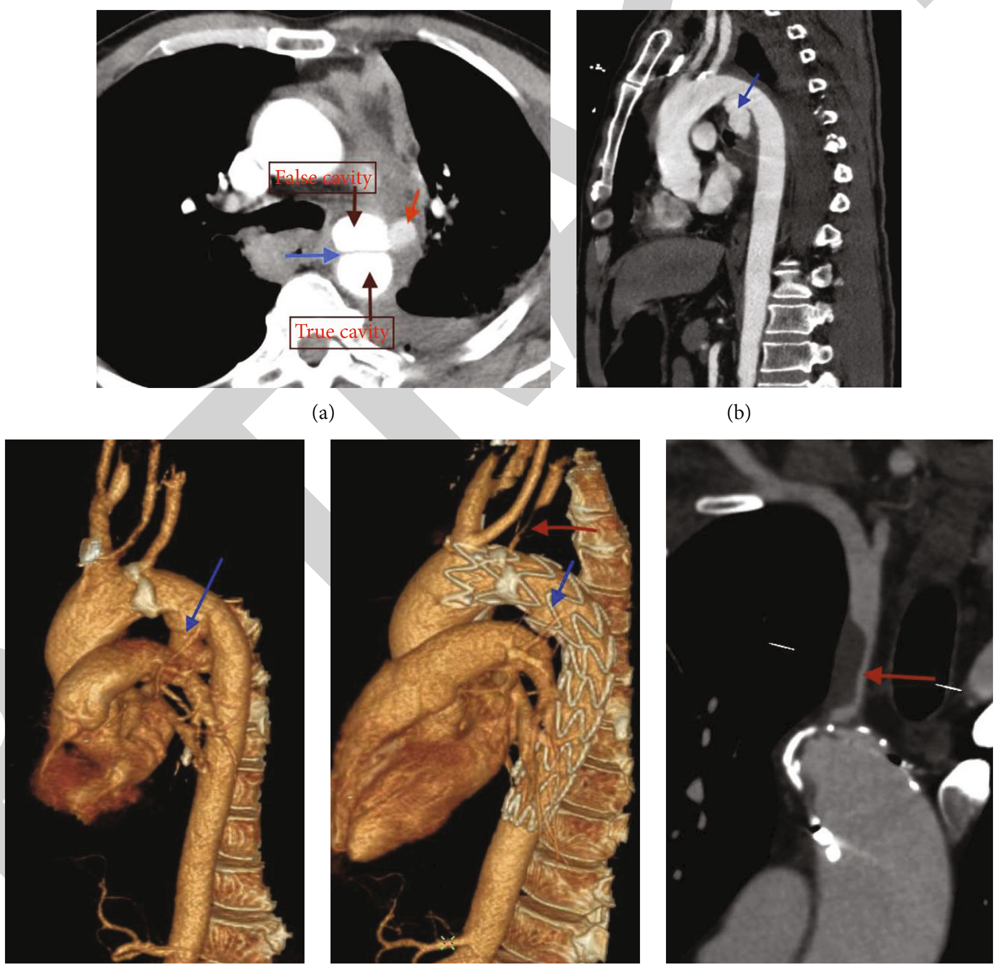
on the lesser curvature side and distal side of the left subclavian artery and one case with a rupture in both sites. To prevent blood leakage, the position was fixed to ensure that the proximal end of the rupture > 2 cm was covered. The diameter of the covered stent was determined at 10–15% magnification. The stent covered the ruptured lesion of the aortic dissection. Poststent release imaging revealed full coverage of the left subclavian artery in two cases (the intimal rupture was 1 cm distal to the subclavian artery), with no complaints of postoperative dizziness (the subclavian artery was taking blood from the vertebral artery). Furthermore, the subclavian artery was partially shielded by a covered stent in three cases. In the other four patients, the subclavian arteries are visualised well, and the stent in one patient was placed in the subclavian artery (Figure 1).

2.3. Results. Two patients with severe multiple injuries had stable vital signs postoperatively and were treated in the general vascular surgery ward without complications such as delayed bleeding, infection, or dizziness. Given the



(a) (b)

Figure 2: Aortic CTA (a) 9 days following injury in case 2 suggests aortic dissection and formation of intermural haematoma. Aortic CTA (b) 50 days after aortic covered stenting suggests intermural haematoma resorption, no extravasation of contrast, and good visualisation of the subclavian artery. CTA: computed tomography angiography.



(a) (b)

(c) (d) (e)

Figure 3: Aortic CTA (a) 1 h after severe multiple injuries in case 3 suggests formation of aortic dissection and extravasation of contrast. Aortogram (b, c) during emergency treatment detected an intimal rupture in the aorta approximately 1.5 cm distal to the lesser curvature side and the subclavian artery. Aortic CTA (d, e) 5 months after aortic covered stenting (the subclavian artery is partially covered) suggests the disappearance of the dissection, no extravasation of contrast and severe stenosis of the subclavian artery. CTA: computed tomography angiography.

conservative treatment required for both vertebral and rib fractures, these two patients were discharged from the hospital 1 week after surgery for rehabilitation.

Two patients who also had craniocerebral injuries remained relatively stable after ICU treatment for intracranial injury and other multiple injuries. However, repeat CTA of the chest and abdomen revealed dissection accompanied by intermural haematoma (Figure 2). Consequently, aortic covered stenting was performed. The patient was discharged from the hospital for rehabilitation because there was no severe postoperative intracranial haemorrhage, and multiple injuries had gradually improved.

One patient (Figure 3) with severe multiple injuries underwent emergent aortic covered stenting, splenectomy, and thoracoscopic removal of pleural haematocele. However, subsequent pulmonary contusion accompanied by pulmonary infection and hypoxaemia led to a dysfunctional ventilatory weaning response. Therefore, tracheotomy and aggressive treatment were initiated, which improved the patient's condition. As the patient can breathe independently without the ventilator, the patient was discharged for rehabilitation after staying in the hospital for 34 days. A CTA performed during hospitalisation in this patient with severe multiple injuries (Figure 1) revealed that the dissection had separated the entire thoracoabdominal aorta, with true luminal stenosis and involvement of the left subclavian, mesenteric, and left common iliac arteries. Therefore, a thoracic aortic branch (left subclavian artery) was stented. An angiogram revealed patency of the subclavian artery. Postoperative changes were observed without reports of dizziness, abdominal pain, or bowel ischaemia. Therefore, this patient was discharged for rehabilitation 1 week after surgery.

The other four patients underwent emergency aortic covered stenting. After ICU treatment to stabilise their condition, they underwent second-stage orthopedic surgery and were successfully discharged from the hospital for rehabilitation.

During rehabilitation, repeat arterial CTA demonstrated the disappearance of the aortic dissection and resorption of the intermural haematoma. However, there was occlusion of the left subclavian artery in two cases, varying degrees of stenosis of the left subclavian artery in four cases and good visualisation of the subclavian artery in three cases.

The three outcomes of the left subclavian artery are mainly related to the distance of the rupture of the aorta from the opening of the left subclavian artery after trauma. When the distance is >3 cm, it is possible that the covered stent does not cover the left subclavian artery, and the postoperative angiography shows good results; if the distance is <1 cm, to prevent blood leakage from the rupture, the distal end of the covered stent will cover the subclavian artery. The CTA review may not show the stenosis if the patient has complications such as upper limb ischemia or insufficient blood supply to the vertebral artery; if the distance is between 1 and 3 cm, the subclavian artery may be partially covered and easily form a local thrombus, and the CTA review may show a partially developed stenosis. Nowadays, the application of the aortic stent with subclavian artery branches can effectively avoid the risk of the blockage of the subclavian artery and is worth promoting.

3. Discussion

In the emergency management of patients with trauma, patients with multiple injuries exhibited critical and complex conditions. In particular, severe multiple injuries from traffic accidents and high-energy injuries following falls accompanied by TAD are major obstacles to successful resuscitation. Unfortunately, this is exactly true in severe multiple injuries accompanied by TAD, which has a lower mortality rate than severe craniocerebral trauma alone [6]. Because cases of severe multiple injuries accompanied by TAD are clinically rare and approximately 85% of patients with TAD are already dead before hospital arrival, there is less experience with such patients and proactive screening for TAD is not possible, resulting in misdiagnoses and missed diagnoses.

An analysis on patients presented at our hospital revealed that an accurately diagnosed TAD was relatively rare until 2017. In addition, the observation that most patients referred from lower-level hospitals do not undergo aortic CTA reflects the dilemma of missed diagnoses. In the treatment of patients with severe multiple injuries accompanied by severe craniocerebral trauma, multiple rib fractures with haemopneumothorax, abdominal visceral injuries, and pelvic fractures, the early and targeted improvement of aortic CTA to exclude aortic dissection and aortic vascular injury impose high demands on the ED surgeon.

Reasons for missed diagnosis in the ninth patient: the patient fell from a height causing a cervical-thoracic spine injury with spinal cord injury and bilateral upper limb movement limitation. After an emergency consultation by an orthopedic specialist, the patient was transferred back to the resuscitation room after performing a plain computed tomography (CT) of the head, neck, chest, and abdomen. The CT report concluded the following: two lung contusions, multiple rib fractures, bilateral scapula fractures, cervical and thoracic spine fractures, right lateral fluid pneumothorax, splenic contusion and laceration, mesenteric injury, and pelvic fracture. The multidisciplinary consultation did not reveal a clear need for emergency surgery, and it was recommended that an enhanced CT examination of the thorax and abdomen be performed if necessary, and the patient was admitted to the intensive care unit (ICU) for treatment. To prevent the cervicothoracic fracture and spinal cord injury from being aggravated by moving the patient, a bedside review ultrasound was performed to monitor the main treatment. Once the patient's condition was relatively stable for 12 days, computed tomography angiography (CTA) of the thorax and abdomen was performed to detect the TAD. The main reason for the missed diagnosis was that the orthopedic specialist and the ICU bedside physician were not thorough with the advanced diagnosis of TAD and did not perform an aortic CTA examination to investigate the vascular injury the first time the patient presented at the emergency department. In addition, they lacked the concept of diagnosis by enhanced CT to investigate the organ and vascular injury in patients with severe multiple injuries, which led to the missed diagnosis of the occult injury that could not be detected by ultrasound and flat scan CT.

Literature review demonstrated the progressive improvement in the diagnosis and therapeutic efficacy of TAD in recent years owing to the popularity of enhanced CT and the use of aortic covered stents. Xiao et al. [7] performed second-stage nonfatal definitive surgery after applying minimally invasive intra-aortic luminal stenting combined with thoracic close drainage, external pelvic fixation stenting, and comprehensive postoperative ICU treatment. The injury control strategies derived from their practice have demonstrated satisfactory treatment outcomes of TAD. Regarding surgery timing, a systematic analysis of 1742 patients with TAD by von Oppell et al. [8] revealed that 10.3% of patients with relatively stable preoperative conditions had rupture and bleeding, leading to death. Therefore, early surgical treatment was recommended. Currently, CTA has diagnostic sensitivity and specificity of 94% and 100%, respectively, for aortic dissection. Therefore, direct examination in the CT room, next to the resuscitation room, is feasible, time-saving, and efficient and is the preferred method for diagnosing aortic dissection. In 1997, Semba et al. [5] reported EVGE with a covered stent for the treatment of TAD. Subsequently, accumulating evidence confirmed the effectiveness and acceptance of this approach [9]. Endovascular covered stenting is also associated with long-term complications, such as endoleaks, graft failure, technical failure, iliac vessel injury, and embolism of collateral vessels [9–11]. The use of aortic covered stents in subclavian artery branches can be effective in reducing complications of subclavian artery occlusion and stenosis. Good preoperative planning of EVGE according to CTA recommendations can greatly contribute to achieving successful surgical outcomes with short operative time [12].

CTA findings [13, 14] of aortic dissection include intimal and calcified internal shift, division of the aorta into true and false lumens by an intimal flap and formation of a double-lumen aorta. The presence of pleural and pericardial effusions can clarify the involvement of aortic branches such as the brachiocephalic trunk of the aortic arch and right internal carotid, subclavian, visceral superior mesenteric, renal, and iliac arteries. In addition, to analyse the condition of the patient and provide endovascular treatment, potential large-vessel and visceral injuries such as liver, spleen, and kidney injuries following multiple injuries can be detected promptly. Moreover, bedside cardiac ultrasonography is an excellent complement to CTA and can further confirm the presence of pericardial effusion and tricuspid regurgitation and evaluate cardiac function [15, 16].

TAD and spontaneous aortic dissection have similar symptoms. It is reported [17] that 76–96% of patients present with laceration-like chest and back pains. However, such pains can cause confusion, as patients are prone to chest injuries, rib fractures, abdominal trauma, and direct injuries to the spine. In unconscious patients with severe craniocerebral injury, preliminary judgment can only be made based on the causes of injury and findings of physical examination.

To request aortic CTA, the patient's family should be informed of the following factors to clarify the presence or absence of dissection: (1) causes of injury. These include car accidents, fall from a height and history of other thoracic and abdominal traumas. (2) Clinical manifestations. (i) The difference in the systolic blood pressure of upper limbs exceeds 20 mmHg; the blood pressure of the lower limbs is even lower than that of the upper limbs, which has a specific diagnostic value [18]. (ii) The patient has increased blood pressure possibly caused by TAD. In other words, the patient who should have been in haemorrhagic shock due to multiple injuries paradoxically did not present a significant decrease in blood pressure. (iii) A murmur in the aortic area is heard on cardiac auscultation, suggesting the presence of dissection accumulation and aortic insufficiency. (iv) No clear signs of craniocerebral injury are present based on neurological perception. (3) Bedside cardiac ultrasound and FAST-B ultrasound is done immediately after injury and reveal pericardial effusion and dissection. (4) Imaging manifestations.

CTA is required in cases where the following signs are found on plain CT: (i) chest trauma with haemothorax alone, without haemopneumothorax, is detected especially on the left side of the chest; the bleeding may not be from an intercostal artery but from a ruptured arterial dissection. (ii) Mediastinal widening with blurred aortic borders is detected on plain CT of the chest. (iii) Significant pericardial effusion is found. (iv) Abdominal pain cannot be explained by abdominal CT alone; in this case, enhanced CT is required to rule out organ ischaemia due to arterial dissection. (v) Pericardial effusion and dissection are identified based on high-definition bedside cardiac ultrasonography. (vi) Dissection signs are detected based on plain CT, such as intimal and calcified internal shift. Because multiple injuries accompanied by TAD are easily masked by other diagnoses, misdiagnosis and missed diagnoses occur frequently. Therefore, an early and rapid differential diagnosis with enhanced CT is the most effective method. Indeed, early diagnosis is the key to improving the outcomes of subsequent treatments. The consequences of a missed diagnosis can be unbearable and can directly lead to the loss of the opportunity to resuscitate or even death. In this study, a patient whose TAD was detected later had a large and cumulative multivessel aortic dissection, inhibiting the treatment efficacy.

The principles of our team in the treatment of patients with severe multiple injuries accompanied by TAD are as follows: (1) the priority is to activate a collaborative MDT trauma team to resuscitate patients with severe multiple injuries and provide targeted treatment for cases accompanied by TAD. (2) In view of the patient's fear and irritability owing to persistent and severe pain caused by chest injury and other injuries, analgesics and sedatives are administered to relieve pain and promote cooperation with treatment. (3) In cases accompanied by haemorrhagic shock, limited fluid resuscitation is required to rehydrate in appropriate amounts. In addition, timely supplementation of red blood cells, plasma, and vasoactive drugs is necessary to maintain blood pressure. Moreover, platelet, fibrinogen, and prothrombin complex transfusions are important to correct coagulation disorders; early surgical intervention to control bleeding is also essential. (4) Blood pressure and heart rate control are required to circumvent severe bleeding and bleeding from ruptured aortic dissection due to elevated and fluctuating blood pressure. (5) Aortic dissection induced by other surgical extracorporeal manoeuvres and open thoracoabdominal procedures should be prevented. According to normal protocols, it is reasonable to prioritise EVGE procedures for the closure of aortic intimal ruptures during emergency procedures. (6) Despite the lack of randomised controlled studies on the efficacy of open surgery versus endovascular treatment of patients with traumatic aortic injury, endovascular treatment has gradually replaced traditional open surgery, with significant improvements in mortality and morbidity. For Stanford type B aortic dissection, minimally invasive EVGE with covered stents is performed. For Stanford type A aortic dissection, the “smoke tube-and-window” technique with covered stents is gradually replacing vessel replacement by thoracotomy that requires massive heparinisation for anticoagulation and is very invasive [19]. However, for patients with aortic valve involvement or coronary ischaemia, vessel replacement by thoracotomy is required. The three outcomes of the left subclavian artery are mainly related to the distance of the rupture of the aorta from the opening of the left subclavian artery after trauma. When the distance is >3 cm, it is possible that the covered stent does not cover the left subclavian artery, and the postoperative angiography shows good results; if the distance is <1 cm, to prevent blood leakage from the rupture, the distal end of the covered stent will cover the subclavian artery. The CTA review may not show the stenosis if the patient has complications such as upper limb ischemia or insufficient blood supply to the vertebral artery; if the distance is between 1 and 3 cm, the subclavian artery may be partially covered and easily form a local thrombus, and the CTA review may show a partially developed stenosis. Nowadays, the application of the aortic stent with subclavian artery branches can effectively avoid the risk of the blockage of the subclavian artery and is worth promoting. (7) For cases combined with haemothorax, the recommended procedure is to first isolate the rupture with an aortic covered stent to control bleeding and then perform thoracic close drainage. This sequence can avoid the aggravation of rupture, bleeding, and rapid deterioration caused by a drop in thoracic pressure after drainage of pleural effusion. (8) According to the principles of injury control surgery for critically ill patients with multiple injuries, simple and effective emergency procedures such as external pelvic stenting, traction for fractures of the extremities, vascular embolisation of bleeding sites, and enterostomy are required. In addition, comprehensive treatment in the ICU after surgery is necessary. Once the patient is out of the acute trauma stage, second-stage definitive surgery, such as internal fixation of fractures and enterostomy retraction, should be performed promptly. (9) The complex condition of patients with severe multiple injuries requires specific assessment and communication with the family, depending on the patient’s status.

In conclusion, in patients with severe multiple injuries owing to car accidents, falls and chest compression where TAD cannot be excluded, a positive diagnosis should be made based on the causes of injury, signs and symptoms, and imaging findings. ED surgeons must be aware of the importance of aortic CTA. Despite the potential increase in the number of negative diagnoses, life-threatening missed diagnoses can be avoided. In cases of TAD, early and safe endovascular minimally invasive EVGE can close the injured aortic intima and restore normal blood flow to the aorta. Injury control surgery is required during emergency procedures. Comprehensive postoperative ICU treatment and second-stage definitive surgery are also essential. Overall, the presented continuous and seamless treatment process is a key factor for the successful management of patients with severe multiple injuries accompanied by TAD.

I. Thoracic and lumbar spine fractures. II. Brain contusion and laceration, subdural haematoma on both frontal and temporal regions and lung contusion. III. Spleen rupture, lung contusion, multiple rib fractures on the left side, left clavicle fracture, thoracic spine fracture, pelvic fracture, and bilateral pleural effusion. IV. Multiple rib fractures and fluid pneumothorax, lung contusion and laceration, scapular fracture, sternal fracture, left femoral trochanter fracture, pelvic fracture, and pericardial effusion. V. Multiple fractures of the sternal body, rib fractures, mediastinal emphysema, right pneumothorax, right sacral fractures, closed abdominal injuries, and bilateral haemothorax. VI. Subarachnoid haemorrhage, intraventricular haemorrhage, atlantoaxial subluxation, multiple bilateral rib fractures, left-sided haemopneumothorax, pulmonary contusion, pericardial effusion, mediastinal emphysema, lumbar spine fracture, and left fibular fracture. VII. Epidural hematoma, subarachnoid haemorrhage, skull fracture, lung contusion, pleural effusion, spleen rupture, pelvic fracture, right ankle fracture, and cervical spinous process fracture. VIII. Head trauma, traumatic wet lung, bilateral rib fracture, and closed abdominal injury. IX. Two lung contusions, multiple rib fractures, bilateral scapula fractures, thoracic spine fractures, right lateral fluid pneumothorax, splenic contusion and laceration, mesenteric injury, and pelvic fracture.

Data Availability

The data used to support the findings of this study are available from Xiaodong Cao upon request.

Ethical Approval

This study was approved by the ethics committee of our hospital.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors’ Contributions

Jiaming Zhang and Jinyu Xu are co-first authors and they contributed equally to this work.

Acknowledgments

This study was supported by the Top Talent Support Program for Young and Middle-Aged People of Wuxi Health Commission (Project nos. BJ2020007 and HB2020019).

References

[1] A. Agostinelli, D. Carino, B. Borrello et al., "Blunt traumatic injury to the thoracic aorta treated with thoracic endovascular aortic repair: a single-centre 20-year experience," *Interactive Cardiovascular and Thoracic Surgery*, vol. 28, no. 1, pp. 17–22, 2019.

[2] M. Szostek, W. Jakuczun, M. Oseka et al., "Endovascular treatment of traumatic rupture of thoracic aorta: long term results," *International Angiology*, vol. 35, no. 2, pp. 129–139, 2016.

[3] B. M. Sheehan, A. Grigorian, C. Virgilio et al., "Predictors of blunt abdominal aortic injury in trauma patients and mortality analysis," *Journal of Vascular Surgery*, vol. 71, no. 6, pp. 1858–1866, 2020.

[4] D. C. Tong and J. Breeze, "Damage control surgery and combat-related maxillofacial and cervical injuries: a systematic review," *The British Journal of Oral & Maxillofacial Surgery*, vol. 54, no. 1, pp. 8–12, 2016.

[5] C. P. Semba, N. Kato, S. T. Kee et al., "Acute rupture of the descending thoracic aorta: repair with use of endovascular stent-grafts," *Journal of Vascular and Interventional Radiology*, vol. 8, no. 3, pp. 337–342, 1997.

[6] R. S. Smith and F. C. Chang, "Traumatic rupture of the aorta: still a lethal injury," *American Journal of Surgery*, vol. 152, no. 6, pp. 660–663, 1986.

[7] L. Xiao and Z. Zheng-zheng, "Application of damage control strategy in traumatic aortic dissection," *Chinese Journal of Integrated Traditional and Western Medicine in Intensive and Critical Care*, vol. 23, no. 5, pp. 543-544, 2016.

[8] V. Oppell, T. T. Dunne, M. K. De Groot, and P. Zilla, "Traumatic aortic rupture: twenty-year meta-analysis of mortality and risk of paraplegia," *The Annals of Thoracic Surgery*, vol. 58, no. 2, pp. 585–593, 1994.

[9] M. Cline, K. J. Cooper, M. S. Khaja, R. Gandhi, Y. C. Bryce, and D. M. Williams, "Endovascular management of acute traumatic aortic injury," *Techniques in Vascular and Interventional Radiology*, vol. 21, no. 3, pp. 131–136, 2018.

[10] M. E. García Reyes, G. Gonçalves Martins, V. Fernández Valenzuela, J. M. Domínguez González, J. Maeso Lebrun, and S. Bellmunt Montoya, "Long-term outcomes of thoracic endovascular aortic repair focused on bird beak and oversizing in blunt traumatic thoracic aortic injury," *Annals of Vascular Surgery*, vol. 50, pp. 140–147, 2018.

[11] S. W. Chen, K. B. Lee, M. A. Napolitano et al., "Complications and management of the thoracic endovascular aortic repair," *Aorta*, vol. 8, no. 3, pp. 49–58, 2020.

[12] M. Teraa, C. E. Hazenberg, I. B. Houben, S. Trimarchi, and J. van Herwaarden, "Important issues regarding planning and sizing for emergent TEVAR," *The Journal of Cardiovascular Surgery*, vol. 61, no. 6, pp. 708–712, 2020.

[13] W. C. Methodius-Ngwodo, A. B. Burkett, P. V. Kochupura, E. D. Wellons, G. Fuhrman, and D. Rosenthal, "The role of CT angiography in the diagnosis of blunt traumatic thoracic aortic disruption and unsuspected carotid artery injury," *The American Surgeon*, vol. 74, no. 7, pp. 580–585, 2008.

[14] N. A. Orabi, L. E. Quint, K. Watcharotone, B. Nan, D. M. Williams, and K. M. Kim, "Distinguishing acute from chronic aortic dissections using CT imaging features," *The International Journal of Cardiovascular Imaging*, vol. 34, no. 11, pp. 1831–1840, 2018.

[15] G. Mastrogiovanni, P. Masiello, R. Leone, S. Iesu, and G. Di Benedetto, "Emergency surgical management of acute aortic dissection: role of transesophageal echocardiography," *Giornale Italiano di Cardiologia*, vol. 29, no. 10, pp. 1137–1141, 1999.

[16] T. Yoshimuta, T. Okajima, K. Harada, M. Mori, K. Hayashi, and M. Yamagishi, "Impact of the right parasternal view with supine positioning for echocardiographic visualization of acute type A aortic dissection," *Journal of Echocardiography*, vol. 10, no. 1, pp. 38-39, 2012.

[17] A. Agostinelli, D. Carino, B. Borrello et al., "Blunt traumatic injury to thethoracic aorta treated with thoracic endovascular aortic repair:a single-centre 20-year experience," *Interactive Cardiovascular and Thoracic Surgery*, vol. 28, no. 1, pp. 17–22, 2019.

[18] Y. Von Kodolitsch, A. G. Schwartz, and C. A. Nienaber, "Clinical prediction of acute aortic dissection," *Archives of Internal Medicine*, vol. 160, no. 19, pp. 2977–2982, 2000.

[19] D. Pang, D. Hildebrand, and P. Bachoo, "Thoracic endovascular repair (EVGE) versus open surgery for blunt traumatic thoracic aortic injury," *Cochrane Database of Systematic Reviews*, vol. 2, no. 2, pp. 283–289, 2019.