Penetrating Aortic Injury due to Broken Ribs and Preventive Measures

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Abstract
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We herein report two cases of patients that underwent prophylactic operations to prevent aortic injuries in association with fractured ribs. Penetrating aortic injuries induced by fractured ribs remain fatal. Prophylactic operations appear effective. However, the indication for such operations should be clarified further in the future.

Introduction

Thoracic aortic injury caused by rib fractures is rare. In such cases, emergency surgery is usually required due to unstable circulation.¹ The location of left-sided posterior rib fractures from flail chest is a risk factor for penetrating aortic injury.² Some patients show delayed aortic penetrating injury due to moving fractured ribs. Prophylactic operations to prevent such injuries have been reported.³ As no reviews have focused on penetrating aortic injury due to fractured ribs and preventive measures, we herein report our cases and review the relevant literature. The protocol of this study was approved by our institutional review board, and the examinations were conducted according to the standards of good clinical practice and the Declaration of Helsinki.

Case Presentations

Case 1
A 65-year-old man who sometimes lost his memory after drinking alcohol noticed left chest and neck pain after the ingestion of a massive amount of alcohol. His symptoms did not improve after 2 days, and he could not walk by himself. He, therefore, called an ambulance. He was transported to our hospital by ground and air ambulance due to a severe hypoxic state. On arrival, he had a clear consciousness. Physical examination revealed the following: blood pressure, 170/118 mm Hg; heart rate, 122 beats per minute; percutaneous oxygen saturation, 97% on 10 L per minute of oxygen by mask; and body temperature, 37.7°C. He had subcutaneous hemorrhage in the left chest with flail chest and severe subcutaneous emphysema at the upper trunk. Whole body computed tomography (CT) with contrast revealed multiple left rib fractures (II–XII), bilateral hemopneumothorax, left lumbar transverse process fractures (I–III), left clavicular fracture, and right renal cystic injury. In addition, the ninth fractured rib was adjacent to the descending aorta (►Fig. 1). He underwent bilateral thoracostomy. He was admitted to the intensive care unit (ICU) under the prohibition of the left decubitus position. On day 2, his hypoxia deteriorated due to atelectasis and he underwent tracheal intubation with mechanical ventilation for

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internal fixation. He underwent tracheostomy on hospital day 3, removal of the fifth fractured rib on the hospital day 5, and internal fixation for left clavicular fracture on the 8th hospital day. On the 12th day, mechanical ventilation was withdrawn and the tracheal tube was removed on the 14th hospital day. After rehabilitation, he was discharged on foot on hospital day 23.

Case 2
A 76-year-old man with hypertension was knocked more than 3 m by a car moving at the speed of 30 km per hour. He was transported to our hospital by ground and air ambulance. On arrival, he had clear consciousness. Physical examination revealed the following: blood pressure, 127/85 mm Hg; heart rate, 114 beats per minute; percutaneous oxygen saturation, 92% on 10 L per minute of oxygen by mask; and body temperature, 35.0°C. He had left chest pain and tenderness with flail chest. Whole body CT with contrast revealed multiple left rib fractures (I–X), multiple right rib fractures (I, V–VII), bilateral hemopneumothorax, unstable thoracic spinal fractures (IV and V), traumatic subarachnoid hemorrhage, and left foot fracture. In addition, the fifth fractured rib was adjacent to the descending aorta (►Fig. 2). He underwent left thoracostomy, tracheal intubation, and mechanical ventilation for internal fixation. He was admitted to the ICU under the prohibition of left decubitus position. He underwent posterior internal fixation for the thoracic spine with screws and rods and fixation of the fifth fractured rib with wires on hospital day 7, tracheostomy on hospital day 9, and internal fixation for foot fracture on hospital day 14. Removal of the tracheal tube failed due to difficult excretion of sputum, and he was transferred to another hospital for rehabilitation.

Discussion
There are only seven previous reports on prophylactic operations to prevent the aortic injuries induced by fractured ribs.1,3–8 We summarized these cases, including the present two cases in ►Table 1. As a result, prophylactic surgery appears to be effective. In addition, evaluation using axial CT images is necessary to evaluate the relationship between the edge of the fractured ribs and the descending aorta, at least for patients with flail chest. The remaining clinical questions concern the indications for prophylactic operations, the operative method, and alternate conservative treatment, such as internal fixation for flail chest using mechanical ventilation with positive end-expiratory pressure. Concerning the indications for prophylactic operations, fractured ribs in contact with the descending aorta are considered to be an absolute indication for operation. The minimal safe distance between the edge of the fractured rib and the descending aorta has not yet been investigated. In addition, internal fixation for flail chest using mechanical ventilation with positive end-expiratory pressure may be useful for preventing penetrating aortic injuries induced by fractured ribs. Our department pursues such management for patients when the distance from the edge of the fractured ribs to the descending aorta exceeds 1 to 3 cm. At the present, the decision to operate depends on the consent of both the patient and surgeon. In such cases, the development of a scale would be helpful, including such factors as radiological or anatomical findings that could be considered “high risk,” thereby indicating the need to perform prophylactic procedures. However, developing such a scale is currently impossible due to the fact that there are just too few patients with data that can be fully evaluated. Further accumulation of case reports on penetrating aortic injuries induced by fractured ribs is necessary to resolve the remaining clinical questions.

Penetrating aortic injuries induced by fractured ribs remain potentially fatal. Prophylactic operations appear effective; however, the concrete indications of such operations remain to be clarified.

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Table 1  Previous reports on prophylactic operations to prevent the aortic injuries induced by fractured ribs

| No. | Author          | Year | Age (y) | Sex | Mechanism of injury | Penetration | Ribs | Flail chest | Chest tube drainage | Mechanical ventilation | Complication                     | Treatment                                      | Outcome     |
|-----|-----------------|------|---------|-----|---------------------|-------------|------|-------------|---------------------|------------------------|-----------------------------|-----------------------------------------------|-------------|
| 1   | Zhao et al[^1]  | 2021 | 54      | F   | Falling object      | No          | 5,6,7,8 | No          | No                  | No                     | Lung, spine           | Internal fixation                | Survival    |
| 2   | Bartscherer et al[^3] | 2019 | 21      | F   | Train accident      | No          | 5    | Yes         | Yes                 | Yes                    | Lung, spleen, extremity | Plate                     | Survival    |
| 3   | Uemura et al[^4] | 2016 | 19      | F   | Traffic accident    | No          | 9,10 | No          | Yes                 | Yes                    | Lung, scapula, spine, liver, pelvis | Resection of fractured rib | Survival    |
| 4   | Funaki et al[^5] | 2014 | 66      | F   | Traffic accident    | No          | 8    | No          | Yes                 | No                     | Lung            | Video-assisted thoracoscopic resection of fractured ribs | Survival    |
| 5   | Kobayashi et al[^6] | 2012 | 81      | M   | Traffic accident    | No          | 7    | Yes         | Yes                 | Yes                    | Lung            | Resection of fractured rib | Survival    |
| 6   | Carter et al[^7] | 2011 | 43      | F   | –                   | No          | 5    | –           | No                  | No                     | Lung            | Resection of rib | Survival    |
| 7   | Sata et al[^8]  | 2007 | 50      | M   | Building accident   | No          | 9    | Yes         | Yes                 | Yes                    | Lung, spleen | Repair of flail chest | Survival    |
| 8   | Present         | 2007 | 65      | M   | Fall                | No          | 9    | Yes         | Yes                 | Yes                    | Lung, clavicular, kidney | Resection of fractured rib | Survival    |
| 9   | Present         | 2007 | 76      | M   | Traffic accident    | No          | 10   | Yes         | Yes                 | Yes                    | Lung, clavicular, kidney | Resection of fractured rib | Survival    |

Abbreviations: F, female; M, male.
Conflict of Interest
The authors declare no conflict of interest related to this article.

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