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Comparative studies of different types of osteosynthesis on the human corpse preparation in bilateral antero-lateral flail chest

Sina Grupp[a], Veronika Fürst[b], Thomas Buder[c], Alexander Fichte[b], Sebastian Krinner[a], Roman T. Carbon[b], Friedrich F. Hennig[a], Andreas Langenbach[a], Stefan Schulz-Drost[a,b,*]

[a] University hospital of Erlangen, Department of Orthopedic and Trauma Surgery, Krankenhausstr. 12, 91054 Erlangen, Germany
[b] University hospital of Erlangen, Department of Pediatric Surgery, Krankenhausstr. 12, 91054 Erlangen, Germany
[c] University of Erlangen, Institute of Anatomy I, Krankenhausstr. 12, 91054 Erlangen, Germany

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ABSTRACT

Introduction: Bilateral flail chest injuries are challenging in treatment and comparatively often require an operative stabilization of the anterior chest wall to re-establish normal physiological conditions of the chest wall in shape and statics. Various procedures have been described which are technically sophisticated for the surgeon. Consequently there is an increasing interest in potentials of operative care and their effectiveness on the anterolateral chest wall.
Materials and methods: 12 Human cadavers were prepared and the natural Sternum Position (NP) was marked. A digital probe was fixed to the sternum at the height of the 4th intercostal space in order to measure and compare the stability of the thorax. Readings were taken of the sternal displacement at 1–5 cm sagittal distance from NP in starting conditions and from every combination of materials. Serial osteotomies were performed on 2 locations on ribs 2–8 to induce bilateral flail chest.
Afterwards the stabilization was achieved with different implants:

- Transsternal metalstrut.
- Several combinations of locking plate fixation.

Results: The osteotomies lead to a subsidence of the sternum occurred to almost 75 mm from NP which corresponds to a maximal unstable situation. The unstable chest wall showed substantially more stabilization through the use of locking plates. Our materialcombinations showed a stability of up to 60% of normal. The more ribs were treated osteosynthetically, the higher the stability of the chest wall.
Discussion and conclusions: Locking plate fixation offers anatomically realignment of the ribs whereas metal strut support only lifts up the chest wall, but could not provide realignment of the dislocated ribs.

Introduction

Discussion pertaining to the operative possibilities of rib fractures has intensified in recent years.

There is increasing interest in the operative treatment of flail chest injuries and their effectiveness on the anterolateral chest wall [1].

One must consider, however, the consistent high numbers of high-speed car accidents associated with chest trauma [2–4]. On the other hand, the increase in human lifespan is also relevant to this discussion. A bilateral flail chest leads to a severe instability of the thorax and is associated with high lethality. It is attributed to grade 5 in the internationally used Abbreviated Injury Scale (AIS), which corresponds to a critical injury with a high mortality risk.

A flail chest is diagnosed in cases in which more than three ribs are fractured in at least two places [5], which creates an isolated segment that has lost contact with the rest of the bony chest wall.

* Corresponding author at: University Hospital of Erlangen, Department of Orthopedic and Trauma Surgery, Krankenhausstr. 12, 91054, Erlangen, Germany.
E-mail addresses: sina.grupp@uk-erlangen.de (S. Grupp), v.fuerst@gmx.de (V. Fürst), thomas.buder@fau.de (T. Buder), alexander.fichte@uk-erlangen.de (A. Fichte), sebastian.krinner@uk-erlangen.de (S. Krinner), roman.carbon@uk-erlangen.de (R.T. Carbon), friedrich.hennig@uk-erlangen.de (F.F. Hennig), andreas.langenbach@uk-erlangen.de (A. Langenbach), stefan.schulz-drost@uk-erlangen.de, stefan.schulz-drost@gmx.de (S. Schulz-Drost).

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The degree of instability is primarily dependent on the localization of the rib fractures, the number of rib fractures and the fracture pattern.

In blunt chest traumas, the frequency of flail chest has been reported to range from 6 to 15% and in the case of polytrauma, the frequency can be as high as 33% [6,7]. As the severity of injuries to the bony hemithorax increases, the rate of accompanying injuries also increases.

Patients with anterior instability of the chest, which includes bilateral costochondral separation and a free floating sternum, suffer from a sternum dissociated from the hemithoraces [8].

The risk of respiratory insufficiency increases with proximity to the sternum [9] because the respiratory mechanism is acutely threatened by the presence of this injury, especially when the sternum itself breaks in addition to the ribs [7].

A flail chest with a floating sternum occurs mostly in patients who suffered blunt chest trauma against the anterior chest wall.

Depending on the localization of a bilateral flail chest, it is referred to as it anterior or anterolateral flail chest [10] (Fig. 1).

This type of injury has a significantly higher risk of injury than unilateral anterolateral instability and is therefore also assigned to AIS grade 5.

Rib fractures are associated with an average mortality rate of 12% [11–14]. If more than three ribs are fractured, the mortality rate is estimated to be approximately 30% [3]. If a flail chest occurs, the mortality rate can approach 40% [7,15–18].

Operative therapy

In the literature, the advantage of an operative fixation of rib fractures has been described in cases of persistent pain, misalignment and instability of the chest wall [19–21].

The objectives of operative fixation are the restoration of the integrity of the thoracic wall, alignment of the ribs and the achievement of a stable situation for pulmonary function.

Complications and the duration of the stay in hospital, including age and concomitant injuries, have been significantly reduced via operative fixation [5,22–24].

We focused on the anterior instability of the chest wall caused by a direct impact trauma, such as steering wheel trauma during traffic accidents or after mechanical resuscitation [25,26].

The aim of this work was to clarify which osteosyntheses enabled anatomical reconstruction of the chest wall and restored sufficient stability in anterior and anterolateral locations.

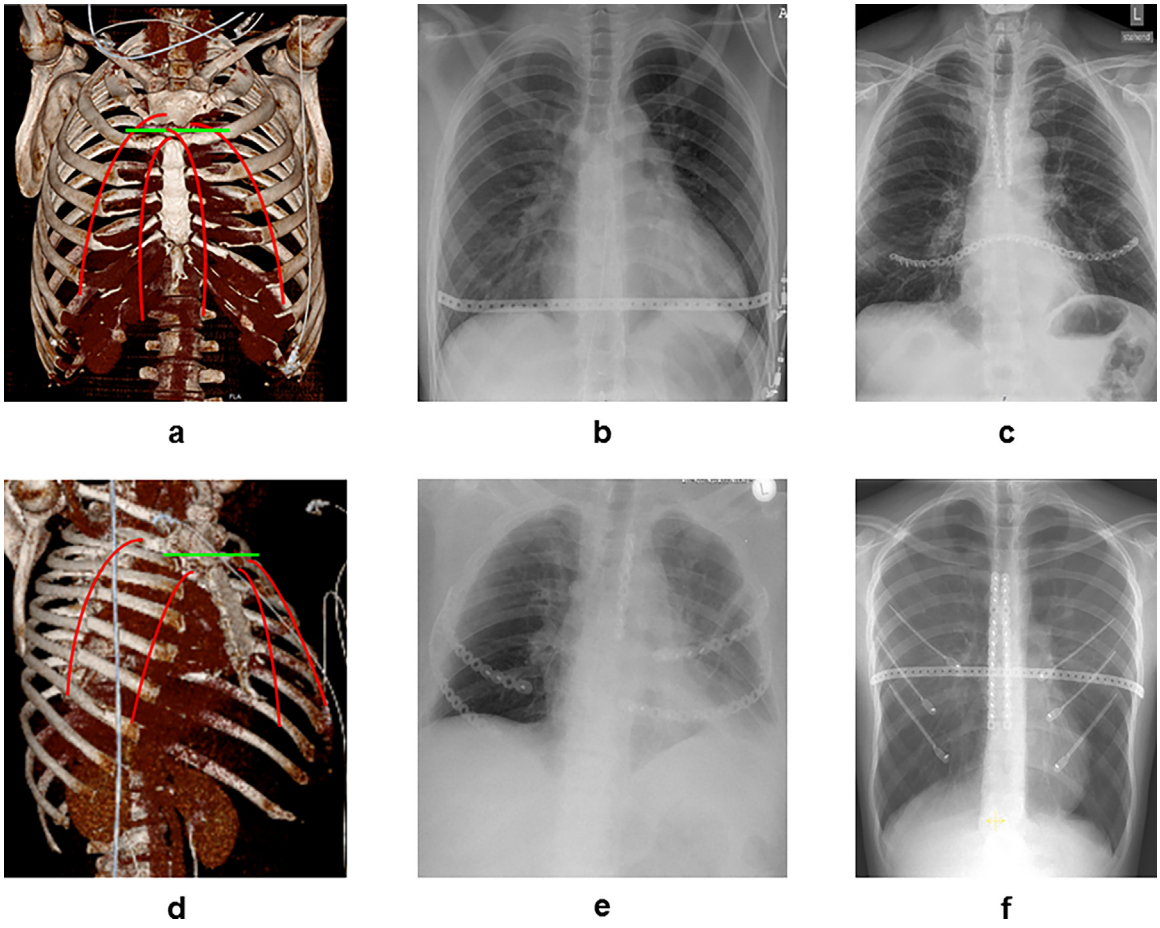

Fig. 1. Clinical examples of anterior FC injuries. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
A Fractures in anterior FC: bilateral fractures nearby the sternum and nearby the osteochondral conjunction (red lines), transverse fracture of the manubrium sterni.
B Stabilization with one transsternal metal bar; typical fixation during the correction of a pectus excavatum.
C ESCR: Sternal fixation and transverse locked plate wich fixes the 5th pair of ribs and the sternal body in patient A.
D Fractures in anterolateral FC: bilateral fractures nearby the osteochondral conjunction and nearby the anterior axillary line (red lines), transverse fracture of the manubrium sterni.
E Sternal fixation and bilateral anterolateral plating in patient D.
F Hybrid fixation of an anterolateral instable chest wall with sternal plating, intramedullary splinting of the 3rd–5th ribs bilaterally and support of the anterior chest wall with a transsternal metal bar; possible fixation also in wide based pectus excavatum.

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