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Surgical Stabilization of Costoclavicular Injuries - A Combination of Flail Chest Injuries and a Clavicula Fracture

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Rezumat

Stabilizarea chirurgicală a leziunilor costoclaviculare - O combinație de leziuni toracice cu volet costal și o fractură claviculară

Date generale: Leziunile cu volet costal (FCI) sunt asociate cu o rată ridicată de morbiditate şi mortalitate. Având în vedere că asocierea unei fracturi de claviculă concomitente cu FCI agravează chiar rezultatul, întrebarea care se pune este cum pot fi aceste leziuni costoclaviculare (CCI) gestionate chirurgical.
Metode: 11 pacienți cu CCI au fost tratați chirurgical prin osteosinteză a claviculei şi a coastelor subiacente prin placă blocată, prin abordări chirurgicale limitate, sub anestezie generală. Pacienții au fost urmăriți la 2, 6, 12, 26 şi 52 de săptămâni.
Rezultate: Toți pacienții au prezentat o deformare severă a peretelui toracic din cauza fracturilor puternic deplasate ale coastelor şi claviculei. Ei sufereau de durere şi de restrângerea mişcărilor respiratorii. Peretele toracic a putut fi restabilit la forma normală în toate cazurile, cu vindecare lipsită de complicații a oaselor şi confort sporit al pacientului. Fracturile claviculei şi celei de-a doua coaste au fost gestionate printr-o abordare inovatoare clavipectorală, iar celelalte prin abordări standard ale peretelui anterolateral şi posterolateral. Doi pacienți s-au plâns de amorțeală în zona intervenției laterale şi de durere periscapulară persistentă.
Concluzii: Stabilizarea chirurgicală ar putea reprezenta terapia adecvată în CCI cu fracturi dislocate, deoarece acestea ar putea cauza deformări severe şi pierderea funcției peretelui toracic şi a umărului.

Cuvinte cheie: leziune costoclaviculară, claviculă, fractură costală, volet costal, cutia toracică, deformarea peretelui toracic

Abstract

Background: Flail chest injuries (FCI) are associated with a high morbidity and mortality rate. As a concomitant clavicle fracture in FCI even worsens the outcome, the question is how can those costoclavicular injuries (CCI) be managed surgically.

Methods: 11 patients with CCI were surgically treated by a locked plate osteosynthesis of the Clavicle and the underlying ribs through limited surgical approaches under general anesthesia. Patients were followed up after 2, 6, 12, 26 and 52 weeks.

Results: All patients showed severe chest wall deformity due to severely displaced fractures of the ribs and the clavicle. They were suffering from pain and restriction of respiratory movements. The chest wall could be restored to normal shape in all cases with uneventful bone healing and a high patient convenience. Fractures of the clavicle and the second rib were managed through an innovative clavipectoral approach, the others through standard approaches to the anterolateral and the posterolateral chest wall. Two patients complained about numbness around the lateral approach and lasting periscapular pain.

Conclusions: Surgical stabilization might be the appropriate therapy in CCI with dislocated fractures since they would cause severe deformity and loss of function of the chest wall and the shoulder.

Key words: costoclavicular injury, clavicle, rib fracture, flail chest, rib plating, chest wall deformity

Introduction

Flail chest injuries are commonly known as severe injuries with a high rate of complications (1,2). A variety of investigations could show the relationship on the one hand to concomitant organ injuries and on the other hand to the number of rib fractures. Several scores had been developed based on these findings with the aim to calculate the risc of morbidity and mortality of Flail Chest injuries (FCI) (3). Best investigated are those injuries in the framework of a polytrauma. Data from the German Trauma Registry DGU® could proof that almost every second severely injured patient (ISS >=16) suffers from relevant rib fractures (AIS >=2) and every 6th patient sustained a FC injury which is associated with a high rate of multiorgan failure (MOF) and mortality (4). Furthermore an additional sternal fracture (SF) in FCI accelerates the due of mechanical ventilation and the risc of concomitant cardiac injuries as well as those of the thoracic spine (5).

However even an additional fracture of the clavicle (CF) has been made responsible to be associated with more severe pattern of injuries in FCI. A Dutch working group investigated a rather large collective and showed a higher risc of lung injuries and chest wall deformities concomitant to an additional CF in FCI (6). The Clavicle therefore had been named as a gatekeeper of the thorax. Vice versa rib fractures seem to be a predictor for a higher risc of a dislocated CF (7).

These findings go alongside our clinical experience that we gained in between the last years: CF in combination with FCI seemed to be associated with more severely displaced rib fractures and gross dislocated CF on the ipsilateral side.

Since these costoclavicular injuries (CCI) represented a severe loss of integrity of the upper quarter of the body and were very challenging in their treatment we followed them up prospectively.

The question which had been arisen for the

last years is, which surgical procedure allows a sufficient treatment of those severe injuries? This manuscript is meant as a critical review to the clinical experience in the treatment of CCI at a Level-I-Trauma center.

Methods

Between Jan 2014 and June 2016 11 patients with CCI were surgical stabilized by addressing the ribs and the clavicle. The patients were prospectively followed up. Those who were treated conservatively were not included into this study. The indication for the operation was set by a senior surgeon and approved by the head of the department.

Preoperatively a detailled proper clinical examination of the patient has been carried out with the focus on thoracic pain, instability of the chest wall and any deformity as well as any impalement of respiratory function. Once a CCI had been detected together with any of the clinical findings a CT scan of the chest in multisliced technique (Siemens Somatom definition AS+, 128 slices, Munich, Germany) had been carried out. The Images were assessed in axial, sagittal and coronal planes as well as in a multi-planed reconstruction in the volume rendering (VRT) mode.

The procedure was carried out under general anesthesia providing the possibility of single lung ventilation. The time of the stabilization of the chest wall was chosen as soon as possible after the trauma in patients under stable conditions whereas the procedure was carried out after the recovering from life threat in the patients who were suffering from a polytrauma (8).

Positioning

A full lateral decubitus position had been chosen for the management of the rib fractures in the first step. The ipsilateral arm was kept mobile on a TRIMANO 3D Support Arm® (MAQUET Holding B.V. & Co. KG, Rastatt, Germany). The clavicle was then treated in a sitting position (modified beach chair) or in a supine position.

Approaches

The posterior approach was established first if the posterior and posterolateral ribs were intended to be managed operatively. The arm has been put in a maximal frontward position to gain up a maximum distance in between the medial margin of the scapula and the spinal processes. After the completion of subcutaneous dissection, the latissimus dorsi, trapezius and rhomboid muscles are detached from their origin at the spinal processes.

To adress the lateral and anterolateral rib fractures, an axillary approach had been established with the arm in a more backward position now. The subcutaneous dissection showed the anterior margin of the latissimus dorsi muscle which had been retracted posteriorly to be preseved. The anterior serratus muscle had been detached from its origin in total to preserve its fibers and the important neurovascular bundle of the long thoracic nerve.

An Alexis Wound retractor (Applied medical, Rancho Santa Margarita, USA) had been inserted thus providing best overview while protecting the rim of the wound from drying out. After the fixation of the ribs the muscles had been reinserted to their anatomical origin with strong filaments (Vicryl® USP 1, Ethicon, Summerville, New Jersey, USA) and the scin had been closed thereafter.

To approach the clavicle a modified clavipectoral approach had been performed by a horizontal skin incision in parallel to the 2nd rib just below the clavicle. Alternatively a longitudinal incision, following the mid-clavicle line, had been carried out. The subcutaneous tissue had been dissected in order to establish a well approach to the major pectoral muscle. After this a muscle sparing approach to the sublaying ribs becomes necessary. It was performed by a blunt dissection in between the muscle bundles what gives you the option for three approaches for the 2nd, 3rd and 4th rib. The neurovascular bundle which includes the supraclavicular nerve had been identified and protected. Once the distinct fracture site had been identified, the minor pectoral muscle had been hold away for the management of the 2nd rib, or it had been

detached from the ribs origin to gain access to the 3rd and 4th rib.

Fixation of the Ribs

Once the approach to the chest wall was made, the fractures of ribs were pinpointed and fixed starting from posterior to lateral and anterior if indicated. A reduction to an anatomic alignment was followed by a locked titanium plate osteosynthesis in a low-profile-design with at least three screws at each main fragment of the ribs (9) (MatrixRib®, 1,5 mm thickness, 2,9 mm screws; DePuySynthes CMF, Oberdorf, Switzerland). Single fractures had been stabilized through an intramedullary splint which had been secured with one locked screw of appropriate length (MatrixRib® splints 3, 4 or 5 mm, 2,9 mm screws, DePuySynthes CMF, Oberdorf, Switzerland).

All ribs showing a dislocated fracture were stabilized. Afterwards the adjacent ribs were checked for their alignment and stability. They were stabilized if it was considered to be necessary (8).

The fixation of the ribs in their anterior aspect had been performed through this approach employing minimal invasive plate osteosynthesis (MIPO) in trokar technique or with the 90 degree drill and screwdriver (10).

Fixation of the Clavicle

After reduction of the fracture, a locked plate was positioned and fixed on the anterosuperior surface of the clavicle with nonlocking screws at the first two holes (Königssee Impantate GmbH, Aschau, Germanyor alternatively De Puy Synthes, Oberdorf, Switzerland) Locking screws were placed at the remaining holes of the plate. Ideally, a minimum of 3 bicortical screws was placed on each side of the fracture to ensure rigid fixation. If additional interfragmentary compression was necessary or possible, lag screws were placed. Finally, fascia and skin were closed in layers.

Follow up

Each patient was followed up immediately after operation as well as after two, six, twelve, 26 and 52 weeks. At each time a clinical examination was carried out with the focus of wound healing and soft tissue, stability and function of the chest wall, the clavicle and the shoulder, regarding pain and other concerns of the patients. Chest X-rays were taken immediately after the operation, as well as after 6 and 12 weeks. They were observed for proper inflation of the lung, pleural effusion and the alignment of the bony chest wall as well as the position of the implants.

Results

In the group, 11 patients (3 female, 27.3%) were included with combinations of rib and clavicle fractures. Epidemiological aspects and the exact distribution of fracture patterns are shown in the *Tables 1* and *2*.

Clavicle

The clavicle showed a midshaft fracture in 9 cases and a fracture of the lateral third in 2 cases. The posterior ribs were fractured in all of the 11 cases, 8 cases showed moderate and severe dislocations, so they were also osteosynthetically treated. In the lateral region of the chest wall, 10 of 11 patients showed fractures with moderate or severe dislocation. Only one patient had no rib fractures in this area (*Table 2*).

Ribs and Deformity of the Chest Wall

Also in the anterior region of the chest wall, 10 patients in the group showed fractures predominantly with the involvement of the cartilaginous rib parts. However, a severe dislocation was observed only in one of the cases, furthermore in 3 of these cases showed undislocated cartilage fractures. All of the patients showed deformity of the affected hemithorax with a descent of the shoulder, dislocated clavicle fracture, and impression of the chest wall in the affected fracture region. In the posterior rib region, interspinoscapular, a high degree of dislocation of the rib fractures led to a dorsal

Table 1. The collective

Case nr.	Gender	Age (Years)	Mechanism of injury	Side	Other injuries	Duration to operative treatment (days)	Hospital stay (days)
1	F	43	Car accident	R	hemopneumothorax	3	11d
2	M	56	Bicycle	L	Scapular fracture left, pneumothorax, lung contusion	6	14d
3	M	47	Bicycle	L	Lung contusion	5	18d
4	M	62	Motorcycle	L	Pneumothorax, lung contusion, olecranon fracture, hand fracture	5	17d
5	M	59	Bicycle	L	Pneumothorax, lung laceration, pneumatocele	2	14d
6	M	63	Car accident	L	Lung contusion, pneumothorax	6	22d
7	F	51	Car driver side collision against bus	L	Lung contusion, laceration, pneumothorax, blunt abdominal injuries, head trauma, pelvic and lumbar spine fracture	10	36d
8	M	71	Fall	L	None	2	7d
9	F	64	Pedestrian vs. car	R	pneumo- and hemothorax, lower leg fracture	7	28d
10	M	55	Surfing crash	R	pneumothorax	10	18d
11	M	72	Fall	L	Lung laceration, pneumothorax, scapular fracture, lung contusion	8	22d
Mean value (min, max, stabw)	8 M 3 F	58,5 (43, 72, 9,2)		3 R 8 L		5,8 (2, 10, 2,8)	18,8 (7, 36, 8,1)

Table 2. The patterns of injury and theri treatment

Case nr.	Location of the fracture of the clavicle	Operative fixation	Fractures at the ribs posterior (eg. I-V)	Displacement*	Operative fixation	Fractures at the ribs lateral (eg. II-IV)	Displacement*	Operative fixation**	Fractures at the ribs anterolateral (eg II-IV)	Displacement*	Operative fixation
1	midshaft	Locked plate	II-V	severe	II-IV	none	--	--	I, II cartilage	none	--
2	midshaft	Locked Plate + screw	I-IV	severe	II-IV	VI	moderate	--	I-III cartilage	none	--
3	midshaft	Locked Plate + screw	II-IX	severe	III-V	V+VI	moderate	V+VI	none	--	--
4	Lateral third	Locked plate + screw	II-VII	severe	III-V	VIII+IX	moderate	--	II-VII	none	--
5	midshaft	Locked plate	II-IX	Severe	II-VI	II-VIII	severe	III-V	II-IV	moderate	II
6	Lateral third	Hook plate	III+IV	none	--	II-VII	severe	III-VI, V+VI**	II-IV	moderate	II+III
7	midshaft	Locked plate	II-XI	severe	III-VI	III-VII	severe	IV-VII	II+III	moderate	II
8	midshaft	Locked plate	II-IV	moderate	III+IV	II-VII	severe	II-V	II-IV	moderate	II
9	midshaft	Locked plate	II-VI	moderate	III+IV	II-VI	severe	III-VI	III-V	moderate	IV
10	midshaft	Locked plate	III-IX	mild	--	II-VII	severe	III-V	II-IV	severe	III+ IV
11	midshaft	Locked plate	II-VII	mild	--	II-VI	severe	II-V	III+IV	moderate	--
Σ	9 midshaft 2 lateral		11		8	10		8	10		6

*Displacement None, mild (< half shaft), moderate ≤ shaft, severe (≥ shaft, shortening, deformity)
** Stabilization with rib splint

deformity, which was clearly visible as a hunch, especially in the case of slimy soft tissues and a narrow paraspinous musculature. Here, the affected patients gave severe pain and a motion disability of the arm. In particular, the sliding function of the scapula over the thoracic wall was restricted.

In the lateral, axillary region, rib fractures predominantly presented due to a painful hunched posture and palpable instability. In the case of a dislocation of the rib fractures, there was an impression of the thoracic wall in the sense of a rib valley, which longitudinally followed the position of the upper arm over the chest wall.

In the anterior region, patients complained of pain at the thoracic wall, especially parasternal in the cartilaginous region of the ribs when the ribs are affected, or in the case of an overlapping, heavily dislocated fracture with an anterior hunch formation of the ribs.

From the day of the accident to the time of the indication for surgery, an average of 5,8 days elapsed (*Table 1*). All of the patients received an X-ray control before the indication for operation has been made. In each of these cases the dislocation of the ribs and the clavicle was markedly increased in comparison with the initial findings.

Results of Operative Care

The follow-up control of the clavicle fractures showed stable plate osteosynthesis in all cases with complete consolidation of the fractures in the anatomical position. No pseudoarthrosis and no material failure were observed.

In four of the 11 cases, the deformed second rib has been stabilized through a clavipectoral approach in combination with the osteosynthesis of the clavicle.

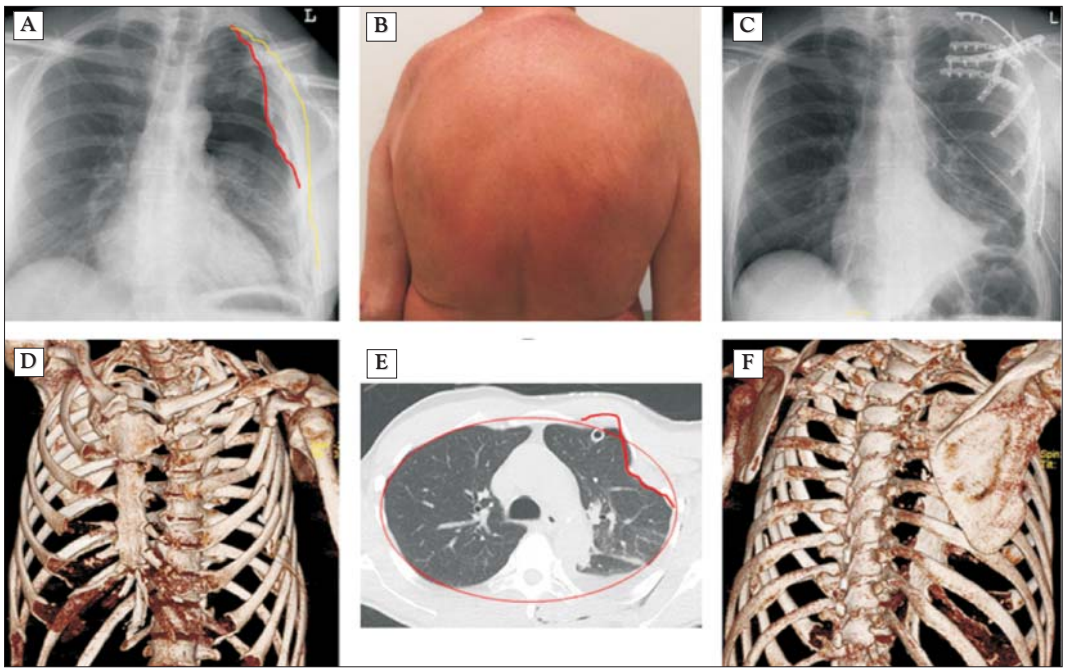

Figure 1. Costo-Clavicular-Injury on the left side with severe dislocation (Case 5). **(A)** severe impression of the left chest wall (medial line) in comparison to the anatomic level (lateral line). The clavicle shows gross dislocation with descensus of the shoulder; **(B)** clinical view from the back: severe descensus and deformity of the left shoulder; **(C)** postoperative result. The anatomy had been restored completely through locked plates at the posterior and anterolateral chest wall as well as at the clavicle and the second rib; **(D)** the CT Scan shows the deformity in its VRT reconstruction; **(E)** the ribs are deeply impressed anterolateral and a protrusion with rib buckle of the anterior rib results consecutively; **(F)** the VRT view from the back shows the posterior fractures II-VI on the left side.

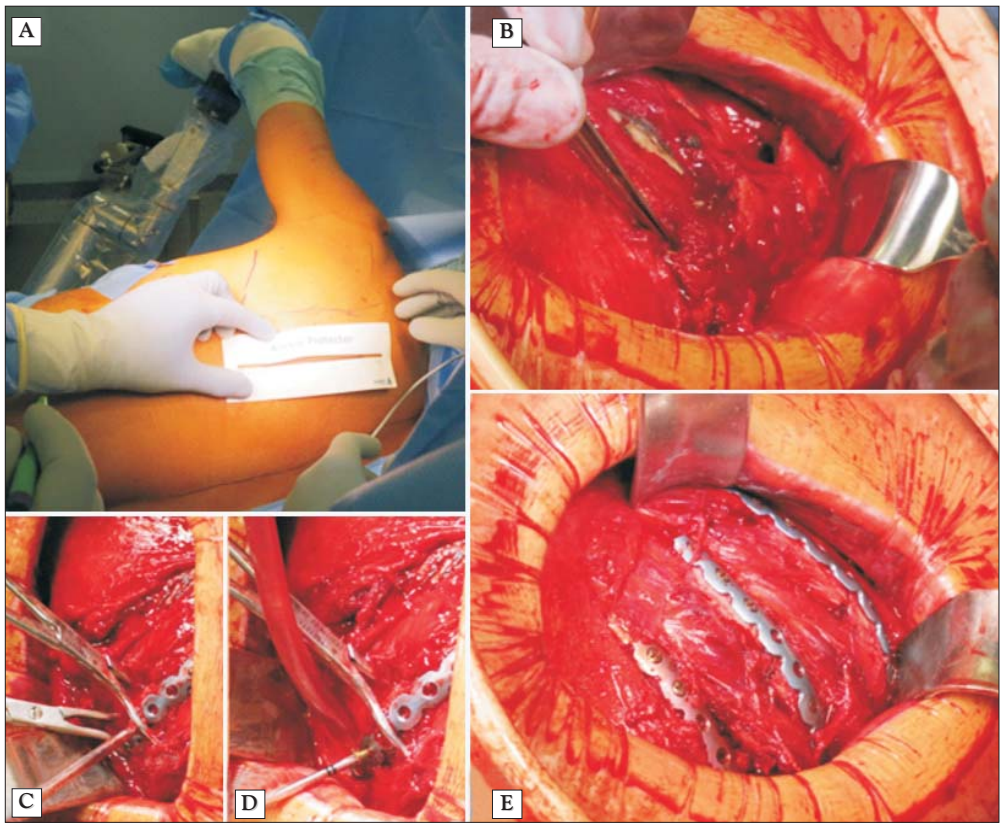

Figure 2. The posterior (interspinoscapular) approach (Case 5). **(A)** The posterior region of the chest wall was reached through an interspinoscapular incision between the margo medialis of the scapula and the processus spinosus of the thoracic spine, having the rib in the center of the injured region. The arm had been put in a forward position to gain up the access to the posterior chest wall in between the scapula and the spine as much as possible. **(B)** The trapezius and rhomboid muscles were detached from the spinal processes. This means to dissect the tissue subcutaneously until the muscle's root can be identified to keep the muscle completely when detaching it.Once done, the fractures of the posterior chest wall are accessible without any problems. **(C)** The fractures are reducted with special forceps and aligned to an anatomic prebended plate. The wholes are drilled through a 90° drill guide. **(D)** A locked screw with threaded head is inserted. **(E)** the initial dislocation and deformity of the posterior ribs had been properly reduced and fixed by locked plates.

The continuous follow-up showed a regular plate position with regular consolidation of the ribs without remaining deformity. Accompanying nerve or vascular damage were not observed.

In three further cases an anterior fixation of the rib fractures III and IV was performed via the axillary approach in combination with minimally invasive fixation of the anterior rib portion using trokar-technique (minimally invasive plate osteosynthesis - MIPO) (11). A total of eight patients were treated with lateral axillary access to the rib fractures. The center of instability with fixation of all dislocating fractures was addressed, non-dislocating peripheral fractures were treated conservatively. The follow-up examinations showed a regular healing, regular material position and no remaining dislocation of the ribs. Muscular insufficiency and neurovascular damage were also not observed. In 3 of 11 cases, the patients described a low numbness around the OP-scar.

Posterior access was provided to 8 of the 11 cases with dislocated rib fractures. Here, too, the deformity was adequately treated in all cases. A material dislocation did not occur, nor did neuromuscular insufficiency, so that all patients showed a regular scapula function.

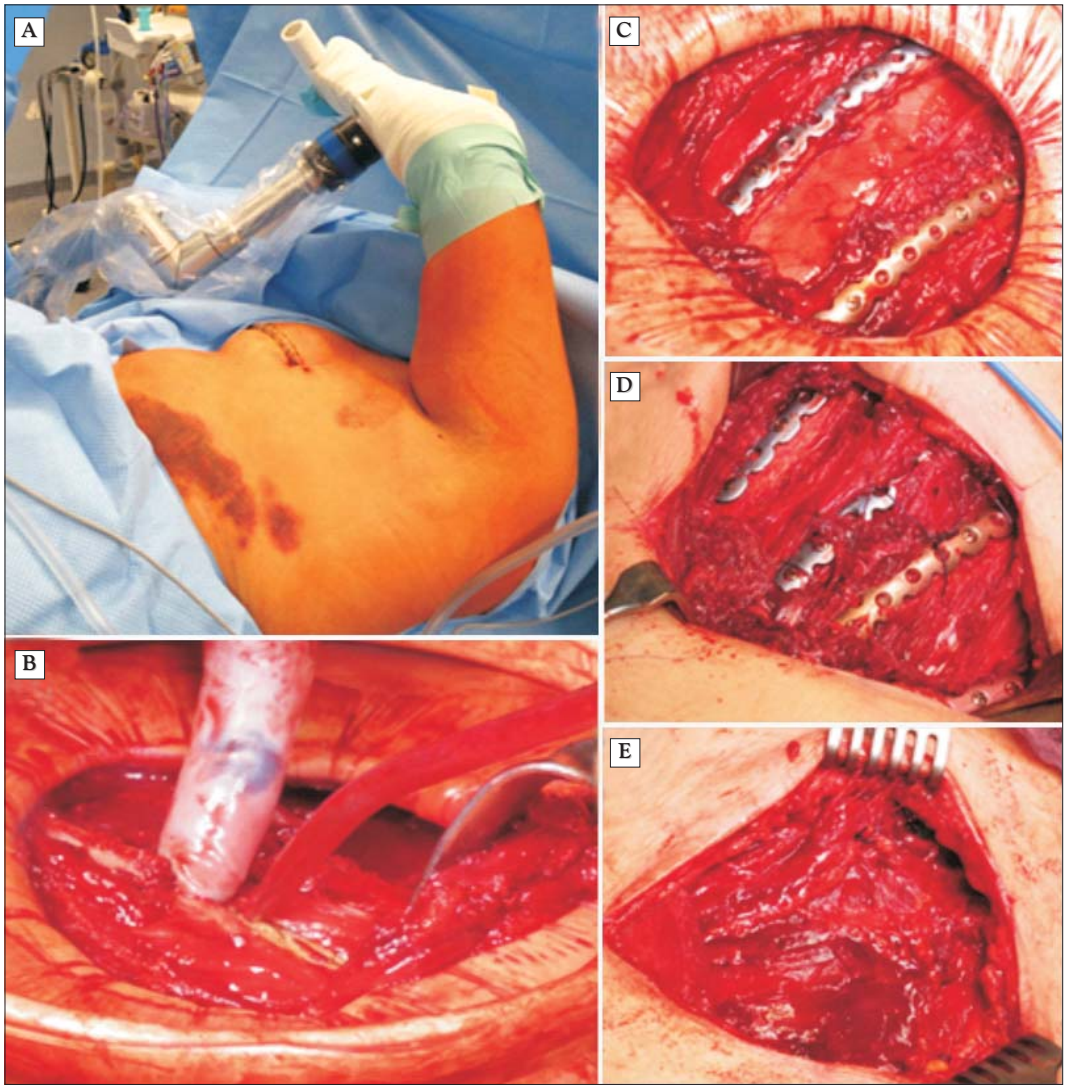

Figure 3. The lateral (axillary) approach (Case 5). **(A)** The lower rim of the major pectoral muscle, the anterior rim of the latissimus dorsi muscle and the level of ribs intended to treat are identified as anatomic lan marks. The arm is moved into a backward position to have the scapula posterior as well and thus a free access to the lateral chest wall. The arm is kept mobile through TRIMANO® 3D Support Arm. **(B)** After preparation through skin and subcutaneous tissue the anterior edge of the serratus anterior muscle needs to be identified. The major pectoral muscle was moved cranially for this procedure. Then, subsequently the serratus muscle was detached from the chest wall preserving its continuity and furthermore respecting anatomical layers. Following this procedure, the long thoracic nerve and its adjacent vessels are preserved in an easy and secure way. **(C)** The ribs are fixed by locked plates once any intrathoracic pathology had been managed. **(D)** the thoracotomy has been closed with strong sutures. **(E)** One of the key steps in muscle sparing approaches is to put the muscles in their anatomic position again. In this case, serratus anterior muscle had been fixed with sutures to his origin.

Miscellaneous

Soft tissue

The Op wounds healed completely in all patients and showed complete wound closure already after 14 days. In 3 out of 11 cases, a regional numbness remained below the scar on the axillary approach. Neuromuscular insufficiency did not occur.

Pain

In 2 out of 11 cases, a painful restriction of the movement of the shoulder has occurred; here patients complain of convulsive muscle pain at

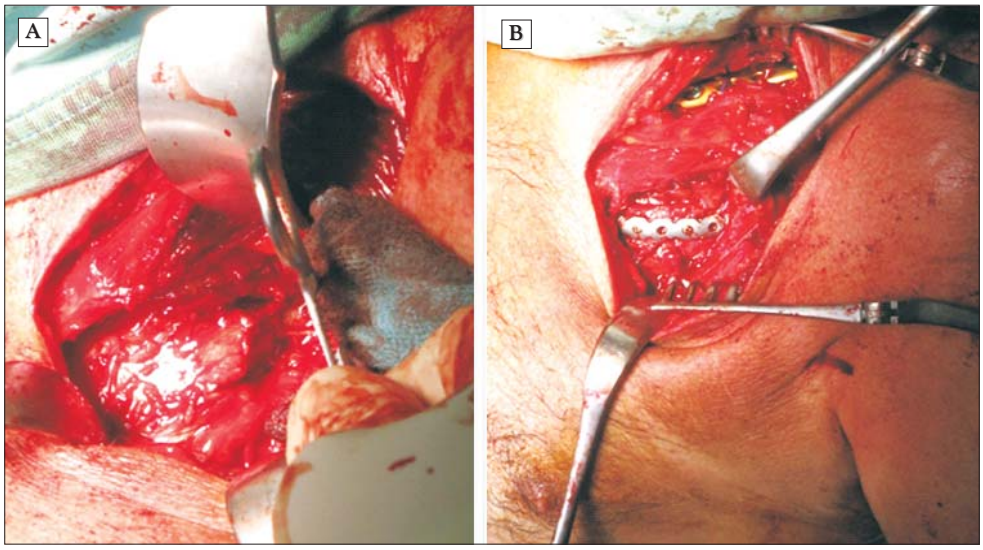

Figure 4. The clavipectoral approach (case 8). **(A)** The split in between the bundles of the major pectoral muscle shows the dislocated fractures of the second rib on the left side. The minor pectoral muscle is hold away by the hook (bottom of the figure). **(B)** The clavicle and the second rib had been fixed with a locked plate through a combined approach clavipectoral.

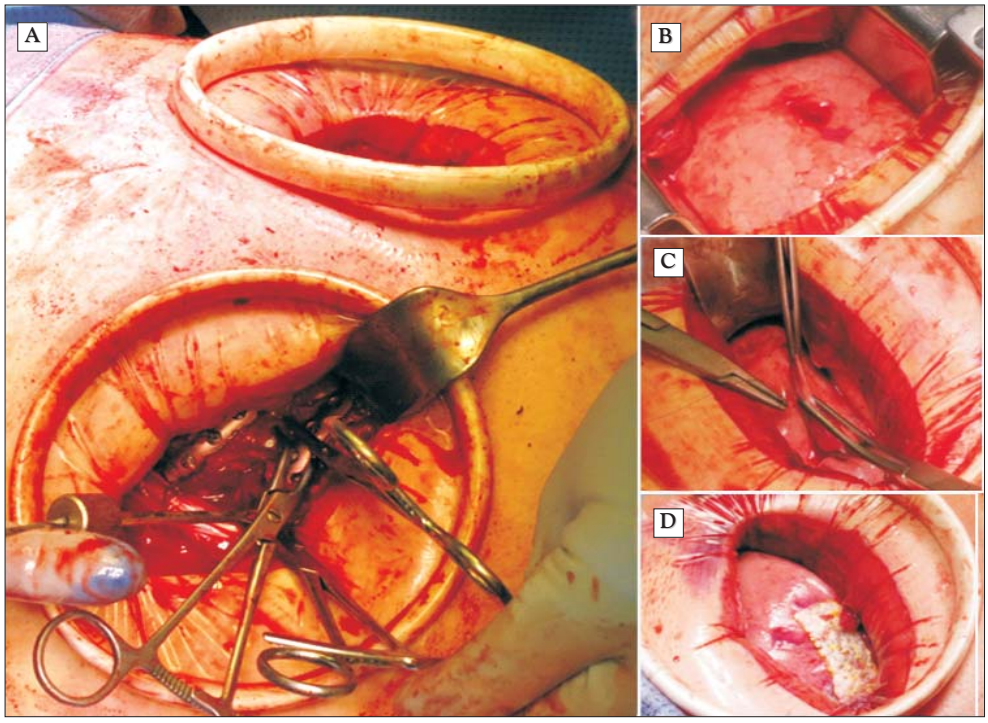

Figure 5. Chances of the minimal approaches. **(A)** The combination of two or more limited incisions gives access to the posterior (lower approach) and the lateral (upper approach) region of the chest wall for example. Alexis® Retractor offers optimal opening of the approach and prevents the soft tissue from bleeding and drying out. **(B)** Limited incisions allow to adress concomitant organ injuries such as lung lacerations which usually appear in relationship to dislocated rib fractures. **(C)** lacerations can be managed by a running suture for example. **(D)** minor lacerations can be managed by sealing (Tachosil®, Takeda Pharma, Berlin, Germany)

elevation of the shoulder over 90°. Both patients reported complaints infraclavicular and posterolateral around the scapula. The soft parts around the clavicle healed without complications in all cases.

Except for these two patients, no patients need pain relieving medication after the 12th week.

All patients of the inclusion group showed a regular respiratory function during the follow-up, in particular a regular mobility of the chest wall without any paralysis of the thoracic wall or its parts.

Discussion

CCI as a New Entity of Injury

The present group of patients describes a combination of lesions of which each have been well investigated. Both of them, the clavicle as well as the ribs, are described in detail in the literature according to their injuries and treatment options. However, the aspect of the combined occurrence of unstable chest wall injuries and ipsilateral clavicular fracture appears interesting. Looking at the fracture patterns listed and observed here, it is noticeable that the upper quadrant of the thorax is predominantly affected. The intrinsic stability of the thoracic wall is almost exclusively achieved by the ribs starting from posterior to the vertebral column and ending into the sternum in an arcuate direction, as well as their intercostal soft tissue composites. They provide protection function for the thoracic internal organs and enable the breathing

The thoracic wall is covered by the shoulder-arm complex, dominated by the scapula and its leading muscles. This almost encompasses the entire upper thoracic wall in the anterior part by the major pectoral muscles leading to the upper arm, underneath the scapula the minor pectoral and the anterior serratus muscles in the anterolateral region. The rhomboid, trapezius and latissimus muscles connect the scapula and the spine posteriorly (12). From a biomechanical point of view, therefore, it is interesting in fractures of this region which parts lose their stability and which ones still offer sufficient resistance. If there is an isolated fracture of the clavicle, multiple fragments of the fracture are also attributed to the risk of a remaining deformity and shortening caused by the tensile forces of the shoulder muscles.

In the overwhelming majority of cases, however, a very good chance of healing can be expected without a substantial malposition under conservative therapy (13). In the current discussion of traumatology, the operative therapy is attributed an advantage with regard to the minimization of a pseudoarthrosis formation, which in turn can already be regarded as an indicator of high stress on the clavicle by muscle pull (14).

In the opposite case, rib fractures or rib fractures series often do not have any significant consequences if the statics of the hemithorax remains intact. Unstable rib fractures, on the other hand, may lead to complications, as well as clinically strongly dislocated fracture patterns. If, however, the ipsilateral clavicle and therefore the shoulder belt remains intact, it is often possible to observe the same moderate dislocations or even a decrease of them in different fracture constellations, which is probably due to muscular tension. On the contrary, the unstable segmental fractures can be drawn by muscle pull into an increasing misalignment, which then entails complications.

From these points of view, it is very clear that clavicle fractures can experience a far greater dislocation when the underlying supporting chest wall itself loses its stability and is impressed. Conversely, the defective unstable chest wall is also pulled into a stronger deformity by the pressure of the descending shoulder under muscle pull. From these points of view a spontaneous correction of the deformity cannot be expected from a logical point of view. Thus, when the combination injury occurs, the patient should be told about the possibility of an operative treatment of the ribs and the clavicle.

Considerations for the Operative Treatment

Mainly four regions of the hemithorax need to be considered in the operative care. On the one hand, the clavicle itself and, in close proximity,

the anterolateral portions of the second and, if appropriate, third rib, which can be ideally managed through a combined clavipectoral approach in a very innovative method. The stability of the thoracic wall itself will be very easy to manage via limited muscle-conserving approaches following a surgical standard (8). Thus a posterior, interspinoscapular approach is established over the center of the rib-fracture series, laterally located fractures can be achieved well via an axillary access also in muscle-saving technique. The anterior fractures are supplied according to their severity and extent. Thus the 3rd - 7th rib can be achieved excellently from the axillary approach via the described minimal invasive method, for example on order to fix a plate with screws. In the case of serial gross dislocating fractures or a concomitant sternum fracture, the establishment of another median anterior approach should be considered. However, this was not required in this collective. The median anterior approach would typically be performed in a supine position of the patient or a modified beach-chair positioning, as it is also employed in the stabilization of the clavicle. In opposite, the posterolateral, lateral and anterolateral ribs are best treated in a lateral decubitus position with a mobile and steril drapped ipsilateral arm (15,16).

Benefit of Patients

In severe dislocated rib fractures, significantly restrictive deformities of the thoracic wall were observed in the present group, thus disruptive rib hunches in the posterior region, which restricted the mobility of the scapula, and in the anterior region likewise rib hunches next to the sternum which had a painful and cosmetically unfavorable effect (17). The lateral depression of the ribs, on the other hand, was clinically more difficult to visualize, since here a very powerful muscular and soft tissue covering of the region naturally exists. However, these patients often complained about pain.

Of course, in this context the risk of a vascular nerve muscular lesion or even a numbness of the skin needs to be balanced over a remaining and painful deformity of the ribs.

From this consideration, the indication for surgery has been made restricted. Only grossly dislocating fractures were a primarily indication for operation (18). However once the decision for an operative procedure has been made, the moderately dislodging fractures were stabilized as well, if necessary, in order to restore sufficient stability of the whole hemithorax, in the case of FCI.

All patients in the group complained of severe physical limitations and pain before surgery. They all reported a significant improvement in the symptoms after surgery (19). In only three cases were there superficial numbness feelings on the skin, but no neurovascular restrictions or even muscular insufficiency had been seen. Whether the remaining painful conditions that have occurred in a few cases can be interpreted as a postoperative episode, or as a trauma-related one, can be difficult to differentiate since all patients also had considerable pain before the operation. In any case, a regular breathing mechanism and breathing performance could be achieved again in these cases.

To summarize, CCI are serious injuries to the upper hemithorax. They significantly affect the statics of the thorax wall and the shoulder girdle and can result in remaining malposition and dysfunction. This case series is therefore intended to draw attention to unstable fracture combinations of the clavicle and the ribs, and to examine patients for existing deformities and their symptoms. If there is a dislocation of the upper hemithorax with marked dislocation, an operative care should be considered, for example following the procedure shown in this manuscript. The overwhelming majority of the described collective showed very good postoperative results and a high quality of life (20,21).

Conclusions

CCI describe a severe injury to the hemithorax with the risk of remaining deformities of the shoulder girdle and the adjacent chest wall. If, on the other hand, CCI are detected in the course of clinical and radiological diagnostics in a timely manner and their severity is correctly assessed, they can be successfully managed by a locked

plate osteosynthesis through muscle-sparing surgical approaches. Concomitant intrathoracic injuries can also be treated as part of this procedure.

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Conflicts of Interest

The senior author has a consultant agreement with DePuySynthes and he is an advisory member of the AO TK Thoracic Surgery Expert Group (THEG).

Ethical Policies

This is a retrospective cohort study. No experiments on humans or animals had been done.

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