CIRUGÍA ESPAÑOLA

www.elsevier.es/cirugia

Original article

Surgical fixation of rib fractures with clips and titanium bars (STRATOS™ System). Preliminary experience

Pablo Moreno De La Santa Barajas,[a,] María Dolores Polo Otero,[a] Carlos Delgado Sánchez-Gracián,[b] Manuel Lozano Gómez,[c] Alberto Toscano Novella,[c] Julia Calatayud Moscoso Del Prado,[b] Sonsoles Leal Ruiloba,[d] and Maria L. Choren Durán[e]*

[a]*Servicio de Cirugía Torácica, Hospital POVISA, Vigo, Spain*
[b]*Servicio de Radiología, Hospital POVISA, Vigo, Spain*
[c]*Servicio de Cirugía General, Hospital POVISA, Vigo, Spain*
[d]*Servicio de Anestesia y Reanimación, Hospital POVISA, Vigo, Spain*
[e]*Unidad de Codificación Diagnóstica, Hospital POVISA, Vigo, Spain*

ARTICLE INFORMATION

Article history:
Received May 6, 2010
Accepted June 10, 2010

Keywords:
Titanium bars and clips
Rib fractures
Internal fixation

ABSTRACT

Introduction: Rib fractures are very common in closed chest injuries. The majority of these patients suffer significant pain with movement and cough.
The purpose of this study is to assess the usefulness of titanium rib bars and clips in stabilising rib fractures.
Material and methods: Twenty-two patients with rib fractures were treated with open reduction and internal fixation between 2008 and 2009. Indications for treatment were defined as; 1) Patients with unstable chest (13 patients), 2) Patients with pain or instability due to rib fractures (6 patients), and 3) Significant traumatic deformities of the chest wall (3 patients). Age, traumatic mechanism, chest and associated injuries, surgical data, complications and follow-up were prospectively analysed. The surgical technique is described.
Results: The majority of patients were extubated immediately after surgery. All patients with pain or instability showed a subjective improvement or disappearance of pain after the surgery. Four patients had a wound infection which had to be drained. After 3 months, 55% of the patients had returned to work or normal life. The results in each group are described.
Conclusions: Open reduction with internal fixation of rib fractures is a good alternative. The use of titanium rib bars and clips give good clinical results, are easy to apply and have few complications..

*Corresponding author.
E-mail address: pmoreno@povisa.es (P. Moreno De La Santa Barajas).

Fijación quirúrgica de las fracturas costales con grapas y barras de titanio (sistema STRATOS). Experiencia preliminar

Palabras clave:
Grapas y barras de titanio
Fracturas costales
Fijación interna

RESUMEN

Introducción: Las fracturas costales son muy frecuentes en los traumatismos torácicos cerrados. La mayoría de estos pacientes tienen un dolor importante con los movimientos y con la tos. El objetivo de este estudio es valorar la utilidad de las grapas costales y barras de titanio en la estabilización de las fracturas costales.

Material y métodos: Entre los años 2008 y 2009, veintidós pacientes con fracturas costales fueron tratados con reducción abierta y fijación interna. Se definen las indicaciones para el tratamiento: 1) Pacientes con el tórax inestable (13 pacientes); 2) pacientes con dolor o inestabilidad por fracturas costales (6 pacientes); 3) deformidades traumáticas importantes de la pared torácica (3 pacientes). Los datos se analizaron de forma prospectiva. Se analizaron: edad, mecanismo traumático, lesiones torácicas y asociadas, datos intraoperatorios, complicaciones y seguimiento. Se describe la técnica quirúrgica.

Resultados: La mayoría de los pacientes fueron extubados en el postoperatorio inmediato. Todos los pacientes con dolor o inestabilidad mostraron mejoría subjetiva o desaparición del dolor tras la cirugía. Cuatro pacientes presentaron infección de la herida que tuvo que ser drenada. Después de 3 meses el 55% de los pacientes había vuelto a su trabajo o a su vida habitual, y a los 6 meses el 91%. Se describen los resultados en cada grupo.

Conclusiones: La reducción abierta con fijación interna de las fracturas costales, en un grupo seleccionado de pacientes, es una buena alternativa. La utilización de grapas costales y barras de titanio produce buenos resultados clínicos, su aplicación es fácil y tiene escasas complicaciones.

Introduction

Rib fractures are very commonly associated with chest trauma.[1] Mortality and morbidity increase according to the number of rib fractures and the age of the patients.[2,3] Most of these patients have significant pain with movement and coughing. After 30 days of trauma almost all patients still require analgesics, and work days or normal activity lost reaches 70 days on average.[4] Patients with more severe chest wall injuries, such as flail or unstable chest, may suffer permanent disability.[5]

Surgical fixation of rib fractures, especially with unstable chest, has gained popularity in the last 15 years. Several papers have shown that surgical stabilisation should be considered in the treatment of unstable chest as it decreases hospital stay and complications.[6,7] Surgical stabilisation of rib fractures as a treatment for acute pain or post-traumatic non-union has also been described.[8-10] Surgical stabilisation of rib fractures can reduce pain and decrease the use of mechanical ventilation in selected patients. Rib plates and clips are not recent innovations,[11] but the use of titanium in their construction is. Titanium has been used in different types of prosthetics (dental, wrists, etc.) with good results. This article details our initial experience with titanium plates and clips to stabilise fractured ribs.

Material and method

From January 2008 to December 2009, 22 patients underwent surgical reduction and internal fixation of rib fractures using titanium bars and clips from STRATOS (Strasbourg Thoracic Osteosyntheses System, MedXpert, Heitersheim, Germany).

The selection criteria used for rib fracture stabilisation was as follows:

1) Patients with unstable chest who could not be removed from mechanical ventilation and who, in the chest surgeon's opinion, would benefit from the stabilisation of the chest wall, once the alternatives were explained to the family and informed consent was given. The ideal candidate is a patient with few extrathoracic injuries who can clearly not be disconnected from the ventilator after 5 to 7 days due to chest wall incompetence. After this period, the patient is ventilated with a support pressure of less than 5 cm, checking that the unstable chest continues. If the unstable segment is still prominent, the patient is a potential candidate for stabilisation. Also included in this group were unstable chest patients requiring non-invasive ventilation support. Patients with severe concomitant injuries requiring mechanical ventilation (head trauma, severe pulmonary contusion, or acute respiratory distress syndrome) were not considered as candidates for chest wall stabilisation.
2) Patients in significant pain due to movement of the rib fractures were offered the surgical option, explaining that the procedure for controlling pain and disability is not considered as a routine treatment. The ideal patient in this category should have minimum extrathoracic injuries and have spent at least 7 days without pain control with conventional analgesics (epidural analgesia, oral or intravenous analgesia). Alternatively, it may be a patient

discharged with oral analgesic treatment which has failed to control the pain after at least 1 month.

3) Those patients with significant traumatic defects or deformities of the chest wall, where repair is considered useful to improve stability.

A database was compiled prospectively of preoperative, intraoperative, and follow-up data. Three-dimensional computed tomography (CT) was used whenever possible to better assess all rib fractures and the extent of their displacement in order to plan the best surgical approach.

Our surgical technique for rib fracture fixation is performed with endotracheal intubation. The position of the patient depends on the location of the fracture: supine for anterior fractures and lateral decubitus for the middle third and posterior fractures. Incision of the skin and subcutaneous tissue is performed in the central area of the injury. The fracture is exposed by avoiding muscle section, where possible, to reduce postoperative morbidity. Exploratory thoracoscopy is also used in cases of suspected intrapleural injury. The fractures are exposed by dissecting the least amount of surrounding tissue as possible. The periosteum is elevated only in the areas of the fracture to facilitate their reduction and identify the intercostal neurovascular bundle. Once all the fractures are identified and reduced (Figure 1a), the decision to use either clips or clips and a stabiliser bar is made, depending on the fracture size and position. The two clip sizes can be used depending on the fracture length. For fitting, the anatomical curve is chosen for the injury site, and the teeth of the clips are placed around the rib perimeter using the specific instruments, while identifying and protecting the intercostal pedicle at all times to avoid trapping (Figure 1b). In most cases it is not necessary to open the pleura and the entire surgery is performed extrapleurally. Once the rib fractures are fixed and the stability of the wall checked, it is closed in layers by placing a subcutaneous drain to prevent seroma formation, particularly in fractures of the posterior rib arcs. In very unstable ribs or ribs with multiple fractures, the bar and clip system is used. Having identified the rib fractures and reduced them as explained above, the clips are hooked onto the bar. The distance is measured and the bar cut to the exact size and attached to the clips at the ends. It is sometimes necessary to place a support clip in the centre of the bar to improve its stability (Figure 2). All patients were given intravenous antibiotics until the drain was removed.

Demographic data were recorded for all patients, as well as the injury severity score (ISS), abbreviated injury scale (AIS), the number of broken ribs and the number of fractures. Also, the cause of the injury and the time from injury to surgery were recorded. The length of stay in hospital and the ICU were measured. The surgical data recorded were: duration of surgery, the number of ribs stabilised and the number of patients requiring blood transfusion. Postoperative complications were also recorded. Follow-up was performed in all patients at least until discharge. Chest CT and control spirometry were performed after 3 months to assess evolution (Table 1).

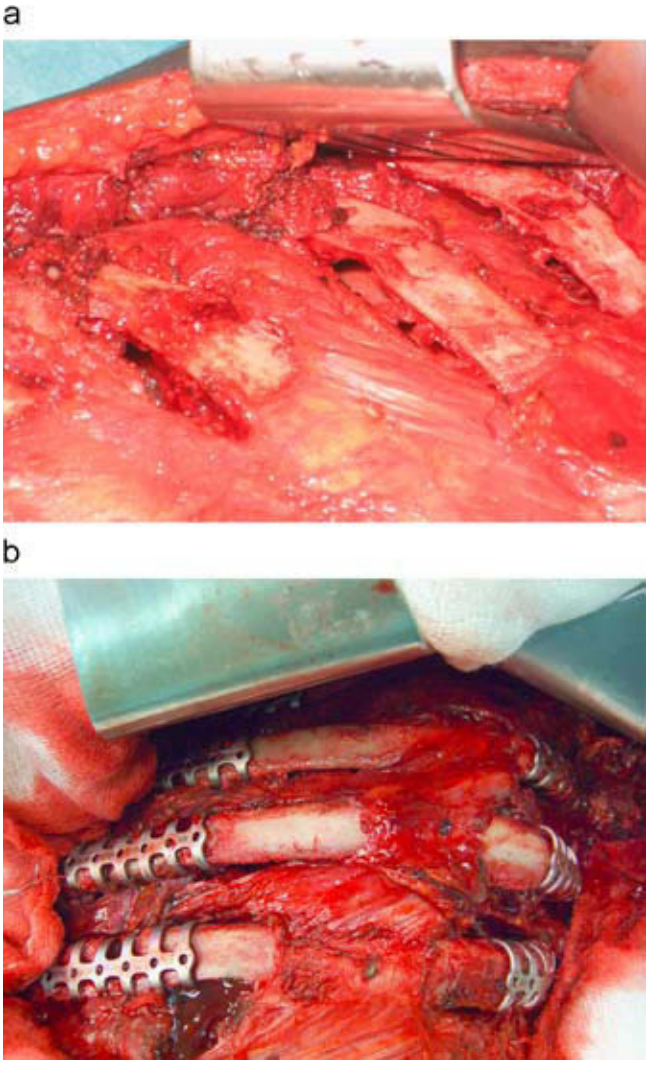

Figure 1 – a) Open reduction of fractured ribs; b) internal fixation of rib cage with titanium clips.

Figure 2 – Internal fixation of rib cage with titanium bars.

Table 1 – Range in brackets

	Total	Unstable chest	Pain/Instability	Chest wall deformity
No. of patients	22	13	6	3
Age, years	53 (31-76)	57 (31-76)	49 (39-63)	44 (33-62)
Sex, M:F	18:4	10:3	6:0	2:1
ISS	20 (9-34)	22 (12-34)	17 (9-24)	18 (9-29)
No. patients AIS≥3	5	4	1	0
Rib cage fractures	19 (4-17)	10 (4-17)	3 (2-4)	11 (9-13)
Fractured ribs	6 (2-12)	7 (4-12)	3 (2-4)	8 (7-9)
Cause of injury				
Motor vehicle	9	7	0	2
Fall	9	5	3	1
Crushing	3	0	3	0
Running-over	1	1	0	0
Surgery delay, days	67 (1-260)	12 (2-28)	188 (81-260)	6 (1-11)
ICU stay				
Total	7 (0-54)	13 (0-54)	0	1 (0-3)
Preoperative period	3 (0-12)	5 (0-12)	0	1 (0-3)
Postoperative period	0 (0-4)	1 (0-4)	0	0 (0-1)
No. patients on mec. ventilation	6	6	0	0
Days mec. ventilation Preop	3 (0-17)	4 (0-17)	0	0
Days mec. ventilation Postop	0 (0-7)	1 (0-7)	0	0
Hospital stay				
Hospitalisation, days	25 (4-76)	36 (11-76)	8 (4-10)	20 (9-27)
Surgery				
Mean surgical time, minutes	223	229	174	260
No. ribs stabilised	5 (2-13)	6 (3-13)	3 (2-4)	5 (5-6)
No. patient transfusions	5	3	1	1
Complications				
Pneumonia	1	1	0	0
Wound seroma	4	3	0	1
Follow-up				
%FVC 3 months	82% (61-104)	84% (61-104)	78% (64-89)	82% (78-88)
$\%FEV_1$ 3 months	81% (59-104)	82% (59-104)	77% (59-87)	86% (79-95)
Return to work average, days	108	74	151	138
Return to work 3 m	12	7	4	1
Return to work 6 m	20	12	5	3

AIS indicates Abbreviated Injury Scale; F, female; ISS, Injury Severity Score; M, male; mec. ventilation: mechanical ventilation.

Results

In 22 patients (18 men and 4 women) with a mean age of 53 years and an average ISS of 20, rib fracture stabilisation was performed using titanium clips and bars. The causes of the injury included: motor vehicle accidents (n=9), fall from height (n=9), crushing (n=3) and running-over (n=1). No patient showed any allergy to titanium or infection due to the clips. No plate needed to be removed due to pain or rejection.

Unstable chest

Thirteen patients with a mean age of 56 years and an average ISS of 22 underwent chest wall stabilisation on average 12 days after the trauma. Three patients had significant associated extrathoracic injuries (AIS=3). Two patients had a pulmonary contusion which was resolved prior to surgery. No patient had brain damage. Five patients were intubated on admission with extubation attempts failing before surgery. Three patients with severe facial trauma underwent tracheotomy preoperatively. Extubation was successful in all patients: on average, 4 days after surgery, with 8 patients extubated immediately after surgery. One patient was fitted with a pacemaker after episodes of bradycardia during the postoperative period, extubation was not possible after 23 days and the patient underwent tracheotomy. Chest CT was used to decide the approach to surgery and follow-up (Figure 3).

There were no intraoperative complications. No patient required a blood transfusion during the postoperative period. Three patients had a wound seroma requiring drainage, before placing a routine subcutaneous drain. One patient had

postoperative pneumonia that required prolonged mechanical ventilation. Follow-up for all patients was performed to an average of 10 months. Lung function was normal in all cases during follow-up. Eleven patients returned to work or normal activity during the first 6 months of the monitoring period.

Painful and unstable fractures

Six patients, with an average age of 49 years and an average ISS of 17 underwent chest wall stabilisation on average 6.2 months after the trauma. All patients were referred from other institutions with chronic pain that increased with movement and a chest CT showing displacement or lack of consolidation of the rib fractures (Figure 4). Patients were referred to the outpatient department to assess the possibility of surgical treatment with the intention of relieving the pain and stabilising the chest wall. At the time of surgery, no patient had other injuries or extrathoracic sequelae. Only those fractures that were not consolidated were stabilised, with an average of 3 ribs, using clips in all cases. The average hospital stay was 8 days. One patient had a neurogenic tumour in the posterior mediastinum which was resected by VATS (Video-Assisted Thoracic Surgery). No patient had intraoperative or postoperative complications.

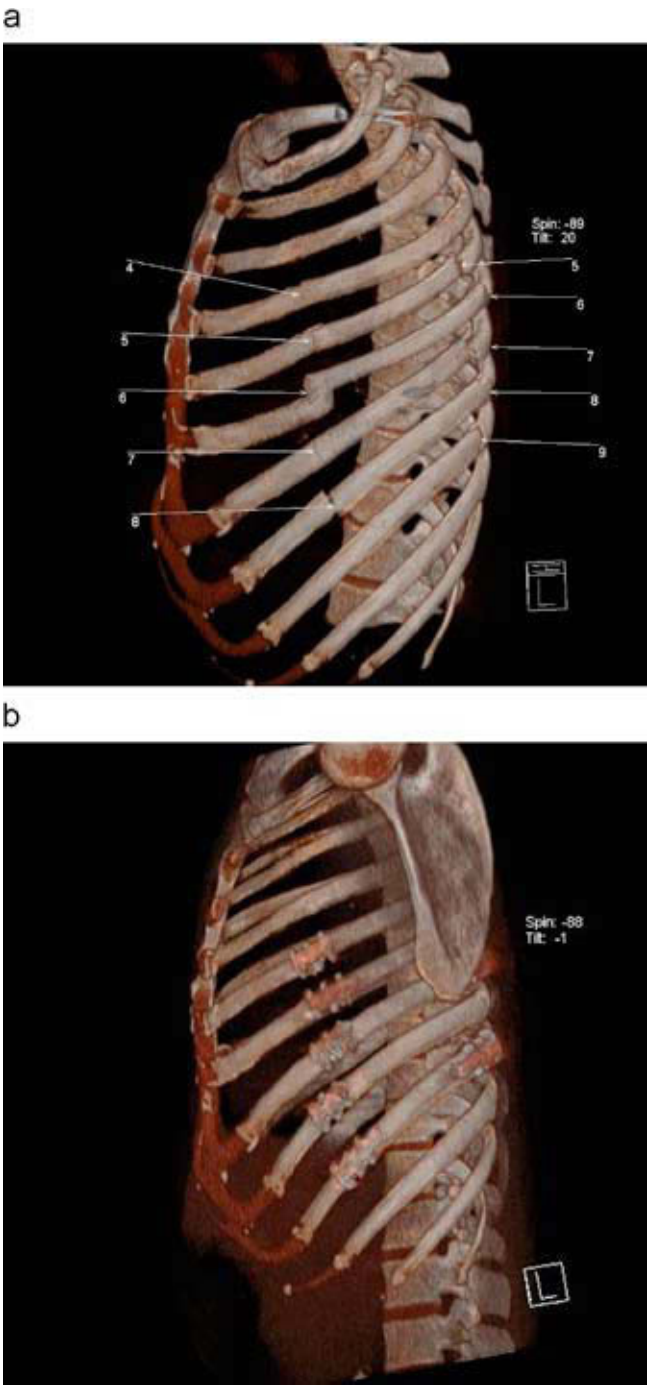

Figure 3 – Unstable chest: a) chest CT–preoperative study; b) chest CT–postoperative study.

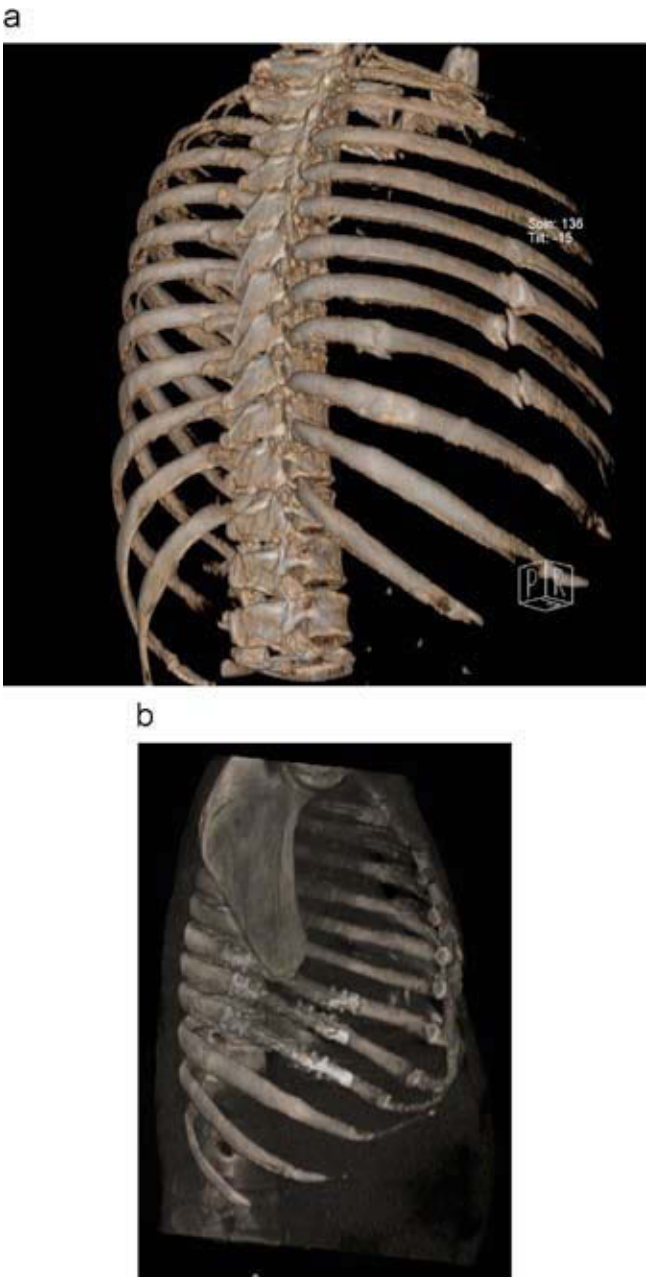

Figure 4 – Chest pain: a) chest CT–preoperative study; b) chest CT–postoperative study.

All patients improved after surgery, such that after 21 days no analgesia was needed, and the sensation of mobility in the ribs had gone. All patients returned to work or normal activity after an average of 2 months.

Thoracic wall defects

Three patients, with an average age of 44 years and an average ISS of 18, underwent chest wall stabilisation on average 6 days after the trauma. The cause of injury was motor vehicle accidents in 2 cases and crushing in 1 case. Extrathoracic injuries were minimal. The average number of broken ribs was 8, with an average of 11 fractures. On average, 5 ribs were fixed. One patient had a wound seroma that required drainage. The average hospital stay was 20 days, and only one patient required admission to the ICU. CT was used to compare the stability of the fractures and the recovery of the anatomy (Figure 5). After three months, pulmonary function tests were normal, and after 6 months all patients had resumed their personal life and returned to work without analgesic treatment.

Discussion

This case series demonstrates the efficacy of titanium clips and bars for unstable chest fixation, the reconstruction of traumatic chest wall defects and the reduction and surgical fixation of mobile and painful, displaced rib fractures. It is the first time a patient series using this technique has been published. Stabilisation with titanium clips seems to allow patients with unstable chest to be removed from a ventilator and leads to subjective pain reduction of rib fractures. Postoperative complications were rare, and long-term trends show the stability of fractures in all patients and a return to a full personal and working life for most of them. The surgical technique is simple and generally does not need large muscle dissection. Although operative stabilisation of rib fractures cannot be recommended at present as a widespread technique, it can be recommended in a selected group of patients with chest wall lesions to improve outcomes.

The rib clips and bars have benefits over other rib fracture stabilisation systems. Titanium has extraordinary tissue compatibility and resists corrosion on contact with air and in a biological environment.[12] Therefore, titanium is especially indicated for long term implants, and lasts a lifetime, from current knowledge. Conventional steel implants lose their tolerance, because small rupture lines appear on the surface during handling or bending. This can lead to the metal deteriorating and corroding, causing a tissue reaction at the implant site.[13] In contrast to steel, pure titanium is spontaneously renewed in a biological environment due to osseointegration,[14] even after being bending or deforming. Therefore, titanium implants are clinically inert and corrosion-free. Material-related damage to the tissues is almost impossible. And because titanium is more flexible than steel, titanium clips and bars can be fitted more easily and accurately to the contour of the ribs. Titanium maintains its shape when contoured and can be adjusted tightly to the ribs without putting pressure on the fractures. Allergic reactions caused by titanium are extremely rare.[15] The use of chest CT is essential for the determination of rib fractures in different locations. The use of pure titanium as an osteosynthesis material provides

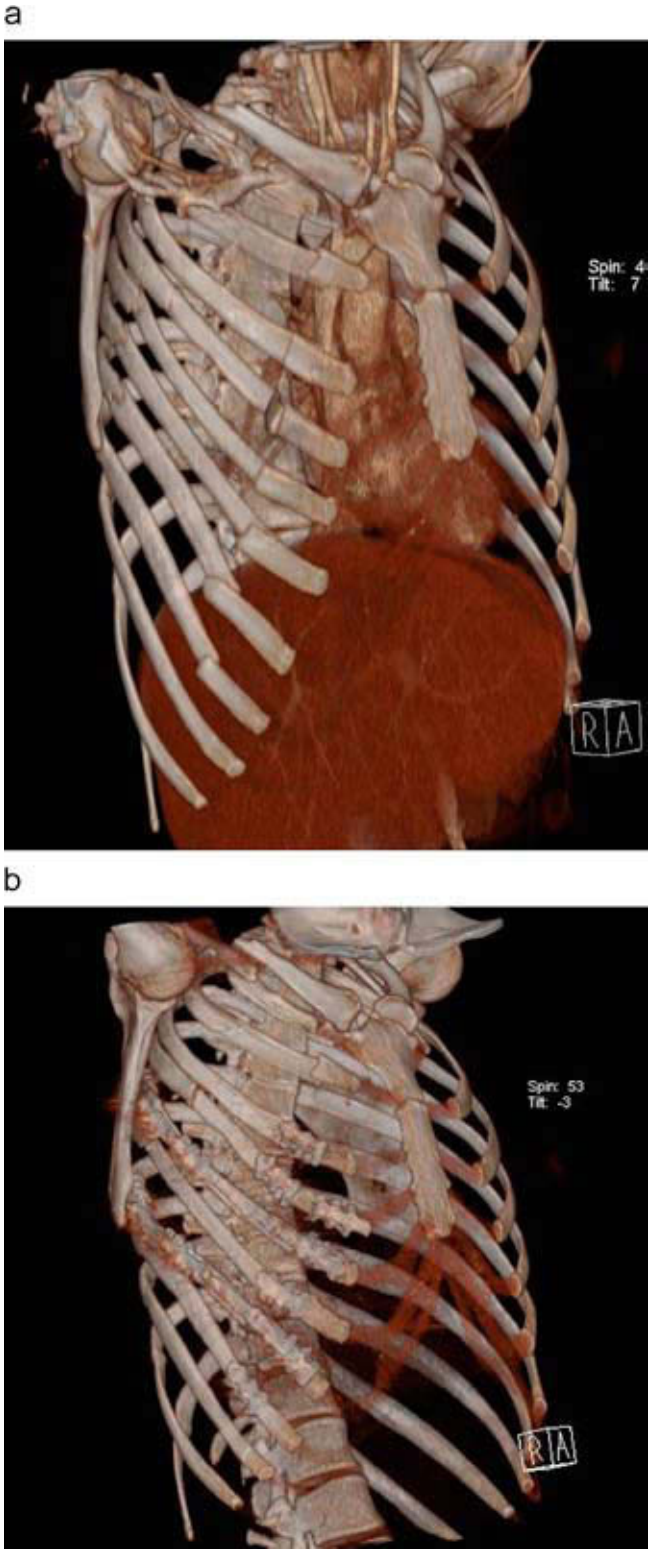

Figure 5 – Chest wall deformity: a) chest CT–preoperative study; b) chest CT–postoperative study.

clear images on CT or MRI. This is of great importance, especially in patient follow-up.[16]

Surgical stabilisation of rib fractures shortens the extubation time of patients with unstable chest, relieves pain and reduces the time for patients returning to work in a condition similar to that of the general population.[17] Titanium clips and bars are easily implanted and cause minimal complications.

Conflicts of interests

The authors affirm that they have no conflicts of interests.

REFERENCES

1. Ziegler DW, Agarwal NN. The morbidity and mortality of rib fractures. J Trauma. 1994;37:975-9.
2. Flagel BT, Luchette FA, Reed L, Esposito TJ, Davis KA, Santianello JM, et al. Half-a-dozen ribs: the breakpoint for mortality. Surgery. 2005;138:717-25.
3. Bulger EM, Arneson MA, Mock CN, Jurkovich GJ. Rib fractures in the elderly. J Trauma. 2000;48:1040-7.
4. Kerr-Valentic MA, Arthur M, Mullins J, Pearson TE, Mayberry JC. Rib fracture pain and disability: can we do better? J Trauma. 2003;54:1058-64.
5. Beal SL, Oreskovich MR. Long-term disability associated with flail chest injury. Am J Surg. 1985;150:324-6.
6. DiFabio D, Benetti D, Benvenuti M, Mombelloni G. Surgical stabilization of post-traumatic flail chest. Our experience with 116 cases treated. Minerva Chir. 1995;50:227-33.
7. Tanaka H, Yukioka T, Yamaguti Y, Shimizu S, Goto H, Matsuda H, et al. Surgical stabilization or internal pneumatic stabilization? A prospective randomized study of management of severe flail chest patients. J Trauma. 2002;52:727-32.
8. Campbell N, Conaglen P, Martin K, Antippa P. Surgical stabilization of rib fractures using Inion OTPS wraps-tchniques and quality of life follow-up. J Trauma. 2009;67:596-601.
9. Quell M, Vecsei V. Surgical stabilization of thoracic wall fractures. Unfallchirurg. 1991;94:129-33.
10. Cacchione RN, Richardson JD, Seligson D. Painful nonunion of multiple rib fractures managed by operative stabilization. J Trauma. 2000;48:319-21.
11. Judet R. Costal osteosíntesis. Rev Chir Orthop Reparatrice Appar Mot. 1973;59(Suppl 1):334-5.
12. Hauser J, Koeller M, Bensch S, Halfmann H, Awakowicz P, Steinau HU, et al. Plasma mediated collagen-I-coating of metal implant materials to improbé biocompatibility. J Biomed Mater Res A. 2010;20. In press.
13. Bedi RS, Beving DE, Zanello LP, Yan Y. Biocompatibility of corrosion-resistant zeolite coating for titanium alloy biomedical implants. Acta Biomater. 2009;5:3269-71.
14. Meyer J. Visualization of osseointegration of maxilla and mandible dental implants. Int J Comput Assist Radiol Surg. 2010;5:69-76.
15. Sicilia A, Cuesta S, Coma G, Arregui I, Guisasola C, Ruiz E, et al. Titanium allergy in dental implant patients: a clinical study on 1500 consecutive patients. Clin Oral Implants Res. 2008;19:823-35.
16. Livingston DH, Shogan B, John P, Lavery RF. CT diagnosis of rib fractures and the prediction of acute respiratory failure. J Trauma. 2008;64:905-11.
17. Mayberry JC, Kroeker AD, Ham LB, Mullins RJ, Trunkey DD. Long-term morbidity, pain, and disability alter repair of severe chest wall injuries. Am Surg. 2009;75:389-94.