No benefit to surgical fixation of flail chest injuries compared with modern comprehensive management: results of a retrospective cohort study

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Background: Chest wall trauma is a common cause of morbidity and mortality. Recent technological advances and scientific publications have created a renewed interest in surgical fixation of flail chest. However, definitive data supporting surgical fixation are lacking, and its virtues have not been evaluated against modern, comprehensive management protocols.

Methods: Consecutive patients undergoing rib fracture fixation with rib-specific locking plates at 2 regional trauma centres between July 2010 and August 2012 were matched to historical controls with similar injury patterns and severity who were managed nonoperatively with modern, multidisciplinary protocols. We compared short- and long-term outcomes between these cohorts.

Results: Our patient cohorts were well matched for age, sex, injury severity scores and abbreviated injury scores. The nonoperatively managed group had significantly better outcomes than the surgical group in terms of ventilator days (3.1 v. 6.1, $p = 0.012$), length of stay in the intensive care unit (3.7 v. 7.4 d, $p = 0.009$), total hospital length of stay (16.0 v. 21.9 d, $p = 0.044$) and rates of pneumonia (22% v. 63%, $p = 0.004$). There were no significant differences in long-term outcomes, such as chest pain or dyspnea.

Conclusion: Although considerable enthusiasm surrounds surgical fixation of flail chest injuries, our analysis does not immediately validate its universal implementation, but rather encourages the use of modern, multidisciplinary, nonoperative strategies. The role of rib fracture fixation in the modern era of chest wall trauma management should ultimately be defined by prospective, randomized trials.

Contexte : Les traumatismes à la paroi thoracique sont une cause courante de morbidité et de mortalité. Dernièrement, des avancées technologiques et des articles scientifiques ont ravivé l'intérêt à l'égard du traitement chirurgical du volet costal. Les données fiables appuyant la fixation chirurgicale sont toutefois rares, et les avantages de cette technique n'ont pas été comparés à ceux de protocoles de prise en charge complets et modernes.

Méthodes : Nous avons jumelé des patients consécutifs admis dans 2 centres régionaux de traumatologie entre juillet 2010 et août 2012 pour une fixation d'une fracture des côtes à l'aide de plaques verrouillées avec un groupe témoin rétrospectif présentant des blessures de type et de gravité semblables, toutefois pris en charge selon des protocoles multidisciplinaires modernes ne nécessitant aucune intervention chirurgicale. Nous avons ensuite comparé les issues à court et à long terme dans ces cohortes.

Résultats : Les cohortes étaient bien appariées sur le plan de l'âge, du sexe et des indices de gravité des blessures. Les résultats des patients n'ayant pas subi d'intervention chirurgicale étaient significativement meilleurs que ceux de l'autre groupe en ce qui concerne le nombre de jours sous ventilation assistée (3,1 c. 6,1; $p = 0{,}012$), la durée du séjour aux soins intensifs (3,7 c. 7,4 jours; $p = 0{,}009$), la durée totale du séjour à l'hôpital (16,0 c. 21,9 jours; $p = 0{,}044$) et le taux de pneumonie (22 % c. 63 %; $p = 0{,}004$). Aucune différence significative n'a été observée en ce qui concerne les répercussions à long terme telles que les douleurs thoraciques ou la dyspnée.

Conclusion : Si la fixation chirurgicale des blessures au volet costal suscite un grand enthousiasme, les résultats de notre analyse n'appuient pas le recours systématique à cette intervention, mais encouragent plutôt l'utilisation de stratégies modernes multidisciplinaires sans intervention chirurgicale. En conclusion, le rôle de la fixation des fractures des côtes dans la prise en charge moderne des traumatismes à la paroi thoracique devrait être défini dans le cadre d'études prospectives randomisées.

Flail chest, which often signifies a combination of significant mechanical instability of the chest wall and underlying pulmonary parenchymal injury, is among the most severe and complex forms of chest trauma, with associated mortality of up to 33%.[1] Associated injuries include hemopneumothorax and pulmonary contusion, and common complications are pneumonia and respiratory failure requiring mechanical ventilation. Management of flail chest remains an area of active interest and debate, as morbidity and mortality have not declined susbtantially over the years.[2] There has been no substantial improvement in the outcomes of flail chest injuries ince the 1970s, when Trinkle and colleagues[3] demonstrated the benefits of optimizing lung function using comprehensive multidisciplinary care rather than reducing chest wall instability using mandatory invasive mechanical ventilation.

Continued advances in critical care medicine have supported a long era of nonoperative management as the standard of care for flail chest. The Eastern Association for the Surgery of Trauma (EAST) guidelines recommend optimal analgesia, particularly with epidural anesthesia,[4] aggressive chest physical therapy and pulmonary toilet, supplemental oxygenation, and positive pressure ventilation as needed for respiratory failure.[5]

Recently, promising studies of surgical fixation of flail chest injuries have prompted many centres to reconsider the added importance of reducing the instability of the chest wall in patients with flail chest. Three small, randomized controlled trials (RCTs) and a meta-analysis of 11 comparative studies have demonstrated improved short- and long-term outcomes following surgical stabilization of flail chest. However, these small studies have not yet triggered a universal change in the nonoperative status quo. In this study, we evaluated a new program of surgical fixation of flail chest by comparing the outcomes of operative and nonoperative management in the modern era of comprehensive, multidisciplinary, nonoperative care.

Methods

We conducted this retrospective matched cohort study at 2 major trauma hospitals in Vancouver, Canada. All patients with a flail chest injury who presented to either the Vancouver General Hospital or the Royal Columbian Hospital between July 2010 and August 2012 were considered for surgical fixation with the Synthes MatrixRIB fixation system. Criteria for flail chest fixation required that the patient have 3 or more adjacent, displaced, segmental rib fractures with evidence of respiratory compromise (functional vital capacity < 20 mL/kg or need for noninvasive or invasive mechanical ventilation), despite adequate analgesia. We included in this study patients aged 19 years or older who underwent operative repair of their flail chest (as per the above criteria) and in whom 3 or more fractured ribs were repaired with the MatrixRIB system.

The MatrixRIB fixation system was chosen as a standard approach to operative repair. This system, with its low profile, lightweight, precontoured plates and locking screws, was found to be relatively straightforward to use and to provide a stable and secure repair in most instances.

Patients who underwent surgical repair were independently matched to historical controls from 2008–2011 for same abbreviated injury score (AIS) and age within 5 years using the British Columbia Trauma Registry. Attempts were also made to match for AIS codes from other body regions and for presence of pulmonary contusion. The diagnosis of pulmonary contusion was made by reviewing patient charts and imaging reports for the diagnosis made at the time of injury.

All patients were subjected to the same rigorous medical management practices, in accordance with EAST guidelines.[4,5] The same multimodal analgesia strategies were used in both groups and included epidural anesthesia; aggressive chest therapy and pulmonary toiletting were performed regularly in all patients, and ventilatory support with positive pressure ventilation was applied as needed.

Our primary end point was total ventilator days, and our secondary outcomes were length of stay (LOS) in the intensive care unit (ICU), total hospital LOS, rate of pneumonia, mortality and long-term quality of life measures. End points, such as LOS, death and rate of pneumonia, were gathered through the BC Trauma Registry. Quality of life surveys were done either in person or over the phone and involved the EQ-5D-5L survey as well as visual analogue scales, dyspnea scales and employment screening questions.[7]

Statistical analysis

We used the Fisher exact test and Wilcoxon rank-sum test as appropriate for our statistical analysis, considering our small sample size.

Results

Nineteen surgical patients qualified for this study (14 from Vancouver General Hospital and 5 from Royal Columbian Hospital), and they were successfully matched to 36 nonoperative control patients. Patient demographic characteristics are outlined in Table 1. The surgical group was made up of 11 men (79%) and had an average age of 53 years. Patients in both groups had significant trauma burden, with average ISS of 31 and 29 in our case and control groups, respectively. Chest injury contributed significantly to injury severity, as the chest region had the highest AIS (4.3 in the case group and 4.1 in the control group). There was no significant difference between the case and control groups for any AIS. Twenty percent of the patients in each group were intubated on arrival to the

emergency department; 79% of surgical patients and 36% of control patients eventually required intubation.

Presence of pulmonary contusion was not well matched between the groups; all 19 of the patients in the fixation group had some degree of pulmonary contusion, whereas only 21 of the control patients had documented pulmonary contusions. Interestingly, all control patients with documented pulmonary contusions were from a single site.

In-hospital outcomes are shown in Table 2. Our primary outcome, invasive mechanical ventilation days, showed that nonoperatively managed patients required a mean of 3.1± 5.5 days on a ventilator, which is significantly less than the case group, which required a mean of 6.1± 5.9 days of ventilation (p = 0.012). Our secondary outcomes also favoured nonoperative management. Length of stay in the ICU (3.7 v. 7.4 d, p = 0.009), hospital LOS (16.0 v. 21.9 d, p = 0.044) and rate of pneumonia (22% v. 63%, p = 0.004) all showed significantly better outcomes in our control group, whereas mortality was not significantly different. The average time to surgery was 6.3 ± 3.6 days.

Long-term outcomes are shown in Table 3. Response rates were 47% for the control group and 85% for the case group, which are excellent for a follow-up questionnaire. Results from the EQ-5D-5L were not significantly different between groups for mobility, self-care, usual activities or anxiety/depression, but scores were significantly lower in the control group for pain/discomfort (2.0 v. 3.4). This did not seem to be the result of their thoracic trauma, however, as when specifically assessing chest pain, no difference was found between groups. Total health visual analogue scale scores were almost identical, and dyspnea classes were not significantly different between the groups. Additionally, while there was a trend toward improved return to work in the surgical group, this did not reach statistical significance.

Table 1. Demographic and clinical characteristics of study sample

	Group; mean ± SD or no. (%)		
Characteristic	Cases n = 19	Controls n = 36	p value
Age, yr	53.1 ± 14.3	56.5 ± 15.9	0.42
Sex			0.54
Male	15 (79)	25 (69)	
Female	4 (21)	11 (31)	
ISS	31.4 ± 9.6	29.3 ± 8,1	0.48
Intubated on arrival to ED			> 0.99
Yes	4 (21)	7 (19)	
No	15 (79)	29 (81)	
Maximum AIS score			
Head and neck	2.8 ± 1.0	3.21 ± 0.97	0.37
Face	1.4 ± 0.55	1.6 ±0.79	0.85
Chest	4.3 ± 0.56	4.1 ± 0.46	0.27
Abdomen and pelvic contents	2.5 ± 0.71	2.5 ± 0.79	0.93
Extremities and pelvic girdle	2.7 ± 0.60	2.4 ± 0.63	0.16
External	1.0 ± 0.0	1.0 ± 0.22	0.53
Pulmonary contusion			< 0.001
Present	19 (100)	21 (58)	
Absent	0 (0)	15 (42)	

AIS = abbreviated injury scale; ED = emergency department; ISS = injury severity score; SD = standard deviation.

Table 2. In-hospital outcomes

	Group; mean ± SD or no. (%)		
Outcome	Cases n = 19	Controls n = 36	p value
Ventilator days	6.1 ± 5.9	3.1 ± 5.5	0.012
ICU LOS, d	7.4 ± 6.7	3.7 ± 6.0	0.009
SCU LOS, d	5.4 ± 5.6	3.7 ± 3.7	0.26
ICU + SCU LOS, d	12.8 ± 9.5	7.3 ± 6.5	0.002
Hospital LOS, d	21.9 ± 13.2	16.0 ± 12.1	0.044
Pneumonia			0.004
Present	12 (63)	8 (22)	
Absent	7 (37)	28 (78)	
Death			> 0.99
Yes	1 (5)	1 (4)	
No	18 (95)	35 (96)	

ICU = intensive care unit; LOS = length of stay; SCU = special care unit; SD = standard deviation.

Discussion

Modern interest in flail chest fixation is the result of new studies and new technologies that favour improved outcomes with surgical fixation. Three RCTs have been published in the last dozen years that demonstrate significant improvements following surgical management of a flail chest when compared with nonoperative management. A salient RCT by Tanaka and colleauges[8] demonstrated not only improved in-hospital data, such as length of mechanical ventilation, days in the ICU and rate of pneumonia, but also significant improvements in long-term outcomes, such as chest pain, chest tightness, dyspnea, time to return

Table 3. Long-term outcomes

	Group; mean (95% CI)*	
Outcome	Cases n = 11	Controls n = 18
Mobility	2.1 (1.3–2.9)	1.8 (1.3–2.3)
Self-care	1.6 (1.2–2.1)	1.3 (0.9–1.7)
Usual activities	2.4 (1.7–3.1)	2.2 (1.6–2.9)
Pain/discomfort	3.4 (2.6–4.1)	2.0 (1.7–2.3)*
Anxiety/depression	2.3 (1.5–3.1)	1.6 (1.2–2.1)
VAS score	65 (45.7–84.2)	67.2 (56.3–78.0)
VAS chest pain	1.9 (0.6–3.3)	0.8 (0.1–1.5)
Dyspnea class	1.0	0.6
Return to employment, %	36	23

CI = confidence interval; VAS = visual analogue scale.
*Unless indicated otherwise.

to work, and ability to return to high-activity work. Granetzny and colleagues[9] demonstrated the same short-term results, but also with reduced total hospital LOS, and Marasco and colleagues[10] found ICU LOS, rate of pneumonia and length of noninvasive mechanical ventilation to be reduced following surgical repair. When considering all available data up to 2012 in a meta-analysis, Slobogean and colleagues[11] found this conclusion was still supported. Interestingly, however, the RCT by Marasco and colleagues was the only study to compare operative management with current standards of nonoperative care, and they found far fewer improvements in outcomes with operative fixation.[10]

The postoperative outcomes of our study are very similar to previously published postoperative outcomes. Where our study differs from others, however, is in our nonoperative outcomes. Days on a ventilator, ICU LOS and hospital LOS, and rate of pneumonia were all significantly lower in our conservatively managed patients than our surgical patients. What is more astounding, however, is how our outcomes compare with previously published outcomes in nonoperative patients.[6,8–12,14–20] When compared with the RCT by Marasco and colleagues, days on a ventilator in our study were less than half of theirs, ICU LOS in our study was more than 11 days shorter, and hospital LOS was 9 days shorter, while their pneumonia rates were 3 times higher than ours.[10] Despite our retrospective matched cohort design, our study raises some interesting questions for future examination, especially considering that the only other North American study on this topic also found no significant improvements in LOS or ventilator days with flail chest fixation.[12] Perhaps it is a reflection of the North American critical care practices, or that critical care has universally improved since some of these studies were done (e.g., patients in the study by Tanaka and colleagues[8] were randomized between 1992 and 1998).

Limitations

Our study does have its limitations. It is a small study, with only 19 cases of surgically managed patients. This is a recurring problem: the sum of cases in all 3 RCTs (which have profoundly influenced discourse in this area) is only 61.[8–10] Our study is also limited by its retrospective nature and the practices of the time as patients who were selected for flail chest fixation were not improving despite excellent medical care, leading to a selection bias that would favour outcomes for nonoperatively managed (control) patients. Similarly, time to surgery was almost a week in our study, and earlier operative intervention may have resulted in better outcomes as atelectasis, myopathy and infection would not have had time to advance. However, patients in the study by Tanaka and colleagues[8] were not randomized until 5 days postinjury and were operated at 8 days, while those in the study by Marasco and colleagues[9] were randomized at 2.5 days and operated over 2 days later. Despite these delays, both groups found significant improvements with surgery. Therefore, while our delay seemed substantial, it was not expected to affect outcomes.

A confounding factor was our inability to match for presence of pulmonary contusion. While matched for age, sex, ISS and AIS, 100% of the fixation group had some degree of pulmonary contusion, whereas only 58% of the control group did. The remarkable difference in rates may have come primarily from differences in detection and reporting of this injury at 1 of the 2 study sites. All 9 control patients from 1 study site had no recorded pulmonary contusions. It is possible that this injury was not properly documented or coded in the registry at this hospital, as there are no good ways to determine or measure pulmonary contusion on radiographs, so the interpretation of what should have been included in the registry may have differed between hospitals. However, severity of injury, as reflected by the ISS and chest AIS scores, did not differ between hospitals or between patient groups, and all other covariates were well matched. Based on the even distribution of all other markers of injury severity between cases and controls, we believe that the patient groups were well matched and that the true difference in pulmonary contusion rates may be less than what we reported.

Conclusion

Current multidisciplinary care practices for the management of flail chest injuries produce excellent results for both short- and long-term outcome measures. The days on a ventilator, ICU LOS, total LOS and rate of pneumonia for operative patients in our study are very similar to previously published results, while our control patients had substantially better outcomes than those published previously.[6,8–12,14–20] This supports the notion that surgical fixation of flail chest is not required for all patients.

For a common, life-threatening problem such as flail chest, the assessment of new therapeutic technologies has tremendous implications in terms of both clinical outcomes and cost. While existing trials have produced an exciting signal that favours the broader use of rib fracture fixation for flail chest, these trials, with all their methodological and temporal limitations, have not yet dispelled equipoise regarding the role and indications for surgical fixation in chest wall trauma. Large RCTs are needed to help define management strategies in this complex area and to guide the thoughtful implementation of a promising strategy in thoracic trauma. Until then, individual therapeutic decisions must account for patient-specific benefits and risks, recognize and account for limitations in the literature, and acknowledge uncertainty in this rapidly evolving area.

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