Case Report

Frame-Composite Mesh: A New Method to Treat Complex Unstable Flail Chest: A Case Report

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A middle aged Thai male was admitted suffering from a severely unstable flail chest caused by an elephant having trampled on the upper right part of his chest. He failed to respond to conservative treatment and conventional surgery could not be performed due to the bony defect in the chest wall. Consequently, a frame-composite mesh was designed and constructed in close collaboration with Chiang Mai University's Biomedical Polymers Technology Unit. After implantation, the patient could be taken off a mechanical ventilator successfully without any adverse event. Two weeks after surgery, he was found to have good pulmonary function and so the clinical outcome was judged to be successful.

Keywords: *Unstable flail chest, Composite mesh, Chest wall reconstruction*

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The recommendations in flail chest management are multimodality dimensions including ventilator support to balance ventilation perfusion mismatch from pulmonary contusion(1), maintaining adequate pulmonary toilet, adequate fluid resuscitation without excessive fluid overload, pain management(2) and some controversial aspects in various surgical techniques of chest wall fixation(3). Most surgical management of unstable flail chest involves internal fixation using multiple techniques. However; these techniques are impossible or extremely difficult to perform in cases where there is a wide area of bone loss with comminuted rib fractures and large defects. In the present study the authors describe a new technique and a novel improvised implant to meet the surgical challenge for this type of patient.

Case Report

A middle-aged man was admitted to Chiang Mai university hospital suffering from a severe unstable flail chest caused by an elephant having trampled on the upper right part of his chest. In addition to hemopneumothorax and a right lung contusion, his chest X-ray and CT reconstruction showed a flail segment in the region of his 1st-5th ribs with disruption of the 3rd to 5th ribs from sternochrondal junction and a large defect between the 2nd and 3rd ribs at the anterior aspect of the right chest wall (Fig. 1, 2). Although he could still breathe spontaneously, he had a marked tachypnea and paradoxical movement of his right upper chest leading to hypercapnic hypoxemia. Consequently, he was intubed and positive mechanical ventilation employed on the day of admission. Within a few days, the amount of intercostal draining blood decreased and ventilation improved. However, when the authors tried to reduce the ventilatory support by using a spontaneous low pressure support (5-7 cm H_2O) mode, the patient could not tolerate it. He extubated by himself several times during the first two weeks of admission but could not breathe effectively because of the unstable flail segment in his right upper thorax. Therefore, re-intubation was performed. It was concluded that, in order to treat this

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Fig. 1 Chest X- ray taken on the day of admission revealed flail segment at right upper chest and massive hemothorax

Fig. 2 CT reconstruction of the large bony defect at right upper chest

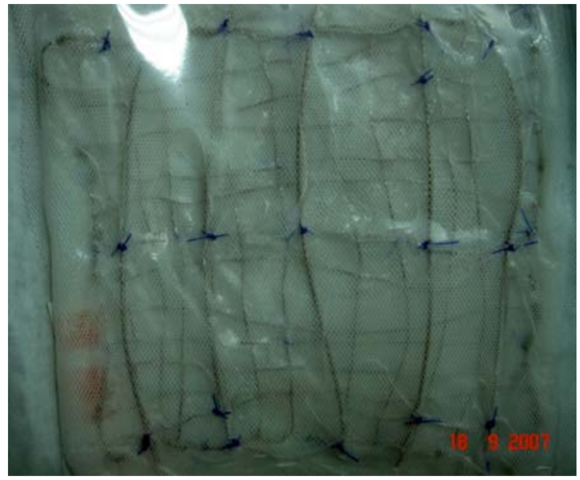

Fig. 3 Photograph showing the frame-composite mesh after sterilization and packing

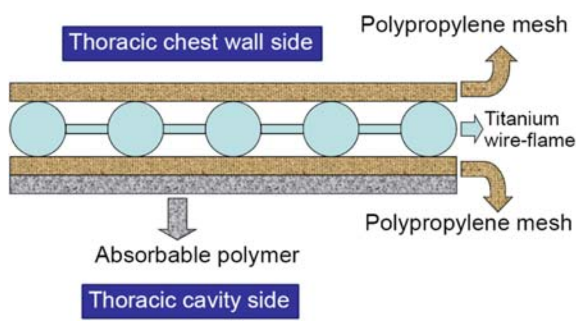

Fig. 4 Diagram showing the construction of the frame-composite mesh. Skeletal axis of mesh was created by titanium wire flame and sandwiched in between two layers of a polypropylene mesh. The inner side was coated by absorbable polymer. (The skeletal axis and polypropylene mesh was created by Dr.Kaweesak Chittawatanarat and absorbable polymer layer was generated by Robert Molloy and Chutiporn Laokul)

patient, the authors needed to design and fabricate a framework which could close the chest wall defect.

In collaboration with the Biomedical Polymers Technology Unit of the Department of Chemistry, Faculty of science, Chiang Mai University, a 15 cm x 15 cm frame-composite mesh was designed and fabricated. This composite mesh consisted of four layers and three different types of material (Fig. 3 and 4). Titanium wire was chosen for the framework of the mesh since it was light in weight, biocompatible and could be easily manipulated into the required shape. This was then sandwiched in between two layers of a polypropylene net, the purpose of which was to act as a scaffold for coating on one side (the inner side) with a thin, transparent, flexible sheet of a slowly absorbable polymer. This polymer was a random co-polyester of L-lactide and ε-caprolactone in a 50:50 mol % ratio.

The operation to implant this frame-composite mesh in the patient was performed at the end of the 2nd week after his admission. The incision was made at the right pectoral groove. Intra-operative findings revealed a thoracic cage defect about 8 cm x 12 cm in area which exposed the lung parenchyma as well as a tearing of the clavipectoral fascia and some part of the pectoralis minor muscle. However, the major part of the pectoralis muscle was still intact. The mesh, shaped manually to match the contours of the cage defect, was implanted in the retropectoral space and tethered with the surrounding soft tissue (Fig. 5).

Following the operation, the patient could be disconnected from the mechanical ventilator and extubated the next morning uneventfully. As a result, he was able to be discharged from the hospital after several more days of observation. Two weeks after his discharge (Fig. 6, 7), he was well and had good pulmonary function (FVC 2.63 L (70%), FEV1 2.10 L (67%), FEV1/FVC 83%).

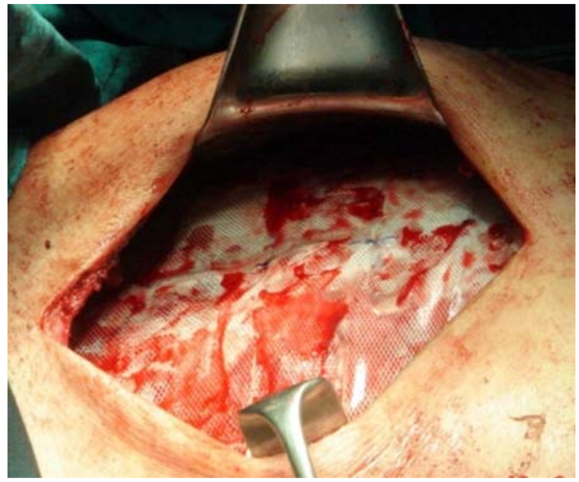

Fig. 5 After mesh implantation to cover the chest wall defect via incision at right pectoral groove

Discussion

In addition to the appropriate conservative treatment of severe flail chest patients, some of them need surgical intervention and several benefits have been reported in these cases compared to the conservatively treated patients such as maintaining chest contours, less chest wall deformity, less restrictive impairment of pulmonary function, as well as decreased ICU and hospital length of stay[(4)]. Surgical management of flail chest mostly involves rib fixation utilizing various techniques. There are four types of fixation devices that may be used for the surgical fixation of ribs, namely: plate fixation, intramedullary device insertion, vertical bridging and wiring[(5)]. However; there are several limitations to these techniques such as large gap defects of rib fracture, large comminuted component defects, as well as the large area involvement of

Fig. 6 Chest X-ray taken two weeks after implantation revealed mesh position at right upper chest and resolved of hemothorax

Fig. 7 Photograph of the patient's chest two weeks after implantation showed pectoral groove incision and chest contour. The scar (arrow) was injury site

traumatic pathology. An alternative approach is to use a purpose-designed prosthetic device to cover such a large defect. Up until now, most describing the use of these techniques in reconstructive surgery have been for congenital disorders and after en bloc resection of tumours. For example, Heroit et al reported a chest wall reconstruction using Marlex mesh in the unusual case of a flail chest patient with a congenital neuro-fibromatosis and chest wall defect. The authors claimed excellent cosmetic and functional results[6]. Yoshino et al used a full thickness chest wall reconstruction using a transverse rectus abdominis myocutaneous flap in combination with polypropylene mesh and stainless steel mesh in the case of a 71 year old man who underwent recurrent lung cancer en bloc resection. They too reported good post-operative results in terms of pain control with no flail chest or dyspnea symptom[7]. Weyant et al reported less respiratory complications following the routine use of a rigid prosthesis for reconstruction of the large, anteriorly or laterally located defects after chest wall resection[8].

In the presented case, the authors initially tried to use conservative methods to treat the presented patient but it was found that he could not tolerate the removal of ventilator support. It was suspected that this intolerance was due to chest wall compliance and respiratory pump failure from the unstable flail segment. On the other hand, conventional methods of surgical intervention were difficult to perform due to the large size of the defect. Consequently, and in collaboration with the Biomedical Polymers Technology Unit, the authors used a polypropylene mesh on a titanium wire frame as the skeletal structure of a prosthesis. The pulmonary side of this mesh was coverd by a slowly absorbable polymer because the authors were concerned that the frictional effects of a non-absorbable material on the lung tissue might lead to bronchopleural fistula after long-term grinding between the pulmonary tissue and the prosthesis. After implantation, the patient could immediately be taken off ventilator support without any adverse effects. A previous paper describing a large case series of rib fixations and chest wall reconstructions from various causes reported improved vital capacity and forced expiratory volume in 1 second (FEV1) as well as a higher predicted total lung capacity (TLC) within 6 months after surgery[9]. However; as far as the authors know, there has been no previous literature report concerning pulmonary function after prosthesis insertion. In the case of the presented patient, two weeks after implantation be showed excellent pulmonary function. The limitation of the authors' case study is that it has not been possible to monitor the patient's long-term recovery since his discharge due to his travel and economic constraints.

Conclusion

The use of this purpose-designed frame-composite mesh represents a new method for treating complex unstable flail chest injuries safely in terms of closing a large defect and shortening the ventilator and intubation days. However, further studies still need to be conducted in order to evaluate fully the effectiveness of the mesh and also the long-term outcome of this method.

References

1. Kishikawa M, Yoshioka T, Shimazu T, Sugimoto H, Yoshioka T, Sugimoto T. Pulmonary contusion causes long-term respiratory dysfunction with decreased functional residual capacity. J Trauma 1991; 31: 1203-10.
2. Easter A. Management of patients with multiple rib fractures. Am J Crit Care 2001; 10: 320-7.
3. Bastos R, Calhoon JH, Baisden CE. Flail chest and pulmonary contusion. Semin Thorac Cardiovasc Surg 2008; 20: 39-45.
4. Izuo M, Ishida T, Iino Y. Chest wall resection and reconstruction for locoregionally advanced or recurrent breast cancer. Jpn J Surg 1988; 18: 687-93.
5. Engel C, Krieg JC, Madey SM, Long WB, Bottlang M. Operative chest wall fixation with osteo-synthesis plates. J Trauma 2005; 58: 181-6.
6. Heriot AG, Wells FC. An unusual case of flail chest: surgical repair using Marlex mesh. Thorax 1997; 52: 488-9.
7. Yoshino N, Yamauchi S, Akimoto M, Hisayoshi T, Koizumi K, Shimizu K. A case report on a full-thickness chest wall reconstruction with poly-propylene mesh and stainless steel mesh concurrently using a transverse rectus abdominis myocutaneous flap. Ann Thorac Cardiovasc Surg 2006; 12: 445-8.
8. Weyant MJ, Bains MS, Venkatraman E, Downey RJ, Park BJ, Flores RM, et al. Results of chest wall resection and reconstruction with and without rigid prosthesis. Ann Thorac Surg 2006; 81: 279-85.
9. Lardinois D, Krueger T, Dusmet M, Ghisletta N, Gugger M, Ris HB. Pulmonary function testing after operative stabilisation of the chest wall for flail chest. Eur J Cardiothorac Surg 2001; 20: 496-501.

รายงานผู้ป่วย 1 ราย โดยการใช้โครงตาข่ายแบบองค์ประกอบตาข่ายหลายชนิดทั้งละลายและไม่ละลายในผู้ป่วยที่มีกระดูกซี่โครงหักหลายซี่ที่มีการหายใจผิดปรกติ

กวีศักดิ์ จิตตวัฒนรัตน์, นเรนทร์ โชติรสนิรมิต, กำธน จันทร์แจ่ม, โรเบิร์ต มอลลอย, จุติพร เลากุล

ผู้ป่วยชายไทยกลางคนถูกช้างกระทืบบริเวณทรวงอกด้านขวา และก่อให้เกิดกระดูกซี่โครงหักหลายซี่ และเกิดช่องโหว่ขนาดใหญ่ทำให้ผู้ป่วยหายใจเองไม่ได้ถึงแม้จะให้การรักษาแบบประคับประคองอย่างที่สุด การผ่าตัดด้วยวิธีเดิมไม่สามารถใช้ได้เนื่องจากมีรอยโหว่ขนาดใหญ่ คณะผู้วิจัยได้ร่วมกันสร้างแผ่นโครงตาข่ายแบบองค์ประกอบหลายชนิด เพื่อนำมาใช้เป็นผนังช่องทรวงอกเทียมแก่ผู้ป่วยโดยความช่วยเหลือของหน่วยโพลิเมอร์ทางชีวภาพ คณะวิทยาศาสตร์ มหาวิทยาลัยเชียงใหม่ภายหลังจากทำการผ่าตัด เพื่อใส่โครงตาข่ายแก่ผู้ป่วย พบว่าผู้ป่วยสามารถหายใจเองได้ และถอดเครื่องช่วยหายใจได้โดยไม่มีความผิดปรกติ หลังการผ่าตัดสองสัปดาห์ ภายหลังจากติดตามพบว่าผู้ป่วยมีอาการทางคลินิกที่ดี และมีผลการตรวจการทำงาน ของปอดที่ปรกติ