Trauma Surgery & Acute Care Open

Minimally invasive chest wall stabilization: a novel surgical approach to video-assisted rib plating (VARP)

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Received 5 August 2019
Revised 11 October 2019
Accepted 31 October 2019

To cite: Diaz JJ, Azar FK. *Trauma Surg Acute Care Open* 2019;**4**:e000366.

ABSTRACT

The current morbidity of rib plating is due to the size of the incision required to perform an open procedure. We describe a minimally invasive laparoscopic approach to rib plating. A cadaver model was used to develop the surgical technique by performing both left and right posterior-lateral rib plating. A small incision was made over the auscultatory triangle. The potential working space is developed under the posterior shoulder girdle and the scapula. A table-based retractor was used to elevate the scapula and the muscles. Two separate ports were placed: one camera port and one working port. In three cadaver models, 12 rib fractures were plated and the surgical technique is described. This novel technique will likely allow for faster recovery and was especially useful in the subscapular space.

Level of evidence II.

INTRODUCTION

Chest wall trauma is a source of significant morbidity and mortality.[1 2] The rate of complications for chest trauma increases with age, number of rib fractures, and displaced or flail segments.[3–5] Early rib fixation has been shown to yield better outcomes.[4 6] Studies have demonstrated a decrease in the duration of mechanical ventilation, length of intensive care unit (ICU) days, and overall hospital length of stay.[7–10] There appears to be less of a need for tracheostomy or non-invasive ventilatory measures after extubation in patients who have undergone chest wall stabilization.[7 11] Functional outcomes are also improved, particularly subjective measures of pain, quality of life, mobility, and disability.[12]

The main concern with rib plating has been the morbidity of the surgical approach. Initially, surgeons used standard thoracotomy incisions (posterior thoracotomy or anterior thoracotomy incisions) which divided the muscle groups. Occasionally some surgeons would include overzealous surgical debridement of the chest wall injury. This resulted in loss of the chest wall integrity and would require mesh closure of large chest wall defects. Thoracic surgeons developed muscle sparing incisions for intrathoracic procedures. Many experienced rib plating surgeons adopted these techniques to minimize the soft tissue injury to the chest wall. As with any operation, there is a learning curve for rib fracture fixation.

Since the introduction of laparoscopy in the 1990s, minimally invasive techniques have yielded improved patient outcomes. The current morbidity of rib plating is the size of the incisions required to perform an open procedure. The aim of this study was to determine the surgical techniques for the minimally invasive video-assisted rib plating (VARP).

ANATOMIC STUDY

Procedures, techniques, and materials

Three fresh cadavers were used as the model for development of the series of surgical techniques for the development of a VARP. The primary goal was to not divide any muscles. The initial step was to develop a space underneath the shoulder muscle girdle. The scope of vision was estimated based on creating an incision at the auscultatory triangle. This became our initial access site and a port was placed into the space along the posterior axillary line at the level of the auscultatory triangle (figure 1). It was determined that lateral and posterior-lateral rib fractures would be the most easily accessible based on creating the space underneath the muscle girdle.

Development of the operative field

The cadavers were positioned in a standard lateral decubitus position. A small 3–4 cm transverse incision was made over the auscultatory triangle and dissection continued onto the thoracic rib cage. In the first cadaver no rib fractures were created, we sought to delineate the steps of the procedure and demonstrate a proof of concept. Initially, the space was developed with a hernia balloon spacemaker device (Covidien Spacemaker Medtronic). This created a sufficient space to work in.

During the second cadaver procedure, the rib fractures were created prior to the development of the operative space. During the inflation of the spacemaker balloon, it was noted that our cadaver demonstrated more volume expansion of the balloon into the chest cavity as opposed to external direction. It was noted that the hernia balloon may create additional rib fracture displacement in a very unstable chest wall. This could create additional chest or lung injury.

In the third cadaver, the fractures were created prior to development of the operative space. We did not use the spacemaker balloon. Once the incision was made at the auscultatory triangle, a sponge clamp was used to develop the operative space (figure 2).

Setting up the retraction

An initial CO_2 insufflation was attempted but this resulted in extensive subcutaneous air. There was inadequate exposure of the surgical space with the CO_2 insufflation only. We decided that a simple table-based retractor was used to maintain the

Figure 1 In a cadaver model, an incision is made at the auscultatory triangle to access the potential space under near the posterior aspect of the shoulder girdle.

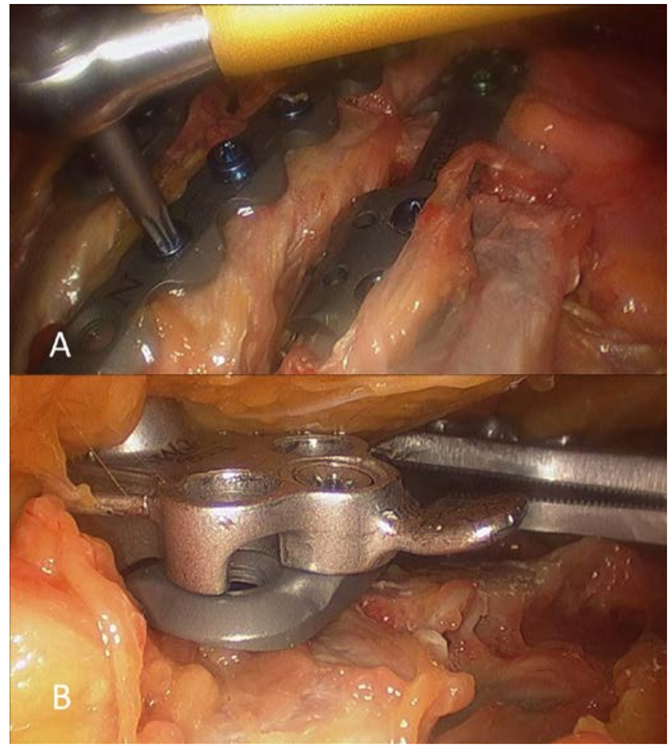

Figure 3 (A) A magnified endoscopic view of the rib plate being secured. (B) A close-up view of the low-profile 'drill guide' on the plate. The surgeon is positioning the plate with the clamp holding the profile drill guide.

operating space by elevating the scapula and tenting the muscles up (figure 3). In addition, it was necessary to maintain an open wound at the auscultatory triangle to move the instruments (drill handle, clamps, and rib plate) into the space.

For all the procedures, two separate ports were placed: one 10 mm port for the camera was placed along the posterior axillary line at the level of the auscultatory triangle and one 5 mm working port between the camera and the auscultatory triangle incision. Posterior-lateral rib fractures were created from T3-7 from subscapular to lateral position. Acute Innovations RibLoc system 50, 75, and 110 mm plates were used for rib plating. The U-plate design allows for the initial reduction of the fracture and hold the reduction in place without additional clamps (figure 3).

Figure 2 Sponge clamp is a surgical instrument with a gauze sponge attached to the end.

Results

1. The *auscultatory triangle* is a consistent anatomic structure and a landmark that can be used to dissect down to the chest wall. It allows for creation of the surgical space in the initial site.
2. The development of the space can be created using a 'sponge clamp'. A balloon spacemaker device should not be used as during the inflation process unstable rib fractures may become more displaced.
3. A table-based self-retaining retractor is required to maintain the surgical exposure (figure 4).
4. Visualization of lateral and posterior fractures can be visualized at multiple levels, including the subscapular and paraspinal spaces with additional magnification.
5. The overlying soft tissues on the fractured ribs are cleared using long surgical instruments to expose the fracture site and the periosteum.
6. The fractured segments can be reduced using thoracic instruments, including a long right-angle clamp to elevate displaced rib fractures.
7. The auscultatory triangle incision is the access point into the surgical field for the rib plates and the right-angle drill.
   A. The plates are introduced into the space, positioned, and the fracture reduced.
   B. A low-profile right-angle drill is used to secure the plate to the fractured rib.
8. Longer plates 75 mm and above require careful precontouring prior to securing them.
9. Prior to the final drilling and securing of the screws, the additional magnification of the scope allows careful placement of the plate (on top of the rib and centered over the rib fracture).

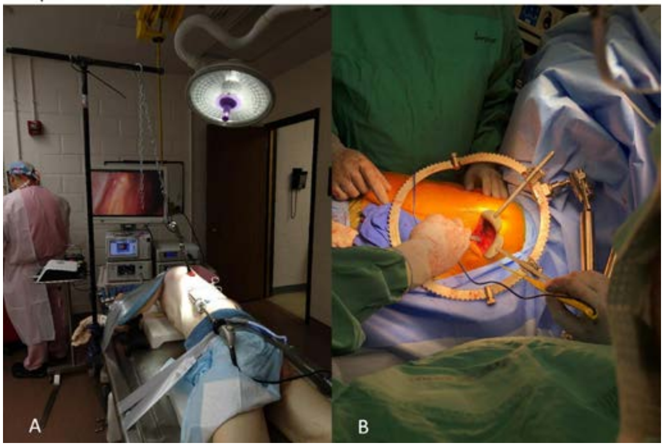

Figure 4 (A) During the cadaver model part of the study, a makeshift table-based retractor is set up. (B) Surgical set-up for Minimally Invasive Rib Plating, a standard Bookwalter table-based retractor system using a segmented ring. A long Richardson blade is inserted through the incision at the auscultatory triangle and placed under the scapula to maintain the surgical field.

CASE REPORT

These anatomic findings were modified slightly and employed clinically. The patient is a 53-year-old man who presented to a level 1 trauma center after being involved in a motor vehicle crash. He was the unrestrained driver of a car that crashed into a tree. He had multiple left-sided rib fractures with a flail segment and hemothorax. The patient's respiratory status did not improve during the course of 3 days with maximal multimodal pain management including an epidural pain catheter and aggressive pulmonary toilet. He had persistent spells of sharp incapacitating pain along his left chest and could not pull volumes greater than 300 mL on incentive spirometry.

A 3D reconstruction was done on his admission CT scan (figure 5). His left ribs were fractured at multiple levels: ribs 2 and 3 fractured posteriorly but not displaced, rib 4 fractured posteriorly with displacement, rib 5 fractured in a flail pattern laterally and posteriorly, and rib 6 fractured laterally with displacement. After informed consent was obtained, he was taken to the operating room for evacuation of hemothorax and chest wall stabilization.

The patient was placed in the right lateral decubitus position. A small incision was made posteriorly along the inferior aspect of the scapula. The dissection was carried down to the chest wall and a plane was developed with blunt dissection using a sponge stick. A Bookwalter was used to exposure placing a long Richardson blade underneath the scapula to develop the operative filed. A separate incision was made and a trocar was placed in the midaxillary line through which a laparoscope was introduced. The posterior fractures on ribs 4 and 5 were visualized. They were reduced and the anterior surface of the ribs close to the fractures was cleaned off. The fractures were bridged and plated with 50 mm Acute Innovations RibLoc plates. Identification of the anterior-lateral fractures proved difficult as the fracture on fifth and sixth ribs was directly under the anterior serratus muscle. The laparoscope was removed. A separate incision was made directly over the anterior-lateral fractures on ribs 5 and 6. Two 50 mm plates using standard open technique. Prior to closure, the left hemithorax was drained thoracoscopically and a chest tube was left in place.

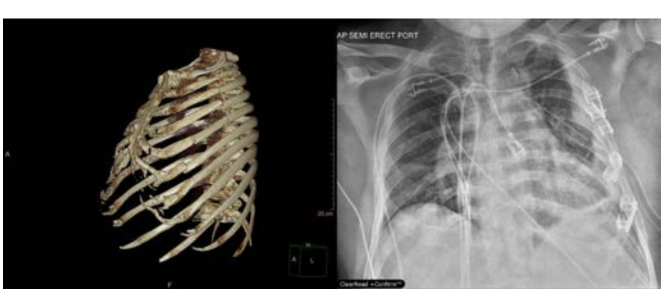

Figure 5 Preoperative 3D CT scan of the chest and postoperative chest X-ray of a patient after rib plating.

The patient was brought to the ICU postoperatively. A chest radiograph was done to confirm adequate drainage of the pleural space. He was maintained on a ventilator for 48 hours and was extubated to high flow nasal cannula. During the course of the next 24 hours he was weaned to room air. His chest drain was removed. His pain was negligible and he was walking the halls independently. He was discharged on postoperative day 4. On his follow-up appointment, he continued to feel well without any disabling symptoms.

Pitfalls of the VARP technique

Operative timing

The patient went to the operating room on postopertive day 5. By this time the tissues appeared more hemorrhagic which made visual identification of the fractures challenging. Also, there was more oozing from the tissues as the traumatic inflammation of the tissues had increased the degree of vascularity. This resulted in more tissue bleeding adding to the difficulty visualization of the injury.

Injury patterns

There is yet no standardization of chest wall injuries. The American Association for the Surgery of Trauma Abbreviated Injury Scale chest wall injury score is inadequate to describe the injury for operative management. We propose the following (figure 6):

Anterior: from the sternum to the anterior axillary line.

Lateral: from the anterior axillary line to the posterior axillary line.

Posterior-lateral: from the posterior axillary line to the angle of the rib.

Posterior: from the angle of the rib to the head of the rib.

The importance of defining the injury patterns is critical as it dictates whether or not a particular surgical approach will be effective. We determined that the VARP approach is ideal for posterior-lateral injuries specifically for the subscapular rib fractures. Lateral rib fractures can also be performed. Our patient had rib fractures on the boarder of the anterior and lateral aspect. This required a separate incision to address these injuries.

Instrumentation

Like any new procedure, many of our current surgical instruments are not specifically designed for this type of surgery.

DISCUSSION

Chest wall stabilization is still an evolving science and has shown promising results in certain patients. In this study, the authors aimed to prove a feasibility and clinical application of a new, minimally invasive method for rib plating to obviate some of the morbidity associated with the procedure as was shown to be true with the culmination of abdominal laparoscopy, much of which has become standard of care.[13]

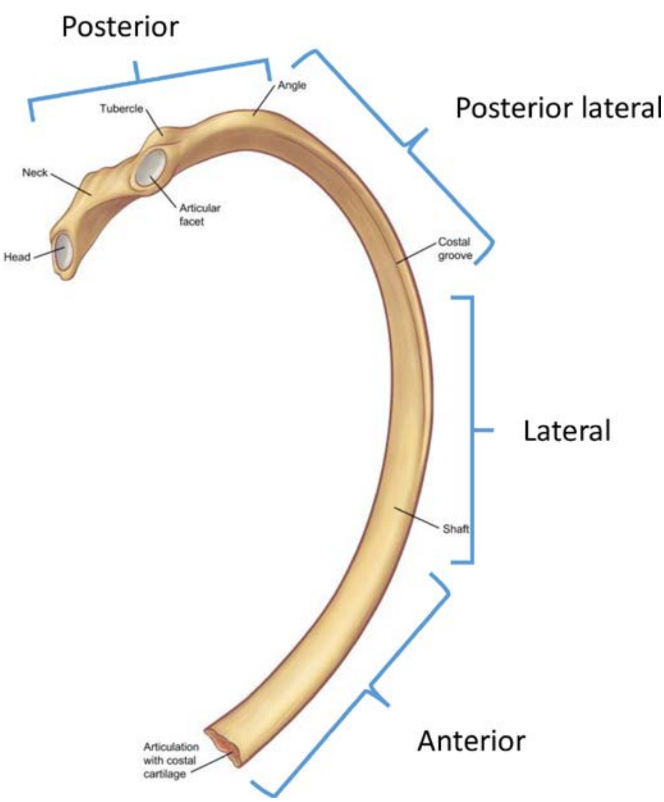

Figure 6 Rib anatomy and surgical approach.

Minimally invasive surgery as a field has evolved during the last century. In 1901, the Russian surgeon Dimitri Oskarovich Ott performed the first endoscopic examination of the abdominal viscera through a posterior vaginal incision.[13] The first laparoscopic procedure in the USA was done at the Johns Hopkins Hospital, where Bertram Bernheim used a 12 mm proctoscope to evaluate the peritoneal cavity through an epigastric incision, later confirming his observations with laparotomy.[14]

The course of minimally invasive chest wall stabilization may have similarities with the success of minimally invasive cholecystectomy. With the development of better lens technology, Erich Muhe performed the first laparoscopic cholecystectomy in Germany in 1985, about 100 years after the first open cholecystectomy. In 1987, Phillipe Mouret performed the first video-guided laparoscopic cholecystectomy in France, obviating the need for the surgeon to hold the scope with one hand to view through it. Early reports of laparoscopy were met with much skepticism and criticism, but with perseverance, by 1993 laparoscopic cholecystectomy was deemed the procedure of choice for uncomplicated cholelithiasis.[15] By this time the patients presented to their surgeons requesting for a specific operation. It would be several years before the data were developed which demonstrated laparoscopic versus open cholecystectomy was superior.

The master-slave concept where a surgeon sits on a console and performs surgery remotely emerged in the late 1990s.[16] During the last decade, we have seen a boom in the use of robotic surgery, which has led to improved ergonomics when compared with traditional laparoscopy.[17 18] If the outlook of minimally invasive rib plating has any resemblance to the emergence of laparoscopy in other disciplines, robotic approaches may be a part of the foreseeable future.

Similarly, technology in the setting of chest wall stabilization continues to evolve. The concept of operative stabilization of rib fractures has been around since the 1950s. It was not until the mid-2000 that the technological advancement with the operative systems to make the procedure safe. There are many devices that can be used for plating, including unicortical of bicortical fixation systems.[2] These authors used a second-generation, U-plate Acute Innovations RibLoc system which allows for purchase on the front and back of the fractured rib. With increasing experience, surgeons are able to stabilize multiple levels through smaller incisions. Thoracoscopic rib fixation was recently proven to be feasible. This method allows for visualization and stabilization of all rib segments from inside the thoracic cavity.[19] This method allows for video-assisted washout but calls for single-lunge ventilation and will likely require surgeons to have more advanced training. The technique described in this article allows for an extrathoracic/VARP approach using standard plating assisted by laparoscopy.

Some authors have advocated partial surgical stabilization of numerous fractures, including those ribs which are readily accessible. This idea prevents additional incisions, and doing so appears to have similar outcomes on restoring chest wall physiology.[20] However, leaving fractured ribs, particularly those that are displaced, in a malaligned position can cause long-term pain. An extrathoracic minimally invasive approach to rib plating may allow the surgeon to address multiple fractured levels along the chest wall through a few small incisions. This can be accomplished by creating an operative field and not dividing any muscles.

With the advent of laparoscopy has come smaller incisions which are both esthetically appealing and cause less trauma, thus decreasing morbidity. We have demonstrated feasibility of minimally invasive technique for chest wall stabilization in the cadaver model. As with any new surgical procedures, there is a learning curve and correct patient selection. We have demonstrated in a cadaver model the fesability of VARP with a particular injury pattern, and defined the initial surgical steps. This procedure now requires application in the general patient population to further define the patient indications which is best done in a prospective study.

Funding This project received research grant from Acute Innovations, Industry Grant $30 000.00.

Competing interests JJD receives honorarium for consulting services from Acute Innovations.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information.

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