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Brief Report

The use of cadaver models to diagnose rib fractures: A pilot study

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ABSTRACT

Background: In the emergency department, rib fractures are a common finding in patients who sustain chest trauma. Rib fractures may be a sign of significant, underlying pathology, especially in the elderly patients where rib fractures are associated with significant morbidity and mortality. To date, no studies have evaluated the ability of ultrasound to detect rib fractures using cadaver models and subsequently use this model as a teaching tool.

Objectives: The purpose of this study was to determine if it is possible to generate rib fractures on cadaver models which could be accurately identified using ultrasound.

Methods: This was a cross-sectional study performed during one session at a cadaver lab. A single hemithorax from four adult cadavers were used as models. Single rib fractures on each of rib five through eight were created. Four subjects, blinded to the normal versus fractured ribs, were asked to identify the presence of a fracture on each rib.

Results: A total of 8 of 16 potential ribs had fractured induced by study staff. Mean accuracy was 55% for all subjects. The overall sensitivity and specificity for detecting rib fractures was 50% (CI: 31.89–68.11) and 59.38% (CI: 35.69–73.55) respectively. The overall PPV and NPV was 55.17% and 54.29% respectively.

Conclusions: In this pilot study, subjects were not able to detect induced rib fractures using ultrasound on cadaver models. The use of this model as a teaching tool in the detection of rib fractures requires further investigation.

1. Introduction

In the emergency department (ED), rib fractures are a common finding in patients who sustain chest trauma. Although rib fractures are not always clinically relevant, they may be a sign of more significant, underlying pathology. This concern is especially real in the elderly patient population where rib fractures are associated with significant morbidity and mortality. [1,2] Chest radiography has remained the initial test of choice for suspected rib fractures, despite its low sensitivity. The literature suggests that ultrasound (US) may be an even more sensitive imaging modality in the diagnosis of rib fractures than chest radiography. [3-7] In a meta-analysis by Yousefifard et al. the pooled sensitivity and specificity of ultrasonography in the detection of thoracic bone fractures was 0.97 and 0.94 respectively, while for chest radiography it was 0.77 and 1.0 respectively. [8]

The use of US has become a standard diagnostic tool in the ED [9]. The known advantages of US in the ED include its wide availability, portability, safety, favorable time and cost factors [10]. As the use of ED US expands, the need for US education and training continues to increase. Providing a means of educating practitioners and encouraging the use of US as a method for diagnosing rib fractures in the ED can be highly valuable.

Studies have shown that various US applications can be effectively learned in a short time frame [11-13]. It is often difficult to educate trainees in the use of US for specific conditions in real-time due to a variety of reasons, including uncertainty of when these conditions will present in the ED, patient discomfort or safety. A number of studies have evaluated the use of cadaver models as a viable alternative to patients or live models for US education [14-16]. These results support the use of US as an effective teaching modality in the diagnosis of different pathologies and performance of procedures performed in the ED. Studies have shown that cadaver models can be useful in the US evaluation of cranial and long bone fractures. [17] Despite this, no studies to date have evaluated the ability of US to detect rib fractures using cadaver models and subsequently use this model as a teaching tool. The

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purpose of this study was to determine if it is possible to generate rib fractures on cadaver models which could be accurately identified using US.

2. Materials and methods

This was a cross-sectional study performed in a single session at the Bioskills Education Center, an affiliate teaching center of the Northwell Health System in New Hyde Park, New York (Fig. 1).

A single hemithorax from four adult cadavers were used as the model for rib fractures. Cadavers were accepted as a convenience sample without regard to age, sex, or pre-existing disease. No cadavers had evidence of trauma or tissue disruption to areas being tested. Before the initiation of the study, different methods to fracture the ribs were tested by the study investigator. These methods included trauma shears, hammer, wood and metal chisels. It was determined via cadaver ultrasound that the hammer and metal chisel method created a fracture that most closely resembled the sonographic appearance of an actual rib fracture. This is similar to the mechanism described by Demers et al. for their evaluation of long bone fractures.

Immediately prior to the start of the study, two study investigators made a single incision in the anterior axillary line directly above ribs five through eight on each single hemithorax for each of the four cadaver models. This was done to conceal which ribs were fractured by investigators. Single rib fractures for ribs five through eight were then created using a hammer and metal chisel. Fractures were induced by the same study investigators in the same fashion to minimize variation. For each cadaver model, this allowed for a maximum of four rib fractures and a minimum of zero rib fractures. All incisions were then sutured closed so that subjects were not able to directly visualize the presence or absence of a rib.

The subjects were four Registered Diagnostic Medical Sonographer (RDMS) certified, emergency medicine attending physicians, who had each completed postgraduate fellowship training in emergency US. For each rib, subjects were asked to indicate whether a fracture was present. Each subject was advised to scan the area of the rib where the incision was present in both the transverse and sagittal plane using a high frequency, 10 MHz linear transducer. Subjects were permitted to adjust US machine controls and settings as desired. Subjects recorded their findings, of whether or not a fracture was present, on a pre-designed, standardized report form to record the data obtained during the study procedures.

2.1. Data collection and processing

The data was collected and managed using Research Electronic Data Capture (REDCap), a secure, web-based application designed to support data capture for research studies at Staten Island University Hospital. The data were analyzed using descriptive statistical methods and were expressed as frequency counts and percentages for categorical variables or as mean and standard deviation or median and interquartile range (IQR), as appropriate, for continuous variables. Results were presented as proportions or mean difference, with 95% confidence intervals. Data analysis was conducted using the SAS® System Version 9.3 (SAS Institute Inc., Cary, NC).

3. Results

A total of 8 of 16 potential ribs had fractured induced by study staff. All subjects evaluated each of the 16 ribs. Fig. 2 illustrates the accuracy of correctly identifying a normal or fractured rib by an individual sonographer. Mean accuracy was 55% for all subjects. Fig. 3 illustrates the sonographic appearance of a normal and fractured cadaver rib viewed in the transverse and sagittal plane.

The overall sensitivity and specificity for detecting rib fractures was 50% (CI: 31.89–68.11) and 59.38% (CI: 35.69–73.55) respectively. The overall PPV and NPV was 55.17% and 54.29% respectively.

4. Discussion

The use of US has become vital in the ED. Studies have shown that the use of cadaver models is a viable alternative to patients or live models. There is evidence that cadaver models can be used for a variety of conditions, including the evaluation of long bone fractures. However, there is still no research on the ability of US to detect rib fractures using cadaver models and subsequently use this model as a teaching tool.

In this pilot study, there was considerable variation in an individual subject's ability to detect a rib fracture. The overall sensitivity for detecting rib fractures using US on cadaver models was 50%. This is considerably lower than what has previously been reported in the literature on living patients and studies of long bone fractures in cadavers. [17]

The difficulty in correctly identifying rib fractures in this study was in part due to the ability to distinguish between the cortex of the rib and visceral pleura without the aid of a spontaneously breathing patient (Fig. 4). The visceral pleura of the cadavers on US appear as a hyperechoic line, which is similar to the sonographic appearance of the rib cortex.

Cadaver #3 had the lowest percentage of ribs accurately identified. This may have been due to the state of preservation and body habitus of this specific cadaver. The thorax was shrunken as compared to the other cadavers used for this study. As a result, the ribs were spaced close together, making it difficult to distinguish an individual from an adjacent rib on US. However, even with the removal of this cadaver the sensitivity and specificity remained low.

Fig. 1. Single cadaver hemithorax with sutures over the area of previous incision and possible rib fracture.

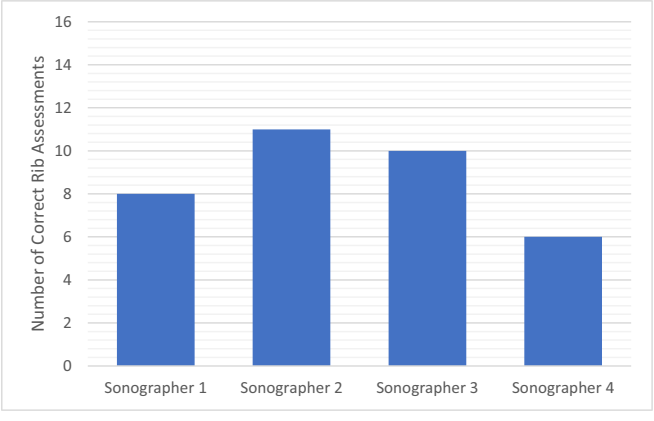

Fig. 2. Accuracy in identifying normal or fractured rib by individual sonographer and cadaver.

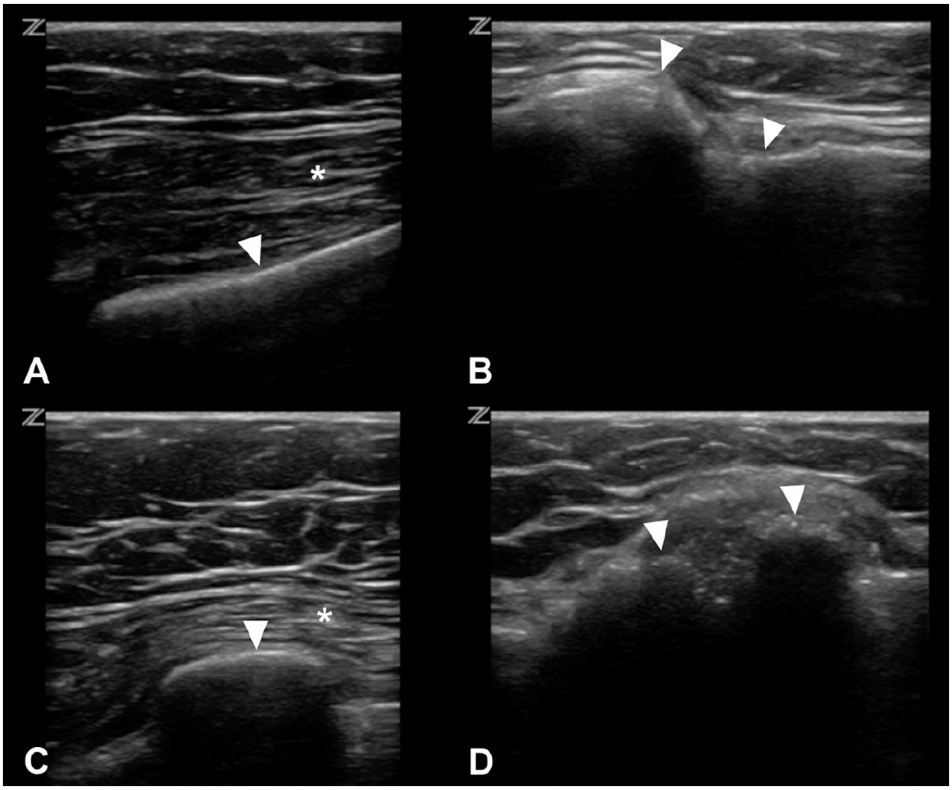

Fig. 3. Panels A and C represent the normal sonographic rib (arrowhead) appearance in the sagittal and transverse plane respectively. The asterisk represents adjacent thoracic soft tissue. Panels B and D represents fractured rib seen in the sagittal and transverse plane respectively. The area between the arrowheads is the site of fracture rib.

5. Limitations

There were several limitations to this study that warrant consideration. The study was constructed as a pilot study, including 4 subjects and 16 cadaver ribs, at a single center. Furthermore, due to cost feasibility, cadavers were accepted as a convenience sample without regard to age, sex, or pre-existing disease. Pilot studies are a crucial phase of the research process, allowing a quick examination of the feasibility of a specific approach. They are often a necessary, initial step when exploring innovative interventions. Although the results of this pilot study did not indicate that a cadaver model is a useful tool in detecting rib fractures on US, they should be interpreted with caution. Due to the cost and difficulty in obtaining cadavers, only 4 cadaver hemithoraces were utilized in the study. Further studies including more significant sample size, with cadavers of similar demographics, preservation state and body habitus and at more than one institution may be necessary.

Fig. 4. Sagittal view of rib (arrowhead) with adjacent hyperechoic (arrow) visceral pleural.

Another consideration is the method of creating fractures that was used in this study. Although the incision used to create fractures was not specific to the fracture site, it did potentially lead to bias since the subjects were looking for an abnormality in that area. Despite this, subjects were still not able to consistently identify the presence of a fracture and another method, leading to less bias was not identified. There is no consensus on the method which should be used for inducing fractures. However, in this study, investigators utilized several methods before it was determined the hammer and chisel method most closely resembled an actual rib fracture on US in humans. This is similar to the conclusion and methodology described by Demers et al. for their evaluation of long bone fractures. One could argue that another method may be more accurate.

6. Conclusions

In this pilot study, subjects were not able to detect induced rib fractures using US on cadaver models. The use of this model as a teaching tool in the detection of rib fractures requires further investigation.

References

[1] Barnea Y, Kashtan H, Skornick Y, et al. Isolated rib fractures in elderly patients: mortality and morbidity. Can J Surg 2002;45(1):43–6.
[2] Holcomb JB, McMullin NR, Kozar RA, Al et. Morbidity from rib fractures increases after age 45. J Am Coll Surg 2003;196(4):549–55.

[3] Hwang E, Lee Y. Simple X-ray versus ultrasonography examination in blunt chest trauma: effective tools of accurate diagnosis and considerations for rib fractures. J Exerc Rehabil 2016;12(6):637–41.
[4] Griffith JF, Rainer TH, Ching AS, et al. Sonography compared with radiography in revealing acute rib fracture. AJR Am J Roentgenol 1999;173(6):1603–9.
[5] Rainer TH, Griffith JF, Lam E, et al. Comparison of thoracic US, clinical acumen, and radiography in patients with minor chest injury. J Trauma 2004;56(6):1211–3.
[6] Uzuna M, Beksaça B, Karab A, et al. Ultrasonography as a better diagnostic efficiency in rib fracture. J Exp Clin Med 2013;30:133–5.
[7] Turk F, Kurt AB, Saglam S. Evaluation by US of traumatic rib fractures missed by radiography. Emerg Radiol 2010;17(6):473–7.
[8] Yousefifard M, Baikpour M, Ghelichkhani P, et al. Comparison of ultrasonography and radiography in detection of thoracic bone fractures; a systematic review and meta-analysis. Emergency 2016;4(2):55–64.
[9] Healey MA, Simons RK, Winchell RJ, et al. A prospective evaluation of abdominal US in blunt trauma: is it useful? J Trauma 1996;40:875–83.
[10] Ultrasound guidelines: emergency, point-of-care and clinical ultrasound guidelines in medicine. Ann Emerg Med May 2017;69(5):e27–54.
[11] Marshburn TH, Legome E, Sargsyan A, et al. Goal-directed US in the detection of long-bone fractures. J Trauma 2004;57(2):329–32.
[12] Tayal V, Blaivas M, Mandavia D, et al. Policy statement: emergency US guidelines. Ann Emerg Med 2009;53:550–70.
[13] Hedelin H, Tingström C, Hebelka H, et al. Minimal training sufficient to diagnose pediatric wrist fractures with US. Crit Ultrasound J 2017;9(1).
[14] Miller R, Ho H, Ng V, et al. Introducing a fresh cadaver model for US-guided central venous access training in undergraduate medical education. West J Emerg Med 2016;17(3):362–6.
[15] Hoyer R, Means R, Robertson J, et al. US-guided procedure in medical education: a fresh look at cadavers. Intern Emerg Med 2016;11(3):431–6.
[16] Zaia BE, Briese B, Williams SR, et al. Use of cadaver models in point-of-care emergency ultrasound education for diagnostic applications. J Emerg Med 2012 Oct;43(4):683–91.
[17] Demers G, Migliore S, Bennett DR, et al. Ultrasound evaluation of cranial and long bone fractures in a cadaver model. Mil Med 2012;177(7):836–9.