The benefits and limitations of ultrasound in the diagnosis of rib fractures from the emergency department to the sports field: A narrative review

Why have imaging guidelines stopped short of supporting ultrasound as a primary diagnostic modality for rib fractures?

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ABSTRACT: Ultrasound promises to be a rapid, radiation-free alternative to chest X-ray for the diagnosis of rib fractures in blunt chest trauma, and this promise has been raised repeatedly over the last decade. Results have been encouraging, and reviews have consistently concluded that ultrasound appears to be the superior diagnostic modality. However, authors have stopped short of recommending changes in practice, and chest X-ray remains the recommended study in both Canadian and American radiology guidelines. In this narrative review, a search of three primary databases was performed to consider the current balance of evidence and discuss concerns that have, thus far, weighed against the broad application of ultrasound in this role. This review suggests that the potential applications for ultrasound in rib fracture diagnosis warrant its consideration for expanded use from emergency rooms to athletics venues.

Introduction

Rib fractures are common concerns across the scope of medicine, with cohort studies in America and Canada identifying rib fractures in 10% of all trauma presentations and over 30% of minor chest trauma presentations to emergency departments.[1,2]

The mainstay of rib fracture diagnosis has been the chest radiograph. Both the most recent Canadian Association of Radiologists' referral guidelines and American College of Radiology's guidelines indicate a chest X-ray as the most appropriate imaging modality in adults with suspected rib injuries from minor blunt trauma.[3,4] However, there has been growing evidence over the past 2 decades that ultrasound is superior to X-ray in the detection of chest wall fractures, including fractured ribs.[5,6]

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While the weight of evidence has been in favor of ultrasound as the more sensitive technique in several previous reviews,[7-11] none has concluded that ultrasound should replace, or join, conventional chest X-ray as a first-line diagnostic study for rib fractures following minor chest trauma. Imaging guidelines also continue to indicate chest X-ray as the most appropriate investigation.[3,4] This review aims to examine why these analyses have stopped short of supporting any change in practice and if ultrasound's use as a primary diagnostic modality for rib fractures is worth further investigation and study. A search of three primary databases was performed to include an updated picture of original studies in a discussion of the balance of evidence on this topic and expand on whether the identified benefits and drawbacks of ultrasound in rib fracture imaging justify why imaging guidelines have not adopted ultrasound as a recommended modality.

Methods

Search terms and criteria were determined based on an initial literature search and on previous reviews in this subject area. PubMed, Embase (via Ovid), and Google Scholar were searched between 5 December 2017 and 16 January 2018, and the search was updated with all new studies to 25 June 2019 using the keywords "ultrasound" or "ultrasonography" or "sonography" or "chest film" or "chest X ray" and "rib fractures" or "chest wall fracture." All results were then reviewed for inclusion based on whether they met the criteria of being available online in English and represented original studies directly comparing the diagnostic ability of ultrasonography and chest X-ray in detection of human rib fractures. Reviews, editorial

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articles, case reports, and studies with patient populations of less than 10 were excluded from the main comparison between ultrasound and X-ray with regard to rib fracture diagnosis. Systematic reviews and meta-analyses were not included in the comparison table but were identified for consideration in the discussion.

Results

Of the total search results (PubMed: 338 results returned, Embase: 446 results, Google Scholar: 820 results), 13 studies were identified that matched the stated selection criteria. These are presented in the Table. Overall, 12 of the 13 studies that met our inclusion criteria support ultrasound as more sensitive than X-ray for the detection of rib fractures, with only one study (Hurley and colleagues[20]) concluding equivalent sensitivity exists between ultrasound and X-ray. All five studies that included a reference or gold standard to confirm the initial ultrasound fracture diagnosis found ultrasound to be superior to X-ray.[5,17-19,22]

Discussion

The results of the literature search support the view that ultrasound is a more sensitive and accurate modality for the diagnosis of rib fractures with 12 of the 13 included studies concluding ultrasound was superior to chest X-ray. Only Hurley and colleagues[20] concluded their results were not sufficient to support ultrasound over X-ray, and theirs was the smallest of any included study at only 14 participants.

In seven of the 12 studies that concluded in support of ultrasound, the study design allowed comparison of the number of fractures diagnosed by the two modalities, and in each case ultrasound identified at least twice the number of fractures as did X-ray.[12-14,18,19,22,23] In terms of formal pooled sensitivities, there has been only one completed meta-analysis (by Yousefifard and colleagues[8] in 2016), which found the sensitivity of ultrasound for rib fractures in the studies they examined was 0.97 (95% CI 0.93-1.00) with the sensitivity of chest X-ray at 0.77 (95% CI 0.57-0.97).[8] The remaining five of 12 studies presented in the Table supported ultrasound but did not allow for a comparison of true sensitivity as they included only participants with negative X-rays and examined them with ultrasound to identify missed fractures. The drawback of this study design is discussed below as a limitation in the evidence for ultrasound.

Despite the balance of evidence supporting the diagnostic superiority of ultrasound, both the Canadian Association of Radiologists and American College of Radiology guidelines continue to recommend chest X-ray as the most appropriate imaging in the case of suspected rib fracture from minor blunt trauma, with the American College listing chest ultrasound in the lowest appropriateness category and the Canadian Association not mentioning ultrasound at all.[3,4] This contrast between evidence and guidelines raises the question: are there significant limitations that undermine these presented results and explain why ultrasound should not be considered a first-line choice for rib fracture diagnosis? The four major limitations of ultrasound and its supporting evidence raised in previous literature reviews and guidelines are discussed below, along with potential counterarguments.

There exists recent evidence that ultrasound has greater sensitivity than chest X-ray for rib fracture diagnosis relative to CT.

1. Variability between patients and fracture sites

One potential limitation is that ultrasound is not equally sensitive in its ability to diagnose chest wall fractures in all areas of the rib cage. It has been noted that ultrasound has difficulty visualizing the subscapular and infraclavicular portions of the upper ribs.[21] The body habitus of the patient is also a factor as ultrasound is less sensitive in obese patients and those with large breasts.[13,16,21] Perhaps reflecting these limitations, the meta-analysis by Yousefifard and colleagues found that, contrary to the significant sensitivity superiority of ultrasound, the specificity of radiography was slightly higher than ultrasound (100% versus 94%).[8] The authors concluded that, based on the calculated likelihood ratios, a negative result on an ultrasound was more useful than a negative radiograph; however, visualizing a fracture on a radiograph is slightly more reliable than a positive ultrasound. They also noted, however, that it appeared that using a higher frequency of ultrasound was associated with narrowing of this specificity gap.[8]

2. Lack of appropriate gold standards

Lalande and Wylie of Laval University conducted a short review in 2014 and identified what they viewed as the most significant issue with existing studies supporting ultrasound: the frequent lack of a reference or gold standard modality for comparison and confirmation of identified fractures.[10] Consistent with this point, only five of the 13 studies identified in our search had any follow-up to confirm the initial ultrasound diagnosis of fracture. That is, the majority of studies assumed 100% specificity for ultrasound, which, as discussed in the previous section, has not been found to be true. Furthermore, five of the 13 studies identified in our search[5,15-17,21] included patients only on the basis of a negative X-ray and performed a subsequent ultrasound to look for missed fractures. In these cases, there is no way to compare the number of fractures missed by ultrasound to those missed by X-ray. However, while Lalande and Wylie reported that they did not identify any studies with reference standards, our search found two[5,18] that used uptake on bone scan to confirm the presence of ultrasound-identified fractures and three others[17,19,22] that used a repeated ultrasound at 1 to 3 weeks, after callus formation and remodeling had begun, to confirm the fractures identified at first presentation. Therefore, it appears that ultrasound has uniformly been found to be superior to radiograph in studies that included confirmatory reference standard imaging.

In their 2019 systematic review, Battle and colleagues also identified the variability in standards as an issue with existing evidence.[9] They concluded that further studies using CT as the gold standard were needed to fully assess ultrasound diagnostic accuracy. While a study directly comparing chest X-ray and ultrasound to a reference CT is lacking, and could be valuable, there have been four studies in the last

TABLE. Literature search results organized by publication date for comparison of diagnostic accuracy of ultrasound and chest radiography in the diagnosis of rib fractures.

Study	n	Modalities compared	Reference standard?	Modality comparison result	Key study conclusions
Pishbin and colleagues, 2017[12]	61	Chest X-ray (PA and oblique) and ultrasound	No	Ultrasound detected 98.3% of fractures found by any method, oblique X-ray 45.8%, PA chest 40.7%.	Ultrasound is more sensitive than radiography for rib fracture diagnosis.
Lalande and colleagues, 2017[13]	96	X-ray (oblique rib view) and ultrasound	No	27/96 (28%) of patients were diagnosed with rib fracture on point of care (POC) ultrasound but not on initial X-ray versus 11/96 patients (11%) with diagnosis on X-ray but not POC ultrasound.	Ultrasound is a feasible technique for rib facture diagnosis in an emergency department setting to complement radiography.
Hwang and Lee, 2016[14]	201	Chest X-ray and ultrasound	No	Rib fracture detected in 34.3% (69) of patients by radiography but 84.6% (160) by ultrasound.	Ultrasound offers greater accuracy than radiography for rib fracture diagnosis; larger RCT is needed.
Uzun and colleagues, 2013[15]	55	Chest X-ray (AP) and ultrasound	No	In 47/55 trauma patients agreed by three physicians to have negative chest X-rays had rib fractures diagnosed by ultrasound.	Ultrasound by an experienced radiologist is required for early diagnosis of rib fractures in trauma patients.
Lee and colleagues, 2012[16]	93	Chest and rib series X-ray, CT and ultrasound	No	64/93 patients (68.8%) found to be negative for fractures on both radiography and CT by two surgeons and two radiologists were found to have chondral fractures on ultrasound.	Chest ultrasound can help diagnose sternal and costal cartilage fractures missed by conventional radiology.
Turk and colleagues, 2010[17]	20	Chest X-ray (PA and oblique) and ultrasound	Repeat ultrasound at 1–3 weeks to confirm callus formation.	All 20 patients had clinical suspicion of fracture and normal X-ray, but ultrasound detected 26 fractures in 18/20 patients.	Ultrasound is more sensitive than radiography for chest wall fractures and should be routine in those with clinical suspicion but negative X-ray.
Paik and colleagues, 2005[18]	58	Chest X-ray (AP and oblique lateral views) and ultrasound	Bone scan uptake, biopsy and follow-up	Ultrasound revealed 36/37 (97%) of rib fractures as compared to 16/37 (43%) found by X-ray. Ultrasound also identified 94% of confirmed bone metastasis compared to 39% visible on X-ray.	Ultrasound is more reliable and accurate than X-ray for rib lesions. Ultrasound is recommended as a modality to evaluate patients with question of rib metastasis.
Rainer and colleagues, 2004[19]	88	Chest X-ray (PA and oblique), ultrasound and clinical judgment	Repeat ultrasound at 3 weeks to confirm fracture by callus/ remodeling	Ultrasound sensitivity for chest wall fractures was 80.3 (95% CI 69.5-88.5) compared to 23.7 (95% CI 14.7-34.8) for X-ray and 26.0 (95% CI 15.8-36.3) for clinical impression alone, meaning only one in five fractures seen on ultrasound was visible on X-ray.	Ultrasound at presentation to emergency is significantly more accurate than X-ray or clinical judgment at detecting rib and sternal fractures.
Hurley and colleagues, 2004[20]	14	Chest X-ray (PA and oblique rib) and ultrasound	No	Oblique X-ray identified 13/15 fractures found with any modality, PA chest 11/15 and ultrasound 14/15	Ultrasound use does not significantly increase the detection of rib fractures in trauma and does not justify its routine use.
Kara and colleagues, 2003[21]	37	Chest X-ray and ultrasound	No*	15/37 (40.5%) of patients with negative X-ray results had boney or chondral rib fracture on ultrasound.	Ultrasound is a useful modality to identify fractures missed by X-ray.
Griffith and colleagues, 1999[22]	50	Chest X-ray (PA and oblique) and ultrasound	Repeat ultrasound at 3 weeks to confirm remodeling	Chest radiograph revealed eight fractures in 6/50 patients (12%) while ultrasound identified 83 fractures in 39/50 (78%)—10 times as many fractures in 6 times as many patients. Repeat ultrasound at 3 weeks confirmed all identified fractures as well as 12 fractures not seen by either modality initially.	Ultrasound is able to reveal more fractures in patients than radiography, but further studies are needed to determine the appropriate role for ultrasound in medical practice.
Dubs-Kunz, 1996[23]	122	Chest X-ray and ultrasound	No	Diagnosis of rib fracture by ultrasound was twice as sensitive as radiography (75 rib fractures seen on ultrasound, 36 on X-ray, all X-ray findings also visible on ultrasound).	Though rib fracture diagnosis does not result in clinical change, psychological factors of correct diagnosis can be important for dealing with pain, and ultrasound is the more sensitive modality.
Wischhöfer, 1995[5]	21	Chest X-ray and ultrasound	Bone scan uptake to confirm lesion location	Rib fractures identified in 16/21 patients with clinical suspicion of fracture but normal X-ray. Confirmation of ultrasound identified lesions by bone scan revealed seven further likely fractures.	Ultrasound is more reliable for fracture diagnosis than X-ray, but can miss nondislocated fractures, likely due to patient respiration during the exam.

Abbreviations: CT—computed tomography, PA—posteroanterior, AP—anteroposterior

* Kara and colleagues state that most patients had a repeat chest X-ray after 2 to 4 weeks to monitor established fracture site healing, but as it is not clear the number of patients who underwent this repeat chest X-ray or the percentage of ultrasound-detected fractures that were confirmed by this process, we have not considered this to be a reference study in this review.

2 years comparing either CT and ultrasound or CT and chest X-ray that can shed light on whether a CT reference is likely to change the overall picture. Of the CT and ultrasound comparisons, ultrasound sensitivity varied from 100%[24] to 67%[25] (specificity 98.99% and 98% respectively) versus the CT standard. In X-ray and CT comparisons, sensitivity varied from 40%[26] to 48.8%[27] with specificity ranging from 99% to 100% respectively. Also of note, in their 2012 study, Lee and colleagues diagnosed 64 chondral rib fractures in 93 minor chest trauma patients who had both a negative CT and chest X-ray.[16] Thus, there exists recent evidence that ultrasound has greater sensitivity than chest X-ray for rib fracture diagnosis relative to CT and, based on the results of Lee and colleagues, it also seems that CT is not a definitive gold standard for this comparison if it misses chondral fractures visible on ultrasound.

3. Increased imaging time with ultrasound

Another issue raised by several studies has been that completing an ultrasound scan takes longer than a X-ray, thus delaying diagnosis.[16] X-ray views can be accomplished in a few minutes while the time for a formal ultrasound is reported to be anywhere from 10 to 30 minutes longer in the studies we identified.[16,20,22] This concern, however, compares the time to completion after the study has begun in the radiology department. As portability and quality of ultrasound improves,[28] its use by emergency physicians at initial presentation of minor blunt trauma may in fact speed up rib fracture diagnosis by helping triage in busy emergency departments where there is otherwise a significant wait for X-rays, not to mention X-ray interpretation.[7] Evidently, in cases of significant chest trauma, when the identification of underlying organ damage is time sensitive, the time to perform an ultrasound study for rib fractures could have significant implications compared to X-ray or CT.[29] However, in major trauma the clinical situation is very different and not the focus of our discussion. Similarly, our review does not address the evident impact of user training on speed or sensitivity as the focus is on whether existing evidence supports a potential benefit of ultrasound in this application. If the conclusion is that it does, then questions of provider training would be an area for further investigation.

4. Lack of impact on management

A final point frequently raised against recommending ultrasound over X-ray in the case of suspected rib fracture, including in both the Canadian and American radiology guidelines,[3,4] is that increased sensitivity in the diagnosis of rib fracture is in fact not necessary and would not change management. All that is required is to rule out any dangerous associated pathology, and an X-ray is sufficient for this in cases where the mechanism of injury is not severe enough to support immediate CT.[30]

The use of ultrasound for stress fracture injuries has the potential to help prevent misdiagnosis and convince motivated athletes to allow these fractures time to heal without exacerbation, shortening recoveries.

Several points counter the view that including ultrasound to diagnose a greater proportion of rib fractures correctly is of no benefit. First, a reliable assessment of fractures is important for educating a patient on the likely timeline and approach for resolution of their pain and ability to return to work.[7] As well, a correct diagnosis may have implications for legal claims and/or avoiding physician litigation.[14,15,19] Furthermore, it is not the case that missed rib fractures all resolve without complications, with evidence that rib fractures increase the risk for many pulmonary complications including delayed hemothorax, pneumothorax, and pneumonias.[1,31-33] It therefore follows that identifying any fractures is important to correctly risk stratify patients. Two populations that highlight the potential risks associated with missed rib fractures are the elderly and athletes. In geriatric populations, rib fractures are linked to increased mortality and morbidity.[21,34] One cohort study of trauma patients admitted to a Canadian tertiary centre found rib fractures were independently associated with a five times greater risk of death in those 65 or over compared to younger patients.[32] For athletes, reinjury following a premature return may result in a greater severity of damage and prolonged recovery.[22] Chest wall bony injuries are relatively common in contact sports such as rugby, where decisions on whether a player is safe to return to a match may need to be made quickly on pitch sidelines where ultrasound is the only accessible modality.[35] Rib fractures in noncontact sports may also significantly impair an athlete's ability to train and compete, for example in rowing where rib stress fractures have been identified as accounting for a greatest amount of training time lost by elite athletes.[36] The use of ultrasound for stress fracture injuries has the potential to help prevent misdiagnosis and convince motivated athletes to allow these fractures time to heal without exacerbation, shortening recoveries.[37] Given ultrasound has the advantage of not exposing a patient to ionizing radiation, as well as the decreasing cost and size of ultrasound machines, it is increasingly useful outside hospital settings for sports physicians at competition or training venues and emergency medical providers in rural settings.[28]

Conclusion

This narrative review supports ultrasound as the more sensitive diagnostic modality and considers the concerns raised by previous reviews on this topic. Examining the benefits and drawbacks to the use of ultrasound in rib fracture diagnosis highlights its potential for positive impact on patients and supports its continued consideration for practice guidelines and provider training. ■

Competing interests

None declared.

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References on page 82

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Continued from page 78

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