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REVIEW ARTICLE

Comparison of Ultrasonography and Radiography in Detection of Thoracic Bone Fractures; a Systematic Review and Meta-Analysis

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Abstract

Introduction: The potential benefit of ultrasonography for detection of thoracic bone fractures has been proven in various surveys but no comprehensive conclusion has been drawn yet; therefore, the present study aimed to conduct a thorough meta-analytic systematic review on this subject. **Methods:** Two reviewers independently carried out a comprehensive systematic search in Medline, EMBASE, ISI Web of Knowledge, Scopus, Cochrane Library, and ProQuest databases. Data were summarized as true positive, false positive, true negative and false negative and were analyzed via STATA 11.0 software using a mixed-effects binary regression model. Sources of heterogeneity were further assessed through subgroup analysis. **Results:** Data on 1667 patients (807 subjects with and 860 cases without thoracic fractures), whose age ranged from 0 to 92 years, were extracted from 17 surveys. Pooled sensitivity and specificity of ultrasonography in detection of thoracic bone fractures were 0.97 (95% CI: 0.90-0.99; I2= 88.88, p<0.001) and 0.94 (95% CI: 0.86-0.97; I2= 71.97, p<0.001), respectively. The same measures for chest radiography were found to be 0.77 (95% CI: 0.56-0.90; I2= 97.76, p<0.001) and 1.0 (95% CI: 0.91-1.00; I2= 97.24, p<0.001), respectively. The sensitivity of ultrasonography was higher in detection of rib fractures, compared to fractures of sternum or clavicle (97% vs. 91%). Moreover, the sensitivity was found to be higher when the procedure was carried out by a radiologist in comparison to an emergency medicine specialist (96% vs. 90%). **Conclusion:** Base on the findings of the present meta-analysis, screening performance characteristic of ultrasonography in detection of thoracic bone fractures was found to be higher than radiography. However, these characteristics were more prominent in detection of rib fractures and in cases where was performed by a radiologist.
Key words: Thoracic fractures; ultrasonography; radiography; diagnostic tests, routine

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Introduction:

Early diagnosis of rib fractures can rapidly indicate the source of thoracic pain and be helpful in pain management of trauma patients. Other than pain, rib fractures have been reported to be associated with morbidity and mortality in elderly patients (3-5). In most emergency departments, ultrasonography is considered as one of the most useful screening tools for rapid evaluation of trauma patients (6). Application of ultrasonography for assessment of chest wall injuries has been reported from 1980s (7). Since then the technology of ultrasound devices has significantly improved so that images with higher resolutions are obtained. In light of these improvements, the diagnostic value of this modality has been considerably enhanced (9). In this regard, studies have illustrated a considerably high diagnostic value of ultrasonography in detection of thoracic fractures, even higher than that of chest radiography (8, 10-12). For instance in his narrative review, Chan referred to ultrasonography as a reliable diagnostic tool for detection of thoracic bone fractures (13). Nevertheless, still no comprehensive review has been carried out comparing the diagnostic values of chest ultrasonography and radiography in detection of thoracic fractures. One solution is to perform a meta-analysis on the available evidence (15, 16). Accordingly, the present systematic review and meta-analysis aimed to determine the diagnostic values of chest ultrasonography and radiography in detection of thoracic bone fractures.

Methods:

Search strategy and selection criteria

The study protocol was established based on the guidelines of Meta-analysis of Observational Studies in Epidemiology statement (MOOSE) (19). After selection of keywords from Medical Subject Heading (MeSH) terms and EMTREE, two reviewers (M.Y, P.G) independently carried out an extended systematic search in databases of Medline (via PubMed), EMBASE (via OvidSP), ISI Web of Knowledge, Scopus, Cochrane Library, and ProQuest without any time or language limitations. The keywords included "Ultrasonography" OR "Sonography" OR "Ultrasound" OR "Radiography" OR "Chest Film" OR "Chest Radiograph" combined with "Rib Fractures" OR "Chest Wall Fracture" OR "Sternum Fracture" OR "Sternal Fracture" OR "Clavicle Fracture" OR "Scapula Fracture". Additionally, the bibliographies of original and review articles as well as Google Scholar were also searched. All the studies evaluating the diagnostic accuracy of ultrasonography or chest radiography in detection of chest wall fractures were assessed. Review and editorial articles, case reports and studies with sample populations of less than 10 patients were excluded.

Data extraction

Two reviewers (M.Y, P.G) independently worked on summarizing the data regarding assessing quality of studies, baseline characteristics of patients (age, gender, the number of patients with and without hemothorax, the etiology of hemothorax), the characteristics of ultrasonography device (transducer, frequency), physicians in charge of imaging interpretation, blinding status, sampling method (consecutive, convenience), study design

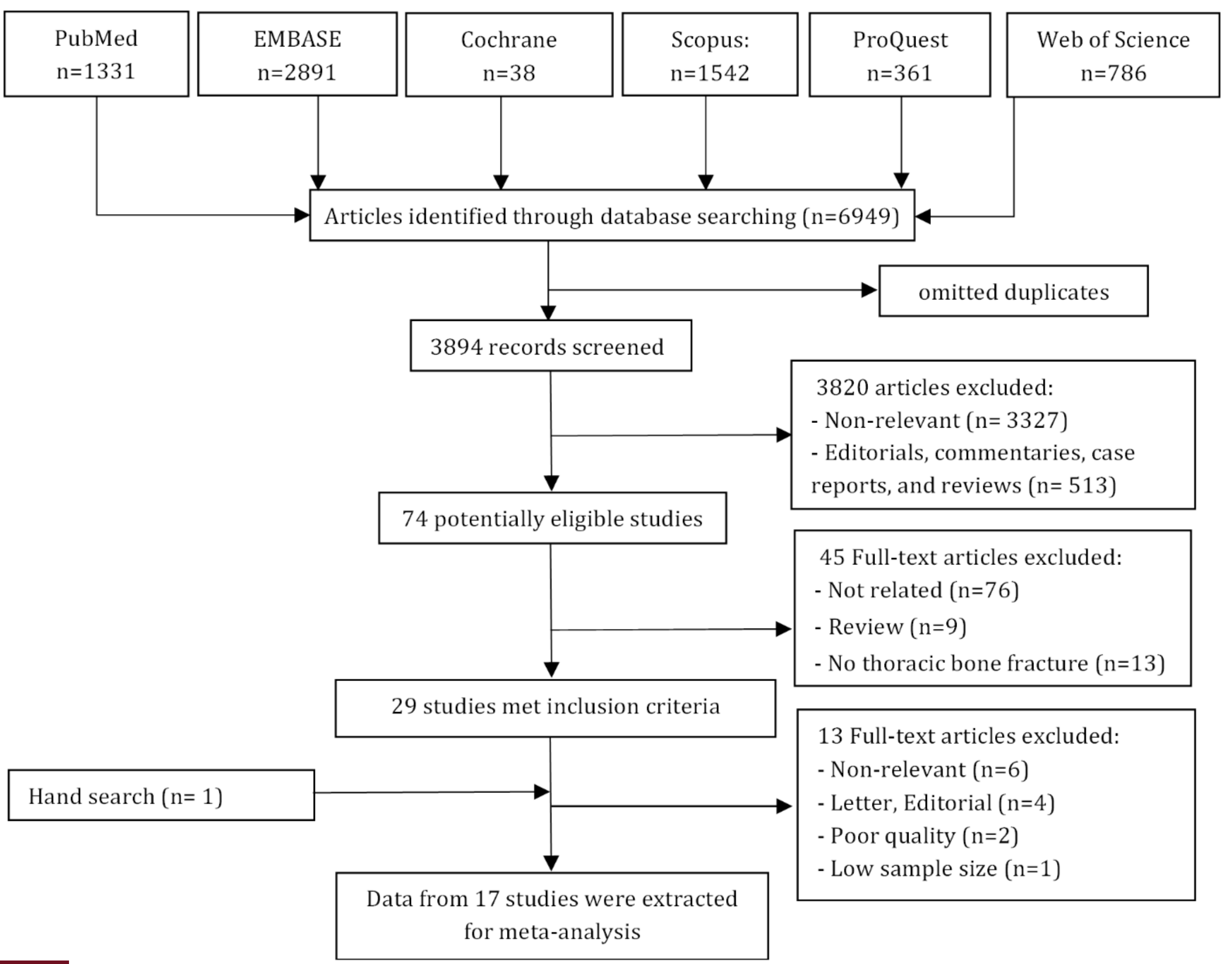

Figure 1: Flowchart of the study.

Table 1: Charecteristics of included studies

Study	No. of patient (+ / -)	Age[1] (years)	Male (%)	Reference / Index	Transducer / Operator	Sampling / Fracture	Weaknesses
Hendrich 1995 (1)	15 / 30	45 (29-61)	57.8	CXR / US	7.5 MHz / Radiologist	Convenience / sternum	Low sample size Possibility of selection bias
Engin 2000 (2)	18 / 5	35.4 (18-75)	82.6	CXR / US	7.5 MHz / Radiologist	Convenience / Sternum	Retrospective design Low sample size Possibility of selection bias
Hurley 2004 (8)	15 / 5	31 (16-55)	78.6	CT / US, CXR	12.5 MHz / Radiologist	Consecutive / Rib	Low sample size
Rainer 2004 (11)	76 / 12	51 ± 19	59	CT / US, CXR	5-to 10-MHz / Radiologist	Convenience / Sternum	
Jin 2006 (10)	23 / 16	45.2 (15-82)	52	CT / US, CXR	5-to 9-MHz / Radiologist	Convenience / Multiple	Low sample size Possibility of selection bias
Traub 2007 (14)	68 / 73	47 .2 (18-89)	75	CT / CXR	NA / Radiologist	Convenience / Rib	Retrospective design Possibility of selection bias
Wootton-Gorges 2008 (17)	131 / 94	0.2 (0.1-0.5)	41.7	CT / CXR	NA / Radiologist	Consecutive / Rib	Retrospective design Possibility of selection bias Low sample size
Cross 2010 (18)	43 / 57	10.7 (1-17)	87.3	CXR / US	10- to 15-MHz/ EP	Convenience / Clavicle	Possibility of selection bias
Weinberg 2010 (20)	25 / 187	13 (3-23)	NR	CT / US	7.5- to 10-MHz/ EP	Convenience / Clavicle and rib	Possibility of selection bias
You 2010 (21)	24 / 12	43 (8-73)	52.8	CT / US	7-to 12-MHz / Radiologist	Consecutive / Rib	Low sample size
Szucs-Farkas 2011 (22)	39 / 24	64.4 ± 14.7	73	CT / CXR	NA / Radiologist	Convenience / Rib	Retrospective design Low sample size Possibility of selection bias
Yazkan 2012 (23)	83 / 83	40.8 (16-92)	73.5	CT / CXR	NA / Surgeon	Consecutive / Rib	Retrospective design
Błasińska 2013 (24)	34 / 26	NR	NR	CT / CXR	NA / Radiologist	Consecutive / Multiple	Low sample size
Chardoli 2013 (25)	51 / 149	37.9 (16 - 90)	84	CT / CXR	NA / EP	Convenience / Rib	The interpretation of the CXR and CT were not in blind fashion Possible selection bias
Uzun 2013 (12)	92 / 8	28 (15 - 40)	73	CT / US, CXR	NR / Radiologist	Consecutive / Rib	Possibility of reporting bias
Hoffstetter 2014 (26)	15 / 24	61 (24-87)	60.7	CT / CXR	NA / Radiologist	Consecutive / Multiple	Retrospective design Low sample size
Park 2015 (27)	55 / 55	56.2 (16.9)	57.4	CT / CXR	NA / Radiologist	Consecutive / Rib	Low sample size

1, (+ / -): number of patient with fracture / number of patient without fracture; 2, Number are presented as mean ± standard deviation or (range).
CT: Computed tomography; CXR: Chest radiography; EP: Emergency physician; NA: Not applicable; NR: Not Reported; US: Ultrasonography.

(retrospective, prospective). Finally the number of true positive (TP), true negative (TN), false positive (FP), and false negative (FN) cases were extracteded. Disagreements were discussed with the third reviewer (M.H) and a solution was proposed. In cases of data inaccessibility, the corresponding authors of the articles were contacted. Data presented as charts were extracted via the method proposed by Sistrom and Mergo (28). In cases where only the sensitivity and specificity were presented, reliable web-based programs were used to calculate the number of TP, TN, FP, and FN cases.

Quality assessment

Quality of the studies were assessed based on the guidelines of 14-Item Quality Assessment of Diagnostic Accuracy Studies (QUADAS2) tool (29). The quality assessment were performed based on following items: acceptable reference tests, accounting for indeterminate results, avoiding differential verification bias, disease progression bias, incorporation bias and verification bias, blind index test interpretation, blind interpretation of reference test, explained withdrawal, relevant clinical data available, and representative spectrum. A total grading of poor, fair, and good was attributed to each survey and only the fair and good studies were included in the meta-analysis.

Statistical analysis

Analysis was performed using STATA 11.0 statistical software via MIDAS module. To evaluate the screening performance characteristics of ultrasonography and radiography in detection of chest wall fractures, summary receiver operative curves (SROCs) were drawn and pooled sensitivity, specificity, positive likelihood ratio and negative likelihood ratio with 95% confidence interval (95% CI) were calculated. Due the high heterogeneity between the included studies, mixed-effects binary regression model was used. Heterogeneity was evaluated through calculations of I2 and $\chi 2$ tests and a P value of less than 0.1 together with an I2 greater than 50% were considered as positive heterogeneity (30). Subgroup analysis was performed to identify the source of heterogeneity. Deek's asymmetry funnel plot was used to search for publication bias. In all the analyses, p value of less than 0.05 was considered as statistically significant.

Results:

Study characteristics

17 out of 3894 studies found in the comprehensive search were included in the systematic review and meta-analysis (1, 2, 8, 10-12, 14, 17, 18, 20-27). 5 studies had assessed the diagnostic accuracy of ultrasonography in detection of thoracic bone fractures (1, 2, 18, 20, 21), 8 diagnostic value of chest radiography (14, 17, 22-27), and 4 diagnostic values of ultrasonography and radiography simultaneously (8, 10-12). 1667 cases (807 with and 860 without fractures) were extracted from the 17 mentioned articles, whose age ranged from 0 to 92 years old. Figure 1 shows the inclusion process of articles and table 1 summarizes the characteristics of included studies. No publication bias was observed (Figure 2).

Meta-analysis

The results of the analyses are presented as SROCs and Funnel plots in Figures 3 to 5. The area under the curve of SROC for ultrasonography and radiography in detection of chest wall fractures were found to be 0.99 (95% CI: 0.97-0.99) and 0.97 (95% CI: 0.96-0.99), respectively (Figure 3). Pooled sensitivity and specificity of ultrasonography in detection of thoracic bone fractures were 0.97 (95% CI: 0.90-0.99; I2= 88.88, p<0.001) and 0.94 (95% CI: 0.86-0.97; I2= 71.97, p<0.001), respectively (Figure 4-A). These characteristics for radiography were found to be 0.77 (95% CI: 0.56-0.90; I2= 97.76, p<0.001) and 1.0 (95% CI: 0.91-1.00; I2= 97.24, p<0.001), respectively (Figure 5-A). In addition, pooled positive and negative likelihood ratios of ultrasonography were 16.26 (95% CI: 6.26-38.87; I2= 59.14, p<0.001) and 0.03 (95% CI: 0.01-0.11; I2= 86.76, p<0.001), respectively (Figure 4-B), while these measures for radiography were reported to be 774.63 (95% CI: 7.0-8573.0; I2= 96.62, p<0.001) and 0.23 (95% CI: 0.11-0.48; I2= 96.94, p<0.001), respectively (Figure 5-B).

Subgroup Analysis

There were significant heterogeneity between the articles (Figure 4 and 5). Subgroup analysis was performed to remove its effects and find its probable sources. Table 2 presents the results of this analysis. Specificity of ultrasonography in detection of thoracic bone fractures was directly correlated with frequency of transducer (90% vs. 95%). The sensitivity of this modality was found to be higher in detection of rib fractures rather than fractures of clavicle or sternum (97% vs. 91%). Moreover it was found that the sensitivity would be higher if the procedure is performed by a radiologist (96%) compared to an emergency medicine specialist (90%). Sample size was another source of heterogeneity. Studies with sample sizes of greater than 100 patients reported higher diagnostic accuracies for ultrasonography in detection of thoracic bone fractures (97% vs. 91%).

As can be seen in Table 2, the most important factor affecting sensitivity of chest radiography is the interpreting physician. The sensitivity was found to be 66% when the radiogram was interpreted by an emergency medicine specialist while it was 80% when interpreted by a radiologist. Furthermore, consecutive sampling method compared with convenience (80% vs. 73%) and sample size of more than 100 patients (82% vs. 73%) were also found to be sources of heterogeneity.

Discussion:

Base on the results of the present meta-analysis sensitivity of chest ultrasonography in detection of thoracic

Table 2: Subgroup analysis of diagnostic accuracy for chest radiography and ultrasonography in detection of thoracic bone fractures

	No. of studies	Bivariate random-effect model					
		Sensitivity (95% CI)	P	Specificity (95% CI)	p	heterogeneity, I^2	P*
Ultrasonography							
Patient enrollment							
Consecutive	3	0.98 (0.95-1.00)	0.01	0.90 (0.77-1.00)	0.55	43.0 %	0.18
Convenience	6	0.95 (0.90-0.99)		0.91 (0.86-0.96)			
Operator							
Emergency physician	3	0.90 (0.81-0.98)	<0.001	0.90 (0.83-0.97)	0.09	21.0 %	0.28
Other physician	6	0.96 (0.93-0.99)		0.91 (0.84-0.98)			
Sample size							
< 100	6	0.91 (0.84-0.97)	0.01	0.90 (0.83-0.97)	0.04	12.0 %	0.32
≥ 100	3	0.97 (0.94-1.00)		0.93 (0.87-0.98)			
Frequency of transducer							
5-10 MHz	6	0.94 (0.89-0.99)	0.62	0.90 (0.85-0.95)	0.03	0.0 %	0.51
10-15 MHz	3	0.95 (0.88-1.00)		0.95 (0.89-1.00)			
Type of fracture							
Rib	4	0.97 (0.93-1.00)	0.01	0.89 (0.83-0.96)	0.01	45.0 %	0.16
Sternum / Clavicle	5	0.91 (0.84-0.97)		0.93 (0.94-0.98)			
Radiography							
Patient enrollment							
Consecutive	7	0.80 (0.59 - 1.00)	0.70	1.00 (1.00 - 1.00)	0.99	0.0 %	0.70
Convenience	5	0.73 (0.45 - 1.00)		1.00 (0.98 - 1.00)			
Operator							
Emergency physician	3	0.66 (0.27 - 1.00)	0.53	1.00 (1.00 - 1.00)	0.99	0.0 %	0.78
Other physician	9	0.80 (0.63 - 0.98)		1.00 (1.00 - 1.00)			
Sample size							
< 100	7	0.73 (0.49 - 0.97)	0.44	1.00 (1.00 - 1.00)	0.99	0.0 %	0.57
≥ 100	5	0.82 (0.61 - 1.00)		1.00 (1.00 - 1.00)			
Type of fracture							
Rib	8	0.77 (0.57 - 0.97)	0.56	1.00 (1.00 - 1.00)	0.99	0.0 %	0.98
Sternum / Clavicle	4	0.77 (0.48 - 1.00)		1.00 (1.00 - 1.00)			

*, P value < 0.1 was considered as significant for heterogeneity; CI: Confidence interval.

bone fractures following trauma was prominently higher than radiography (97% vs. 77%). Yet, the specificity of radiography was found to be significantly higher than ultrasonography in this regard (100% vs. 94%). On this basis and according to calculated likelihood ratios, a negative result of ultrasonography in detection of thoracic fracture is more reliable than radiography (negative likelihood ratio=0.03), while a positive result of chest radiography is more reliable than ultrasonography (positive likelihood ratio=774.63).

Ultrasonography had a higher sensitivity in diagnosis of rib fractures rather than other chest wall bones, while the type of fracture had no effect on diagnostic value of radiography. This finding can be ascribed to the higher attention that physicians pay to rib fractures rather than other chest wall bones such as scapula and sternum.

Fractures are diagnosed via ultrasonography based on observation of cortical bone disruption. In cases of small fractures, detection of this sign in sonogram and distinguishing it from other findings is highly dependent on the skills of the operator. The role of operator's skills in detection of injuries via ultrasonography was verified in the present study as well (31-34). Ultrasonography by a radiologist has a higher sensitivity compared to emergency medicine specialist. The present study found that the specificity of this modality increased with frequencies of higher than 10MHz which might be due to the higher resolution obtained with higher frequencies (35), making it easier to detect the signs of fracture.

Some narrative review articles and qualitative systematic reviews are indicative of the potential benefit of ultrasonography in detection of chest wall fractures. In this regard, Chan, in his systematic review conducted on studies indexed in Medline, declares that ultrasonography has a higher sensitivity in detection of thoracic bone fractures compared to radiography (13). Finding the diagnostic accuracy of ultrasonography to be two times the ability of radiography in fracture diagnosis, Dietrich et al. also referred to ultrasonography as a useful diagnostic tool for detection of rib fractures (36). The results of the present meta-analysis were congruent with these findings.

Presence of considerable heterogeneity between the included articles and simultaneous inclusion of retrospective and prospective studies in the meta-analysis were major limitations of this study. Subgroup analysis was performed to overcome the heterogeneity problem.

Conclusion:

Base on the findings of the present meta-analysis, screening performance characteristic of ultrasonography in detection of thoracic bone fractures was found to be higher than radiography. However, these characteristics were more prominent in detection of rib fractures and in cases where was performed by a radiologist.

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Conflict of interest:

None

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Authors' contributions:

All authors passed four criteria for authorship contribution based on recommendations of the International Committee of Medical Journal Editors.

References:

1. Hendrich C, Finkewitz U, Berner W. Diagnostic value of ultrasonography and conventional radiography for the assessment of sternal fractures. Injury. 1995;26(9):601-4.
2. Engin G, Yekeler E, Güloğlu R, Acunaş B, Acunaş G. US versus conventional radiography in the diagnosis of sternal fractures. Acta Radiol. 2000;41(3):296-9.
3. Barnea Y, Kashtan H, Skornick Y, Werbin N. Isolated rib fractures in elderly patients: mortality and morbidity. Can J Surg. 2002;45(1):43-6.
4. Bergeron E, Lavoie A, Clas D, et al. Elderly trauma patients with rib fractures are at greater risk of death and pneumonia. J Trauma Acute Care Surg. 2003;54(3):478-85.
5. Bulger EM, Arneson MA, Mock CN, Jurkovich GJ. Rib fractures in the elderly. J Trauma Acute Care Surg. 2000;48(6):1040-7.
6. Forouzanfar MM, Safari S, Niazazari M, et al. Clinical decision rule to prevent unnecessary chest X-ray in patients with blunt multiple traumas. Emerg Med Australas. 2014;26(6):561-6.
7. Wongwaisayawan S, Suwannanon R, Prachanukool T, Sricharoen P, Saksobhavivat N, Kaewlai R. Trauma Ultrasound. Ultrasound Med Biol. 2015:[In press].
8. Hurley ME, Keye GD, Hamilton S. Is ultrasound really helpful in the detection of rib fractures? Injury. 2004;35(6):562-6.
9. Saraogi A. Lung ultrasound: Present and future. Lung India. 2015;32(3):250-7.
10. Jin W, Yang DM, Kim HC, Ryu KN. Diagnostic values of sonography for assessment of sternal fractures compared with conventional radiography and bone scans. J Ultrasound Med. 2006;25(10):1263-8.
11. Rainer TH, Griffith JF, Lam E, Lam PKW, Metreweli C. Comparison of thoracic ultrasound, clinical acumen, and radiography in patients with minor chest injury. J Trauma. 2004;56(6):1211-3.
12. Uzuna M, Beksaça B, Karab A, Küçükdurmazc F, Kırcalıd BA, Tetika C. Ultrasonography as a better diagnostic efficiency in rib fracture. J Experiment Clin Med. 2013;30:133-5.
13. Chan SS. Emergency bedside ultrasound for the diagnosis of rib fractures. Am J Emerg Med. 2009;27(5):617-20.
14. Traub M, Stevenson M, McEvoy S, et al. The use of chest computed tomography versus chest X-ray in patients with major blunt trauma. Injury. 2007;38(1):43-7.
15. Ebrahimi A, Yousefifard M, Mohammad Kazemi H, et al. Diagnostic Accuracy of Chest Ultrasonography versus Chest Radiography for Identification of Pneumothorax: A Systematic Review and Meta-Analysis. Tanaffos. 2014;13(4):29-40.
16. Hosseini M, Yousefifard M, Aziznejad H, Nasirinezhad F. The Effect of bone marrow derived mesenchymal stem cell transplantation on allodynia and hyperalgesia in neuropathic

animals: A systematic review with meta-analysis. Biol Blood Marrow Transplant. 2015: [In press].
17. Wootton-Gorges SL, Stein-Wexler R, Walton JW, Rosas AJ, Coulter KP, Rogers KK. Comparison of computed tomography and chest radiography in the detection of rib fractures in abused infants. Child Abuse Negl. 2008;32(6):659-63.
18. Cross KP, Warkentine FH, Kim IK, Gracely E, Paul RI. Bedside ultrasound diagnosis of clavicle fractures in the pediatric emergency department. Acad Emerg Med. 2010;17(7):687-93.
19. Stroup DF, Berlin JA, Morton SC, et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. JAMA. 2000;283(15):2008-12.
20. Weinberg ER, Tunik MG, Tsung JW. Accuracy of clinician-performed point-of-care ultrasound for the diagnosis of fractures in children and young adults. Injury. 2010;41(8):862-8.
21. You JS, Chung YE, Kim D, Park S, Chung SP. Role of sonography in the emergency room to diagnose sternal fractures. J Clin Ultrasound. 2010;38(3):135-7.
22. Szucs-Farkas Z, Lautenschlager K, Flach PM, et al. Bone images from dual-energy subtraction chest radiography in the detection of rib fractures. Eur J Radiol. 2011;79(2):e28-32.
23. Yazkan R, Ergene G, Tulay CM, Güneş S, Han S. Comparison of Chest Computed Tomography and Chest X-Ray in the Diagnosis of Rib Fractures in Patients with Blunt Chest Trauma. JAEM. 2012;11:171-5.
24. Błasińska-Przerwa K, Pacho R, Bestry I. Pneumonol Alergol Pol. Pneumonologia Alergologia Polska. 2013;81(6):518-26.
25. Chardoli M, Hasan-Ghaliaee T, Akbari H, Rahimi-Movaghar V. Accuracy of chest radiography versus chest computed tomography in hemodynamically stable patients with blunt chest trauma. Chin J Traumatol. 2013;16(6):351-4.
26. Hoffstetter P, Dornia C, Schafer S, et al. Diagnostic significance of rib series in minor thorax trauma compared to plain chest film and computed tomography. J Trauma Manag Outcomes. 2014;8:10.
27. Park JB, Cho YS, Choi HJ. Diagnostic accuracy of the inverted grayscale rib series for detection of rib fracture in minor chest trauma. Am J Emerg Med. 2015;33(4):548-52.
28. Sistrom CL, Mergo PJ. A simple method for obtaining original data from published graphs and plots. Am J Roentgenol. 2000;174(5):1241-4.
29. Whiting PF, Rutjes AW, Westwood ME, et al. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. Ann Intern Med. 2011;155(8):529-36.
30. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ. 2003;327(7414):557.
31. Abbasi S, Farsi D, Hafezimoghadam P, Fathi M, Zare MA. Accuracy of emergency physician-performed ultrasound in detecting traumatic pneumothorax after a 2-h training course. Eur J Emerg Med. 2013;20(3):173-7.
32. Bui-Mansfield LT, Chen DC, O'Brien SD. Accuracy of ultrasound of musculoskeletal soft-tissue tumors. Am J Roentgenol. 2015;204(2):W218.
33. Fine D, Perring S, Herbetko J, Hacking C, Fleming J, Dewbury K. Three-dimensional (3D) ultrasound imaging of the gallbladder and dilated biliary tree: reconstruction from real-time B-scans. Br J Radiol. 1991;64(767):1056-7.
34. Lee JH, Jeong YK, Park KB, Park JK, Jeong AK, Hwang JC. Operator-dependent techniques for graded compression sonography to detect the appendix and diagnose acute appendicitis. Am J Roentgenol. 2005;184(1):91-7.
35. Majumdar S, Kumar PS, Pandit A. Effect of liquid-phase properties on ultrasound intensity and cavitational activity. Ultrason Sonochem. 1998;5(3):113-8.
36. Dietrich CF, Mathis G, Cui XW, Ignee A, Hocke M, Hirche TO. Ultrasound of the pleurae and lungs. Ultrasound Med Biol. 2015;41(2):351-65.

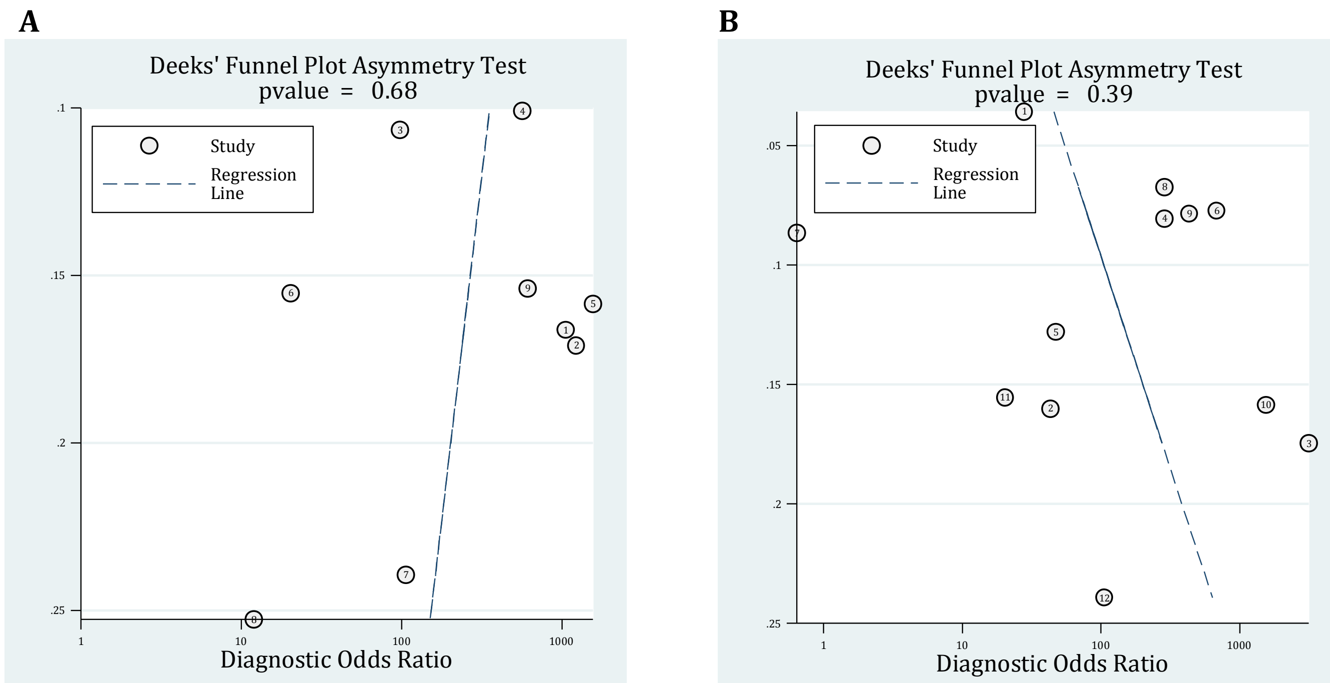

Figure 2: Deeks' funnel plot asymmetry test for assessment of publication bias. P values < 0.05 was considered as significant. Ultrasonography (A); Radiography (B). ESS: Effective sample sizes.

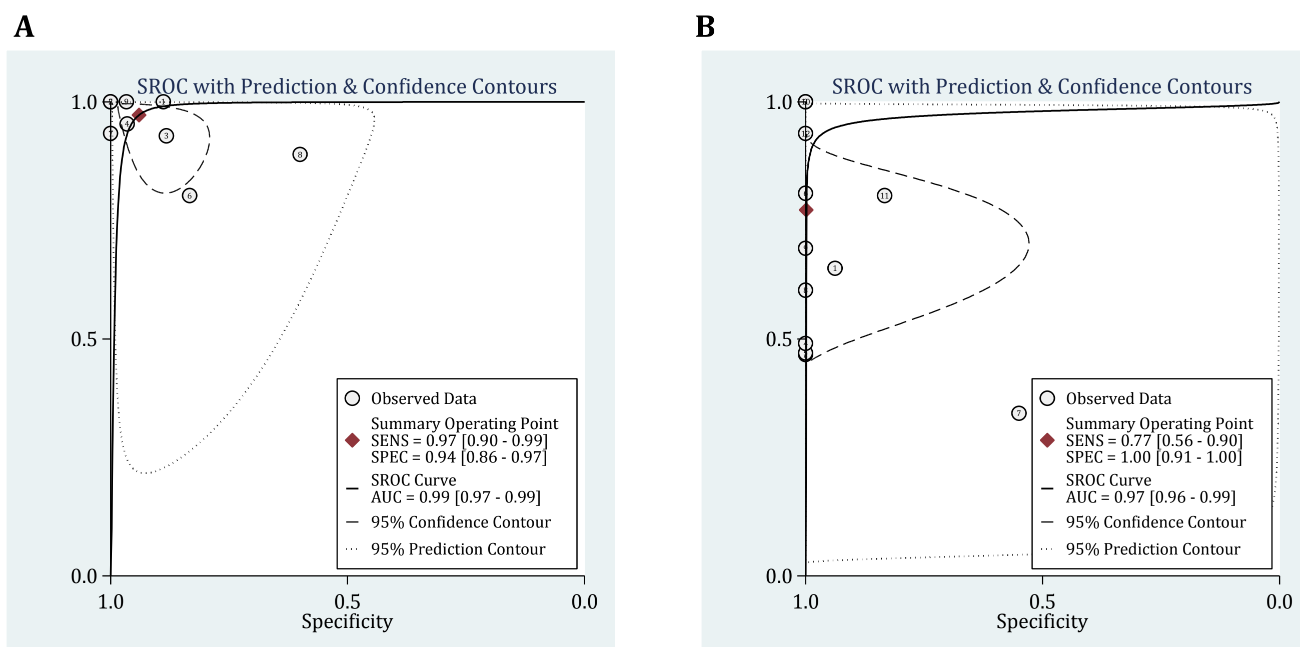

Figure 3: Summary receiver operative curves (SROC) for ultrasound (A) and chest radiography (B) in detection of thoracic bone fractures. AUC: Area under the curve; SENS: Sensitivity; SPEC: Specificity.

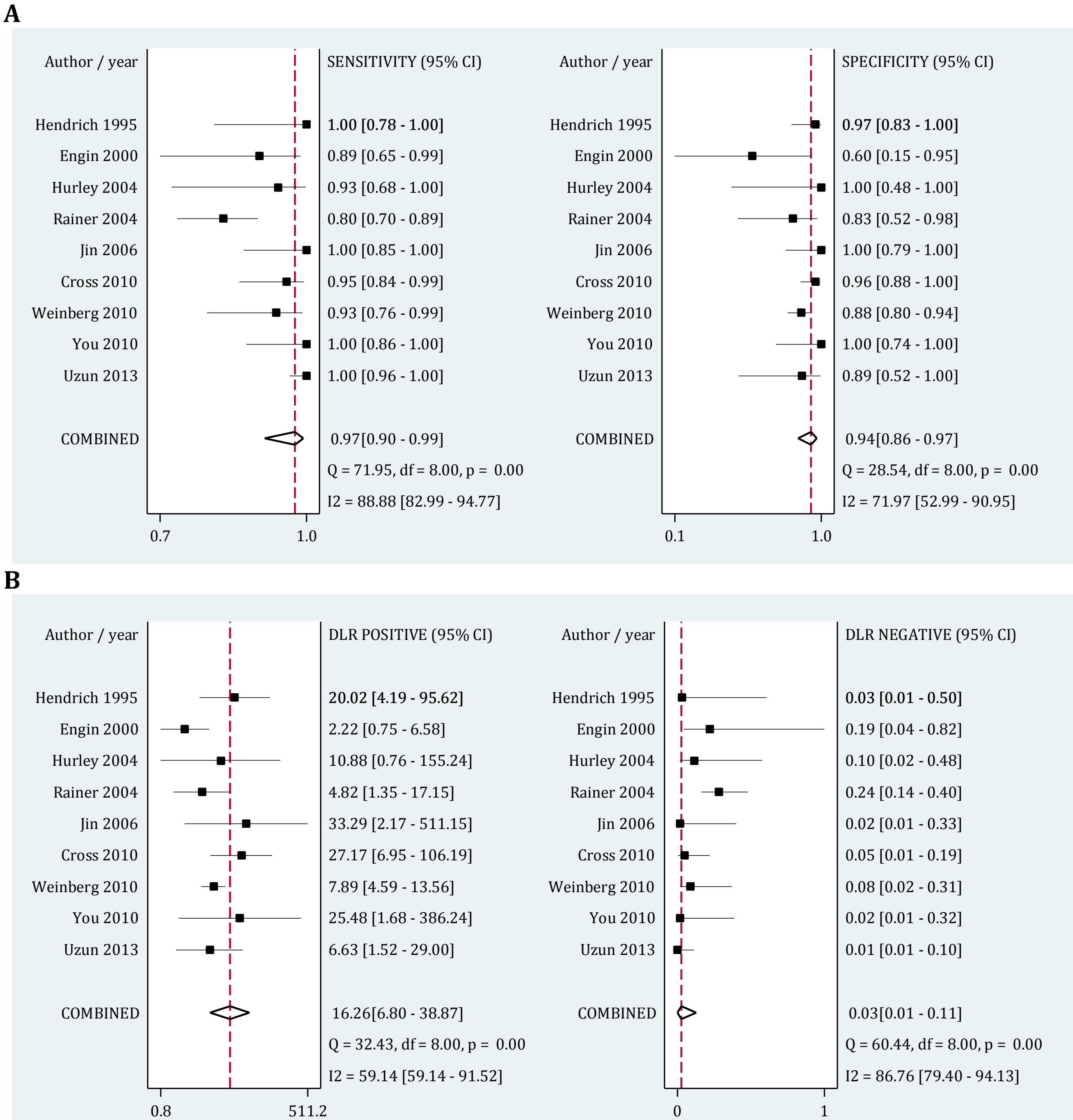

Figure 4: Forest plot of screening performance characteristics of chest ultrasonography in detection of thoracic bone fractures. Sensitivity and specificity (A); Diagnostic likelihood ratio (DLR) (B). CI: Confidence interval.

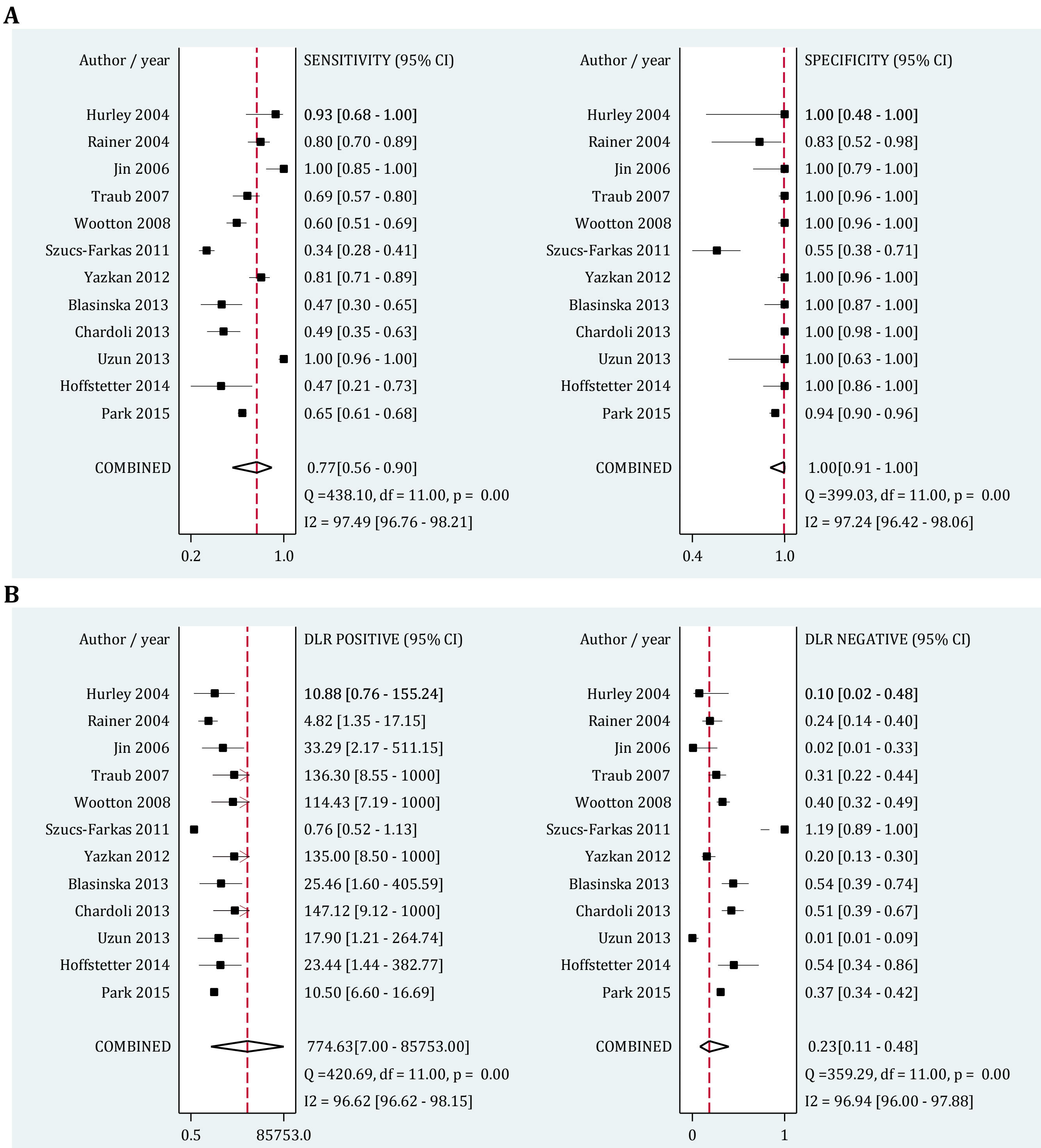

Figure 5: Forest plot of screening performance characteristics of chest radiography in detection of thoracic bone fractures. Sensitivity and specificity (A); Diagnostic likelihood ratio (DLR) (B). CI: Confidence interval.