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**Thoracic ultrasound: An adjunctive and valuable imaging tool in emergency, resource-limited settings and for a sustainable monitoring of patients**

Trovato FM *et al.* Thoracic ultrasound

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**Abstract**

Imaging workup of patients referred for elective assessment of chest disease requires an articulated approach: Imaging is asked for achieving timely diagnosis. The concurrent or subsequent use of thoracic ultrasound (TUS) with conventional [chest X-rays- (CXR-)] and more advanced imaging procedures (computed tomography and magnetic resonance imaging) implies advantages, limitations and actual problems. Indeed, despite TUS may provide useful imaging of pleura, lung and heart disease, emergency scenarios are currently the most warranted field of application of TUS: Pleural effusion, pneumothorax, lung consolidation. This stems from its role in limited resources subsets; actually, ultrasound is an excellent risk reducing tool, which acts by: (1) increasing diagnostic certainty; (2) shortening time to definitive therapy; and (3) decreasing problems from blind procedures that carry an inherent level of complications. In addition, paediatric and newborn disease are particularly suitable for TUS investigation, aimed at the detection of congenital or acquired chest disease avoiding, limiting or postponing radiological exposure. TUS improves the effectiveness of elective medical practice, in resource-limited settings, in small point of care facilities and particularly in poorer Countries. Quality and information provided by the procedure are increased avoiding whenever possible artefacts that can prevent or mislead the achievement of the correct diagnosis. Reliable monitoring of patients is possible, taking into consideration that appropriate expertise, knowledge, skills, training, and even adequate equipment’s suitability are not always and everywhere affordable or accessible. TUS is complementary imaging procedure for the radiologist and an excellent basic diagnostic tool suitable to be shared with pneumologists, cardiologists and emergency physicians.

**Key words:** Thoracic ultrasound; Pneumonia; Pleural effusion; Pneumothorax; Clinical risk management; Overdiagnosis; Wastebasket diagnosis

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**Core tip:** Thoracic ultrasound (TUS), with some technical limitations, may provide useful imaging of pleura, lung and heart disease. The field of application of TUS are pleural effusion, pneumothorax, and lung consolidation. Paediatric and newborn disease are suitable for TUS investigation aimed at the detection of congenital or acquired chest disease avoiding or limiting radiological exposure. TUS improves the effectiveness of medical practice in resource-limited settings, in small point-of-care facilities, in hostile environment and in poorer countries. Monitoring of patients is possible, depending on disease and context, not asking to the procedure more than it can give.

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**FOREWORD**

The history of imaging in medicine is an adventurous and generous history of high impact ideas, of courage and ingenious translation. This story originates from Marie Curie and her family, especially her daughter, Irene, a Nobel laureate too[1]. They, at the beginning and during the First World War, on 1914, developed and worked inside the mobile field hospitals that Marie Curie had established, training radiographers and technicians and convincing the surgeons to trust in the new technology: It was estimated that over one million wounded men were X-rayed in her units throughout the War[1].It may be now easy to ignore, but this history, here briefly summarized, can help us to understand the root and the link between genius, emergency, limited resources and quality of training in a field which is the daily work of most physicians working with chest imaging.

**OVERVIEW**

The recall above reported is needed, even writing of ultrasound, since depicts a detailed model of practice and application of a sustainable innovative diagnostic and of another extremely useful tool in resource-limited settings and in hostile and dangerous situations. It also represents an organizational paradigm supported by ethical reasons. Despite Marie Curie and other heroic pioneers of radiology suffered from long-term radiation damage, the concept of maximum security for that time was highly respected. If claims of clinical risk management criteria, so often warranted nowadays, are not inspired to ethically, medically and scientifically proven aims and evidence, a botched management may ultimately damage doctors and patients, as well as society and population within an organizational machine scarcely productive if not harmful.

Emergency or elective assessment of chest disease requires often an articulated clinical approach to chest imaging, addressed also to the diagnosis of co-morbidities. Clinicians are often facing complex conditions, due to uncertainty or severity of the clinical presentation or to the hurry in which they are called to operate[2-4].

Indeed, despite elective thoracic ultrasound (TUS) may provide useful imaging of pleura, lung and heart disease, emergency scenarios are its current most developed field of application for detecting unsuspected, or for confirming physical signs of, pleural effusion, pneumothorax, and lung consolidation[5-7]. Paediatric and newborn disease are particularly suitable for TUS investigation aimed at the detection of congenital or acquired chest disease avoiding, limiting or postponing radiological exposure[8,9]. TUS can improve the effectiveness of elective and emergency medical practice in resource-limited settings, in small point of care facilities and particularly in poorer Countries[10]. Ultrasound is an excellent risk-reducing tool, which acts by: (1) increasing diagnostic certainty; (2) shortening time to definitive therapy; and (3) decreasing risks from blind procedures that carry an inherent level of complications[11-15]. Actually, the help of skilled ultrasound approaches in emergency or elective medicine is a pivotal component for preventing overdiagnosis and wastebasket diagnosis, apart avoiding as much as possible the risk of missing or erroneous diagnosis. Overdiagnosis, is the diagnosis of “disease” that will never cause symptoms, distress, or death during a patient’s lifetime, or that are not the real determinant of a clinical presentation. Wastebasket diagnosis, is a vague, or even completely fake, medical label given for essentially non-medical reasons, such as to reassure the patient by providing an official-sounding label, to make the provider look effective, or to obtain approval for treatment; wastebasket diagnosis often and likely represents a heterogeneous group of disease and conditions[16]. The diagnostic refinements that can quickly provide a timely and expert patient’s assessment by ultrasound are, in our experience, a significant cornerstone fostering precision, clarity and quality in any medical approach.

An important step toward the management of risk is insuring that physicians are properly trained and credentialed according to national guidelines such as those set by ACEP[15]. Proper quality assurance and improvement programs should be in place to identify and correct substandard practice, due to some variability of information of the published reports. Lastly, the standard of care for emergency ultrasound is the performance and interpretation of ultrasound by a physician certified in other specialties or in different settings: In these conditions credentials should have different goals, scope of practice, documentation requirements, and consequently should not be comparable to emergency medicine[12].

**CLINICAL RISK ANALYSIS**

The most relevant field of possible application of TUS is the diagnosis of lung consolidation, which is also one of the most critical diagnostic field of radiology. TUS may become a reliable tool capable of diagnosing pneumonia with high accuracy. Nonetheless, in the meanwhile, it is still a complementary source of information more than a promising attractive alternative to chest radiography and thoracic computed tomography (CT) scan: Most published studies, aimed at the definitions of the usefulness of lung ultrasound as a lone procedure for the diagnosis of pneumonia, are seemingly limited by methodological biases. Actually, as excellently summarized in a recent metanalysis[17], the most reputed studies on this topic, were “conducted to identify the usefulness of lung ultrasound for the diagnosis of pneumonia, but with inconsistent and inconclusive results”[17]. Nonetheless, the same accurate metanalysis reports the results in 1080 subjects from a selected group of nine studies and concludes that “lung ultrasound is a capable of diagnosing pneumonia with high accuracy and is a promising attractive alternative to chest radiography and thoracic CT scan”, with a “97 % sensitivity and a 94% specificity”. In this regard, several matter of concern persists: there are many part of the lung which are blinded to the ultrasound imaging since, due to skeletal barrier no more than 70% of lung is realistically explorable by TUS[14]. The other not minor concern is that lung consolidation due to any cause - pneumonia or cancer - is not discriminated by ultrasound, also using more advanced ultrasound techniques, such as transient elastography[18]. In both cases the need of a radiological approach, after the preliminary diagnosis of consolidation and mainly if the clinical and/or the ultrasound picture persists, is evident, and the claimed high sensitivity and specificity may need some mitigation[14].

“Risk management in radiology is primarily developed and fostered to help safeguard patients, working personnel and the entire organisation. Protection of the organisation is largely grasped in terms of finance management. Potential drawbacks are linked to unreliable results that could damage its reputation”[19]. This is a particularly sensitive topic, since, apart the scientific foundation of some well conducted clinical trial, the reference to a diffuse “good practice” for TUS diagnosis could still be a slippery slope. “The essence of risk management is to survey all potential reasons for an inaccurate report in advance so that procedures can be put in place to prevent them”[20]. There are still relevant variations in imaging tests accuracy, due to technical reasons of the procedure itself or to inconclusive results and reports due to organization or individual professional limitations; therefore, even the analysis of associated risks has lacked uniformity in the cost-utility literature[21-26].

The central themes of the relevance of TUS in the cost-benefit analysis are the difficult appreciation of the times, ways, quality and consequences which are related to a systematic use of the procedure in emergency and the topics related to contexts, in elective, specialized, intensive or primary care, and in other areas yet.

Frequent and relevant applications, by which TUS may affect beneficially modulating the diagnostic and therapeutic pathways, are summarized in Table 1.

Also in these cases, the integration with more advanced radiological procedure is mandatory. This is true in emergency TUS, in which field the topic of unexpected clues is more frequently reported, but it is equally true in elective TUS, performed by radiologists or by internists-pneumologists.

**EMERGENCY: OPPORTUNITIES AND RELIABILITY**

Emergency ultrasound is a standard emergency medicine procedure and is included in any definitions of the practice of emergency medicine[15,16]. Since several years, also TUS is a component of this framework, which should be articulated within the specificity of the subsets in regards to risk management and to the clinical scenario, differently demanding according to affordability and policies[14,27-29].

The most relevant and relatively recent application of TUS in emergency is the quick detection of pneumothorax, by the significantly wide disappearance of the pleural line sliding[30-32]; this is a preliminary clinical diagnosis. It is precious in conditions of extreme facility shortage, where urgent intervention may be required and no timely confirm is available[33,34]. Nonetheless, TUS diagnosis of pneumothorax usually requires an urgent confirm, by CXR or CT, better to be available before any intervention procedure[35].

There is a widespread indication to TUS, and notably using the information derived by a great number of artefact, for the diagnosis of acute heart failure[36]. Actually, for this purpose, the detection of a great number of B-lines by TUS is not an imaging technique, but a bulk indication of chest-pulmonary pathology. These artefacts, preventing the view of details of the underlying condition, provide a generic information: Patients with congestive heart failure, COPD, pulmonary fibrosis and many other conditions, including the normal lung and the empty chest cavity in lung resection patients, may present numerous and diffuse B-lines (ring-down)[37,38]. Moreover, it is unpractical the semi-quantitative use of this criterion for monitoring congestion in intensive care[39-42]. These limitations are well summarized in several reviews and commentaries[43,44]. Also the observation of the increase of the B-lines with ageing, in subjects without specific heart or chest disease[45,46], is a further argument against any great expectation from this criterion. The use of a criterion with so relevant limitations is not neutral, since avert from the use of more suitable criteria, such as echocardiography or radiology, or TUS itself, more adequately performed[47-52]. Despite it was claimed that TUS is a basic application in intensive care units and that can become a useful daily tool in these subsets, such application is not generally used and, actually and quite unexpectedly, after so many years, is still under assessment and evaluation. Reasonably, as smartly and not only polemically commented by an outstanding radiologist, “lung ultrasound in the intensive care unit is an idea that may be too good to be true”[53]. Actually, limitations of the procedure should be taken in account even more in subsets which may increase the source of errors and even the accessibility of the structures to ultrasound imaging[14].Similarly, ultrasound diagnosis of pulmonary embolization does not fulfil definite criteria, and a great caution is needed and further efforts warranted - CT - for reaching a conclusive diagnosis[54].

**NEWBORN AND SMALL CHILDREN**

The use of chest ultrasound in paediatrics is probably the most important, while still the less developed. The most relevant studies were often pioneered in children, since there is a greater easiness for the procedure, much alike the investigation by US of abdomen in newborns, where so much is visible by ultrasound, and the obvious advantage of not using ionizing radiations[55,56]. The search for lung diffuse or lobar consolidation was and is the most relevant field of practice, and can allow the avoidance of radiological investigations[57-59]. Moreover, also the detection of congenital abnormalities[60] and the investigation for the more frequent conditions, first of all pleural effusion, is a great opportunity for the paediatrician and for the radiologist, addressing appropriately to more in-depth investigations by radiological procedures, if needed[61,62]. Despite it was claimed that most chest radiological investigation are useless for the diagnosis of pneumonia in children, in our view there is a persistent need of CXR in several cases, particularly in immune-compromised patients[63-66]. The advantage of a systematic screening in paediatric units for an early diagnosis of ventilator-associated pneumonia may become one of the most relevant indication for the dissemination of the procedure[67,68], even with the persisting limitations of the reliability of the procedure[14,18,69]. Developing Countries too often have very limited resources for imaging facilities, particularly for low-income population. Wasting and even lethal chest disease are still epidemic in many Regions, and the use of TUS is found precious in tuberculosis[70-74]. Patterns of sub-pleural granularity are described in patients with pulmonary miliary tuberculosis diagnosed by chest radiography, in AIDS[75-81], as a complementary tool for any type of chest involvements, and in parasitic disease[82], particularly in cystic and alveolar echinococcosis, particularly in endemic areas, both in adults and in children.

**OCCUPATIONAL AND SPORT MEDICINE, MILITARY AND MOBILE RESCUE SUPPORT**

This is a field of a possible rewarding use of TUS, which is nonetheless still quite neglected. Of the occupational disease that may benefit from an early detection of pleural-lung abnormalities, the most relevant are the asbestos-associated disease, in which an early thickening of the pleural line, above 3 mm, is a clue that can advise for scheduling more timely, if not urgent, CT investigations[14]. Actually, this sign was found useful because associated with pulmonary fibrosis in systemic sclerosis[83,84]; moreover, the detection of nodes in asbestos exposed patients can be managed safely by US guided fine needle aspirate biopsy (FNAB)[85].

TUS in sport medicine, where there is a great use of musculoskeletal US procedures, is still limited, even if the feature of the procedure make it suitable for the early onsite diagnosis of pneumothorax and lung contusions, of pleural effusion and of lung consolidation, all conditions that are more ominous in a subject performing competitive sport activities[86].

Military rescue support is an important sector of application and of experimental development of TUS, due to the frequent occurrence of traumatic or infectious chest disease in war scenarios[87-94]. Its use is warranted in many mobile facilities, including helicopters[33,95-100], even if an integrated use with other procedures, mainly cardiological, deserves a greater level of precision[101].

**ASSESSMENT AND MANAGEMENT OF COMPREHENSIVE ELECTIVE WORKUPS**

Since from its beginning, more than 50 years ago, TUS was developed in association with echocardiography[102-106]. There where and there are limitations related to artefacts, to the type of transducers, to the setting of the equipments[107] and only recently a greater care is devoted in the investigation of the more suitable probes[108]. Considering the mostly debated area of the monitoring of congestion in heart failure patients, the use of pleural effusion as a reference remains still the most objective clue, if present[109-114]. Nonetheless, this area of application is quite far from the tasks of the radiologist, and closer to the job of the cardiologist.

Monitoring is possible in several disease and context, with different degrees of reliability related to specific disease (the procedure is highly suitable for the diagnosis of pleural effusion, fairly suitable for the diagnosis of lung consolidation - superficial pneumonitis or cancer-, and pneumothorax). It is warranted not asking to the procedure more than it can give, because available expertise, knowledge, skills and training, but also the equipment’s suitability, are not always affordable or accessible; the risk of misunderstanding and of interpreting misleading artefacts that may impair quality and information of the procedure must be limited as much as possible[115-117]. The use of TUS for guided chest procedure was and is mainly devoted to pleura and other chest cavities drainage by needle insertion[118-120]. Equally important are the procedures aimed at a precision nodule biopsy[121-124] or to other diagnostic and therapeutic procedures related to diaphragm neuro-muscular disease[125].

**CHEST RADIOLOGY AND ULTRASOUND: WHAT, WHO, WHERE, WHEN, WHY**

Topics of trans-TUS are displayed in several handbooks[126,127], which are also available as e-books. The few images that are presented along this brief overview are available as a movie-appendix of this editorial, and are images and video-clips coupled to show TUS appearance of lung consolidation, of pleural-pericardial effusion and of B-lines artefacts. The question of the possible use of TUS as a screening tool is the same question of lung CT[128,129] as a screening tool for lung cancer: population and individuals at risk should be screened, but the use of TUS as a tool useful for addressing earlier more in depth CT controls is a matter of active current investigation[83,116].

The professionals performing TUS must be optimally trained[130]. In our view, and experience, teaching clinical ultrasound along the 3rd year curriculum of the School of medicine is the optimal choice, beginning as earlier as possible, provided that adequately skilled teachers are available[131-135]; physical examination skills and ultrasound proficiency between trained and untrained medical students improve together[136-139]. Differently, it is quite questionable that very brief periods of training in TUS[140,141] could provide sufficient knowledge and skills, unless they are articulated within a comprehensive US diagnostic and teaching curriculum[142,143]. This is a very important issue since the relevance of a widespread expertise among medical doctors is of pivotal relevance for a sustainable and reliable approach to the diagnosis and management of youngsters with pneumonia[61], an advancement that is a valuable medical breakthrough in children and limited resources subsets[144]. Quoting Thomas Huxley, the biologist, we should say: “Economy does not lie in sparing money, but in spending it wisely”. It is exactly what a wise and expert dissemination of knowledge, skills and machine focused to TUS may achieve, if no unrealistic claim will be placed in the procedure, leading to skipping, when needed*, i.e.*, often, the step of conventional or advanced radiology.

**CONCLUSION**

The field of application of TUS are pleural effusion, pneumothorax, and lung consolidation, both in emergency and in elective subsets. Paediatric and newborn disease are greatly suitable for TUS investigation aimed at the detection of congenital or acquired chest disease avoiding or limiting radiological exposure. This is a still neglected area of application, and its dissemination must be warranted and supported. In any field of application, TUS improves the effectiveness of medical practice in resource-limited settings, in small point-of-care facilities, in hostile environment and in poorer Countries. This is true for all the ultrasound diagnostic applications, and the specific knowledge and skills must be adequately propagated, providing advantages for limiting or more appropriately referring patients in any hospital facility[144,145].

**REFERENCES**

1 **Blair JS**. Marie Curie's other role. *J R Army Med Corps* 2005; **151**: 117-118 [PMID: 16097116 DOI: 10.1136/jramc-151-02-11]

2 **Joyner CR**, Miller LD, Dudrick SJ, Eskin DJ, Bloom P. Reflected ultrasound in the study of diseases of the chest. *Trans Am Clin Climatol Assoc* 1967; **78**: 28-37 [PMID: 6029333]

3 **Rosenberg HK**. The complementary roles of ultrasound and plain film radiography in differentiating pediatric chest abnormalities. *Radiographics* 1986; **6**: 427-445 [PMID: 3317545 DOI: 10.1148/radiographics.6.3.3317545]

4 **Alessi V**, Bianco S, Bianco BP, Capizzi C, Ganci G, Marotta R, Traina G. [The diagnostic potentials of echography in thoracic pathology]. *Radiol Med* 1990; **79**: 438-452 [PMID: 2193321]

5 **Sartori S**, Tombesi P. Emerging roles for transthoracic ultrasonography in pleuropulmonary pathology. *World J Radiol* 2010; **2**: 83-90 [PMID: 21160921 DOI: 10.4329/wjr.v2.i2.83]

6 **Sartori S**, Tombesi P. Emerging roles for transthoracic ultrasonography in pulmonary diseases. *World J Radiol* 2010; **2**: 203-214 [PMID: 21160632 DOI: 10.4329/wjr.v2.i6.203]

7 **Sartori S**, Postorivo S, Vece FD, Ermili F, Tassinari D, Tombesi P. Contrast-enhanced ultrasonography in peripheral lung consolidations: What's its actual role? *World J Radiol* 2013; **5**: 372-380 [PMID: 24179632 DOI: 10.4329/wjr.v5.i10.372]

8 **May DA**, Barth RA, Yeager S, Nussbaum-Blask A, Bulas DI. Perinatal and postnatal chest sonography. *Radiol Clin North Am* 1993; **31**: 499-516 [PMID: 8497587]

9 **Giron J**, Sans N, Fajadet P, Baunin C, Sénac JP. [Thoracic ultrasound]. *Rev Pneumol Clin* 2000; **56**: 103-113 [PMID: 10810196]

10 **Chavez MA**, Naithani N, Gilman RH, Tielsch JM, Khatry S, Ellington LE, Miranda JJ, Gurung G, Rodriguez S, Checkley W. Agreement Between the World Health Organization Algorithm and Lung Consolidation Identified Using Point-of-Care Ultrasound for the Diagnosis of Childhood Pneumonia by General Practitioners. *Lung* 2015; **193**: 531-538 [PMID: 25921013 DOI: 10.1007/s00408-015-9730-x]

11 **Beckh S**, Bölcskei PL, Lessnau KD. Real-time chest ultrasonography: a comprehensive review for the pulmonologist. *Chest* 2002; **122**: 1759-1773 [PMID: 12426282 DOI: 10.1378/chest.122.5.1759]

12 **Dietrich CF**, Hirche TO, Schreiber D, Wagner TO. [Sonographie von pleura und lunge]. *Ultraschall Med* 2003; **24**: 303-311 [PMID: 14562208 DOI: 10.1055/s-2003-42912]

13 **Diacon AH**, Theron J, Bolliger CT. Transthoracic ultrasound for the pulmonologist. *Curr Opin Pulm Med* 2005; **11**: 307-312 [PMID: 15928497 DOI: 10.1097/01.mcp.0000166591.03042.1f]

14 **Sperandeo M**, Rotondo A, Guglielmi G, Catalano D, Feragalli B, Trovato GM. Transthoracic ultrasound in the assessment of pleural and pulmonary diseases: use and limitations. *Radiol Med* 2014; **119**: 729-740 [PMID: 24496592 DOI: 10.1007/s11547-014-0385-0]

15 **American College of Emergency Physicians**. Emergency ultrasound guidelines. *Ann Emerg Med* 2009; **53**: 550-570 [PMID: 19303521 DOI: 10.1016/j.annemergmed.2008.12.013]

16 **Freeman HJ**. Refractory celiac disease and sprue-like intestinal disease. *World J Gastroenterol* 2008; **14**: 828-830 [PMID: 18240339 DOI: 10.3748/wjg.14.828]

17 **Hu QJ**, Shen YC, Jia LQ, Guo SJ, Long HY, Pang CS, Yang T, Wen FQ. Diagnostic performance of lung ultrasound in the diagnosis of pneumonia: a bivariate meta-analysis. *Int J Clin Exp Med* 2014; **7**: 115-121 [PMID: 24482696]

18 **Sperandeo M**, Trovato FM, Dimitri L, Catalano D, Simeone A, Martines GF, Piscitelli AP, Trovato GM. Lung transthoracic ultrasound elastography imaging and guided biopsies of subpleural cancer: a preliminary report. *Acta Radiol* 2015; **56**: 798-805 [PMID: 24951615 DOI: 10.1177/0284185114538424]

19 **The European Society of Radiology**. Risk management in Radiology in Europe. [updated 2004 Nov]. Available from: URL: https://www.myesr.org/html/img/pool/ESR\_2006\_IV\_Riskmanagement\_Web.pdf

20 **Craciun H**, Mankad K, Lynch J. Risk management in radiology departments. *World J Radiol* 2015; **7**: 134-138 [PMID: 26120383 DOI: 10.4329/wjr.v7.i6.134]

21 **Otero HJ**, Rybicki FJ, Greenberg D, Neumann PJ. Twenty years of cost-effectiveness analysis in medical imaging: are we improving? *Radiology* 2008; **249**: 917-925 [PMID: 19011188 DOI: 10.1148/radiol.2493080237]

22 **Otero HJ**, Rybicki FJ, Greenberg D, Mitsouras D, Mendoza JA, Neumann PJ. Cost-effective diagnostic cardiovascular imaging: when does it provide good value for the money? *Int J Cardiovasc Imaging* 2010; **26**: 605-612 [PMID: 20446040 DOI: 10.1007/s10554-010-9634-z]

23 **Fang C**, Otero HJ, Greenberg D, Neumann PJ. Cost-utility analyses of diagnostic laboratory tests: a systematic review. *Value Health* 2011; **14**: 1010-1018 [PMID: 22152169 DOI: 10.1016/j.jval.2011.05.044]

24 **Otero HJ**, Fang CH, Sekar M, Ward RJ, Neumann PJ. Accuracy, risk and the intrinsic value of diagnostic imaging: a review of the cost-utility literature. *Acad Radiol* 2012; **19**: 599-606 [PMID: 22342653 DOI: 10.1016/j.acra.2012.01.011]

25 **Cannavale A**, Santoni M, Passariello R, Arbarello P. Risk management in radiology. *Radiol Manage* 2013; **35**: 14-19; quiz 20-21 [PMID: 24303642]

26 **Wüstner A**, Gehmacher O, Hämmerle S, Schenkenbach C, Häfele H, Mathis G. [Ultrasound diagnosis in blunt thoracic trauma]. *Ultraschall Med* 2005; **26**: 285-290 [PMID: 16123922]

27 **Trovato GM**. Sustainable medical research by effective and comprehensive medical skills: overcoming the frontiers by predictive, preventive and personalized medicine. *EPMA J* 2014; **5**: 14 [PMID: 25250099 DOI: 10.1186/1878-5085-5-14]

28 **Golubnitschaja O**, Costigliola V. EPMA summit 2014 under the auspices of the presidency of Italy in the EU: professional statements. *EPMA J* 2015; **6**: 4 [PMID: 25878761 DOI: 10.1186/s13167-015-0026-2]

29 **Lemke HU**, Golubnitschaja O. Towards personal health care with model-guided medicine: long-term PPPM-related strategies and realisation opportunities within 'Horizon 2020'. *EPMA J* 2014; **5**: 8 [PMID: 24883142 DOI: 10.1186/1878-5085-5-8]

30 **Sartori S**, Tombesi P, Trevisani L, Nielsen I, Tassinari D, Abbasciano V. Accuracy of transthoracic sonography in detection of pneumothorax after sonographically guided lung biopsy: prospective comparison with chest radiography. *AJR Am J Roentgenol* 2007; **188**: 37-41 [PMID: 17179343]

31 **Wernecke K**, Galanski M, Peters PE, Hansen J. Pneumothorax: evaluation by ultrasound--preliminary results. *J Thorac Imaging* 1987; **2**: 76-78 [PMID: 3298684]

32 **Targhetta R**, Bourgeois JM, Balmes P. [Echography of pneumothorax]. *Rev Mal Respir* 1990; **7**: 575-579 [PMID: 2270346]

33 **Press GM**, Miller SK, Hassan IA, Alade KH, Camp E, Junco DD, Holcomb JB. Prospective evaluation of prehospital trauma ultrasound during aeromedical transport. *J Emerg Med* 2014; **47**: 638-645 [PMID: 25281177 DOI: 10.1016/j.jemermed.2014.07.056]

34 **Trovato G**, Sperandeo M. A picture is worth a thousand words: the need for CT for assessment of size and distribution of pneumothorax. *Intensive Care Med* 2014; **40**: 1614-1615 [PMID: 25209129 DOI: 10.1007/s00134-014-3461-y]

35 **Trovato G**, Sperandeo M. Lung Ultrasound in Pneumothorax: The Continuing Need for Radiology. *J Emerg Med* 2016; **pii**: S0736-4679(16)30127-5 [PMID: 27317611 DOI: 10.1016/j.jemermed.2015.01.045]

36 **Cardinale L**, Priola AM, Moretti F, Volpicelli G. Effectiveness of chest radiography, lung ultrasound and thoracic computed tomography in the diagnosis of congestive heart failure. *World J Radiol* 2014; **6**: 230-237 [PMID: 24976926 DOI: 10.4329/wjr.v6.i6.230]

37 **Trovato GM**, Sperandeo M. Sounds, ultrasounds, and artifacts: which clinical role for lung imaging? *Am J Respir Crit Care Med* 2013; **187**: 780-781 [PMID: 23540884]

38 **Trovato GM**, Rollo VC, Martines GF, Catalano D, Trovato FM, Sperandeo M. Thoracic ultrasound in the differential diagnosis of severe dyspnea: a reappraisal. *Int J Cardiol* 2013; **167**: 1081-1083 [PMID: 23167999 DOI: 10.1016/j.ijcard.2012.10.057]

39 **Trovato GM**, Catalano D, Martines GF, Sperandeo M. Is it time to measure lung water by ultrasound? *Intensive Care Med* 2013; **39**: 1662 [PMID: 23740276]

40 **Trovato GM**, Sperandeo M. Objectively Measuring the Ghost in the Machine: B-Lines as Uncertain Measures on Which to Base Clinical Assessment. *JACC Cardiovasc Imaging* 2015; **8**: 1470 [PMID: 26699116 DOI: 10.1016/j.jcmg.2014.12.035]

41 **Trovato GM**, Sperandeo M. The resistible rise of B-line lung ultrasound artefacts. *Respiration* 2015; **89**: 175-176 [PMID: 25592165 DOI: 10.1159/000369037]

42 **Sperandeo M**, Trovato GM, Catalano D. Quantifying B-lines on lung sonography: insufficient evidence as an objective, constructive, and educational tool. *J Ultrasound Med* 2014; **33**: 362-365 [PMID: 24449744 DOI: 10.7863/ultra.33.2.362]

43 **Al Deeb M**, Barbic S, Featherstone R, Dankoff J, Barbic D. Point-of-care ultrasonography for the diagnosis of acute cardiogenic pulmonary edema in patients presenting with acute dyspnea: a systematic review and meta-analysis. *Acad Emerg Med* 2014; **21**: 843-852 [PMID: 25176151 DOI: 10.1111/acem.12435]

44 **Trovato GM**, Sperandeo M, Catalano D. Ultrasound diagnosis of acute pulmonary edema: the oblivion of a great future behind us. *Acad Emerg Med* 2015; **22**: 244-245 [PMID: 25640171]

45 **Ciccarese F**, Chiesa AM, Feletti F, Vizioli L, Pasquali M, Forti P, Zoli M, Zompatori M. The Senile Lung as a Possible Source of Pitfalls on Chest Ultrasonography and Computed Tomography. *Respiration* 2015; **90**: 56-62 [PMID: 26044398 DOI: 10.1159/000430994]

46 **Rea G**, Trovato GM. A Farewell to B-Lines: Ageing and Disappearance of Ultrasound Artifacts as a Diagnostic Tool. *Respiration* 2015; **90**: 522 [PMID: 26440116 DOI: 10.1159/000441010]

47 **Katz JF**, Yucel EK. Point-of-care ultrasonography. *N Engl J Med* 2011; **364**: 2075-206; author reply 2076 [PMID: 21612494 DOI: 10.1056/NEJMc1103704#SA1]

48 **Trovato GM**, Catalano D, Sperandeo M. Assessment of lung ultrasound artifacts (B-lines): incremental contribution to echocardiography in heart failure? *JACC Cardiovasc Imaging* 2014; **7**: 635 [PMID: 24925334 DOI: 10.1016/j.jcmg.2013.11.013]

49 **Catalano D**, Trovato GM, Sperandeo M. Acute heart failure diagnosis by ultrasound: new achievements and persisting limitations. *Am J Emerg Med* 2014; **32**: 384-385 [PMID: 24462395 DOI: 10.1016/j.ajem.2013.12.026]

50 **Trovato GM**, Sperandeo M. Pulmonary ultrasonography: staying within the lines prevents us finding something better on the other side. *Chest* 2015; **147**: e236-e237 [PMID: 26033146 DOI: 10.1378/chest.14-3118]

51 **Trovato GM**, Catalano D, Sperandeo M. M-mode: a valuable tool in cardiology, is not yet ready to use in pneumology. *Respiration* 2014; **88**: 518 [PMID: 25402592 DOI: 10.1159/000367813]

52 **Trovato GM**, Catalano D, Sperandeo M. Echocardiographic and lung ultrasound characteristics in ambulatory patients with dyspnea or prior heart failure. *Echocardiography* 2014; **31**: 406-407 [PMID: 24606228 DOI: 10.1111/echo.12518]

53 **Katz JF**, Bezreh JS, Yucel EK. Lung ultrasound in the intensive care unit: an idea that may be too good to be true. *Intensive Care Med* 2015; **41**: 379-380 [PMID: 25510302 DOI: 10.1007/s00134-014-3606-z]

54 **Maggi M**, Catalano D, Sperandeo M, Trovato G. Comprehensive clinical evidence for pulmonary embolism diagnosis and workup. *Chest* 2014; **145**: 1173-1174 [PMID: 24798850 DOI: 10.1378/chest.13-2792]

55 **Haller JO**, Schneider M, Kassner EG, Friedman AP, Waldroup LD. Sonographic evaluation of the chest in infants and children. *AJR Am J Roentgenol* 1980; **134**: 1019-1027 [PMID: 6768240]

56 **Haran Jogeesvaran K**, Owens CM. Chronic diseases of lung parenchyma in children: the role of imaging. *Pediatr Radiol* 2010; **40**: 850-858 [PMID: 20432003 DOI: 10.1007/s00247-010-1615-9]

57 **Tomà P**, Owens CM. Chest ultrasound in children: critical appraisal. *Pediatr Radiol* 2013; **43**: 1427-1434; quiz 1427-1434 [PMID: 24141909 DOI: 10.1007/s00247-013-2756-4]

58 **Toma P**. Lung ultrasound characteristics of community-acquired pneumonia. *Pediatr Pulmonol* 2013; **48**: 1041-1042 [PMID: 23255323 DOI: 10.1002/ppul.22744]

59 **Toma P**. Lung ultrasound in bronchiolitis. *Eur J Pediatr* 2013; **172**: 713 [PMID: 23328963 DOI: 10.1007/s00431-013-1941-7]

60 **Tomà P**, Rizzo F, Stagnaro N, Magnano G, Granata C. Multislice CT in congenital bronchopulmonary malformations in children. *Radiol Med* 2011; **116**: 133-151 [PMID: 20852957 DOI: 10.1007/s11547-010-0582-4]

61 **Jones BP**, Tay ET, Elikashvili I, Sanders JE, Paul AZ, Nelson BP, Spina LA, Tsung JW. Feasibility and Safety of Substituting Lung Ultrasonography for Chest Radiography When Diagnosing Pneumonia in Children: A Randomized Controlled Trial. *Chest* 2016; **150**: 131-138 [PMID: 26923626 DOI: 10.1016/j.chest.2016.02.643]

62 **Escourrou G**, De Luca D. Lung ultrasound decreased radiation exposure in preterm infants in a neonatal intensive care unit. *Acta Paediatr* 2016; **105**: e237-e239 [PMID: 26880491 DOI: 10.1111/apa.13369]

63 **Pereda MA**, Chavez MA, Hooper-Miele CC, Gilman RH, Steinhoff MC, Ellington LE, Gross M, Price C, Tielsch JM, Checkley W. Lung ultrasound for the diagnosis of pneumonia in children: a meta-analysis. *Pediatrics* 2015; **135**: 714-722 [PMID: 25780071 DOI: 10.1542/peds.2014-2833]

64 **Sperandeo M**, Carnevale V, Muscarella S, Sperandeo G, Varriale A, Filabozzi P, Piattelli ML, D'Alessandro V, Copetti M, Pellegrini F, Dimitri L, Vendemiale G. Clinical application of transthoracic ultrasonography in inpatients with pneumonia. *Eur J Clin Invest* 2011; **41**: 1-7 [PMID: 20731700 DOI: 10.1111/j.1365-2362.2010.02367.x]

65 **Catalano D**, Trovato G, Sperandeo M, Sacco MC. Lung ultrasound in pediatric pneumonia. The persistent need of chest X-rays. *Pediatr Pulmonol* 2014; **49**: 617-618 [PMID: 24178894 DOI: 10.1002/ppul.22941]

66 **Mongodi S**, Via G, Girard M, Rouquette I, Misset B, Braschi A, Mojoli F, Bouhemad B. Lung Ultrasound for Early Diagnosis of Ventilator-Associated Pneumonia. *Chest* 2016; **149**: 969-980 [PMID: 26836896 DOI: 10.1016/j.chest.2015.12.012]

67 **Liccardo B**, Martone F, Trambaiolo P, Severino S, Cibinel GA, D'Andrea A. Incremental value of thoracic ultrasound in intensive care units: Indications, uses, and applications. *World J Radiol* 2016; **8**: 460-471 [PMID: 27247712 DOI: 10.4329/wjr.v8.i5.460]

68 **Sperandeo M**, Filabozzi P, Carnevale V. Ultrasound Diagnosis of Ventilator-Associated Pneumonia: A Not-So-Easy Issue. *Chest* 2016; **149**: 1350-1351 [PMID: 27157222 DOI: 10.1016/j.chest.2016.02.684]

69 **Sperandeo M**, Filabozzi P, Varriale A, Carnevale V, Piattelli ML, Sperandeo G, Brunetti E, Decuzzi M. Role of thoracic ultrasound in the assessment of pleural and pulmonary diseases. *J Ultrasound* 2008; **11**: 39-46 [PMID: 23396553 DOI: 10.1016/j.jus.2008.02.001]

70 **Hunter L**, Bélard S, Janssen S, van Hoving DJ, Heller T. Miliary tuberculosis: sonographic pattern in chest ultrasound. *Infection* 2016; **44**: 243-246 [PMID: 26661658 DOI: 10.1007/s15010-015-0865-8]

71 **Giordani MT**, Giaretta R, Scolarin C, Stefani MP, Pellizzari C, Tamarozzi F, Brunetti E. Ultrasound and infections on the Tibetan Plateau(). *J Ultrasound* 2012; **15**: 83-92 [PMID: 23396850 DOI: 10.1016/j.jus.2012.02.009]

72 **Stolz LA**, Muruganandan KM, Bisanzo MC, Sebikali MJ, Dreifuss BA, Hammerstedt HS, Nelson SW, Nayabale I, Adhikari S, Shah SP. Point-of-care ultrasound education for non-physician clinicians in a resource-limited emergency department. *Trop Med Int Health* 2015; **20**: 1067-1072 [PMID: 25808431 DOI: 10.1111/tmi.12511]

73 **Ramos-Rincón JM**, Cuadros-González J, Malmierca-Corral E, de Górgolas-Hernández M. Medical diagnosis in resource-poor tropical countries. *Rev Clin Esp* 2015; **215**: 43-49 [PMID: 25012088 DOI: 10.1016/j.rce.2014.05.002]

74 **Heuvelings CC**, Bélard S, Janssen S, Wallrauch C, Grobusch MP, Brunetti E, Giordani MT, Heller T. Chest ultrasonography in patients with HIV: a case series and review of the literature. *Infection* 2016; **44**: 1-10 [PMID: 25972115 DOI: 10.1007/s15010-015-0780-z]

75 **Bélard S**, Tamarozzi F, Bustinduy AL, Wallrauch C, Grobusch MP, Kuhn W, Brunetti E, Joekes E, Heller T. Point-of-Care Ultrasound Assessment of Tropical Infectious Diseases--A Review of Applications and Perspectives. *Am J Trop Med Hyg* 2016; **94**: 8-21 [PMID: 26416111 DOI: 10.4269/ajtmh.15-0421]

76 **Brunetti E**, Heller T, Richter J, Kaminstein D, Youkee D, Giordani MT, Goblirsch S, Tamarozzi F. Application of Ultrasonography in the Diagnosis of Infectious Diseases in Resource-Limited Settings. *Curr Infect Dis Rep* 2016; **18**: 6 [PMID: 26781324 DOI: 10.1007/s11908-015-0512-7]

77 **Heller T**, Wallrauch C, Brunetti E, Giordani MT. Changes of FASH ultrasound findings in TB-HIV patients during anti-tuberculosis treatment. *Int J Tuberc Lung Dis* 2014; **18**: 837-839 [PMID: 24902561 DOI: 10.5588/ijtld.13.0029.PMID: 24902561]

78 **Janssen S**, Basso F, Giordani MT, Brunetti E, Grobusch MP, Heller T. Sonographic findings in the diagnosis of HIV-associated tuberculosis: image quality and inter-observer agreement in FASH vs. remote-FASH ultrasound. *J Telemed Telecare* 2013; **19**: 491-493 [PMID: 24222660 DOI: 10.1177/1357633X13512072]

79 **Giordani MT**, Brunetti E, Binazzi R, Benedetti P, Stecca C, Goblirsch S, Heller T. Extrapulmonary mycobacterial infections in a cohort of HIV-positive patients: ultrasound experience from Vicenza, Italy. *Infection* 2013; **41**: 409-414 [PMID: 23001543 DOI: 10.1007/s15010-012-0336-4]

80 **Heller T**, Goblirsch S, Bahlas S, Ahmed M, Giordani MT, Wallrauch C, Brunetti E. Diagnostic value of FASH ultrasound and chest X-ray in HIV-co-infected patients with abdominal tuberculosis. *Int J Tuberc Lung Dis* 2013; **17**: 342-344 [PMID: 23321507 DOI: 10.5588/ijtld.12.0679]

81 **Heller T**, Wallrauch C, Goblirsch S, Brunetti E. Focused assessment with sonography for HIV-associated tuberculosis (FASH): a short protocol and a pictorial review. *Crit Ultrasound J* 2012; **4**: 21 [PMID: 23171481 DOI: 10.1186/2036-7902-4-21]

82 **Li T**, Chen X, Zhen R, Qiu J, Qiu D, Xiao N, Ito A, Wang H, Giraudoux P, Sako Y, Nakao M, Craig PS. Widespread co-endemicity of human cystic and alveolar echinococcosis on the eastern Tibetan Plateau, northwest Sichuan/southeast Qinghai, China. *Acta Trop* 2010; **113**: 248-256 [PMID: 19941830 DOI: 10.1016/j.actatropica.2009.11.006]

83 **Sperandeo M**, De Cata A, Molinaro F, Trovato FM, Catalano D, Simeone A, Varriale A, Martines GF, Trovato G. Ultrasound signs of pulmonary fibrosis in systemic sclerosis as timely indicators for chest computed tomography. *Scand J Rheumatol* 2015; **44**: 389-398 [PMID: 26099251 DOI: 10.3109/03009742.2015.1011228]

84 **Marchbank ND**, Wilson AG, Joseph AE. Ultrasound features of folded lung. *Clin Radiol* 1996; **51**: 433-437 [PMID: 8654011 DOI: [10.1016/S0009-9260(96)80165-6](http://dx.doi.org/10.1016/S0009-9260%2896%2980165-6%22%20%5Ct%20%22_blank)]

85 **Sperandeo M**, Dimitri L, Pirri C, Trovato FM, Catalano D, Trovato GM. Advantages of thoracic ultrasound-guided fine-needle aspiration biopsy in lung cancer and mesothelioma. *Chest* 2014; **146**: e178-e179 [PMID: 25367494 DOI: 10.1378/chest.14-1557]

86 **Jacobson JA**. Ultrasound in sports medicine. *Radiol Clin North Am* 2002; **40**: 363-386 [PMID: 12118829 DOI: [10.1016/S0033-8389(02)00005-2](http://dx.doi.org/10.1016/S0033-8389%2802%2900005-2%22%20%5Ct%20%22_blank)]

87 **Rozanski TA**, Edmondson JM, Jones SB. Ultrasonography in a forward-deployed military hospital. *Mil Med* 2005; **170**: 99-102 [PMID: 15782826]

88 **Hile DC**, Morgan AR, Laselle BT, Bothwell JD. Is point-of-care ultrasound accurate and useful in the hands of military medical technicians? A review of the literature. *Mil Med* 2012; **177**: 983-987 [PMID: 22934381]

89 **Madill JJ**. In-flight thoracic ultrasound detection of pneumothorax in combat. *J Emerg Med* 2010; **39**: 194-197 [PMID: 19880267 DOI: 10.1016/j.jemermed.2009.08.026]

90 **de Kerangal X**, Tourtier JP, Cotez-Gacia S, Grand B, Borne M. FAST and undertriage. *Langenbecks Arch Surg* 2010; **395**: 595-596 [PMID: 20512351 DOI: 10.1007/s00423-010-0624-3]

91 **Ward DI**. Prehospital point-of-care ultrasound use by the military. *Emerg Med Australas* 2007; **19**: 282 [PMID: 17564699]

92 **Melanson SW**, McCarthy J, Stromski CJ, Kostenbader J, Heller M. Aeromedical trauma sonography by flight crews with a miniature ultrasound unit. *Prehosp Emerg Care* 2001; **5**: 399-402 [PMID: 11642593]

93 **Otsuka H**, Sato T, Morita S, Nakagawa Y, Inokuchi S. A Case of Blunt Traumatic Cardiac Tamponade Successfully Treated by Out-of-hospital Pericardial Drainage in a "Doctor-helicopter" Ambulance Staffed by Skilled Emergency Physicians. *Tokai J Exp Clin Med* 2016; **41**: 1-3 [PMID: 27050887]

94 **O'Dochartaigh D**, Douma M. Prehospital ultrasound of the abdomen and thorax changes trauma patient management: A systematic review. *Injury* 2015; **46**: 2093-2102 [PMID: 26264879 DOI: 10.1016/j.injury.2015.07.007]

95 **Burns BJ**, Aguirrebarrena G. Occult traumatic loculated tension pneumothorax--a sonographic diagnostic dilemma. *Prehosp Emerg Care* 2013; **17**: 92-94 [PMID: 22920267 DOI: 10.3109/10903127.2012.710720]

96 **Darocha T**, Gałązkowski R, Sobczyk D, Żyła Z, Drwiła R. Point-of-care ultrasonography during rescue operations on board a Polish Medical Air Rescue helicopter. *J Ultrason* 2014; **14**: 414-420 [PMID: 26674604 DOI: 10.15557/JoU.2014.0043]

97 **Roline CE**, Heegaard WG, Moore JC, Joing SA, Hildebrandt DA, Biros MH, Caroon LV, Plummer DW, Reardon RF. Feasibility of bedside thoracic ultrasound in the helicopter emergency medical services setting. *Air Med J* 2013; **32**: 153-157 [PMID: 23632224 DOI: 10.1016/j.amj.2012.10.013]

98 **Ketelaars R**, Hoogerwerf N, Scheffer GJ. Prehospital chest ultrasound by a dutch helicopter emergency medical service. *J Emerg Med* 2013; **44**: 811-817 [PMID: 23332805 DOI: 10.1016/j.jemermed.2012.07.085]

99 **Hasler RM**, Kehl C, Exadaktylos AK, Albrecht R, Dubler S, Greif R, Urwyler N. Accuracy of prehospital diagnosis and triage of a Swiss helicopter emergency medical service. *J Trauma Acute Care Surg* 2012; **73**: 709-715 [PMID: 22929499 DOI: 10.1097/TA.0b013e31825c14b7]

100 **Hoyer HX**, Vogl S, Schiemann U, Haug A, Stolpe E, Michalski T. Prehospital ultrasound in emergency medicine: incidence, feasibility, indications and diagnoses. *Eur J Emerg Med* 2010; **17**: 254-259 [PMID: 20164777 DOI: 10.1097/MEJ.0b013e328336ae9e]

101 **Bataille B**, Riu B, Ferre F, Moussot PE, Mari A, Brunel E, Ruiz J, Mora M, Fourcade O, Genestal M, Silva S. Integrated use of bedside lung ultrasound and echocardiography in acute respiratory failure: a prospective observational study in ICU. *Chest* 2014; **146**: 1586-1593 [PMID: 25144893 DOI: 10.1378/chest.14-0681]

102 **Joyner CR**. Echocardiography. *Circulation* 1972; **46**: 835-838 [PMID: 5081138 DOI: [10.1161/01.CIR.46.5.835](http://dx.doi.org/10.1161/01.CIR.46.5.835%22%20%5Ct%20%22_blank)]

103 **Joyner CR**. Echocardiography. *Am Heart J* 1975; **90**: 413-419 [PMID: 126014 DOI: [10.1016/0002-8703(75)90419-6](http://dx.doi.org/10.1016/0002-8703%2875%2990419-6%22%20%5Ct%20%22_blank)]

104 **Joyner CR**. Ultrasonic diagnosis of pulmonary embolism--the second time around. *Int J Cardiol* 1984; **6**: 116-120 [PMID: 6746133 DOI: [10.1016/0167-5273(84)90258-4](http://dx.doi.org/10.1016/0167-5273%2884%2990258-4%22%20%5Ct%20%22_blank)]

105 **Kelbel C**, Börner N, Schadmand S, Klose KJ, Weilemann LS, Meyer J, Thelen M. [Diagnosis of pleural effusions and atelectases: sonography and radiology compared]. *Rofo* 1991; **154**: 159-163 [PMID: 1847539 DOI: [10.1055/s-2008-1033105](http://dx.doi.org/10.1055/s-2008-1033105%22%20%5Ct%20%22_blank)]

106 **Fournier D**. [Thoracic ultrasound]. *Schweiz Med Wochenschr* 1997; **127**: 1734-1742 [PMID: 9446192]

107 **Trovato GM**, Catalano D, Sperandeo M, Graziano P. Artifacts, Noise and Interference: Much Ado about Ultrasound. *Respiration* 2015; **90**: 85 [PMID: 25824977 DOI: 10.1159/000375316]

108 **Tasci O**, Hatipoglu ON, Cagli B, Ermis V. Sonography of the chest using linear-array versus sector transducers: Correlation with auscultation, chest radiography, and computed tomography. *J Clin Ultrasound* 2016; **44**: 383-389 [PMID: 26863904 DOI: 10.1002/jcu.22331]

109 **Kataoka H**, Takada S. The role of thoracic ultrasonography for evaluation of patients with decompensated chronic heart failure. *J Am Coll Cardiol* 2000; **35**: 1638-1646 [PMID: 10807471]

110 **Kataoka H**. Pericardial and pleural effusions in decompensated chronic heart failure. *Am Heart J* 2000; **139**: 918-923 [PMID: 10783228]

111 **Kataoka H**. Utility of thoracic sonography for follow-up examination of chronic heart failure patients with previous decompensation. *Clin Cardiol* 2007; **30**: 336-341 [PMID: 17674378]

112 **Kataoka H**. Ultrasound pleural effusion sign as a useful marker for identifying heart failure worsening in established heart failure patients during follow-up. *Congest Heart Fail* 2012; **18**: 272-277 [PMID: 22994441 DOI: 10.1111/j.1751-7133.2012.00285.x]

113 **Oylumlu M**, Davutoglu V, Sucu M, Ercan S, Ozer O, Yuce M. Prognostic role of echocardiographic and hematologic parameters in heart failure patients complicated with incidental pleural effusion diagnosed during echocardiographic evaluation. *Int J Cardiovasc Imaging* 2014; **30**: 907-910 [PMID: 24710708 DOI: 10.1007/s10554-014-0421-0]

114 **Kataoka H**, Madias JE. Effects of heart failure status on electrocardiogram precordial leads and their value for monitoring body fluid changes in heart failure patients. *Int J Cardiol* 2011; **152**: 113-115 [PMID: 21802157 DOI: 10.1016/j.ijcard.2011.07.030]

115 **Trovato GM**, Sperandeo M, Catalano D. Optimization of thoracic US guidance for lung nodule biopsy. *Radiology* 2014; **270**: 308 [PMID: 24354382 DOI: 10.1148/radiol.13131527]

116 **Trovato G**, Sperandeo M, Catalano D. Letter to the editor: Mostbeck G. Elastography everywhere--now even the lungs! Ultraschall in Med. 2014; 35: 5 - 8. *Ultraschall Med* 2014; **35**: 371; discussion 371-372 [PMID: 25127226 DOI: 10.1055/s-0034-1366523]

117 **Sperandeo M**, Dimitri L, Trovato FM, Simeone A, Catalano D, Pirri C, Trovato G. Thoracic Ultra Sound (TUS) integrated approach for FNAB-US guided diagnosis and for monitoring environmental exposed subjects at risk of malignant pleural mesothelioma (MPM) and lung cancer (LC). Overview and preliminary report of TUS monitoring and screening approach. *FASEB J* 2014; **28** Suppl: LB498

118 **Ravin CE**. Thoracocentesis of loculated pleural effusions using grey scale ultrasonic guidance. *Chest* 1977; **71**: 666-668 [PMID: 852349]

119 **Dede D**, Akmangit I, Yildirim ZN, Sanverdi E, Sayin B. Ultrasonography and fluoroscopy-guided insertion of chest ports. *Eur J Surg Oncol* 2008; **34**: 1340-1343 [PMID: 18191364 DOI: 10.1016/j.ejso.2007.12.001]

120 **Fitch MT**, Nicks BA, Pariyadath M, McGinnis HD, Manthey DE. Videos in clinical medicine. Emergency pericardiocentesis. *N Engl J Med* 2012; **366**: e17 [PMID: 22435385 DOI: 10.1056/NEJMvcm0907841]

121 **Trevisani L**, Sartori S, Putinati S, Abbasciano V, Cervi PM. Needle aspiration biopsy and ultrasonic guidance. *Chest* 1994; **106**: 650 [PMID: 7774373]

122 **Sartori S**, Nielsen I, Trevisani L, Tombesi P, Ceccotti P, Abbasciano V. Contrast-enhanced sonography as guidance for transthoracic biopsy of a peripheral lung lesion with large necrotic areas. *J Ultrasound Med* 2004; **23**: 133-136 [PMID: 14756362]

123 **Tombesi P**, Nielsen I, Tassinari D, Trevisani L, Abbasciano V, Sartori S. Transthoracic ultrasonography-guided core needle biopsy of pleural-based lung lesions: prospective randomized comparison between a Tru-cut-type needle and a modified Menghini-type needle. *Ultraschall Med* 2009; **30**: 390-395 [PMID: 19544230 DOI: 10.1055/s-0028-1109442]

124 **Di Vece F**, Tombesi P, Ermili F, Sartori S. Contrast-enhanced ultrasound (CEUS) and CEUS-guided biopsy in the diagnosis of lung abscess in a patient with achalasia: Case report. *Interv Med Appl Sci* 2013; **5**: 31-33 [PMID: 24265886 DOI: 10.1556/IMAS.5.2013.1.6]

125 **Boon AJ**, Sekiguchi H, Harper CJ, Strommen JA, Ghahfarokhi LS, Watson JC, Sorenson EJ. Sensitivity and specificity of diagnostic ultrasound in the diagnosis of phrenic neuropathy. *Neurology* 2014; **83**: 1264-1270 [PMID: 25165390 DOI: 10.1212/WNL.0000000000000841]

126 **Bolliger CT**, Herth FJF, Mayo, PH Miyazawa T. Clinical Chest Ultrasound. Eds. Progress in Respiratory Research, Vol. 37, Karger, Basel, 2009

127 **Sperandeo M**, Trovato G. Ecografia Toracica. Diagnosi e tecniche interventistiche. EDRA. Milan, 2015

128 **Trovato GM**, Sperandeo M, Catalano D. Computed tomography screening for lung cancer. *Ann Intern Med* 2013; **159**: 155 [PMID: 23856687 DOI: 10.7326/0003-4819-159-2-201307160-00016]

129 **van Beek EJ**, Mirsadraee S, Murchison JT. Lung cancer screening: Computed tomography or chest radiographs? *World J Radiol* 2015; **7**: 189-193 [PMID: 26339461 DOI: 10.4329/wjr.v7.i8.189]

130 **Keddis MT**, Cullen MW, Reed DA, Halvorsen AJ, McDonald FS, Takahashi PY, Bhagra A. Effectiveness of an ultrasound training module for internal medicine residents. *BMC Med Educ* 2011; **11**: 75 [PMID: 21955400 DOI: 10.1186/1472-6920-11-75]

131 **Fodor D**, Badea R, Poanta L, Dumitrascu DL, Buzoianu AD, Mircea PA. The use of ultrasonography in learning clinical examination - a pilot study involving third year medical students. *Med Ultrason* 2012; **14**: 177-181 [PMID: 22957320]

132 **Fox JC**, Schlang JR, Maldonado G, Lotfipour S, Clayman RV. Proactive medicine: the "UCI 30," an ultrasound-based clinical initiative from the University of California, Irvine. *Acad Med* 2014; **89**: 984-989 [PMID: 24826849 DOI: 10.1097/ACM.0000000000000292]

133 **Trovato GM**, Catalano D, Sperandeo M. Top or Flop: The Need to Improve Knowledge and Skills Achieved by Ultrasound Medical Curricula. *Acad Med* 2015; **90**: 839-840 [PMID: 26414050 DOI: 10.1097/ACM.0000000000000745]

134 **Chiem AT**, Soucy Z, Dinh VA, Chilstrom M, Gharahbaghian L, Shah V, Medak A, Nagdev A, Jang T, Stark E, Hussain A, Lobo V, Pera A, Fox JC. Integration of Ultrasound in Undergraduate Medical Education at the California Medical Schools: A Discussion of Common Challenges and Strategies From the UMeCali Experience. *J Ultrasound Med* 2016; **35**: 221-233 [PMID: 26764278 DOI: 10.7863/ultra.15.05006]

135 **Dinh VA**, Fu JY, Lu S, Chiem A, Fox JC, Blaivas M. Integration of Ultrasound in Medical Education at United States Medical Schools: A National Survey of Directors' Experiences. *J Ultrasound Med* 2016; **35**: 413-419 [PMID: 26782166 DOI: 10.7863/ultra.15.05073]

136 **Dinh VA**, Dukes WS, Prigge J, Avila M. Ultrasound Integration in Undergraduate Medical Education: Comparison of Ultrasound Proficiency Between Trained and Untrained Medical Students. *J Ultrasound Med* 2015; **34**: 1819-1824 [PMID: 26333569 DOI: 10.7863/ultra.14.12045]

137 **Palma JK**. Successful strategies for integrating bedside ultrasound into undergraduate medical education. *Mil Med* 2015; **180**: 153-157 [PMID: 25850144 DOI: 10.7205/MILMED-D-14-00573]

138 **Dinh VA**, Frederick J, Bartos R, Shankel TM, Werner L. Effects of ultrasound implementation on physical examination learning and teaching during the first year of medical education. *J Ultrasound Med* 2015; **34**: 43-50 [PMID: 25542938 DOI: 10.7863/ultra.34.1.43]

139 **Dinh VA**, Lakoff D, Hess J, Bahner DP, Hoppmann R, Blaivas M, Pellerito JS, Abuhamad A, Khandelwal S. Medical Student Core Clinical Ultrasound Milestones: A Consensus Among Directors in the United States. *J Ultrasound Med* 2016; **35**: 421-434 [PMID: 26782162 DOI: 10.7863/ultra.15.07080]

140 **Dinh VA**, Giri PC, Rathinavel I, Nguyen E, Hecht D, Dorotta I, Nguyen HB, Chrissian AA. Impact of a 2-Day Critical Care Ultrasound Course during Fellowship Training: A Pilot Study. *Crit Care Res Pract* 2015; **2015**: 675041 [PMID: 26346694 DOI: 10.1155/2015/675041]

141 **Chiem AT**, Chan CH, Ander DS, Kobylivker AN, Manson WC. Comparison of expert and novice sonographers' performance in focused lung ultrasonography in dyspnea (FLUID) to diagnose patients with acute heart failure syndrome. *Acad Emerg Med* 2015; **22**: 564-573 [PMID: 25903470 DOI: 10.1111/acem.12651]

142 **Moy RJ**, Chapman AL, Bapusamy A. The effectiveness of an informal teaching programme for junior doctors identifying pleural effusions using ultrasound at the bedside. *J R Army Med Corps* 2010; **156**: 233-235 [PMID: 21275356]

143 **Trovato FM**, Musumeci G. Lung ultrasound: the need of an adequate training for the next generation of internists. *Neth J Med* 2015; **73**: 305 [PMID: 26228202]

144 **Catalano D**, Trovato FM, Pirri C, Trovato GM. Outpatient diagnosis and therapeutic units linked with ED referrals: a sustainable quality-centered approach. *Am J Emerg Med* 2013; **31**: 1612 [PMID: 24070979 DOI: 10.1016/j.ajem.2013.07.008]

145 **Trovato FM**, Catalano D. Diagnosis of Pneumonia by Lung Ultrasound in Children and Limited Resources Subsets: A Valuable Medical Breakthrough. *Chest* 2016; **150**: 258-260 [PMID: 27396790 DOI: 10.1016/j.chest.2016.04.032]

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**Table 1 Thoracic ultrasound - main indications**

**The physical examination by a non-radiologist MD can be usefully completed by a thorough and fast chest exploration. The aims are**

To clarify symptoms already known (dyspnea, chest pain, fever, cough) or detected signs, such as rales, crackles or dullness

To detect unexpected chest abnormalities such as pleural effusion or lung consolidation in subjects with few or no evident respiratory symptom

**Information and clues derived by TUS may focus better to further diagnostic definition, by radiology or by other procedures, avoiding time-wasting and even detrimental choices**

The detection of pneumothorax by TUS is a quite simple and direct diagnosis of a not rare condition (see below), which should be usefully addressed to radiology, often including CT, for confirm. TUS has the great merit of making possible this direct pathway avoiding or postponing the more usual steps of chest pain work-up: cardiological and laboratory investigations and preventive pharmacological drugs

In addition, the detection of subpleural infiltrates after a blunt thoracic trauma, apparently relatively uneventful, can address to a subsequent better focused diagnostic workup

**Signs and symptoms initially addressing to different organs or body areas**

Upper abdominal pain, easily attributable to gallbladder

Lumbar-flank pain, usually attributable to kidneys or spine, should prompt also to a TUS examination, since, with or without fever, the detection of pleural effusion or of downward areas of lung consolidation may address, as not infrequently happens, to a different diagnosis

TUS: Thoracic ultrasound.