Lung ultrasound to detect pneumothorax in children evaluated for acute chest pain in the emergency department: an observational pilot study

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Abstract

Objectives- We prospectively analyzed children with acute chest pain and clinical suspicion of pneumothorax (PNX) evaluated at the pediatric Emergency Department.

Methods- After clinical examination and before Chest X-Ray, children underwent LUS to evaluate the presence of PNX. We enrolled 70 children, 13 (18,57%) received a final diagnosis of PNX.

Results- In all 13 (100%) patients LUS showed the "bar-code sign", the absence of lung sliding and the absence of B lines while in 12 (92,3%) there was the lung point, giving a diagnosis of PNX. All cases had PNX features on CXR. The "bar-code sign", the absence of lung sliding and the absence of B lines had a sensitivity of 100% and a specificity of 100%. The "bar-code sign" had a positive predictive value of 100% and a negative predictive value of 100% for the detection of PNX.

Conclusions- LUS is highly accurate in detecting or excluding pneumothorax in children with acute chest pain evaluated in the pediatric emergency department.

Keywords

Pneumothorax, Children, Lung Ultrasound, Ultrasound, Lung-point

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INTRODUCTION

Spontaneous pneumothorax (PNX) is a relatively uncommon and poorly studied condition in children. A recent review reports an incidence of 3.41 per 100,000 patients younger than age 18 years, while the incidence of secondary non-traumatic pneumothorax in the pediatric population has not yet been exactly established.[1]

Although diagnosis of spontaneous PNX is often clinically suspected in the pediatric Emergency Department (pED) based on history and physical examination, spontaneous PNX is usually detected by chest x-Ray (CXR), since computed tomography (CT) scan (the gold standard for PNX's diagnosis) is not always available and bears a substantial dose of radiation exposure.[2] Similarly, CXR has some limitations as it is not radiation free and the child needs to move from the pED room to the radiology unit, which might be difficult with unstable patients.

Point-of-care ultrasound (POCUS) and lung ultrasound (LUS) are now routinely used in most adult emergency departments: several protocols have been so far developed to evaluate point-of-care LUS to acutely dyspneic patients in the ED. In particular, the BLUE protocol developed by Liechtestein[3] has proved effective in the diagnosis of pneumonia, edema, trauma complications and PNX. In all adult studies on PNX, LUS showed high sensitivity (95%) and specificity of 100%.[3-7] LUS is now considered non-inferior to CXR for the diagnosis of PNX when used by experienced physicians. While emergency guidelines for adults have been published, there have been no specific guidelines for pediatric emergency physicians despite the growing use of point-of-care pulmonary ultrasound in pediatric emergency departments.[8]

Nevertheless, the role of LUS to diagnose PNX in children (other than newborns) evaluated in pED has never been evaluated.

We performed this study to evaluate LUS accuracy in detecting PNX in children with acute chest pain in the pED.

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MATERIALS AND METHODS

This prospective study was conducted between 1st July 2018 and 31st December, 2019 in a tertiary care pediatric hospital with an annual census of about 65.000 ED visits. The ethics committee of our institution (prot 1564 OPBG2018) and the informed consent was obtained.

We consecutively enrolled patients aged 5 to 17 years presenting to the pED with clinically suspected PNX based on sudden onset of acute chest pain plus one of the following signs/symptoms: dyspnea, polypnea (polypnea indicates an increase in respiratory rate associated with an increase in the intensity of respiratory acts, tachypnea indicates only an increase in respiratory rate), diminished breath sounds or hyper-resonant percussion

Patients outside our age range, who declined to participate, with severe conditions requiring immediate life-saving procedures, trauma, pneumonectomy, chronic lung conditions, cardiac abnormalities, tracheal stenosis, with known malignancies or subcutaneous emphysema were excluded from the study. Moreover, if the evaluating clinician suspected a specific disease (gastritis, gastro-esophageal reflux, muscle-skeletal disorders), LUS and CXR were not deemed necessary and not performed. In our Institution, the protocol for the management of children with chest pain evaluated in the pED include clinical examination and ECG, while further examinations (LUS, CXR, blood tests) are requesting only if the evaluating clinician suspect a diagnosis which would require further investigations (e.g. PNX, pericarditis, etc).

After the primary clinical assessment, the same evaluating ED pediatrician performed LUS, always before performing CXR and/or other diagnostic tests.

LUS was carried out by three pediatricians who performed ultrasound scans in the pED for more than 5 years.[9-13] In Italy, there is not a standard POCUS fellowship training during the Pediatric/PEM fellowship, therefore those interested in learning this practice need to follow dedicated courses directed by national societies (including the Italian Sociecty of Pediatrics (SIP) and the Italian Society of Ultrasound in Medicine and Biology (SIUMB) or main Pediatric

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University Hospitals.[14] The three operators performed the national courses within the SIP and one of them (DB) also performed the SIUMB curriculum. All operators are instructors within the Institution and run together courses and studies since years, adopting same clinical/teaching approach to ensure consistency within practice.

They were aware of the patients' medical history and were the ones involved in diagnostic or therapeutic decisions. LUS was performed using a Sonosite MTurbo (Milan, Italy).

Measurements

LUS was performed using a portable ultrasound machine using a high-frequency linear probe (12 mHz). LUS was performed with patients in the supine position as described in the BLUE protocol [3] using B-mode and M-mode settings; the LUS examination protocol was the same we described previously.[9] After sonographic examination, the patient underwent CXR.

POCUS findings

As indicated in the literature, [12, 15-18] ultrasound signs of the pneumothorax are absence of lung sliding, absence of B lines, presence of lung point and barcode in M-mode. Pathophysiologically, pneumothorax is the detachment of visceral and parietal pleura by entrapped air in the pleural space. All ultrasonographic signs are due to the presence of air in pleural space.

Lung sliding represents a regular movement synchronized with respiration that occurs between the parietal and visceral pleura. In case of pneumothorax, the air inside the pleural space prevents the display of the visceral pleura to the ultrasound and therefore “lung sliding” is not observed.

Lung point represents the point between the absence of sliding and the resumption of normal sliding, which represents the physical limit of pneumothorax. Lung point is the point where the

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visceral pleura is again next to the parietal pleura without air interposition and slides with respiration.[19] In M-mode ultrasound the normal sliding generates seashore sing, in case of pneumothorax you find the barcode sign, which is due to the absence of normal movement between the two pleural. (Fig 1).

The images of all children enlisted were reviewed by a different and blinded physician expert in lung ultrasound.

Statistical analysis

Statistical analysis was performed using the SPSS software (IBM SPSS Statistics, version 24.0, Chicago, IL, USA). Values were expressed as means ± standard deviation (SD) for normally distributed continuous variables, median and interquartile range (IQR) for data not normally distributed, or number and percentage (%) for categorical variable. Concordance between LUS and CXR was established with Cohen's kappa index. A p-value <0.05 was considered statistically significant.

Inter-observer reliability with Cohen's kappa was defined: 0.81 ± 1.00 excellent, 0.61 ± 0.80 good, 0.41 ± 0.60 moderate, 0.21 ± 0.40 fair, > 0 ± 0.20 slight, and 0 absent.

RESULTS

Study population

Seven hundred eighty-four consecutive children presented to our pED with a primary complain of acute chest pain during the study period. One hundred and six were excluded because they did not meet the inclusion criteria. One-hundred-thirty received a specific clinical diagnosis that, according to the evaluating physician, precluded the use of LUS and CXR. Of the remaining 548, 478 did not undergo LUS because ultrasonographers were not available; of these only 2 received a final

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diagnosis of PNX. In total, 70 children received LUS because of clinical suspicion of PNX. Thirty (42,85%) children had lower respiratory tract infection (e.g. bronchitis or asthma); 20/70 (28,57%) had pneumonia with or without pleural effusions; 7/70 (10%) had a final diagnosis of myo/pericarditis and 13 (18,57%) received a final diagnosis of PNX. Among the 70 children 44 (62,8%) were male with median age of 10 years and 3 months (IQR 6 years and 9 months- 14 years and 2 months). In ED during the visit 36 (51,42 %) patients presented dyspnea with a mean saturation of 98,36 ± 1,87 % in ambient air.

Fig 2 shows the STARD diagram of flow of participants through the study.

Population with PNX

Among the 13 patients with PNX, 8 (61,5%) were males with a median age of 16 years and 1 month (IQR 15 years -16 years and 7 months). All patients with PNX had acute chest pain, two (15.4%) presented with dyspnea. The mean oxygen saturation was 99,31 ± 1,10 % in ambient air, the heart rate 96,77 ± 15,55 beats per minute and the respiratory rate 20,38 ± 1,71 breaths /minute.

Five (38,5%) patients were diagnosed with secondary pneumothorax, two had uncontrolled allergic asthma, two had suspected collagenopathy and one was smoking cannabis. In 4 children (30,8%) it was a secondary episode of PNX; in 3 cases (23,1%), patients reported a history of chest pain without a specific diagnosis. 11 patients (84,6 %) were admitted for clinical observation, in 4 of them (30,8%) was placed a chest tube.

CT scan was performed in 9 (69,2%) patients, in all cases PNX was described; lung abnormalities (bullae) were found in 4 (30.8%) cases that were not described by LUS. In the other 5 (38,4%) patients, the CT scan showed no pathological conditions predisposing to the pneumothorax. CT scans were performed for patients with large PNX and patients with a relapse.

LUS findings

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In all 13 (100%) patients LUS showed the "bar-code sign", the absence of lung sliding and the absence of B lines while in 12 (92,3%) there was the lung point, giving a diagnosis of PNX. All cases had PNX features on CXR.

In 5 (38,5%) cases the PNX was small and the lung point was identified on the anterior chest surface between the parasternal and anterior axillary line, in 2 cases the lung point was in the right hemithorax while in 3 cases in left hemithorax. In 8 (61,5%) cases the PNX was considered large and in 7 cases the lung point was identified on the lateral surface of the thorax after the mid axillary line, in 3 cases in right hemithorax and in 4 cases in left hemithorax.

The lung point had a sensitivity of 92,3% and a specificity of 100%, a positive predictive value of 100% and a negative predictive value of 98,4 % for the detection of PNX. We did not found the lung point in one child with massive PNX with complete lung collapse.

The "bar-code sign", the absence of lung sliding and the absence of B lines had a sensitivity of 100% and a specificity of 100%. The "bar-code sign" had a positive predictive value of 100% and a negative predictive value of 100% for the detection of PNX.

Therefore, the Kappa Cohen's index is excellent for both, being 0,95 for the lung point and 1 for the "bar-code sign".

The images of all children were reviewed by a different and blinded physician expert in lung ultrasound. The inter-rater agreement was 0.961 with Cohen's kappa coefficient of 0.87, defining an excellent agreement in detecting LUS features of PNX.

DISCUSSION

Our study shows the high accuracy of LUS in detecting PNX in pediatric patients evaluated in the pED for acute chest pain. While the role of LUS for PNX detection is widely described in adult

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patients, to our knowledge this is the first prospective description in children evaluated in the pED for acute chest pain.

Adult studies showed that LUS had a sensitivity of 78.6% (95% CI 68.1–98.1) and a specificity of 98.4% (95% CI 97.3–99.5), while CXR had a pooled sensitivity of 39.8% (95% CI 29.4–50.3) and a specificity of 99.3% (95% CI 98.4–100).[18,20] Our study not only confirms the high sensitivity and specificity of LUS in pediatric patients, but also had even higher accuracy than reported in adult studies.

In particular, the lung point had a sensitivity of 92,3% and a specificity of 100%, a positive predictive value of 100% and a negative predictive value of 98,4 % for the detection of PNX. The "bar-code sign" had a sensitivity of 100% and a specificity of 100%, a positive predictive value of 100% and a negative predictive value of 100% for the detection of PNX. Lung point was negative in one child with massive PNX with complete lung collapse, suggesting that when PNX is suspected, both signs must be looked for to confirm or exclude PNX.

The overall 100% sensitivity and specificity of our pediatric patients can be explained by two factors: first of all, the pediatric chest is easily evaluable with high resolution linear probes (we used 12 mHz) due to smaller chest sizes (less muscles and fat), obtaining high resolution images and greater ease than adults to detect lung point.

In our study, we found excellent agreements (high K scores) when LUS and CXR were compared but also when LUS images were reassessed by an independent operator. Although our study included a small number of children with PNX, a high agreement is a promising result for further studies and also for future inclusion of LUS in the routine assessment of children with suspected PNX.

In daily clinical practice, the evaluation of non-compliant patients (a frequent situation in pediatric practice) may lead to false positive or false negative examinations, therefore a high grade of

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experience along with clinical suspicion are both critical factors when performing LUS. For example, some authors questioned the specificity of the lung point [21-23], but they have been replied by experts in LUS that showed how their false positive/negative results were due to a definitional error and a misinterpretation of images.[24-25]

In addition, a recent study on traumatic PNX in children showed 45.5% sensitivity, however LUS was performed by ultrasound technicians with a convex 2-5 MHz probe: these two factors can, in our opinion, explain the unexpected poor results of Vasquez et al.[26]

Evaluation of PNX requires knowledge of several LUS artifacts including lung sliding, lung point, B-lines and M-mode (Figure 1).[27] The presence of lung sliding rules out PNX in the specific area of LUS examination.[28] However, the absence of lung sliding does definitely indicate PNX. For example, pleurodesis, chronic lung disease or severe parenchymal disease or bronchial occlusion can eliminate lung sliding, although these situations are rare in children. Therefore, when the lung sliding is not looked for, a lung point must be found to confirm PNX.[17] The lung point is 100% specific for pneumothorax in adult studies.[14] In our study, all children with PNX had bar-code sign, absence of lung sliding and B lines in the PNX area, while lung point was present in all but one case of massive PNX, confirming, for the first time to our knowledge, that the adult findings of PNX can be translated to children. The absence of lung point in a case of massive PNX is an important finding that highlights the need of always looking for all signs when a PNX need to be ruled-out/in.

The high accuracy of LUS for PNX in our study can have practical implications. Pediatric studies have shown the high rate of CXRs performed by emergency pediatricians evaluating children with acute chest pain.[29-30] Considering the ability of LUS in detecting PNX, the high negative predictive value for PNX, and the available data on the accuracy of LUS in detecting PNX, the routine application of LUS can allow a high reduction of CXR-related costs and radiation exposure for the evaluation of acute chest pain in the pED.

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Our study showed that the position of the lung point provided a semi-quantitative estimate of PNX size: in case of small PNX, the lung point was located over the anterior chest close to the parasternal line, while in large PNX it was located after the mid axillary line. These findings confirm for the first time in pediatric patients what has been described in adults.[17-18]

In our study, the group of children undergoing LUS received more frequently a diagnosis of PNX compared with those not receiving LUS. This may be due to a number of reasons. LUS were performed by pediatric emergency doctors with experience in LUS. This may have been a bias in the selection group since pediatricians performing LUS were also aware of the clinical presentation of each child. Therefore, being expert in LUS, had possibly a higher level of suspicion to look for PNX compared to the other group of clinicians not performing LUS. In our Institution, chest X-ray is not included in the routine assessment of children evaluated in the emergency department due to chest pain. Our protocol include clinical evaluation and ECG, while chest X-ray/LUS and blood tests are performed only in case of clinical suspiction. It is possible that a number of children diagnosed as “primary chest pain” among those not undergoing LUS may have had an undiagnosed PNX.

Another selection bias may have occurred with the assessment of the four children with a PNX relapse. In these cases, although the suspicion of PNX may have been higher, on a pediatrician perspective, a child with chest pain assessed in the emergency department may have a relapse of PNX, as well as primary chest pain or any other cause of chest pain (like pericarditis). Therefore, we decided to include these patients since they reflect a real practice scenario. In fact, we have to notice that one of the “power” of lung ultrasound is that it can be made directly by the clinician assessing the patient at bed side, aware of clinical findings and clinical suspicion. Therefore, although potentially biased, these scenarios reflect a real-practice situation.

In our study, LUS was not able to detect lung abnormalities (bullae) in 4 patients with recurrent spontaneous pneumothorax. Lung bullae are rare in children and their lung pattern is not yet well

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established, although a recent study on congenital lung malformation described cystic lung lesions in neonates.[31] Therefore, in case of relapses, LUS cannot be considered accurate enough to detect predisposing lung conditions and other images (CXR or CT scan) should be obtained.

Our study has some limitations to address. The low number of children with acute chest pain evaluated by LUS is a limitation of our study; this was due to the fact that in our pED we have 3 certified LUS sonographer that performed the study. Also, as it is an observational pilot study, no formal planning of sample size and power calculation has been carried out. Potential selection biases have been previously highlighted. However, this is the only prospective study evaluating this specific question in children with acute chest pain and we missed only 2 children with PNX.

Conclusion

In conclusion, our study showed high accuracy of LUS in detecting and excluding PNX in children evaluated in the pED for acute chest pain. Further studies on a larger number of children are needed to confirm our findings in order to allow routine application of LUS for pediatric acute chest pain in the ED.

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Authors' contribution

Conception and research design: M.C. Supino, D. Buonsenso, A.M Musolino

Data collection: S. Scateni, P. Valentini, A. Chiaretti

Data analysis and interpretation and drafting the article: P.M.S. Schingo, B. Scialanga, M.C.Supino, M.A.Mesturino, E.Boccuzzi, V. Ferro

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

References

1- Cashen K, Petersen TL. Pleural Effusions and Pneumothoraces. *Pediatr Rev*. 017;38:170-181.

2- Dotson K, Johnson LH. Pediatric spontaneous pneumothorax. *Pediatr Emerg Care*. 012;28:715-20.

3- Lichtenstein DA. BLUE-protocol and FALLS-protocol: two applications of lung ultrasound in the critically ill. *Chest*. 2015;147:1659-1670.

4- Bekgoz B, Kilicaslan I, Bildik F, et al. Ultrasonography in Emergency Department patients presenting with acute dyspnea. *Am J Emerg Med*. 2019; 37:2020-2027.

5- Karagöz A, Ünlüer EE, Akçay O, et al. Effectiveness of Bedside Lung Ultrasound for Clinical Follow-Up of Primary Spontaneous Pneumothorax Patients Treated With Tube Thoracostomy. *Ultrasound Q*. 2018;34:226-232.

6- Staub LJ, Biscaro RRM, Kaszubowski E, et al. Chest ultrasonography for the emergency diagnosis of traumatic pneumothorax and haemothorax: A systematic review and meta-analysis. *Injury*. 2018;49:457-466.

7- Blaivas M, Lyon M, Duggal S. A prospective comparison of supine chest radiography and bedside ultrasound for the diagnosis of traumatic pneumothorax. *Acad Emerg Med*. 2005;12:844-9.

8- Marin JR, Lewiss RE, American Academy of Pediatrics, Committee on Pediatric Emergency Medicine, Society for Academic Emergency Medicine, Academy of Emergency Ultrasound, American College of Emergency Physicians, Pediatric Emergency Medicine Committee, World Interactive Network Focused on Critical Ultrasound. Point-of-care ultrasonography by pediatric emergency medicine physicians. *Pediatrics*. 2015;135:e1113-22.

9- Musolino AM, Tomà P, Supino MC, et al. Lung ultrasound features of children with complicated and noncomplicated community acquired pneumonia: A prospective study. *Pediatr Pulmonol*. 2019;54:1479-1486.

10- Buonsenso D, Curatola A, Valentini P, et al. Chest ultrasound findings in children with confirmed pulmonary tuberculosis in low tuberculosis incidence country. *Pediatr Pulmonol*. 2019;54:1348-1350.

11- Supino MC, Buonsenso D, Scateni S, et al. Point-of-care lung ultrasound in infants with bronchiolitis in the pediatric emergency department: a prospective study. Eur J Pediatr. 2019;178:623-632.

12- Buonsenso D, Supino MC, Giglioni E, et al. Point of care diaphragm ultrasound in infants with bronchiolitis: A prospective study. *Pediatr Pulmonol*. 2018;53:778-786.

13- Buonsenso D, Brancato F, Valentini P, et al. The Use of Lung Ultrasound to Monitor the Antibiotic Response of Community-Acquired Pneumonia in Children: A Preliminary Hypothesis. *J Ultrasound Med*. 2020;39:817-826.

14- Buonsenso D, Malamisura M, Musolino AM. Point-of-Care Ultrasound Training Programs Across Italian Pediatric Residency Schools: A National Survey. Pediatr Emerg Care. 2020 May 19.

15- Lichtenstein D, Mezière G, Biderman P, et al. The lung point: an ultrasound sign specifc to pneumothorax. *Intensive Care Med*. 2000;26:1434–1440.

16- Volpicelli G, Elbarbary M, Blaivas M, et al. International evidence-based recommendations for point-of-care lung ultrasound. Intensive Care Med. 2012; 38:577-91.

17- Chen L, Zhang Z. Bedside ultrasonography for diagnosis of pneumothorax. Quant Imaging Med Surg. 2015; 5:618-23.

18- Mayo PH, Copetti R, Feller-Kopman D, et al. Thoracic ultrasonography: a narrative review. *Intensive Care Med*. 2019;45:1200-1211.

19- Volpicelli G, Boero E, Sverzellati N, et al. Semi-quantifcation of pneumothorax volume by lung ultrasound. Intensive Care Med 2014;40:1460–1467.

20- Alrajab S, Youssef AM, Akkus NI, Caldita G. Pleural ultrasonography versus chest radiography for the diagnosis of pneumothorax: review of the literature and meta-analysis. *Crit Care*. 2017;17:R208.

21- Piette E, Daoust R, Denault A. Basic concepts in the use of thoracic and lung ultrasound (Review). *Curr Opin Anesthesiol*. 2013;26:20–30.

22- Zhongheng Z, Chen L. A physiological sign that mimics lung point in critical care ultrasonography (Letter). *Crit Care*. 2015;19:155.

23- Steenvoorden TS, Hilderink B, Elbers PWG, et al. Lung point in the absence of pneumothorax. *Intensive Care Med*. 2018; s00134-018-5112-1.

24- Santos-Silva J, Lichtenstein D, Tuinman PR, et al. The lung point, still a sign specific to pneumothorax. *Intensive Care Med*. 2019;45:1327-1328.

25- Moreno Aguilar G, Lichtenstein D. Lung ultrasound in the critically ill (LUCI) and the lung point: a sign specifc to pneumothorax which cannot be mimicked. *Crit Care*. 2015;19:311.

26- Vasquez DG, Berg GM, Srour SG, et al. Lung ultrasound for detecting pneumothorax in injured children: preliminary experience at a community-based Level II pediatric trauma center. *Pediatr Radiol*. 2020;50:329-337.

27- Avila J, Smith B, Mead T, et al. Does the addition of M-mode to B-mode ultrasound increase the accuracy of identification of lung sliding in traumatic pneumothoraces? *J Ultrasound Med*. 2018;37:2681–2687.

28- Lichtenstein DA, Menu Y. A bedside ultrasound sign ruling out pneumothorax in the critically ill: lung sliding. *Chest*. 1995;108:1345–1348.

29- Majerus CR1, Tredway TL, Yun NK, et al. Utility of Chest Radiographs in Children Presenting to a Pediatric Emergency Department With Acute Asthma Exacerbation and Chest Pain. *Pediatr Emerg Care*. 2018;25.

30- Neff J, Anderson M, Stephenson T, et al. REDUCE-PCP study: radiographs in the emergency department utilization criteria evaluation-pediatric chest pain. *Pediatr Emerg Care*. 2012;28:451-4.

31- Merli L, Nanni L, Curatola A, et al. Congenital lung malformations: a novel application for lung ultrasound? *J Ultrasound*. 2019;5.

Figure legend

Fig1 “barcode sign” seen in M-mode

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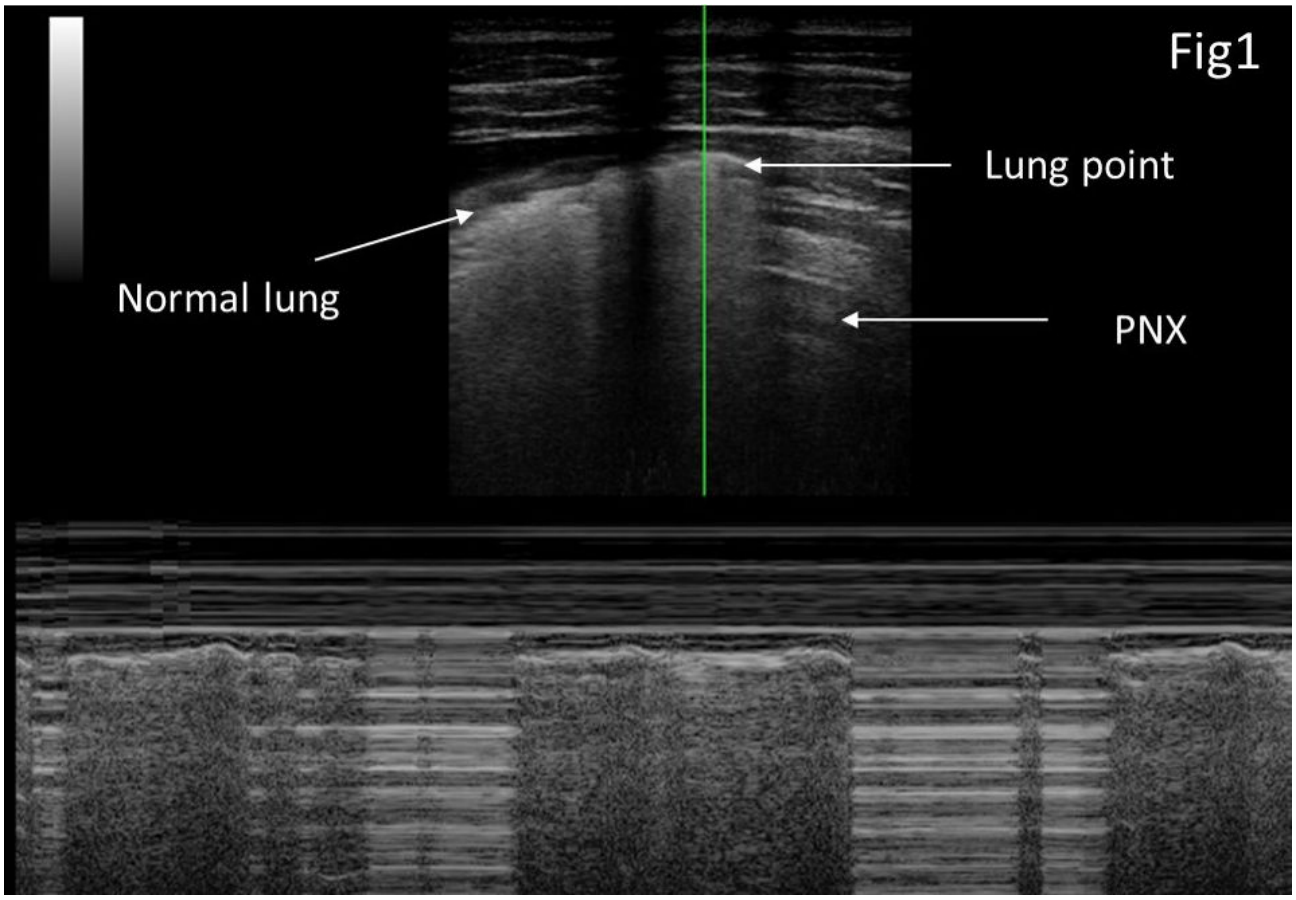

Fig2 STARD diagram of flow of participants through the study