

Syringe plunger aspiration technique (SPAT): a simple bedside and field technique for assessing pneumothorax

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ABSTRACT

Background: A simple technique for diagnosing pneumothorax caused by disease or trauma using the syringe plunger aspiration technique (SPAT) is discussed. It's simple, reproducible and can be helpful where radiographs are not readily available or inconclusive radiographic findings, in patients living at remote places and during mass casualty. Therapeutic needle aspiration is an established strategy for diagnosing pleural fluid collection but its place as a diagnostic tool for pneumothorax is unclear. SPAT minimizes any potential iatrogenic pneumothorax that may occur with a wide bore needle hence the use of size 21G needle and is a favorable screening test.

Objectives: The objective is to provide an easy, reliable appendage for assessing pneumothorax, determining its sensitivity / specificity, and to compare the efficacy of SPAT with other methods

Methodology: This study investigates pneumothorax diagnosis from 2010 to 2012 using 5mls syringe and needle (21G × 1¹/₂”). The study method is a primary intervention one, where a 5mls syringe and hypodermal needle (21G) were inserted at the 4th or 5th intercostal space between the anterior axillary line and midaxillary line under aseptic technique and the plunger drawn, in patients with suspicion of pneumothorax. The presence of aspirated air in the syringe from pneumothorax retains the plunger in place, preventing its retraction back.

Result: A total of 21 patients were reviewed. Syringe plunger aspiration technique's (SPAT) was carried out in all cases with sensitivity of 1, specificity of 0.66, positive predictive value (PPV) of 0.94, negative predictive value (NPV) of 1, and accuracy 0.95. The graduation on the syringe using SPAT was accurate in estimating massive pneumothorax in 4 patients as complete lung collapse by radiograph tally fully with plunger displacement exceeding the 5mls mark.

Conclusion: Our SPAT sensitivity of 100% makes it important as a screening test of pneumothorax where a missed diagnosis can have a grim consequences.

KEYWORDS: Pneumothorax; technique; diagnosis; syringe; aspiration

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Introduction

Pneumothorax is the collection of air in the pleural space.¹ High index of suspicion with prompt intervention can halt progression. Chest radiograph may assist confirmation of pneumothorax when radiolucency with absent lung markings exist, but a number of conditions can increase lucency in radiographs such as abdominal contents within the chest and abnormality of the lung itself². Therapeutic needle aspiration is established (urgent thoracentesis for suspected blood or pus requiring immediate chest tube drainage)³ but gross



paucity exist in assessing needle aspiration as a diagnostic tool for pneumothorax. The objectives of this study are to provide an easy, reliable appendage for assessing pneumothorax with its usefulness in remote location or mass casualty; and to compare the efficacy of SPAT while determining its sensitivity and specificity in the pleural space air collection. Our syringe plunger aspiration technique's (SPAT) ability to detect pneumothorax is a measure of its sensitivity⁴. The fear of iatrogenic pneumothorax or needle injury is minimized. SPAT is a foremost study that can diagnose pneumothorax.

Materials and Methods

Materials include: a pair of surgical gloves, antiseptic, cotton wool with a 5mls syringe and a 21G hypodermal needle.

Method

This is a retrospective study that investigates the diagnosis of suspected air in the pleural space from patients assessed for penetrating chest injuries, blunt chest trauma that are symptomatic and non-trauma chest disease that warranted a form of chest aspiration from 2010 to 2012. Relevant clinical and investigative data were retrieved and analysed from the institution and an outreach in a regional district area. The patients were examined fully. The readily available 5mls syringe and hypodermal needles (21G) were used. After clinical examination and adherence to aseptic technique, the needle was inserted at the 4th or 5th intercostal space between the anterior axillary line and mid-axillary line (Fig.1). Most of our patients were on analgesics for their injuries including parenteral routes for all trauma cases. The

syringe plunger is drawn (Fig.2) and the presence of air (from pneumothorax) in the syringe retains the plunger in place preventing it from snapping or retracting back after initial aspiration of the pleural space (Figs.3&4). This is contrary to situations where empty or normal pleural spaces are aspirated, in which case the plunger retracts speedily when released by the investigator making a 'snap' sound. However, for pneumohaemothorax, the syringe plunger retracts to the level of blood in the syringe, apparently displacing the air back to the pleural space.

SPAT is termed positive when air is retained in the plunger and the level of air in the syringe of pneumothorax may correlate with the volume of pleural air collection as an indicator.

Inclusion criteria include all penetrating chest injuries with symptoms, all blunt trauma to the chest with symptoms or sign and non-trauma chest disease with clinical suspicion of pneumothorax. Blunt chest traumas with no symptoms or sign of chest injury were excluded from the study.

Ethical clearance was received from the University of Maiduguri Teaching Hospital (UMTH), and informed consents were obtained from the patients while procedures were carried out in accordance with the Helsinki declaration⁵.

Statistical Analysis

Determination of predictive values of the diagnostic test, sensitivity and specificity was done using the 2 × 2 table method.

Result

A total of 21 patients were reviewed (19 males and 2 females) with 19 trauma cases and 2



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non-trauma patients who had pulmonary disease. Age ranges from 16 - 55 years with mean of 29.6 years. Fourteen (14) patients had penetrating chest injury (10 from gunshot

wounds and 4 from assault with a dagger) and 5 patients had blunt chest trauma secondary to Road Traffic Accident (RTA).

TABLE 1: Sex distribution, mechanism of injury and management modalities

	Total M + F	Penetrating chest injury [Males =14][Females=0]		Blunt chest injury [M a l e s = 3] [Females=2]		Chest Disease[Male=1] [Females=0]	
		Male(M)	Female(F)	Male(M)	Female(F)	Male(M)	Female(F)
Managed with chest tube	17	12	0	3	1	1	0
Managed conservatively	4	2	0	0	1	1	0
Total	21	14	0	3	2	2	0

Table 2: 2 × 2 table method of predictive values of the SPAT diagnostic test, sensitivity and specificity

Pnenmothorax				
SPAT	Present	Absent	Total	Predictive Values
Positive	18 [A]	1[B]	19	PPV = 18/19=0.95
Negative	0 [C]	2 [D]	2	NPV = 2/2=1
Total	18	3	21	
Sensitivity = [A] / [A] + [C] = 18/18 = 1		Specificity = [D] / [B] + [D] = 2/3 = 0.66		Accuracy = [A] + [D] / total sample = 18+2/21 = 20/21 = 0.95

A=True positive; B=False positive; C=False negative and D=True negative.
Sensitivity =1 specificity=0.66, PPV=0.94, NPV=1, accuracy 0.95



Two were non-trauma chest disease; one had a pneumothorax with associated infective endocarditis from poorly treated pneumonia and the other patient had Koch's disease.

SPAT was carried out in all cases with sensitivity of 1, specificity of 0.66, PPV of 0.94, NPV of 1, and accuracy 0.95. The graduation on the syringe using the syringe plunger aspiration technique was accurate in estimating massive pneumothorax as those patients with complete lung collapse, also confirmed by chest radiograph, showed full plunger displacement exceeding the 5mls mark and this finding was uncommon in other patients that did not show evidence of complete lung collapse.

Fifteen (15) patients had their SPAT done while awaiting retrieval of the Chest X-Rays and the findings correlated. The chances of any possibility for iatrogenic cause of pneumothorax occurring from intervention using SPAT may be more arguable should the Chest X-Ray be taken after, compared against being taken before, which gives a form of blinding. About 17 of the studied patients were managed with chest tube (as under water seal air bubbling further validates pneumothorax) and 3 had no x-rays, while one patient had tension pneumothorax. A patient that showed little air in SPAT around 0.4mls gauge marking, but was not demonstrable by chest radiograph accounted for the only false positive.

Discussion

Examination of patients with thoracic trauma can be difficult owing to the presence of multiple injuries in a majority of cases with chances of missed pneumothorax or haemothorax on initial assessment.² A pneumothorax develops when there is laceration of either the visceral or mediastinal pleura leading to air collection in the pleural space¹. Regardless of the cause, the aim of treatment which is elimination of collected pleural air remains the same for which needle

aspiration provide a simple and easy alternative on therapeutic basis⁶. Paucity of English scientific literature on a diagnostic needle aspiration for assessing pneumothorax exist which our study investigate, leaving a constraint for comparing results with specific relevant studies, but rather with other pneumothorax diagnostic assessing modalities like the thoracic ultrasound, chest X-rays or CT scan. About 173,000 thoracentesis is estimated to be performed by physicians in the USA, annually and an extensive meta-analysis study related to 6,605 thoracentesis with 346 pneumothorax with the former occurring first and causing the later;⁷ which differs with our study that investigate the latter (pneumothorax) coming first and being assessed/diagnosed by the former (thoracentesis) using SPAT. It is essential for pneumothorax to be detected in any trauma patient regardless of its size. This study using SPAT showed a sensitivity of 1, however, calculation does not take account of indeterminate test result, if the test cannot be repeated as was noticed in a case (a first aspiration was negative but a repeat was positive).⁴ A loculation, bullae, Iatrogenic needle injury or indeterminate test could account for a false positive. This may have accounted for PPV of 0.95 which measures how accurately a positive test can predict a positive pathology.^[4] However, Iatrogenic needle injury or pneumothorax is minimized by avoiding SPAT through the anterior chest wall as we shun at lengthy needle with a wide bore and eliminate multiple passes with the needle. In the first systematic review and meta-analysis of pneumothorax rate following thoracentesis in 2010, the risk of pneumothorax was increased when larger needle or catheter were used compared with smaller ones.⁷ There is a male preponderance in our study and specificity of 0.66 shows its ability to exclude the disease, showing a 0.44 (44%) chance that a positive outcome may actually be pneumothorax free, but its accuracy in diagnosing both positive and



negative cases is 0.95. Clinical suspicion of pneumothorax does not warrant outright therapeutic response without confirmation by thoracic ultrasound, chest X-rays or CT scan except in tension pneumothorax. Our technique is novel to pneumothorax diagnosis and having correlated with the chest X-ray findings, it influenced our decision making on some of the patients, especially the 3 that had no chest X-rays and we do believe that, in time, it can be a substitute for confirmation. "The value of sensitivity and specificity cannot be used alone to determine a diagnostic test in a specific patient; they are combined with clinical index of suspicion that the patient has the disease too."⁸ A patient with trauma and two non-trauma cases responded to our technique and may fall under the category of lower degree of clinical suspicion. Besides "the optimal design in assessing the accuracy of a diagnostic test A relevant clinical population that is a group of patients covering the spectrum of disease that is likely to be encountered in the current or future test."⁹

Since work on such diagnostic pneumothorax is far overshadowed with therapeutic needle thoracentesis, nonetheless lessons can be learned. Procedure related risk reveals a pneumothorax related rate were higher in therapeutic thoracentesis (8.4%) than diagnostic thoracentesis (5.2%).⁷ Our findings did not reveal a procedural complication other than mild pains. Sharma and Jinda¹ reported that the depth and size (smaller) of the lesion are the leading cause of iatrogenic pneumothorax. We use a normal 5mls syringe and needle (21G) with a length of 5.5cm from needle hub which is the fitting at the end of the needle that connects to the syringe (3.7 cm free length excluding the hub) as we refrain from use of long cannula needle that could pierce deeply. Another safeguard employed in our technique is excluding the anterior chest wall approach for diagnostic thoracentesis except

for a case of therapeutic thoracentesis for tension pneumothorax that was managed. Despite the use of mid-clavicular line recommendations by international guidelines, other sites do exist, but no compelling particular data supports any site and for most of the emergent use of needle thoracostomy in tension pneumothorax, there is no randomized controlled trial that looks at therapeutic needle thoracostomy, while best evidence relies on expert opinion, case reports and case series.¹⁰ The later reported some incidents with 3 vascular complications occurring within 6 months by Rawlins et al,¹¹ with 2 requiring surgery, and perforation of the subclavian artery from misidentification of the second intercostal space mid-clavicular line (2ICS MCL) with the patient also requiring surgery as reported by Riwoe et al,¹² more reports are growing. Again misidentification of the 2ICS MCL is not uncommon, it was demonstrated in 40% of emergency physician subjects, whom 84% (n=21) were Advanced Trauma Life Support (ATLS) certified and 95% points to the medial aspect of the midclavicular line in a normal elective volunteer.¹³ These calls for worries during emergencies! The medial relation of the 2ICS MCL is the internal mammary artery and mediastinal structures while subcostal neurovascular bundle and subclavian vessels are related from above.¹³ The British Thoracic Society (BTS) guideline¹⁴ and the ATLS,¹⁵ both do recommend the lateral approach using the 4th and 5th intercostal space, as well. Our study followed this recommendation. Other studies are now proposing a mid-hemithorax line that is more lateral, rather than the midclavicular line by Riwoe et al,^{12,14} and patients with thick chest wall may have their choice of needle length adjusted.¹⁴

A male subject with non trauma related pneumothorax in this study was being managed for pulmonary tuberculosis. An evaluation of the lateral chest wall thickness in patients with pulmonary tuberculosis, shows a



mean value of soft tissue thickness in normal healthy Sub-Saharan Africans at 19.25 ± 2.54 mm^[16] and this falls in the confines of our needle choice and adds to our lateral chest wall preference, hence the high sensitivity.

The patient with tension pneumothorax first had SPAT through the lateral chest wall approach, only then, a needle decompression through the 2nd intercostal space, mid clavicular line followed as a transient therapeutic thoracentesis. Zehtabchi S and Rios C.L.¹⁷ demonstrated the use of 16G over the needle catheter in the anterior chest wall with a stopcock and a 60mls syringe but only for a therapeutic approach. Studies also shows that needle passes that are two or more has a higher risk (6.6%) than 1 passes (3.5%).⁷ We experienced a case that had two passes in our subjects. Adoption of a procedure, innovation or technology, is influenced among others, by the learning curve and compatible trend.¹⁸ Needle thoracentesis is so simple that its learning curve is even simpler than its description, while its universal use for pleural fluid assessment makes easy compatibility for translation to diagnostic pneumothorax, that may lead to indiscriminate use as most of the procedures are done by juniors and besides, even for the therapeutic use; “ the number of needle decompressions far exceeds the incidence of tension pneumothorax and should be limited.”¹⁵ Drawing analogy for relatively unknown events, Wernick¹⁰, stated that “Relatively more is known about complications of tube thoracostomy for management of pneumothorax. Some of which may be translatable to needle thoracostomy management.” Iatrogenic pneumothorax is our main concern about our technique's risk, the other being empyema and hence, the comparative analysis with the experience in pleural fluid aspiration.

We avoid the bulky muscles of the anterior axillary line and the mid-axillary line for the course of the long thoracic nerve lying just

behind it, by using the mid of the two landmarks. Again, we are mindful of associated injuries such as rib fracture that existed in some patients and needle depth into the pleura may be restricted in obese patients or with subcutaneous haematoma.

Imaging technique is usually used to confirm diagnosis of pneumothorax but clinical evaluation should be the determinant for assisting initial diagnosis and subsequent management modalities.^[19] Adoption of widespread digital imaging should be taken with caution as small pneumothorax may not be apparent immediately.¹⁹ Wilkerson and stone,²⁰ reported an evidence based review of 4 prospective studies involving 606 subjects, revealing sensitivity of 86% to 98% of detecting pneumothorax using ultrasound scan(USS) after blunt chest trauma while specificity was 97% to 100%.The studies also showed specificity of 100% in all, for cases using supine AP chest radiograph for detecting pneumothorax, the sensitivity were 28% to 75%.²⁰Our SPAT sensitivity of 100% compare favourably to the USS with upper limit of 98%, however SPAT specificity of 66% falls comparably to those of supine AP chest radiograph. Patient that are critically ill in the intensive care unit find AP chest radiograph a favourable appendage, but its sensitivity in detecting pneumothorax is very poor as low as 36% to 48%.²⁰

Chest radiograph is a ready tool for confirmation of air in the pleural space after clinical evaluation though CT scan is superior¹ (but expensive with less accessibility and availability, especially in Africa) and may not be readily available at the scene of accidents or in remote rural setting, while at times radiological confirmation may be obscured by chest wall contusion or subcutaneous haematoma and in patients that are critically ill or unconscious to warrant erect chest films.^{1,2} Again a number of conditions can increase lucency in radiographs other than pneumothorax such



as emphysematous bullae or diaphragmatic hernia.²

Most signs that indicate pneumothorax are not reliable, with ideal erect PA expiratory chest film not realistic to obtain in a critically ill patient and are not recommended for routine diagnosis of pneumothorax, while clinical examination cannot be reliable on pneumothorax size.^{2,21} Other areas where early chest X-ray shows limitations includes exclusion of post-procedural pneumothorax unless high suspicion or clinical complication is glaring.²² An expiratory chest X-ray and lateral decubitus films are sensitive in picking small pneumothorax with the former, owing to compressing the lungs thereby increasing its density.²³ Winter and Smethurst²⁴ reported a new way of simultaneous sternal percussion with chest auscultation to detect pneumothorax in their 1999 case series which helped in two of three patients that had inconclusive chest radiographs. We are of the view that the sensitivity and specificity obtained using SPAT can be a favourable validity test in the screening of pneumothorax for many situations. We acknowledge our sample size is not large and having more of those who don't have a pneumothorax (funding may have facilitated more control group) may influence the specificity accuracy. However, the sensitivity accuracy is reproducible, has validity and is important in screening pneumothorax while poor specificity may "matter less if over-treatment rarely results in adverse effect but may be a serious disadvantage if treatment is highly toxic"²⁵ - which also influences the negative predictive value. High sensitivity is important for a screening test where a missed diagnosis has serious consequences.²⁵ A prospective controlled blind comparison of the test under study and the reference test in a

consecutive series of relevant clinical population is the optimal design for assessing the accuracy of a diagnostic test, but the largest effect of over estimation of diagnostic accuracy was found in case-control studies in which a group with the disease is compared to normal patients that were not part of a relevant control clinical population.^{9,26} Again, only a moderate level rise in post probability level is seen in very low disease prevalence (i.e 1 in 1000). Incidence of primary spontaneous pneumothorax (psp) is 18 in 100,000 in males, 6 /100,000 in females,²⁷ despite a very high sensitivity and specificity,⁸ therefore; a very specific test follows a very positive sensitivity test. In our study, the chest X ray test follows our SPAT technique in the absence of a thoracic ultrasound scan that can be considered a gold standard in the hand of an expert thoracic radiologist. Limitation of this study could be the presence of occult pneumothorax, relatively small sample size, slight comparative group though only two patients were nontrauma cases and further work could increase the reliability of our findings.

Conclusion

Our technique makes emphasis on diagnostic needle thoracentesis and was able to achieve good accuracy in confirmation of pneumothorax with only minor pains exhibited in about 4 patients. This can be a handy tool at the scene of accidents or in remote rural setting. Also at times where radiological confirmation may be inconclusive, obscured by chest wall contusion or subcutaneous haematoma and in patients that are critically ill to warrant erect chest films. We hope SPAT will eventually offer an alternative diagnostic tool for pneumothorax.





Fig. 1: Needle is inserted at the 4th or 5th intercostals space



Fig.2 : The syringe plunger is drawn



Fig. 3: Air retains the plunger (excess of 5mls gauge)



Fig.4: Syringe plunger filled from pneumothorax

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