Occult Pneumothorax in Trauma Patients: Development of an Objective Scoring System

Marc A. de Moya, MD, Christopher Seaver, MD, Konstantinos Spaniolas, MD, Kenji Inaba, MD, Michael Nguyen, BS, MS, PsyD, Yevgeniy Veltman, BA, David Shatz, MD, Hasan B. Alam, MD, and Louis Pizano, MD

Background: The incidence of occult pneumothorax (OPTX) has dramatically increased since the widespread use of computed tomography (CT) scanning. The OPTX is defined as a pneumothorax not identified on plain chest X-ray but detected by CT scan. The overall reported incidence is about 5% to 8% of all trauma patients. We conducted a 5-year review of our OPTX incidence and asked if an objective score could be developed to better quantify the OPTX. This in turn may guide the practitioner with the decision to observe these patients.

Methods: This is a retrospective review of all trauma patients in a Level I university trauma center during a 5-year period. The patients were identified by a query of all pneumothoraces in our trauma registry. Those X-ray results were then reviewed to identify those who had OPTX. After developing an OPTX score on a small number, we retrospectively scored 50 of the OPTXs by taking the largest perpendicular distance in millimeters from the chest wall of the largest air pocket. We then added 10 or 20 to this if the OPTX was either anterior/posterior or lateral, respectively.

Results: A total of 21,193 trauma patients were evaluated and 1,295 patients with pneumothoraces (6.1%) were identified. Of the 1,295 patients with pneumothoraces, 379 (29.5%) OPTXs were identified. The overall incidence of OPTX was 1.8%: 95.7% occurred after blunt trauma, 222 (59%) of the OPTX patients had chest tubes and of the remaining 157 without chest tubes, 27 (17%) were on positive pressure ventilation. Of the 50 studies selected for scoring, the average score was 28.5. The average score for those with chest tubes was 34. The average score for those without chest tubes was 21. The positive predictive value for need of chest tube if the score was >30 was 78% and the negative predictive value if the score was <20 was 70%. Area under the receiver operator characteristic curve was 0.72, which was significant with $p < 0.007$.

Conclusions: The OPTX score could quantify the size of the OPTX allowing the practitioner to better define a "small" pneumothorax. The management of OPTX is not standardized and further study using a more objective classification may assist the surgeon's decision-making. The application of a scoring system may also decrease unnecessary insertion of chest tubes for small OPTXs and is currently being prospectively validated.

Key Words: Pneumothorax, Occult pneumothorax, Trauma, Pneumothorax scoring.

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Since the advent of computed tomography (CT) scanning, the discoveries of abnormalities not initially seen on plain radiographs have dramatically changed the way medicine is practiced today.[1] With this new technology, we now are able to detect small but potentially significant abnormalities. We use CT scanning as a standard of care in many of our blunt and some of our penetrating trauma cases. Naturally, as we increase the use of the CT scan more abnormalities are identified, leaving us with the question of how to treat them.

The occult pneumothorax (OPTX) is defined as a pneumothorax not identified on plain radiograph but rather on follow-up CT scan (Fig. 1A and B).[1] A pneumothorax on CT scan is defined by lucency within the pleural space, usually at the anterior lung base or along the mediastinal pleura, associated with a definite separation of visceral and parietal pleura.[2] If we rely on plain radiography during the screening chest X-ray we miss many of these pneumothoraces. CT scan detects approximately 50% of all traumatic pneumothoraces.[3] Many of the false negatives of plain radiographs are a result of the disadvantaged supine position of the trauma patient with spinal precautions.[2] Cadaveric studies demonstrate that approximately 400 mL of air needs to occupy the pleural space to repeatedly make the diagnosis of pneumothorax with a supine chest radiograph.[4] Trupka described 103 severely injured patients with blunt chest trauma. Of these, 67 had major chest injuries that were missed on the initial chest X-ray. Of these 67, 27 had pneumothoraces and 21 had hemopneumothoraces.[4] OPTXs have been reported to be incidentally found on CT scans in approximately 5% of all trauma patients.[5]

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From the Department of Surgery, University of Miami/Ryder Trauma Center (M.A.d.M., C.S., K.I., M.N., Y.V., D.S., L.P.), Miami, FL; the Division of Trauma, Emergency Surgery, Surgical Critical Care (M.A.d.M., K.S.,, H.B.A.), Massachusetts General Hospital, Boston, MA; and the Division of Trauma (K.I.), University Southern California/Los Angeles County Hospital, Los Angeles, CA.

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Address for reprints: Marc de Moya, MD, 165 Cambridge Street, Suite 810, Boston, Massachusetts 02114; email: mdemoya@partners.org.

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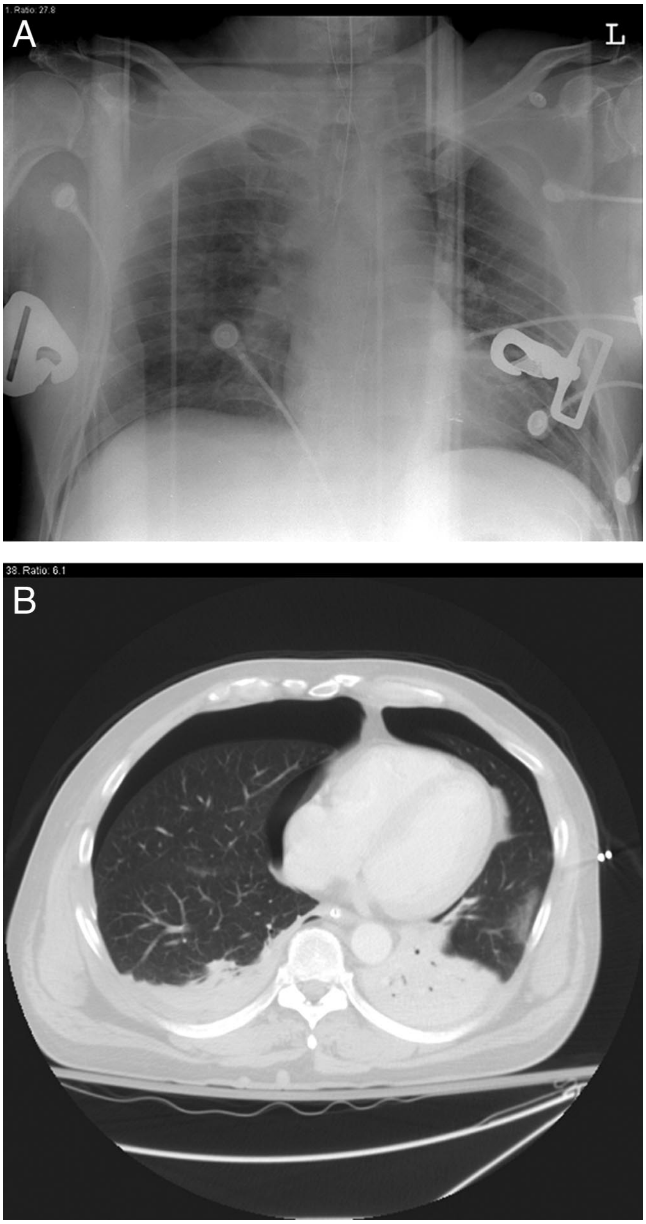

Fig. 1. *(*A*) Supine Anteriopposterior chest X-ray without evidence of pneumothorax. (*B*) Chest CT scan of same patient with bilateral occult pneumothoraces.*

Once the diagnosis of OPTX is made the treatment is not clear and not completely supported by current literature, particularly in the face of positive pressure ventilation. Do all of these OPTX patients need chest tubes? If not, which patients need a chest tube and which do not? Clearly a variable number of these OPTX patients go on to require chest tubes because of cardiopulmonary compromise. However, this number is unclear and unfortunately there are no studies that use purely physiologic parameters for chest tube placement in the face of an OPTX. Given the fact that placement of chest tubes are not benign and have a reported complication rate of 21%,[5] the purpose of this study was to develop a scoring system to potentially guide chest tube placement. It is anticipated that this guide may decrease the number of unnecessarily placed chest tubes in OPTX patients.

The hypothesis of this study is that an OPTX score may objectively quantify the size of the OPTX. There are no objective measures to define "small", so our secondary hypothesis was that a simple objective scoring system could be used to determine a small OPTX. This is an effort to identify those OPTX cases that may not require chest tube placement.

PATIENTS AND METHODS

This is a retrospective review of all trauma patients in a Level I university trauma center during a period of 5 years. We queried the trauma registry of this trauma population to identify those patients with a pneumothorax by International Classification of Diseases, 9th revision (ICD-9) codes (512.0, 512.1, 512.8). The records of those with pneumothoraces were then reviewed to identify those with OPTX. Each patient with a coded pneumothorax was then individually reviewed. Initially, the chest CT scan reading was reviewed and if a pneumothorax was identified the patients then had their initial chest X-ray (CXR) reading reviewed. Those patients with OPTX detected by cervical spine or abdominal CT scans were not included in the cohort. However, none of the patients identified in this fashion had pneumothorax diagnosed by cervical spine or abdominal CT scans. If the CXR showed evidence of a pneumothorax, the case was labeled as an overt pneumothorax. Those without any evidence of pneumothorax on the initial CXR reading were identified as having an OPTX. The initial CXR preceded the chest CT scan. All OPTXs in this series had full chest CT scans, allowing full characterization of the OPTX. All scans were performed on a four-channel multi-detector scanner (Phillips MX 8000, Bothell, WA). The trauma registry identified the demographics of each patient. The side of the pneumothorax, positive pressure ventilation, insertion of chest tube, and score were recorded.

In an effort to develop a scoring system we devised several systems and applied them retrospectively to an initial 10 cases then to a separate 50 cases. Using this model we developed the current system and analyzed it in regard to the 50 selected study patients. The data were analyzed using receiver operator characteristic (ROC) curves created to analyze the OPTX score.

Occult Pneumothorax Score

In an effort to have some objective way of measuring the "small" pneumothorax, a score was developed. The intent of the score was also to weigh the measurements to better predict the need for chest tube drainage. The development of a simple and widely applicable system was needed. The first attempt at a scoring system was made by Garramone[5] and included counting the number of axial images to calculate one dimension and measuring the distance from the chest wall for

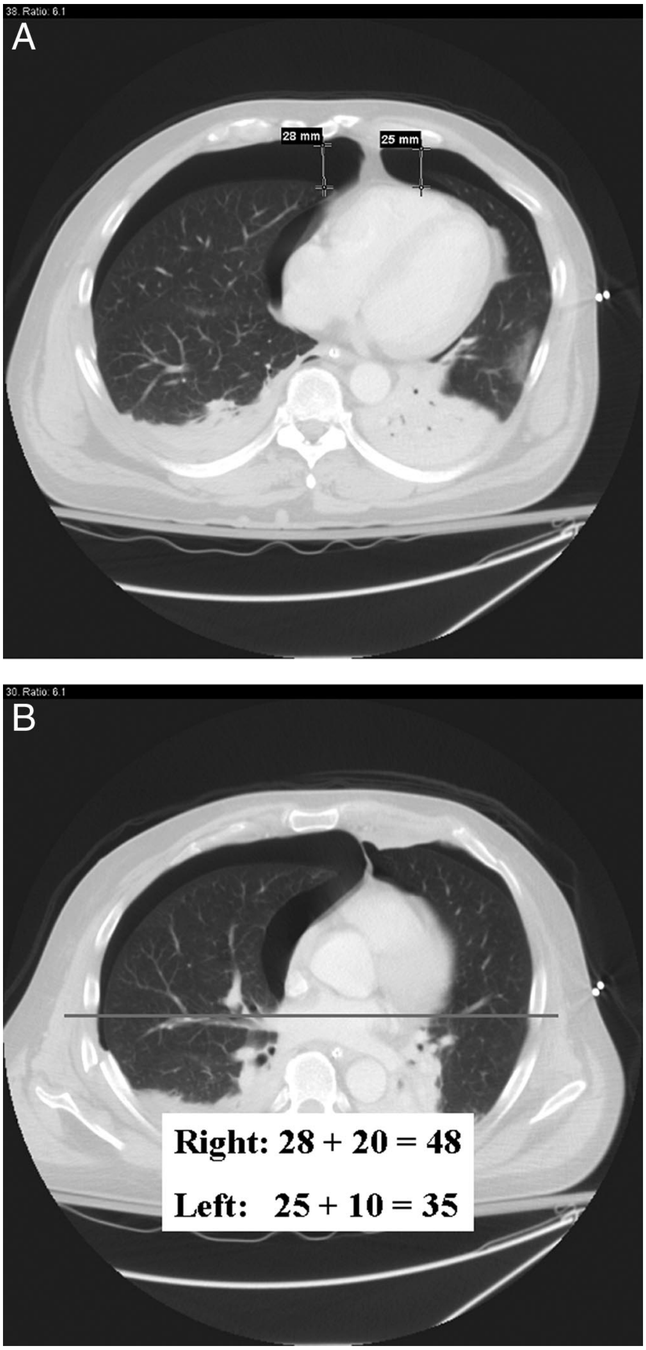

Fig. 2. *(A) Largest dimension (mm) of the largest air collection along a line perpendicular to the chest wall or mediastinum. (B) Pulmonary hilum is then identified and it is determined whether the pneumothorax crosses the transhilar axial plane (red line). The right-sided OPTX demonstrates a pneumothorax crossing this line, however, the left side does not cross the line. If the OPTX does not cross this plane, 10 is added to the dimension. If the OPTX does in fact cross this plane, 20 is added to the largest dimension measured. The summation of the two numbers is the final score.*

another dimension. However, we found it cumbersome to count the axial images and also noticed that there was some variability in the imaging protocol, which changed during the study period from 5 mm to 3 mm. The measurement of the air pocket in millimeters was not characterized well enough to encompass the convolutions of air that form inside the chest. We tested a few strategies on 10 CT scans and came up with the most predictable system.

The OPTX score is composed of two parts: (1) the largest diameter of the air pocket and (2) its relationship to the pulmonary hilum. The largest dimension of the largest air collection along a line perpendicular to the chest wall or mediastinum in millimeters (Fig. 2A) is the first step. The pulmonary hilum is then identified and it is determined whether the pneumothorax crosses the transhilar axial plane (Fig. 2B). If the OPTX does not cross this plane, 10 is added to the millimeters. If the OPTX does in fact cross this plane, 20 is added to the largest dimension measured. The summation of the two numbers is the final score (Fig. 2B).

RESULTS

A total of 21,193 trauma patients were evaluated with 1,295 patients demonstrating pneumothoraces (6.1%). Of the 1,295 patients with pneumothoraces, 379 OPTX were identified (29.5%). The overall incidence of OPTX was 1.8%. The average injury severity score (ISS) was 23 and average base excess was -3.2. There were 269 (71%) men and the average age was 38. A total of 95.7% occurred after blunt trauma. (Table 1). A total of 222 (59%) of the OPTX cases had chest tubes and of the remaining 157 without chest tubes, 27 (17%) were on positive pressure ventilation. (Fig. 3). Of the 50 selected cases, the average score was 28.5 overall. These 50 cases were selected consecutively from the last year reviewed to facilitate ease of review via the new PACS (picture archiving and communication system). The average score for those with chest tubes was 34. The average score for those without chest tubes was 21. The positive predictive value for need of a chest tube if the score was >30 was 78% and the negative predictive value if the score was <20 was 70%(Table 2 and Fig. 4). The area under the ROC curve was 0.72, which was significant with $p < 0.007$.

DISCUSSION

In a recently published study, the chest radiograph was found to miss more than half of all pneumothoraces when studied closely.[3,6] They discovered that the position of the pneumothorax was directly related to the ability to visualize the pneumothorax on a chest radiograph. In our retrospective study, we identified 379 OPTXs, of which 59% had chest tube insertion, and of the remaining OPTX cases without chest tubes, 17% were on positive pressure ventilation. This was consistent with previously published data.[7] It became apparent that despite having what some may consider to be very small OPTXs, chest tubes were still placed. Interest-

Table 1 Demographics

Total number of patients	21,193
Men	269 (71%)
Age (mean)	38 yr
Blunt mechanism	95.7%
ISS (mean)	23
Base Excess (mean)	−3.2

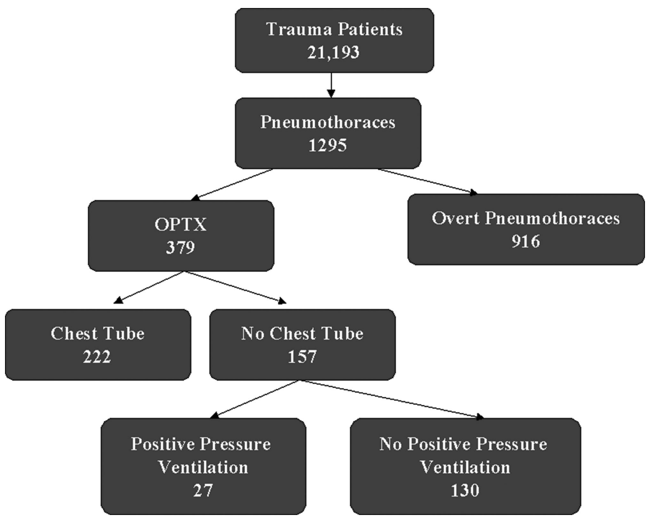

Fig. 3. *Consort diagram.*

Table 2 Predictive Values

Positive predictive value for score >30	78%
Negative predictive value for score <20	70%
Sensitivity	74%

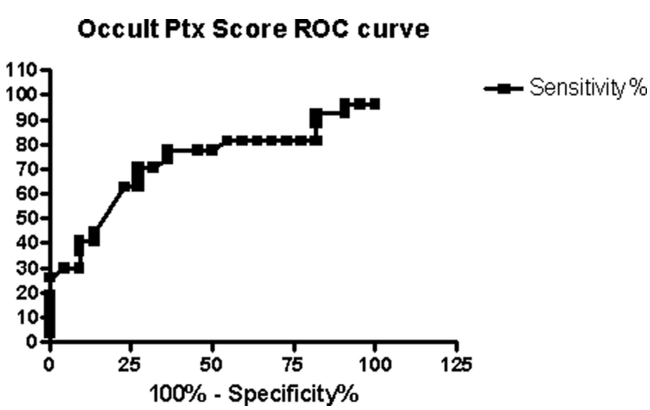

Fig. 4. *ROC curve for the OPTX score: area under the curve = 0.72,* $p < 0.007$.

ingly, in the selected group of 50 scored patients, six had chest tubes placed despite a score less than 20 and four of six (66%) of them were on positive pressure ventilation with no increase in size before placement. Unfortunately, it is difficult to gain an appreciation for why the chest tubes were placed in these patients. However, one may conjecture that it was because of the general discomfort of the staff involved watching a patient with a traumatic pneumothorax.

There have been small studies that show that the observation of OPTXs in those with positive pressure ventilation is a viable option.[8] Enderson and others performed the first randomized prospective trial of tube thoracostomy in patients with occult pneumothorax.[9] They randomly assigned their cohort of OPTX patients to either receive a chest tube (n = 19) or undergo observation (n = 21). They concluded that patients with OPTX on positive pressure ventilation should have a tube thoracostomy placed. However, they did not qualify those OPTXs and the sample size of those randomized to receive chest tubes was small. A second randomized prospective trial, conducted by Brasel et al., randomized patients to either receive a chest tube (n = 18) or undergo observation (n = 21). They conclude that observation of an OPTX is not associated with complications. They go on to conclude that it is safe to observe OPTXs despite positive pressure ventilation.[8]

There have been other models used in a retrospective fashion. Garramone and others[10] published the first study investigating the use of an objective measure to quantify the OPTX in an effort to guide therapy. They looked at 31 OPTXs in 26 patients and found that the size of the pneumothorax correlated with the need for a chest tube. The clinical implications, as in our study, were limited given the lack of clinical parameters for placement of chest tubes. In Garramone's study, CT scans were also limited to abdominal scans and therefore, did not necessarily represent the entire pneumothorax. Nevertheless, they also suggested that the use of positive pressure ventilation did not have a major impact on the small number of patients in their study. In addition, the longitudinal dimension and number of axial CT images did not necessarily correlate with chest tube placement.[10] We also found that longitudinal measurements were difficult and took more time.

Collins followed this study up with an observational study to look at how many patients required chest tube placement and concluded with a sample size of 24 that you could potentially observe those with OPTX.[1] Wolfman et al. also described a classification system for OPTXs. The authors classified OPTXs into three categories: minuscule (size < 1 cm and not visualized in >4 slices), anterior (>1 cm and confined anteriorly), and anteriolateral (crossing the mid coronal line).[11] The applicability of this system is also limited by the inclusion of the longitudinal size as a classification variable. Furthermore, in the prospective evaluation of this system, the decision to place a chest tube was not dependent solely on clinical signs and symptoms. All patients with anterolateral OPTX received a chest tube on diagnosis, and all patients with an anterior OPTX who received positive pressure ventilation early in their stay had a chest tube placed soon after diagnosis.[12] Therefore, the results cannot support the validation of this system. This classification is distinctly different from our OPTX score in that the determination of being lateral is made by examining an axial plane through the pulmonary hilum. Although it makes sense that volumetric information may provide more accurate findings, at this point, it takes time to acquire this information and requires consulting a radiologist. We attempted to describe a system requiring minimal knowledge of how to measure a given distance on a PACS or a hard copy.

Ball et al.[3,6] describe the incidence, risk factors, and outcomes of their cohort of patients with OPTX in two studies in 2005. His group also uses an index for comparative analysis between the groups of patients with occult versus overt versus residual pneumothoraces. The index involves multiplying the number of 5-mm images with evidence of a pneumothorax by the maximal width (in centimeters).[3,6] It was unclear whether the maximal width represented a line drawn perpendicular to the chest wall or the greatest width in any direction. We thought that this might serve to diminish the ability of the score to represent the true size of the pneumothorax. In addition, we found it difficult to assess the number of 5-mm slices at times and may in fact overestimate the size. We decided to use a line perpendicular to the chest wall and not include the number of axial slices.

Our reported overall incidence of OPTX might be a result of sampling error. There was no formal way of identifying patients with OPTX and therefore, we reviewed all patients with traumatic pneumothorax. We used ICD-9 codes to identify the population of those with pneumothorax and perhaps as a result of under-reporting the number of occult pneumothoraces was lower than expected. We recognize the limitations of this data in regard to clinical decision-making. Unfortunately, the indications for placement of each chest tube were unclear and not uniformly available in this data set.

The ATLS guidelines propose chest tube placement in all patients with traumatic pneumothoraces, regardless of whether the pneumothoraces are overt or occult. This philosophy may provide the rationale for chest tube in some of our study cohort with small OPTX. However, the evidence to support this practice is limited. It may be reasonable to closely observe the OPTX and place chest tubes only when clinically indicated. There may be instances when an objective measure of OPTX size may assist in decisions to place chest tubes for OPTX before transfer to a Level I trauma center or if one is needed during an urgent washout of an open fracture, during which the patient will be on positive pressure ventilation for 2 hours.

It was not possible to understand the reason for many of the chest tubes placed in patients with small OPTX. Therefore, conclusions about that group and how they may confound the ROC curve are conjecture. However, there were no documented complications or delayed placements of chest tube in patients with a small OPTX who did not receive a chest tube. In conclusion, the OPTX score quantified the size of the OPTX and may be a tool used to study potential treatment guidelines.

Future directions involve the use of other imaging modalities and better methods to quantify the size of the pneumothorax as a routine. There has been interest in using ultrasound to detect the OPTX but this technique is being developed and requires further validation.[13] Our score is currently being evaluated in an ongoing prospective trial.

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