Prediction of Pneumothorax Rate in Percutaneous Needle Aspiration of the Lung

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Pneumothorax (PTX) is the most common complication associated with percutaneous needle aspiration (PNA) of the lung. Age, sex, cooperation, and lesion size, location, and depth, as well as needle size, number of passes, and radiographic calculation of total lung capacity all have been implicated in influencing the rate of PTX. Pulmonary function testing to assess PTX risk in PNA has not been previously examined. We retrospectively reviewed 159 patients undergoing PNA who had preprocedure spirometry (PFT) and chest roentgenogram (CXR) interpreted for changes of obstruction or restriction to determine if these classifications could stratify patients at high risk for PTX. We also examined single variables to determine their predictive power. Patients with normal PFT and CXR had a 10 percent risk of PTX, and only one such patient needed intervention to treat the PTX. Obstruction by PFT, regardless of CXR findings, predicted a 50 percent PTX rate. Among single variables, FEV₁, proved to be the most significant predictor of PTX. Preprocedure spirometric testing can enhance the assessment of PTX risk and should be routinely performed prior to needle aspiration.

Leyden was the first to obtain pulmonary material for bacteriologic study via lung puncture in 1883, and in 1886 Menetrier utilized needle aspiration to diagnose a pulmonary malignancy. However, the technique did not gain widespread popularity due to technical problems and lack of acceptable radiographic visualization equipment. With improved needle design, sophisticated radiographic imaging, and advanced cytologic preparation and examination, the procedure has enjoyed a renaissance and become widely used to diagnose both benign and malignant lung lesions.

Despite advances in technique, pneumothorax (PTX) has remained the most common complication of this procedure. The PTX rate at our institution is 30 percent. The literature reports a rate of between 15 and 57 percent and suggests a number of variables that may have direct influence on the relative risk of developing this complication. Factors associated with increased risk of PTX include patient age, sex, size and depth of lesion, location, number of needle passes, patient cooperation, and radiographic calculation of total lung capacity. Although total lung capacity as an index of obstructive lung disease has been suggested as a predictor of a high PTX rate, formal pulmonary function testing has not been evaluated to determine its ability to predict a procedural PTX. The purpose of this study was to determine if spirometry (PFT) and chest roentgenogram (CXR) interpretation could improve the prediction rate of PTX in percutaneous needle aspiration (PNA) of the lung.

Material and Methods

The study population consisted of 492 patients undergoing PNA of the lung for benign or malignant lesions at the Medical University of South Carolina Hospital between 1980 and 1985. Patient names were cross-referenced in our pulmonary function laboratory, and 192 were identified to have had pulmonary function testing. Patients were included for analysis if their pulmonary function tests met one of the following criteria: (1) PFT within 12 months of the procedure; (2) severe obstruction or restriction by PFT prior to the procedure, without subsequent evidence of clinical improvement; or (3) normal PFT after the procedure. One hundred fifty-nine patients met these inclusion criteria and formed the patient population. Pulmonary function including simple spirometry was tested with the DS Plus System (Warren E. Collins). The best of at least three efforts was selected for study purposes. Patients were classified according to the following pulmonary function criteria: obstructive: FEV₁ or FVC <70 percent, with FEV₁/FVC ratio <70 percent; restrictive: FVC <70 percent, with FEV₁/FVC ratio >70 percent, and normal: FEV₁, FVC, and FEV₁/FVC ratio >70 percent.

Preprocedure standard 6-foot posterior-anterior (PA) and lateral chest roentgenograms were interpreted by three unbiased radiologists utilizing the following criteria: (1) obstructive disease, if three of the following four criteria were met: hyperinflation, paucity of vascular markings, flattening of hemidiaphragms, or bullous lesions; (2) restrictive disease, if two of the following three criteria were met: small lung volumes, increased interstitial markings, and diffuse interstitial markings; and (3) normal, those who failed to meet the above criteria of obstruction or restriction. If there was disagreement among the three radiologists, the x-ray film was characterized by majority vote. Other variables recorded for analysis included lesion size measured as the greatest diameter of the lesion on PA or lateral roentgenogram, lesion depth as measured from the pleural surface...
Results

Of the group of 159 patients investigated, 128 were men and 31 women. Comparison of variables in relation to development of PTX are shown in Table 1. Their mean age was 61 years, which was not significantly different from those incurring PTX (62.2) and those who did not (60.2). Lesions varied from 1 to 12 cm, with a mean of 2.7 cm in the PTX group and 3.4 cm in the unaffected group (p<0.01). Depth of the lesions varied from 1 to 10 cm with a mean of 4.3 cm in the patients with PTX and 3.3 cm in those without PTX (p<0.01). Seventy-four required one needle pass for diagnosis, 72 two passes, and 13 three or more. A significant difference did not exist in the number of needle passes between the PTX group (1.7) and those without PTX (1.6) (p = NS). Of the 159 patients, 54 (34 percent) incurred a PTX. These were distributed equally among men (34 percent) and women (32 percent) (p = NS). Forty PTX were considered to be small (<25 percent), 13 large (>25 percent), and 3 under tension. Of the 54 instances of PTX, 37 (68 percent) only required observation, 13 (24 percent) had a small bore chest tube placed (Argyle Trocar Catheter, Sherwood Medical, Brunswick Co, with a Heimlich valve, Bard Parker Division of Becton Dickinson), and four (8 percent) had standard tube thoracostomy. Only one patient with PTX who had a normal PFT and CXR needed intervention to treat the PTX.

Utilizing CXR interpretation, 17 of 67 normals (25 percent) by radiographic criteria developed PTX, 33 of 80 obstructive patients (42 percent), and 4 of 12 with restrictive disease (33 percent) developed PTX (p = NS). Utilizing PFT criteria, 10 of 53 normal (18 percent), 31 of 66 obstructive patients (47 percent), and 13 of 40 restrictive patients (32 percent) developed a PTX (p<0.01). When patients were grouped into PFT and CXR subsets, a 3 X 3 table could be formed (Table 2), which revealed the following information significant at the p<0.01 level: a normal PFT and normal CXR interpretation predicted a 10 percent PTX rate, and obstruction by PFT criteria, regardless of CXR interpretation, predicted an approximately 50 percent PTX rate.

When individual variables were examined, several were found to be indicators of a increased risk of PTX. Lesion size was significantly smaller in the PTX group, and lesion depth was significantly deeper in PTX patients. Of all individual PFT parameters decreasing FEV₁ best correlated with increasing PTX rate. As seen in Figure 1, there was a significant

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. in Subset</th>
<th>No Pneumothorax N = 105 (%)</th>
<th>Pneumothorax N = 54 (%)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>(159)</td>
<td>60.2</td>
<td>62.2</td>
<td>NS</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>(128)</td>
<td>84 (66)</td>
<td>44 (34)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>(31)</td>
<td>21 (68)</td>
<td>10 (32)</td>
<td></td>
</tr>
<tr>
<td>PFT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>(53)</td>
<td>43 (82)</td>
<td>10 (18)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Obstructive</td>
<td>(66)</td>
<td>35 (53)</td>
<td>31 (47)</td>
<td></td>
</tr>
<tr>
<td>Restrictive</td>
<td>(40)</td>
<td>27 (68)</td>
<td>15 (32)</td>
<td></td>
</tr>
<tr>
<td>CXR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>(67)</td>
<td>50 (75)</td>
<td>17 (25)</td>
<td></td>
</tr>
<tr>
<td>Obstructive</td>
<td>(80)</td>
<td>47 (58)</td>
<td>35 (42)</td>
<td>NS</td>
</tr>
<tr>
<td>Restrictive</td>
<td>(12)</td>
<td>8 (67)</td>
<td>4 (33)</td>
<td></td>
</tr>
<tr>
<td>Size of lesion, cm</td>
<td>(159)</td>
<td>3.4 ± 1.19*</td>
<td>2.7 ± 2.0*</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Depth of lesion, cm</td>
<td>(159)</td>
<td>3.3 ± 0.22*</td>
<td>4.5 ± 0.34*</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>No. of needle passes</td>
<td></td>
<td>1.6 ± 0.006*</td>
<td>1.7 ± 0.01*</td>
<td>NS</td>
</tr>
</tbody>
</table>

*Mean ± SEM

Chest / 93 / 4 / April, 1988 743

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Table 2—Pneumothorax Rate Combining Spirometry and Chest Roentgenogram (CXR) Interpretation*

<table>
<thead>
<tr>
<th></th>
<th>CXR</th>
<th>NL</th>
<th>OBS</th>
<th>RES</th>
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</thead>
<tbody>
<tr>
<td>FEV1, L</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PFT, no. (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NL</td>
<td>OBS</td>
<td>RES</td>
<td></td>
</tr>
<tr>
<td>53 (18)</td>
<td>66 (48)</td>
<td>40 (32)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>67 (25)</td>
<td>29 (10)</td>
<td>13 (47)</td>
<td>25 (32)</td>
<td></td>
</tr>
<tr>
<td>80 (42)</td>
<td>19 (31)</td>
<td>51 (48)</td>
<td>10 (30)</td>
<td></td>
</tr>
<tr>
<td>12 (33)</td>
<td>5 (20)</td>
<td>2 (50)</td>
<td>5 (40)</td>
<td></td>
</tr>
</tbody>
</table>

No. of patients in each subset (% with pneumothorax in each subset).

*NL, normal; OBS, obstructive; RES, restrictive

Inverse correlation between FEV1 and incidence of PTX (r = -.96, p<0.01). This correlation could be quantified by the formula PTX (%) = 81.5 - (17.3 × FEV1 in liters). There was a trend relating increasing depth of the lesion and rate of PTX (r = .96, p = 0.1).

In addition, we analyzed the next 88 patients undergoing the procedure over the following 18 months to determine if the above formula was accurate when applied to patients. As seen in Table 3, the pneumothorax rate in this additional group was virtually identical to the initial reference group, suggesting the pneumothorax prediction equation to be a useful predictor of pneumothorax risk.

**DISCUSSION**

This study suggests that preprocedure PFT and CXR interpretation can stratify a patient's risk of PTX with PNA. Those patients having normal PFT and CXR are at low risk of developing a PTX (10 percent), whereas those with obstructive PFT criteria, regardless of CXR interpretation, developed a PTX almost 50 percent of the time. In addition to a lower PTX incidence, patients normal by PFT and CXR rarely needed intervention if they did develop PTX. Decreasing FEV1 correlated linearly with increasing PTX rate that could be predicted by a simple formula. The smaller the lesion, and the greater the depth of needle penetration, the more likely was the association of PTX. Although the importance of age, sex, and number of needle passes has been previously emphasized, these were not found to be predictors.

That PFT interpretation enhances the PTX prediction rate is not surprising. Poe et al and Sinner suggested that obstructive lung disease by radiographic criteria increased the risk of PTX in patients undergoing PNA. Although the PFT criteria utilized here measure large airway flows, they imply certain information about the underlying lung parenchyma. Obstruction by PFT criteria is most commonly seen in emphysema and chronic bronchitis, conditions that are associated with an independent risk of PTX even in the absence of manipulation. Restriction by PFT criteria imply stiff, fibrotic lungs, unable to seal quickly after an invasive needle aspiration. In both cases, abnormal PFT were associated with an increased PTX rate when compared with patients with normal PFT. In conjunction with this, FEV1, an important PFT parameter in both restrictive and obstructive lung disease, correlated significantly with the development of PTX, to the point that linear regression analysis allowed significant formula quantification of this risk. When chest roentgenogram interpretation was used to predict PTX rate, we found that only a normal finding improved the prediction rate. Those patients normal by both PFT and CXR criteria had the lowest PTX rate, 10 percent, in comparison to 25 percent of radiographic normal and 18 percent of PFT normal subjects. This suggests that, by our criteria, the roentgenogram alone is not a sensitive predictor of PTX in PNA.

Our study suggests, as do others, that decreasing size and increasing depth of the lesion were associated with a higher PTX rate. St. Louis et al suggested that deeper lesions may result in the needle crossing a greater number of pleural surfaces. Excessive pleural surface penetration has been historically suggested as increasing the PTX rate, but in the present series, aspiration was always planned to cross...
the least number of pleural surfaces possible. Another
variable among deeper lesions is whether they are
parenchymal lesions, hilar nodes, or mediastinal masses. Jereb's study of needle biopsy revealed a
slightly decreased PTX rate for central lesions, but
many of those central lesions were hilar or mediastinal
nodes. The study of Poe and colleagues, which
strongly correlated depth of the lesion with increasing
PTX incidence, only involved patients who had
discrete solid pulmonary parenchymal lesions. Our study,
which had a small number of hilar or mediastinal
lesions (14 percent), suggests a direct trend between
PTX rate and increasing depth of the lesion. Manipu-
lation necessary to obtain tissue from a parenchymal
mass may tear the lung and cause a PTX, whereas
similar manipulation in a hilar or mediastinal mass
may be less likely to induce a PTX.

Lesion size has also been implicated as a factor in
PTX risk. Jereb's study concluded that no difference
did exist in PTX rate between small (<2 cm) and
large (>2 cm) lesions, but others have separated
lesions more critically and shown, as we have, that
decreasing size does correlate with increasing PTX
rate. The longer the aspiration needle remains in
the chest to enter a small lesion may cause a greater risk
of aspirating or tearing adjacent normal lung tissue
and result in the higher PTX rate seen with smaller
lesions.

The implication that smaller, deeper lesions are
more difficult to biopsy and require a greater number
of needle passes, leading to a higher PTX rate, was
not supported by the present study, as the number of
passes was not related to the PTX rate. It is more
likely that the longer time to aspirate smaller, deeper
lesions was the significant factor in PTX development,
not simply the number of passes. The longer the
needle remains in the chest, the greater the chance
of tearing the pleura as the patient breathes or coughs.
If one were to measure dwell time of the needle in
the chest, an increasing PTX rate proportional with
dwell time might be noted.

The spirometric measurements recommended here
to assess the risk of PTX are simple to perform, easy
to interpret, reproducible, and not expensive. They
can be measured just prior to the procedure to quickly
predict the PTX risk. With simple equipment, the
cost of spirometry should be well under $50. Although
not absolutely necessary to perform in all patients
prior to biopsy, spirometric testing is benign, and since
many aspirated lesions are neoplastic, the spirometric
evaluation would eventually be routine, making the
majority of such tests ultimately appropriate.

In conclusion, our study has shown that PFT and
CXR analysis should be helpful in predicting the PTX
rate with PNA. Those with normal roentgenograms
and spirometric tests have a minimal (10 percent) risk
of PTX, whereas those with airway obstruction had a
PTX 50 percent of the time. Individual variables of
size, depth, and FEV1 also correlate with PTX devel-
opment. A simple formula based on FEV1 can be
utilized to accurately predict the risk of PTX for an
individual patient. We believe that spirometry should
be performed in all patients undergoing percutaneous
needle aspiration of the lung to provide both operator
and patient with a more accurate prediction of the risk
of pneumothorax.

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CHEST / 93 / 4 / APRIL, 1988 745