ROUTINE DAILY CHEST RADIOGRAPHY IN PATIENTS WITH PULMONARY ARTERY CATHETERS

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BACKGROUND Pulmonary artery catheters are widely used invasive monitoring devices in critically ill patients. Clinicians disagree about whether daily chest radiographs are needed or clinical parameters alone are sufficient to verify catheter placement.

OBJECTIVES To determine whether daily chest radiographs are needed to assess migration of pulmonary artery catheters.

METHODS One hundred consecutive patients with pulmonary artery catheters were prospectively evaluated. Clinical criteria for optimal position of the pulmonary artery catheters and findings on chest radiographs were compared. Optimal clinical criteria were (1) amount of air required to measure pulmonary capillary wedge pressure: 1.25 to 1.5 mL and (2) pulmonary artery catheter migrated 1 cm or less from initial position.

RESULTS Three hundred ninety comparisons of clinical criteria and radiographic findings were done. Chest radiographs indicated the catheter required repositioning in 15 (4%) of 390 instances but in only 4 (1%) of 310 instances in which bedside clinical findings indicated adequate catheter position. In 69 (18%) of the 390 cases, the clinical criteria for adequate catheter position were not met, but radiographs showed the catheter in an appropriate position. The sensitivity, specificity, accuracy, positive predictive value, and negative predictive value of abnormal clinical criteria were 73%, 82%, 81%, 14%, and 99%, respectively.

CONCLUSIONS Chest radiographs indicated that about 4% of catheters required repositioning. Catheter malposition can be reliably excluded (negative predictive value, 99%) by close observation of specific clinical criteria, so routine daily chest radiographs do not seem justified. (American Journal of Critical Care. 2002;11:261-265)

Since their introduction in 1970, balloon-tipped, flow-directed pulmonary artery catheters have been widely used to monitor hemodynamic parameters in critically ill patients. These catheters are still frequently used for monitoring, despite recent debate about their effectiveness in guiding therapy or improving outcome.

Complications associated with the use of pulmonary artery catheters have been reported in the past 3 decades. One of the most serious complications is pulmonary artery rupture, which, although rare (0.001%-0.47% of cases), has a high mortality rate (~50%). Other reported complications include pulmonary artery pseudoaneurysm, intracardiac knotting, arrhythmias, heart block, infection, thromboembolism, and damage or perforation of the cardiac chamber. Most complications occur when the catheter is being inserted, but they can occur any time the catheter is in use.

In an effort to prevent or further reduce the morbidity associated with these complications, the use of daily chest radiography in patients with pulmonary artery catheters has become common. Little controversy exists that chest radiography should be performed immediately upon insertion of the catheter.

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to verify placement of the catheter tip. In addition, the manufacturer’s recommendations for care of the pulmonary artery catheter used in this study include continuous pressure monitoring and obtaining a chest radiograph “immediately upon insertion and thereafter on a routine basis to ensure that the tip is positioned correctly.” Shoemaker et al also emphasize the importance of chest radiography for monitoring the position of the catheter tip to avoid pulmonary artery rupture. They specifically state that “avoidance of this complication necessitates close monitoring of catheter tip position by means of chest x-ray, monitoring of [pulmonary artery] waveform, and ensuring that the wedge pressure is not obtained with less than 1-1.5 mL of air in the balloon.”

Voyce also recommends obtaining chest radiographs daily in patients with pulmonary artery catheters to assess whether peripheral migration of the catheter has occurred.

Some authors state that after the initial position of the catheter is verified, follow-up radiographs to assess catheter placement are not necessary unless the radiographs are clinically indicated. Alternatively, Fong et al. in a study of the utility of chest radiographs in the surgical intensive care unit (ICU), found that routine daily chest radiographs were justified only in patients with pulmonary artery catheters. It is not clear whether the daily chest radiograph was of benefit for catheter positioning or because the patients with pulmonary artery catheters were acutely ill. In a study of 525 patients, Silverstein et al. seriously questioned the need for any routine radiographs in the surgical ICU. They reported a 1.3% prevalence of “major malposition” of indwelling devices, and less than 1% prevalence of cardiopulmonary abnormalities requiring immediate intervention. Other researchers have questioned the need for obtaining routine daily chest radiographs in the ICU in a variety of populations of patients.

The objective of this study was to evaluate the utility of clinical parameters routinely assessed at the bedside in determining the location of the pulmonary artery catheter, thus perhaps negating the need for routine daily radiography solely to exclude catheter malposition and its potential complications. In our institution, and most likely in others, daily chest radiographs are obtained for that purpose in all patients with pulmonary artery catheters. We hypothesized that careful bedside assessment of clinical parameters of catheter location would indicate adequate catheter position, which would be confirmed by chest radiographs.

**Materials and Methods**

One hundred consecutive patients with pulmonary artery catheters in the trauma and surgical ICUs of the University of Miami/Jackson Memorial Hospital were prospectively evaluated during a 6-month period. The study was approved by the University of Miami institutional review board with waiver of informed consent. All patients were 18 years or older. A preexisting diagnosis of pulmonary hypertension was the only exclusion criterion. The sample was diverse and represented a wide variety of ages and diagnoses (primarily surgical/trauma). The group included 34 females and 66 males, and the mean age was 51 years. Bedside clinical findings were evaluated to determine if they met the criteria for optimal catheter location when the chest radiograph was obtained. Clinical findings and radiographic findings (as interpreted by 1 of a group of 5 experienced attending radiologists who were unaware of the clinical criteria) were compared. Chest radiographs that showed a catheter more than 3 cm from the midline were considered to show abnormal catheter placement. Clinical criteria were defined as follows: (1) amount of air required to obtain a pulmonary capillary wedge pressure tracing: 1.25 to 1.5 mL (normal) versus less than 1.25 mL (abnormal) and (2) centimeter marking of the pulmonary artery catheter at the introducer hub: 1 cm or less migration in or out from the initial position (normal) versus more than 1 cm migration (abnormal).

Clinical findings were evaluated and recorded by the registered nurse caring for the patient or by one of us. All nurses in these ICUs receive both didactic and clinical education on the care of patients with pulmonary artery catheters at the time of hire. Each recorded set of clinical findings was deemed to have met or not to have met the study criteria for optimal placement of a pulmonary artery catheter (as just specified). The clinical findings were then compared with the written interpretation of the chest radiograph, which was recorded as either “catheter required repositioning” or “catheter did not require repositioning.” The pulmonary artery catheter used for the study was the 7.5F OptiQ continuous cardiac output catheter, which is 110 cm long and has a balloon capacity 1.5 mL (Abbott Critical Care Systems, North Chicago, Ill). This catheter is marked every 10 cm along the length of the catheter, enabling clinicians to monitor the depth to which the catheter is inserted. Patients were monitored for complications associated with the catheter (infection, arrhythmia, pulmonary artery rupture or infarction, thrombosis or embolism) for the duration of their stay in the ICU.
The data for the 390 comparisons were compiled, and the number of instances in which clinical findings indicated that catheters needed repositioning was compared with the number of instances in which chest radiographs indicated that catheters needed repositioning (see Table). The positive predictive value, negative predictive value, accuracy, specificity, and sensitivity of bedside clinical criteria were calculated by using the following definitions. The first chest radiograph obtained after initial placement of a catheter was not used in data analysis. The data were analyzed by using multiple comparisons from each patient (N = 390) and also by using only the first follow-up comparison after the initial chest radiograph for verification to eliminate error due to the lack of true independence of comparisons (n = 100).

True-positives were defined as instances in which the bedside clinical findings were abnormal (signifying possible malposition) and a chest radiograph showed the need for catheter repositioning. False-positives were defined as instances in which bedside clinical findings were abnormal and a chest radiograph showed the catheter to be in good position. True-negatives were defined as instances in which bedside clinical findings were normal and a chest radiograph showed the catheter to be in good position. Finally, false-negatives were defined as instances in which bedside clinical findings were normal but a chest radiograph showed the need for catheter repositioning.

Results

A total of 390 sets of bedside clinical findings for catheter location and findings on chest radiographs were compared. The chest radiograph revealed malposition of the pulmonary artery catheter in 15 (4%) of 390 instances. In only 4 (1%) of 310 instances in which bedside clinical findings indicated adequate catheter position did the radiograph show the catheter to be in good position. True-negatives were defined as instances in which bedside clinical findings were normal and a chest radiograph showed the catheter to be in good position. Finally, false-negatives were defined as instances in which bedside clinical findings were normal but a chest radiograph showed the need for catheter repositioning. No complications of distal positioning were noted (defined as pulmonary artery rupture or infarction). In 69 (18%) of 390 instances, the bedside clinical criteria for adequate catheter position were not met, but a chest radiograph showed the catheter was properly positioned (see Table). The distribution of these 69 false-positives was random. The negative predictive value, positive predictive value, sensitivity, specificity, and accuracy of abnormal clinical findings were 99%, 14%, 73%, 82%, and 81%, respectively.

The data were then analyzed by using only the first chest radiograph obtained after initial verification of catheter position (1 data point per patient). When the data were treated this way, only a single instance was false-negative (ie, a chest radiograph showed a catheter that required repositioning, but the clinical findings were normal). This analysis yielded 93 true-negatives, 3 true-positives, and 3 false-positives. With this approach, the specificity was 97%, sensitivity was 75%, accuracy was 96%, positive predictive value was 50%, and negative predictive value was 99%.

Discussion

The principal finding of this study was that abnormal bedside findings had a 99% negative predictive value when used to evaluate the position of a pulmonary artery catheter. This result was the same in both analyses of the data.

Few studies in the literature describe objective radiological criteria for determining adequate catheter location. Zarshenas and Sparschu23 state that if the catheter tip is more than 2 cm lateral to the pulmonary hilum, it is “too peripheral.” In a recent study of complications of central venous catheters, Miller et al24 considered a pulmonary artery catheter malpositioned if it was not found within the pulmonary trunk, the left or right pulmonary artery, or the pulmonary artery in either lower lobe within 2 cm of the cardiac border. Voyce16 states that a pulmonary artery catheter more than 3 to 5 cm from the midline is too peripheral. However, such placement remains subject to the “experienced eye” test. It is questionable whether mildly peripheral placement of a pulmonary artery catheter increases the risk of pulmonary artery rupture if at least 1.25 mL of air in the balloon is required to obtain a pulmonary capillary wedge pressure tracing. This question most likely could not be easily answered in a clinical trial because of the rarity of pulmonary artery rupture. Most, if not all, clinicians would agree that when less than 1 mL of air is required to obtain a pulmonary capillary wedge pressure tracing, the catheter should be pulled back regardless of the findings on a chest radiograph.

<table>
<thead>
<tr>
<th>No. of instances in which chest radiographs and clinical findings indicated that catheter position was normal or abnormal</th>
<th>Chest radiographic findings</th>
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<tbody>
<tr>
<td>Clinical findings</td>
<td>Normal</td>
<td>Abnormal</td>
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<tr>
<td>Normal</td>
<td>306</td>
<td>4</td>
</tr>
<tr>
<td>Abnormal</td>
<td>69</td>
<td>11</td>
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<td>Total</td>
<td>375</td>
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Our findings suggest that malpositioning of a pulmonary artery catheter can be reliably excluded (negative predictive value, 99%) through careful assessment of bedside clinical findings that are routinely monitored by ICU nurses. A chest radiograph should be obtained to verify initial position of the catheter, and the centimeter marking on the catheter should be documented when the hub is locked in place. If the catheter is not manipulated (intentionally or otherwise) and remains secure at the same centimeter marking, it is reasonable to assume that the catheter is in good position if at least 1.25 mL of air is required to obtain a pulmonary capillary wedge pressure tracing.

Of interest, the specificity, accuracy, and positive predictive value increased markedly when the data were analyzed by using only independent comparisons (1 per patient). This phenomenon suggests that bedside clinical findings are most reliable shortly after initial placement of the catheter and become somewhat less reliable over time, although the smaller number of data points used may have affected the results. Also of note, during the course of the study (approximately 6 months), no adverse events occurred as a result of placement and use of a pulmonary artery catheter.

Patients with preexisting pulmonary artery hypertension were excluded from the study because chronic hypertension might lead to vascular changes such as stiffening, dilatation, or stenosis that could alter the reliability of the clinical criteria for positioning we used. Our findings may or may not be generalizable to patients with pulmonary artery hypertension. In patients with pulmonary hypertension, more frequent chest radiographs to assess catheter position may be indicated.

Our relatively small sample size (390 comparisons, 100 patients) limits the ability to generalize these findings and state definitively that the careful use of bedside clinical criteria to evaluate placement of pulmonary artery catheters will eliminate the risk of pulmonary artery rupture. In addition, the bedside clinical criteria chosen for the study represent current clinical criteria for positioning we used. Our findings and state definitively that the careful assessment of bedside clinical parameters after initial verification of catheter position by chest radiography. Most errors detected (accuracy, 82%, 96%) occurred as a result of the clinical criteria not being met but the chest radiograph showing appropriate positioning of the catheter. In these patients, a chest radiograph would have been obtained to exclude malposition of the catheter.

In today’s cost-conscious healthcare environment, it is important that clinicians order diagnostic tests only as indicated, not as a matter of routine. In our study, the use of bedside clinical criteria would have allowed a major reduction in the use of chest radiography to verify catheter position. Critically ill patients with pulmonary artery catheters may require multiple chest radiographs for a variety of clinical conditions. However, the use of routine daily chest radiographs to assess position of a pulmonary artery catheter does not seem justified when specific clinical criteria can be carefully used.

Conclusions
In summary, chest radiographs showed that only 4% of pulmonary artery catheters in this study required repositioning. No complications of distal placement of a catheter in the pulmonary artery (>3 cm from the midline on chest radiograph) were noted in the 100 patients evaluated. We think that malpositioning of a pulmonary artery catheter may be reliably excluded (negative predictive value, 99%) by close observation of specific bedside clinical parameters after initial verification of catheter position by chest radiography. Most errors detected (accuracy, 82%, 96%) occurred as a result of the clinical criteria not being met but the chest radiograph showing appropriate positioning of the catheter. In these patients, a chest radiograph would have been obtained to exclude malposition of the catheter.

REFERENCES


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