

Where Pulmonary Arterial Catheters Go:

Intrathoracic Distribution

Jonathan L. Benumof, M.D.,* Lawrence J. Saidman, M.D.,† David B. Arkin, M.D.,‡
and Michael Diamant, M.D.§

Recent experimental evidence indicates that the position of a pulmonary arterial catheter within the thorax is important because vertical height gradients from catheter tip to main pulmonary artery and left atrium may alter the validity of the pressure measured. The authors therefore examined the intrathoracic distribution of 314 pulmonary arterial catheters which at insertion were advanced to the most proximal position from which pulmonary wedge pressure could be obtained. Five catheters (1.8 per cent) were 6 cm or more cephalad to the carina, and 16 (5.1 per cent) were 9 cm or more lateral to the midline. With peripheral catheters recordings of pulmonary arterial and wedge pressures may be erroneous because future patient position, initiation of positive end-expiratory pressure, and occurrence of low pulmonary arterial and left atrial pressures may convert the region of lung in which the catheter tip lies to a Zone 1 of the lung. (Key words: Equipment, catheters, Swan-Ganz; Heart, vascular pressures, catheterization; Lung, intravascular pressures, pulmonary artery; Ventilation, alveolar pressure; Ventilation, positive end-expiratory pressure.)

CLOSE APPROXIMATION of left atrial pressure by pulmonary-artery wedge pressure requires a blood-filled segment of pulmonary vasculature to serve as an extension of the catheter system. When any part of the system distal to the catheter tip is emptied of blood, the requirement is not fulfilled, and wedge pressure no longer reflects left atrial pressure. Whether pulmonary capillaries and veins contain blood is a function of pulmonary arterial pressure, alveolar pressure, left atrial pressure, and the hydrostatic relationship of these vessels to the left atrium.^{1,2} When a catheter tip locates in a region of the lung that is Zone 1 (a region within the lung where alveolar pressure exceeds pulmonary arterial and venous pressure³), the pulmonary-artery wedge pressure recording will reflect airway pressure rather than left atrial pressure.

Clinical practice dictates that pulmonary arterial catheters be advanced to the most proximal posi-

tion from which a wedge pressure can be obtained.⁴ The question naturally arises as to whether this practice results in catheter placements that are peripheral and therefore potentially in a Zone 1 depending on future airway pressure, factors influencing left atrial pressure, and patient position. Thus, the pressure recorded may be either alveolar or vascular, depending on clinical events and the location of the catheter tip, *i.e.*, alveolar if in Zone 1 and vascular if in a vessel not in Zone 1. Accordingly, we have retrospectively determined the intrathoracic distribution of pulmonary arterial catheters used in our institution during the years 1973-1976.

Methods

Three hundred and ten patients who required catheterization of the pulmonary artery for their clinical care were included in this study. Three of these patients had catheterizations more than once (two had two, one had three), which resulted in a total of 314 catheterizations. All of the patients underwent anesthesia and operation. Ninety-two per cent had open-heart surgery and the remainder had various other procedures. All catheterizations were via the internal jugular vein.

During insertion, all catheters were advanced until pulmonary wedge and arterial pressures could be obtained by balloon inflation and deflation, respectively, without moving the catheter. The first postoperative supine anteroposterior portable chest roentgenogram was used to determine position of the catheter tip. Cephalocaudad distance from the carina and lateral distance from the midline were measured. The carina was used because it could be seen in all patients, is relatively constant in position, and is vertically close to the bifurcation of the main pulmonary artery and 3 cm above the left atrium. The midline (spinous processes of the vertebral bodies) was used as the lateral reference point because the position of the left atrium is midline. We arbitrarily considered 6 cm or more above the carina (9 cm or more above the left atrium) and 9 cm or more from the midline as excessively peripheral (exceeding a normal pulmonary venous pressure of 7 mm Hg).

Results

The large majority of individual catheter tips were located in the right middle and lower lung field (fig.

* Assistant Professor of Anesthesia

† Professor of Anesthesia

‡ Assistant Clinical Professor of Anesthesia

§ Anesthesia Resident III

Received from the Department of Anesthesia, University of California, San Diego, La Jolla, California.

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Address reprint requests to Dr. Benumof: Anesthesia Research Laboratory, M-004, University of California, San Diego, La Jolla, California 92093.

1). The cardiac silhouette is suggested by the distribution, as would be expected from anatomic considerations. From the data in figure 1, frequency distributions from the reference points (carina and midline) were derived.

The cephalocaudad frequency distribution of distances from the carina was basically Gaussian from 2 cm above the carina to 12 cm below the carina (fig. 2a). There were five instances (1.8 per cent) of high (≥ 6 cm above the carina) cephalad placement (possibly Zone 1 when the patient was sitting). Two peaks in the frequency distribution of lateral displacement of catheter tips from the midline were observed (fig. 2b). The larger peak was related to a Gaussian distribution in the right lung (75 per cent) and the second peak at the midline was related to main and right and left main pulmonary arterial catheterizations (16 per cent). Sixteen catheter tips (5.1 per cent) were 9 cm or more lateral to the midline (possibly Zone 1 when the patient was in lateral position). The cephalocaudad and lateral frequency distributions were unaltered by basic medical problem and site of introduction.

Discussion

The principal finding of this study is that when pulmonary arterial catheters are advanced to the most proximal position from which both pulmonary arterial and wedge pressure traces can be obtained, there is a 6.9 per cent incidence of clinically important peripheral catheterizations. Before discuss-

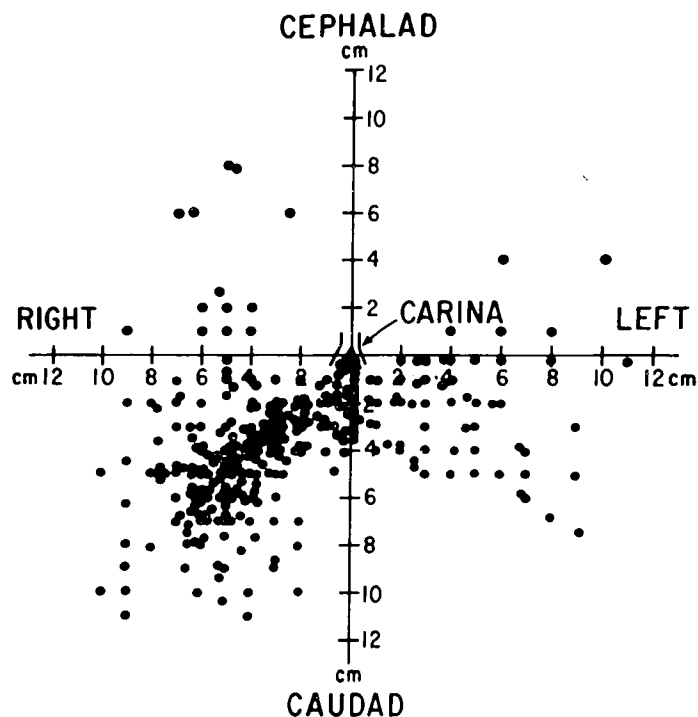


FIG. 1. Intrathoracic locations of individual pulmonary arterial catheters as determined by cephalocaudad distance from the carina as well as lateral distance from the midline.

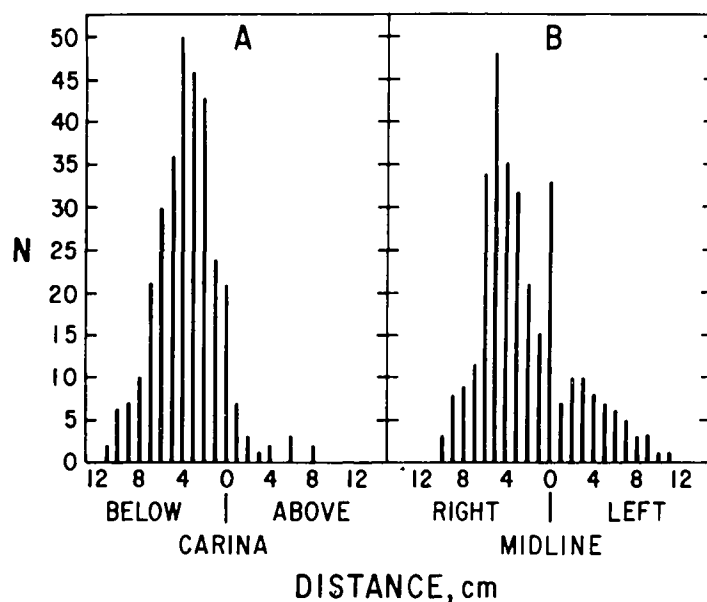


FIG. 2. Frequency distribution of distances from carina and distances from the midline as determined by figure 1.

ing the importance of these findings, consideration should be given to possible sources of variability related to the methods used.

We do not know with complete certainty that all catheters were advanced to the most proximal position from which both pulmonary arterial and wedge pressure traces could be obtained. However, because this is standard practice throughout our department and most (approximately 90 per cent) catheterizations were performed by the authors of this paper, we feel that the potential error was small. The intrathoracic distribution of catheters was unaltered by basic medical problem and therefore the results could not have been appreciably altered by these variables.

Utilization of the first postoperative chest roentgenogram does introduce variability in the data, for several reasons. First, pulmonary arterial catheters tend to slip into a persistent wedge position with time^{4,5} because of the rhythmic contractions of the heart and the pulsatile propelling force of the blood flow. Second, the loop formed by the catheter as it traverses the heart chambers into the pulmonary artery tends to become smaller, causing the end of the catheter to be propelled into smaller branches of the pulmonary artery. For these reasons, some constant error in catheter position may have been introduced. Last, the chest roentgenogram produces a static picture of pulmonary arterial catheter and carina positions when in fact both may move during cardiac and respiratory cycles, respectively. In addition, slight degrees of patient rotation and scoliosis may have limited the accuracy of our measurements. These are random errors that should be considerably damped to a mean (fig. 2a, b) and not alter the basic conclusions.

These findings are clinically important for several reasons. First, peripheral catheterizations occurred often enough to justify a routine chest roentgenogram as soon as possible following catheterization to reduce the possibility of pulmonary infarction. We presently do not advance a catheter that has been introduced from the right internal jugular vein beyond the 50-cm mark even when a wedge pressure cannot be obtained. This reduces the possibility of peripheral catheterization and thereby the possibility of pulmonary infarction^{6,7} and erroneous pressure recordings. Under these circumstances we use the pulmonary diastolic pressure as an index of left atrial pressure. In addition, if at any time following pulmonary arterial catheterization the patient is positioned so as to create a significant vertical hydrostatic gradient, a chest roentgenogram is mandatory to assure correct interpretation of pressure recordings. Clinical examples of such manipulations include the sitting position for posterior-fossa surgery and the lateral decubitus position for thoracotomy and nursing.

Second, the application of positive end-expiratory pressure (PEEP) also requires knowledge of catheter location, because PEEP may prevent pulmonary capillaries and veins from remaining patent. When the catheter tip is proximal to nonpatent capillaries and veins, the wedge pressure recorded will reflect the alveolar pressure rather than left atrial pressure. Clinical discrepancies between pulmonary wedge and directly measured left atrial pressure during the application of PEEP have already been reported by others.⁸⁻¹¹

Third, in patients who have low left atrial pressures from any cause, the likelihood of nonpatent pulmonary veins is also increased. The interaction of low left atrial pressure with patient position, positive airway pressure and PEEP, and pulmonary arterial catheter position greatly increases the clinical circumstances in which the pulmonary wedge pressure may not reflect left atrial pressure.

Last, these findings indicate the need for understanding the relative contributions that patient size, angle of vessel branching, vascular volume, and vascular pressure and flows make to total catheter length insertion. Once these relationships are understood, it may be possible to predict the intrathoracic location of the catheter tip.

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