Case Report

COMMON ARTIFACTS OF PULMONARY ARTERY AND PULMONARY ARTERY WEDGE PRESSURES: RECOGNITION AND INTERPRETATION

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ABSTRACT. Bedside measurement of pulmonary artery pressure and pulmonary artery wedge pressure has an important role in the management of critically ill patients. Unfortunately, waveform abnormalities and artifacts commonly distort numeric values and lead to incorrect therapeutic decisions. The clinical impact of these artifacts is magnified by the digital pressure displays used in most intensive care units. We present here an atlas and an analysis of the artifacts that commonly occur. Use of analog rather than digital pulmonary artery wedge pressure data, when combined with an understanding of the physiological characteristics of patients, can prevent critical errors in patient management.

KEY WORDS. Lung: pulmonary artery pressure; pulmonary artery wedge pressure. Monitoring: blood pressure, artifact

Since the introduction of Swan-Ganz cardiac catheters [1], cardiac catheterization has become a frequently performed bedside procedure in intensive care units. The resulting hemodynamic data provide a picture of the patient’s status that may be invaluable. Data are displayed on highly technological digital bedside monitors. Unfortunately, digital readouts may detect simply the highs and lows during some standard interval and produce data that are entirely artifactual. Hence, measurements designed to reassure the physician or lead to accurate decisions instead frequently become counterproductive. Analysis of an analog strip-chart recording of the pulmonary artery wedge pressure tracing and observation of the status of each individual patient can eliminate artifact from these vital measurements. We present here an atlas of the common artifacts, an analysis of how they occur, and a simple way to handle them using a calibrated analog recorder.

MATERIALS AND METHODS

Patients for this study were selected from the intensive care unit at Denver Presbyterian Hospital of Presbyterian/St Luke’s Medical Center when the bedside monitor indicated a high probability of important artifact in pulmonary artery or pulmonary artery wedge pressures. Digital readouts made by a model #3474CS4JK digital readout computer (General Electric) were compared with an analog reading of pulmonary artery and pulmonary artery wedge pressures obtained with a model RI-5DC recorder (General Scanning, Inc). This device interfaced well with the General Electric system. We wished to obtain characteristic examples, therefore, no attempt was made to assess the frequency of
significant differences between the methods; however, we did note that artifacts of varying importance occurred in the majority of the patients in the intensive care unit. All standard precautions were taken to assure that accurate data would be obtained by both methods. Proper placement of the pulmonary artery pressure catheter was ascertained, and the pressure lines to the patient were examined to make certain that they were free of air bubbles. The transducers were inspected to make certain that they were free of air and that they contained an appropriate amount of water. The analog strip recorder was carefully zeroed to atmospheric pressure at precisely the same altitude as the patient’s heart. The patients were supine in bed during the recordings.

The digital readout computer provided output exactly as it was designed to on all patients, and agreement with the chart recorder was excellent. However, the digital display always interpreted artifacts or abnormal pressure waves that satisfied the programmed criteria as the pulmonary artery systolic, diastolic, or wedge pressures. This occurred because the algorithm for digital display looks at a segment of the pressure tracing, identifies the highest value seen during that interval as systolic, the lowest as diastolic, and continuously averages the waveform to produce a mean. The “mean” reading is usually used to indicate the pulmonary artery wedge pressure. While other, more advanced, algorithms improve on this simplistic approach [2], our monitors demonstrate the problem intrinsic to all such digital displays; namely, that they are unable to completely eliminate artifactual waveforms from consideration in their associated algorithms. We recommend interpretation of the calibrated analog wave and reading the pulmonary artery wedge pressures at end expiration.

The “wedge” state is defined in this paper as the state in which the inflated catheter balloon appears to just occlude the pulmonary artery. We attempted to identify each pressure wave seen on a pulmonary artery wedge pressure tracing and selected as the “true wedge” the portion of the tracing that most closely approximated left ventricular filling pressure. Occasionally, tracings are uninterpretable and must be recognized as such. Uninterpretable tracings most commonly occur when heart rate and respiratory rate are similar. More often there is a relatively stable portion of the trace in the midst of artifacts and abnormal pressure waves that appears to approximate left ventricular filling pressure. When significant V waves are present we read the wedge at the valley of these tracings; we believe that the regurgitant wave does not represent ventricular filling pressure. In the case of respiratory artifacts we attempt to read the values at end expiration as this is the point at which atmospheric and alveolar pressure values are most nearly equal. Although most respiratory artifacts are easily identified from examining the tracing or by watching the patient while data are collected, direct airway pressure recordings are helpful. Most intensive care units do not have the capability for measuring airway pressures continuously, however, and in our experience such recordings are usually not necessary. The examples given in Figures 1-12, all recorded at a chart speed of 5 mm/s, demonstrate how digital displays lead to errors and illustrate how to interpret an analog waveform.

**RESULTS**

Figure 1 shows a negative respiratory artifact. The patient had labored breathing secondary to pneumonia, sepsis, and pulmonary edema. The wedge pressure tracing (PAW) demonstrates large negative excursions (A); hence, the mean wedge pressure (an average of high and low when determined digitally) was less than 0. The actual wedge pressure was approximately 10 mm Hg and could have been accurately measured by setting the digital readout to “systolic.” A similar distortion was produced in the pulmonary artery diastolic (PAD) tracing. The true pulmonary artery systolic pressure (PAS) is marked by small arrows. The true diastolic pressure, identified by the large arrows, was approximately 30 mm Hg. The digital equipment interpreted the pulmonary artery diastolic pressure at 12 mm Hg. This artifact is seen commonly in patients who generate a large negative intrathoracic pressure to breathe, and can occur when patients are either on or off the ventilator.

Figure 2 shows a positive respiratory artifact. This is the pulmonary artery pressure tracing of a patient receiving controlled ventilation. The patient was making no attempt to breathe on his own, but each time the respirator cycled it created positive intrapleural pressure that produced an artifact (A). The artifact was averaged by the digital equipment into the wedge pressure tracing, producing a falsely high reading. The pulmonary artery systolic pressure was distorted in the same fashion. Whereas the digital equipment interpreted the systolic pressure as 50 mm Hg, it was actually only 40 mm Hg.

Placing the patient whose tracing is shown in Figure 1 on a mechanical ventilator, such as was done in the second example, could change a falsely low pulmonary artery wedge pressure to a falsely high one. Thus the act of placing a patient on a ventilator could easily cause an increase of 20 mm Hg in the wedge pressure displayed by digital equipment, when in fact there is no marked change in the patient’s hemodynamic status.