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Failure of a brief educational program to improve interpretation of pulmonary artery occlusion pressure tracings

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Abstract *Objective*: To determine whether a brief educational program can reduce variability of interpretation of pulmonary artery occlusion pressure (PAOP) tracings.
Design: Prospective, observational study.
Participants: Twenty-three intensive care nurses and 18 physicians.
Interventions: Participants interpreted PAOP tracings before and 1 week after receiving a single, brief educational session and/or written materials ("in-service") designed to reduce interobserver variability of PAOP interpretation. Differences between two reference values before and after in-service (mean population and Chief of Critical Care's readings) were compared for both groups.
Results: There were no significant differences in the variabilities in PAOP interpretations before and after in-service in either group.
Conclusions: We conclude that this specific educational program was ineffective in reducing variability of interpretation of PAOP tracings. These data suggest that more comprehensive educational tools and/or sustained programs may be required to improve performance of critical care personnel in PAOP interpretation.

Keywords Pulmonary artery catheter · Right heart catheter · Swan Ganz · Hemodynamics · Critical illness · Wedge pressure

Introduction

Connors and colleagues [1] have demonstrated that the use of pulmonary artery catheters (PAC) in the care of critically ill patients is associated with a higher mortality and longer lengths of stay than when patient care does not include PAC. It is unclear whether this observed increase in mortality was related to insertion and subsequent presence of the catheter or to misinterpretation of data obtained from the PAC. One likely contributor to these findings is the inability of clinicians to measure pulmonary artery pressure tracings reliably, leading to inappropriate and potentially deleterious treatments. Previous studies demonstrated that critical care practitioners performed poorly when asked to interpret a pulmonary artery occlusion pressure (PAOP) from a clear tracing [2, 3, 4, 5]. We recently demonstrated significant intra and interobserver variabilities in measurements of PAOP by physician "experts," physician practitioners who commonly use the PAC, and critical care bedside nurses [5]. To date no study has examined whether educational programs designed to improve performance using the PAC can positively impact interobserver variability. Insofar as large interobserver variability contributes to worse patient outcomes, improving performance of personnel who routinely use PAC data could positively affect outcomes. In this brief communication we demonstrate that a simple educational program, administered once to both physicians and nurses, failed to significantly reduce interobserver variability in interpretation of PAC data.

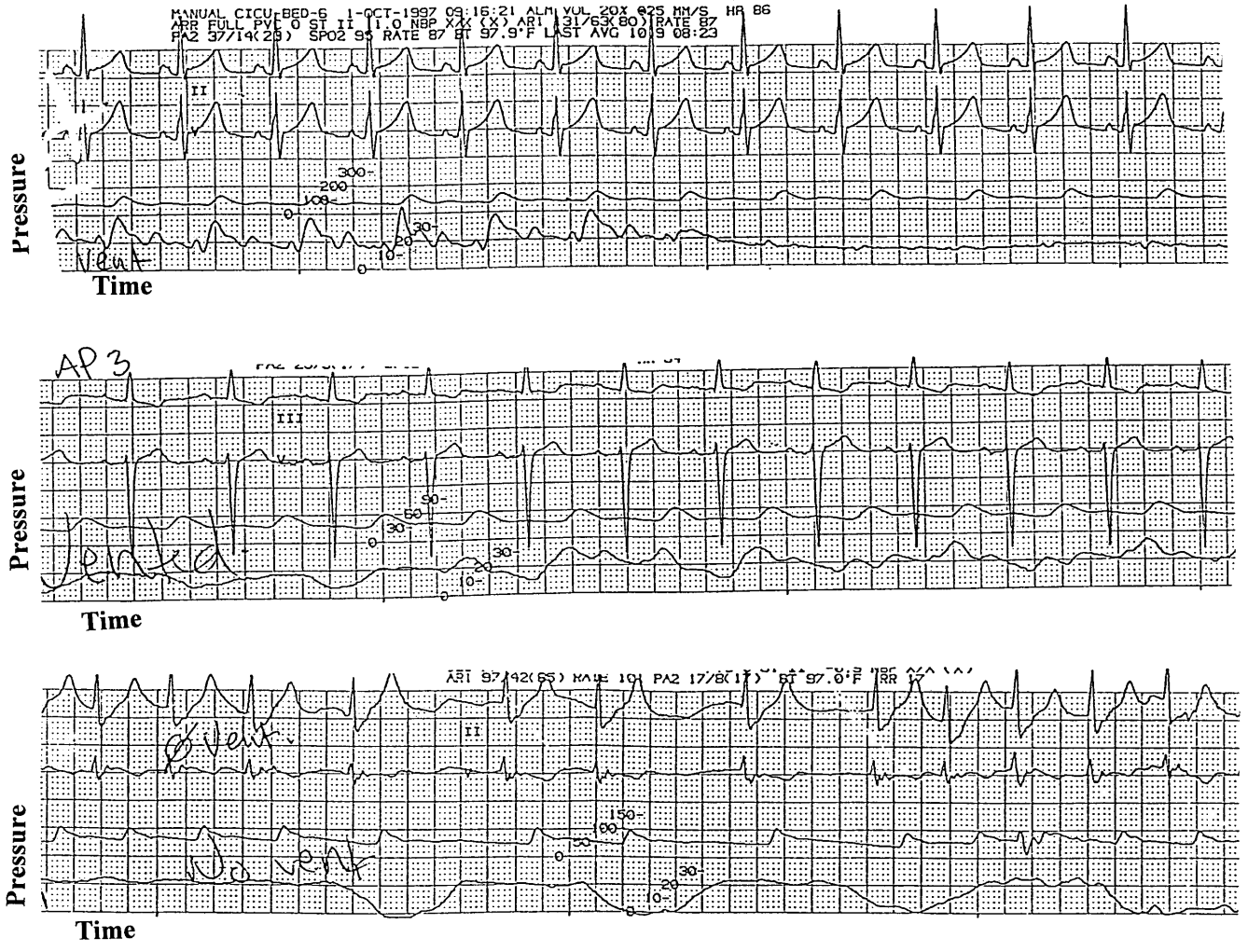

Fig. 1 A–C Pulmonary artery pressure tracings presented in the examination (labels refer to tracings used in Fig. 2)

Methods

This study was performed in a 300-bed community teaching hospital with a 12-bed combined cardiac and general medical intensive care unit (ICU). All of the nurses and physicians surveyed in this study are involved in day-to-day management of patients in our ICU and all routinely interpret and/or use PAC data. In our previous study [6] we presented PAC tracings to a convenient sample of nurses from our medical ICU and to physicians. The physician cohort consisted of Board-certified cardiologists, pulmonary-critical care physicians, and cardiology and pulmonary postgraduate fellows; all but one pulmonologist and no cardiologists were certified in critical care medicine. Of the 23 nurses 6 had advanced certificates in critical care nursing. Large respiratory-phasic variation (RPV) of PAC pressures was independently associated with greater intra and interobserver variabilities in PAC interpretation. Three tracings were chosen to present to our staff because they represented three common clinical situations: one of a patient with small RPV in PAOP, one of a patient on positive pressure ventilation with relatively large RPV, and one of a spontaneously breathing patient with large RPV (see Fig. 1).

Three months after the initial examination we presented an educational "in-service" to both our physicians and critical care nurses. These in-services were presented by our Chief of Critical Care (to physicians) and by two clinical nurse educators (to nurses). These presenters provided a 20-min lecture based upon a structured text hand-out (see "Appendix" and [7]). The in-service also included review of either real or simulated PAOP tracings with large RPV to address methods of proper interpretation for such conditions. A 10-min question/answer session accompanied each presentation. Personnel were *not* told that they would be retested. After 1 week had elapsed, the same three tracings (from the examination 3 months earlier) were presented to nurses and physicians for interpretation. The staff members were asked to submit their interpretations for this study only if they had performed the initial examination and received the in-service.

To assess the short-term efficacy of the in-service, we also presented the identical tracings to seven surgical intensive care unit nurses (who had never seen these tracings), administered the educational program and then retested them 6–7 h later. All but one nurse completed the retest.

Identifying data were not present on the initial examination, and thus comparisons were performed by nonpaired Student's *t*

tests. In addition, the differences in observations from our Chief of Intensive Care's interpretation from the previous study and from combined group (before and after in-service) mean values were compared before and after the in-service by nonpaired Student's *t* test. Since the resolution of each tracing was 4 mmHg/mm, we also analyzed the proportion of observations that were at least 5 mmHg from the reference value, before versus after the in-service. A *p* value less than 0.05 signified statistical significance.

Results

Before the in-service

Twenty-three nurses from our medical intensive care unit and 18 physicians (8 certified cardiologists, 4 certified pulmonary critical care physicians, 6 cardiology and pulmonary fellows) interpreted the three tracings. There was minimal variability of interpretation in the tracing with small RPV (mean 13 ± 2.6 mmHg, range 6–22; Fig. 2A). All but two nurses and one physician identified the PAOP within 4 mmHg of the Chief's and population mean reference values (12 mmHg for both). For the tracing with large RPV in a ventilated patient, group variability was twice that observed for the tracing (A) with minimal RPV (mean 13 ± 5.2 mmHg, range 5–24; Fig. 2B). Variability of readings for the tracing with large RPV in a spontaneously breathing patient was midway between tracings A and B (mean 19 ± 3.3 mmHg, range 10–23; Fig. 2C). The magnitudes of variabilities of PAOP interpretation were similar for nurses and physicians for all three tracings.

After in-service

Sixteen nurses and 18 physicians (8 certified cardiologists, 4 certified pulmonary critical care physicians, 6 cardiology and pulmonary fellows) interpreted the three tracings 1 week after receiving the in-service and/or reviewing the materials presented in the "Appendix." All respondents received the written educational materials or the lecture, and most received both. Variability in interpreting the first tracing was modestly reduced (mean 13 ± 2.0 mmHg, range 8–16; Fig. 2A). All observers identified the PAOP within 4 mmHg of the reference values (12 mmHg for both Chief's and population mean). However, there was no significant change in the magnitude of deviation from the reference value for the group as a whole or for subgroups of nurses versus physicians (see Tables 1, 2).

For the tracing with large RPV in a ventilated patient, group performance was not significantly affected by the in-service (mean 15 ± 6.3 mmHg, range 8–38; Fig. 2B). There was no significant change in the magnitude of deviation from the Chief's value of 10 mmHg or the group mean value of 14 mmHg (see Tables 1, 2),

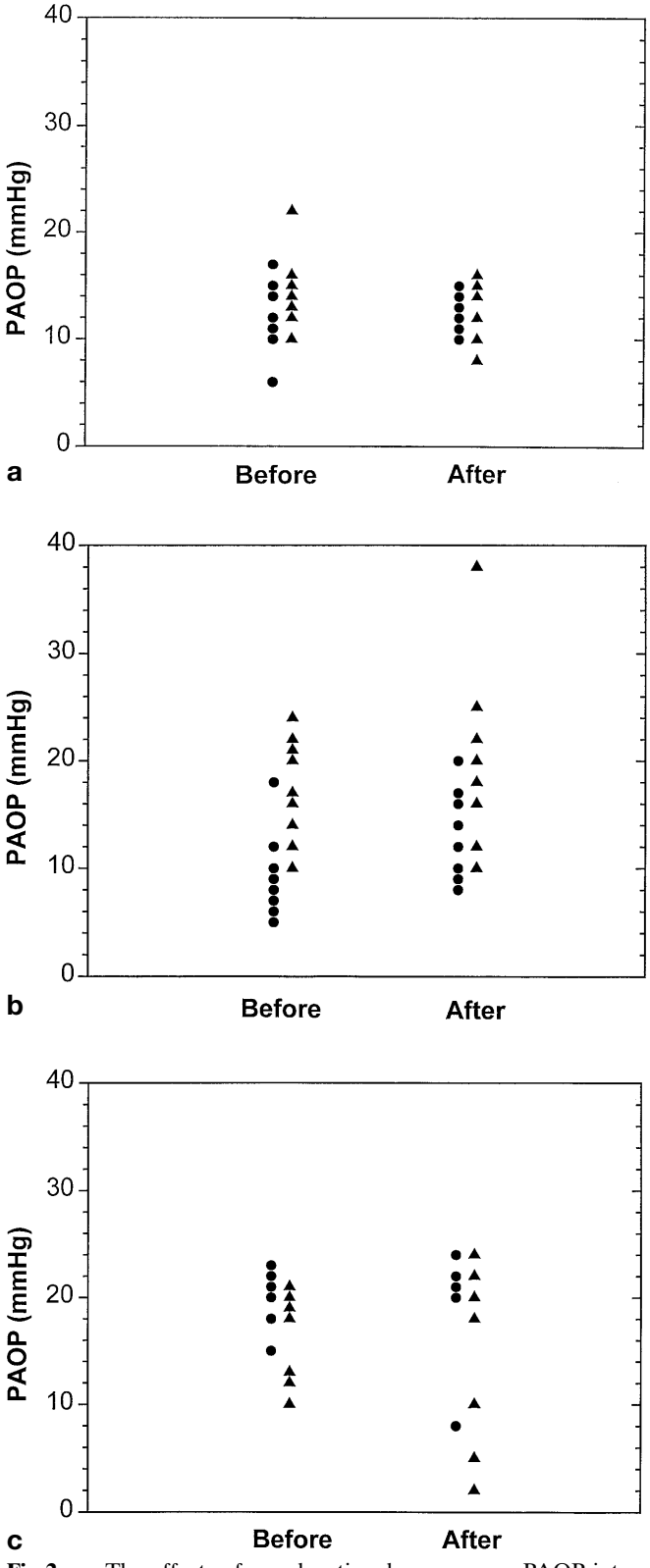

Fig. 2 a–c The effects of an educational program on PAOP interpretation; *circles* nurses readings; *triangles* physicians

Table 1 Differences of PAOP interpretation as compared to that of the Chief of Critical Care

Tracing	Nurses Before In-service	Nurses After In-service	Physicians Before In-service	Physicians After In-service
1A	1.7 ± 0.3	1.4 ± 0.3	1.9 ± 0.6	1.5 ± 0.4
1B	1.9 ± 0.4	3.4 ± 0.7	6.8 ± 1.1	7.9 ± 1.6
1C	2.0 ± 0.3	1.9 ± 0.8	5.1 ± 1.0	4.8 ± 1.4

Table 2 Differences of PAOP interpretation as compared to combined pre- and post-in-service population mean PAOP values

Tracing	Nurses Before In-service	Nurses After In-service	Physicians Before In-service	Physicians After In-service
1A	1.7 ± 0.3	1.4 ± 0.3	1.9 ± 0.6	1.5 ± 0.4
1B	5.0 ± 0.4	4.1 ± 0.5	4.8 ± 0.6	5.7 ± 1.2
1C	1.5 ± 0.2	2.8 ± 0.6	3.3 ± 0.8	3.9 ± 1.2

for the group as a whole or for subgroups of nurses versus physicians. In fact, nurses identified the PAOP within 4 mmHg of the Chief's value in 21 of 23 readings (91 %) before and in 11 of 16 readings (69 %) after the in-service. Physicians' variability also did not change significantly (6/18 within 4 mmHg before and 5/18 after the in-service).

For the tracing with large RPV in a nonventilated patient, group performance was not significantly affected by the in-service (mean 19 ± 5.2, range 2–24; Fig. 2C). There was no significant change in the magnitude of deviation from the Chief's value of 22 mmHg or group mean value of 19 mmHg (see Tables 1, 2), for the group as a whole or for subgroups of nurses versus physicians. All but one nurse identified PAOP within 4 mmHg of the Chief's value both before and after the in-service; 12 of 18 physicians (67 %) read PAOP within 4 mmHg before and 14 of 18 (78 %) after the in-service.

As in our first study [6], the magnitude of variability was significantly greater in interpretation of tracings with large RPV (tracings in Fig. 2B, C) than with minimal RPV (tracing in Fig. 2A), despite the in-service.

Administration of the in-service was associated with a short-term reduction in variabilities of PAOP interpretation in the small cohort of surgical intensive care unit nurses ($n = 6$) who received it. Overall, combining differences from the reference values for this small cohort of observers, differences were reduced by half after the in-service (from a mean difference of 3.6 before to 1.6 mmHg from Chief's values and 3.3 to 1.3 mmHg from the population means, $p < 0.05$). Six of 21 observations were 5 mmHg or more from reference before the in-service and no observations were 5 mmHg or more from reference after the in-service. The sample was too small to analyze performance on each tracing independently.

Discussion

This study demonstrates that variability of interpretation of PAC pressure tracings was not significantly improved, in a sustained manner, after the presentation of a short educational program that had been created specifically to improve recognition of end-expiration on PAOP tracings. The administration of the in-service was, however, associated with a short-term reduction in observational variability among a small cohort of nurses.

There are several possible explanations for these findings. First, the in-service could have been inadequate. The content of the verbal portion of the program essentially reiterated all of the points listed in "Appendix 1," and the way in which to read tracings with large RPV was reviewed with similar tracings. Since administration of the in-service was associated with a marked short-term reduction in variability of PAOP interpretation, the problem is unlikely due the content of the in-service. The second possibility is that, although the materials may successfully change interpretation of PAOP in the short term, the acquired skills do not endure. The individuals may simply revert to their old practice techniques over time. We would suggest that the effort which we put into this in-service was relatively routine; when a practice problem is noted in most ICUs, educational programs of similar scope are frequently administered to improve performance. Our data suggest that to reduce variability in PAOP interpretation in a more sustained manner, repetitive and/or more comprehensive programs may be required. Finally, it is possible that both the initial degree of variability and failure to improve interpretation of PAOP tracings could be related to either institution- or personnel-specific factors. Thus the validity of these results outside this specific cohort of practitioners remains unclear.

Of particular interest is that we again found that the degree of respiratory phasic variation in the PAOP is highly associated with the variability in interpretation by clinicians. Our previous study [6] suggested that difficulty in defining end-expiration in such tracings is most likely responsible for this finding, and our in-service was designed to address this likely explanation. One might argue that our respondents were disadvantaged by their inability to watch the patient and observe which portion of the PAOP waveform corresponded to end-expiration. This argument is certainly appropriate for the tracing in Fig. 1B, where there is significant RPV, and inspiration and expiration are of similar duration. In fact, one might argue that the value recorded by our Chief of Critical Care (10 mmHg), which served as a reference value, was itself an error (violating the decision rule in the "Appendix"). Even if a reference value of 20 mmHg is chosen (in adherence to the in-service), group variability was not significantly reduced by this intervention. Regardless, similar tracings (i.e., those with large RPV and inspiratory:expiratory ratios approaching 1.0) require simultaneous bedside observation of the patient and tracing to correctly identify end-exhalation on the tracing. However, for the tracings in Fig. 1A and C, we would argue that there should be very little variability in interpretation of PAOP, since end-expiration on those tracings is relatively obvious. Nonetheless, one of the most important lessons of this study, which cannot be measured in a paper test, is the importance of observing PAOP tracings *and* patients' respirations to assure that end-expiration is identified correctly. One may also argue with the use of any one observer as a reference standard (in this study we used our ICU Chief's interpretation, since his method was used to design the in-service). However, even when observations were compared to group mean values of PAOP, the in-service failed to affect a reduction in variability of PAOP interpretation. Tracings with large RPV are quite common in critically ill patients, and it is clear that any educational program designed to improve clinicians' performance in interpreting these data must address this question (better than did our educational materials).

The American Thoracic Society Task Force on the PAC has recently completed drafting a comprehensive, educational program, which will soon be published, designed to improve user proficiency in all aspects of PAC (www.thoracic.org/assemblies/cc/cc.html). Obviously, appropriate management decisions are dependent upon careful and accurate use of this device. Moreover, future prospective studies designed to determine the effects of PAC on patient outcomes must presuppose a standardized, reliable approach to interpretation of the pressure data to reduce the likelihood that variability of interpretation significantly impacts the observed results. Thus it is imperative, before such a study and to improve care of those critically ill patients currently undergoing PAC, to educate clinicians and document a reasonable degree of agreement among observers who use the PAC. Our data suggest that a single, educational session, is unlikely to achieve this goal, and suggest that sustained improvement requires a more robust and/or more prolonged program than that studied here.

Appendix

Thank you for participating in our recent study to examine the interobserver variabilities in interpretation of pulmonary artery occlusion pressures (wedge pressures). The study was well received and will be published in the *American Journal of Respiratory and Critical Care Medicine*. It demonstrated that the degree of variability in measuring wedge pressures was the same (*and not very good*) for both physician-physician comparisons and for physician-nurse comparisons. We found that the tracings which lead to the greatest disagreements occur when there is large variability in the PAOP pressures, usually due to the effects of respiration on intrathoracic pressure. We also found that 20–30 % of tracings in which nurses recorded a wedge, either one or both physicians believed the Swan was either over- or underwedged. Several professional societies are designing educational programs to help teach nurses and physicians to perform these measurements properly. As you know, a large study suggested that Swan Ganz catheterization was associated with worse patient outcomes even after carefully adjusting for the severity of illness [1]. Some of us believe that improper measurements may lead to therapies which inadvertently harm patients; so it is very important that we all learn to read wedge pressures well. Again, nurses were just as good at it as Dr. Zarich (chief of cardiology) and I (chief of critical care). This is not a nursing problem, it is everyone's problem. We all need to sharpen these skills. So, a few teaching points:

- The cursor method employed by nurses is extremely accurate and reproducible. However, we should, record a paper tracing every shift, to be included in the chart with your simultaneous cursor reading, to help calibrate and allow retrospective quality checking. Remember, the patient must be leveled in order to measure the correct wedge.
- We should get in the habit of inflating the balloon very slowly; stop injecting as soon as the wedge is recognized and leave it wedged for no more than 10–15 s. The proper wedge tracing can be recognized because it is lower than the pulmonary artery diastolic pressure and the tracing looses the contour (dicrotic notch etc.), or "smooths out," compared to the pul-

monary artery tracing. If the balloon is inflated and the tracing pressures are higher than pulmonary artery diastolic pressure the Swan is likely overwedged; if there is little change in the tracing compared to the pulmonary artery, it is likely underwedged and those values should not be recorded until working with cardiology/pulmonary to assure agreement about the accuracy of the tracing.

– The correct pulmonary artery occlusion (wedge) pressure is measured *at end-exhalation*. The problem is that when patients are breathing vigorously (on or off the ventilator), large variations of pressures can occur between inhalation and exhalation. In addition, some patients (usually patients with obstructive lung disease) can use their respiratory muscles to increase their intrathoracic pressure at end-exhalation thus overestimating the true left heart filling pressure. When there are large variations in the wedge, we all must learn to recognize end-exhalation. The classic teaching is that when a patient is off the ventilator, the peaks of the wedge are the best estimate of end-exhalation and when the patient is on the ventilator the troughs should be used. As a general rule, this is *one* criteria to employ in recognizing end-exhalation in patients with large variations. Unfortunately, some patients on mechanical ventilators can work very hard on inhalation to reduce their intrathoracic pressures and thus end-exhalation, in them, is actually the peaks. The second way to assure you are correctly identifying exhalation is to use a basic principle: exhalation is always longer than inhalation (in both ventilated and nonventilated patients since we do not use inverse ratio ventilation here). So, if you see large negative deflections in the wedge of a ventilated patient which seem to correspond to inhalation and then you see the tracing go up and level off for a longer period, this is most likely end-exhalation. A third test is to actually watch as you're wedged and simply see what part of the tracing most closely corresponds to the end of the patient's exhalation. If you feel that the patient is still trying to exhale at end-exhalation, they are likely using abdominal muscles to raise their "true" wedge and you should note next to your recorded wedge that you feel this is the case.

Some tracings can be very difficult. Whenever there is a question please ask/create physician-nurse consensus about where to measure the wedge. This is important; in some patients it can make the difference between giving more furosemide or giving fluid and this can obviously effect outcomes!

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