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Ventilation for Life

Ventilator Waveforms: An Example of a Structured Approach to Analysis

You are evaluating the results of an arterial blood gas sample. Immediately you begin a process of sorting out the data in a step-by-step fashion. The pH is alkalotic. The arterial carbon dioxide tension ($PaCO_2$) is reduced. The arterial oxygen tension (PaO_2) is reduced. In your mind you have not only "classified" this acid-base problem, but you have probably also identified some possible causes for the abnormalities and have begun to consider some possible solutions.

The same situation occurs when looking at a static 12-lead electrocardiogram (ECG) or a dynamic ECG rhythm. There is an organized process of identifying the p-wave, the QRS complex, and the t-wave. There is then a step-by-step method of evaluating the relationship between the various portions of the tracings.

The release of graphic packages with mechanical ventilators has allowed the bedside clinician the opportunity to better evaluate how the ventilator is interacting with the patient. An inappropriate flow-rate setting can lead to increased work on the part of the patient or could potentially lead to the development of pulmonary barotrauma.

Unfortunately, many respiratory therapists haven't had graphical analysis as part of their initial orientation to ventilators or as part of the respiratory care curriculum in school. This has necessitated that RTs learn new material and develop new analysis skills in order to use the technology more effectively. Additionally, when presented with a graphical display of ventilator pressures and flows, many RTs are overwhelmed by all that they see and haven't developed a step-by-step approach to interpreting what they see.

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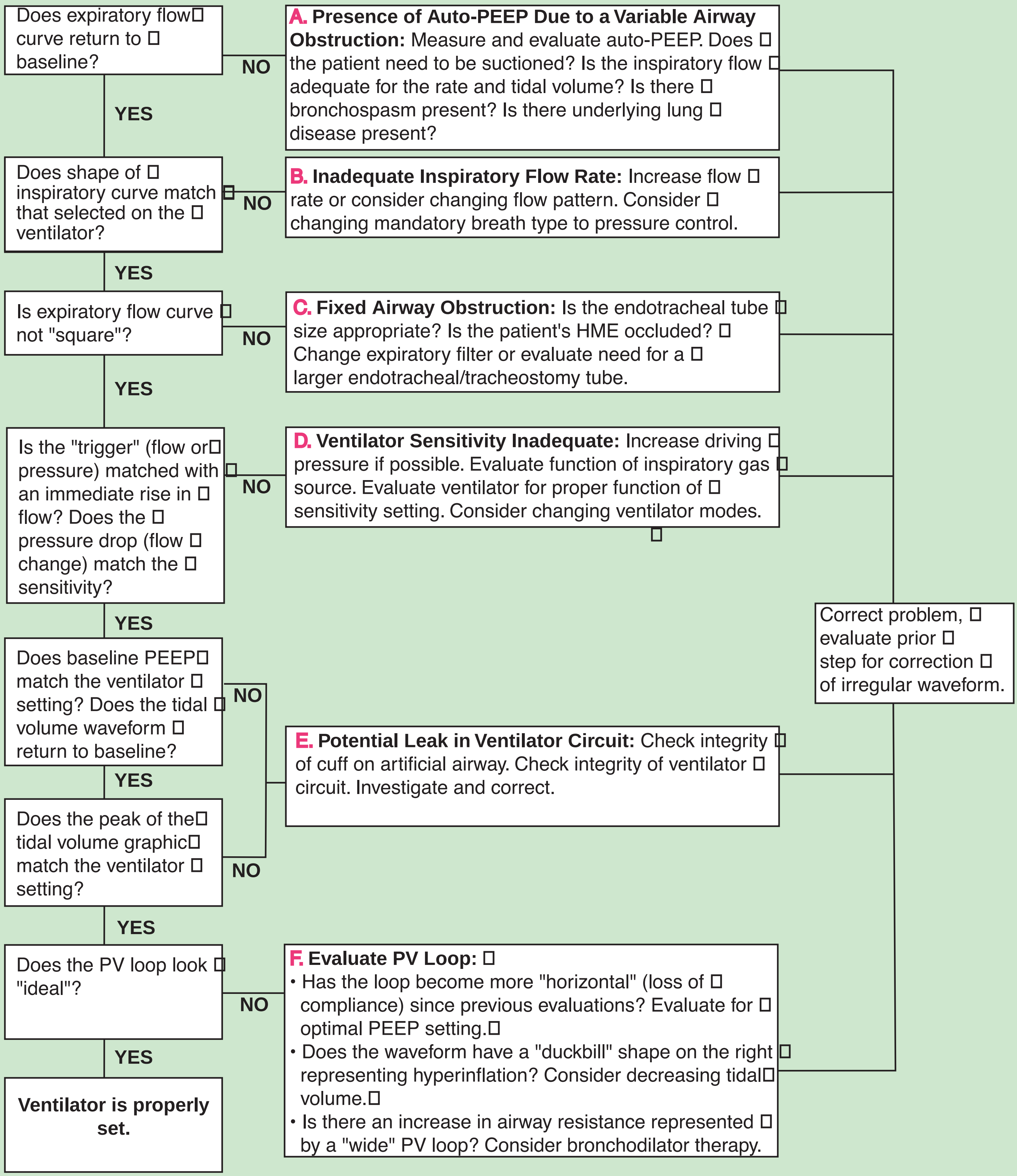
Example of a structured approach

The algorithm in this article outlines an example of a structured method for analysis of a ventilator waveform and helps determine when the ventilator is set inappropriately for the patient at that point in time. Since it forces the user to evaluate the graphical display in a prearranged fashion, the clinician is not intimidated by the display. The algorithm also allows for the evaluation of how the ventilator is interacting with the patient, instead of just documenting a particular parameter's "number."

The algorithm requires that the ventilators have a graphics package available, and it assumes that the user knows how to change from one graphic display

Patient on mechanical ventilator with graphics package



to another. The first part of the algorithm asks a series of questions; and if the answer is "yes" to all questions, the ventilator is deemed to be set appropriately. If any question is not answered affirmatively, the clinician is directed to a second part for further analysis and correction of potential problems before continuing on down the algorithm.

Let's take a closer look at the algorithm's analysis of how the ventilator is working with the patient to deliver a mechanically ventilated breath.

1. *Does expiratory flow curve return to baseline?* A display of flow versus time allows the clinician to evaluate a few things. Looking at the expiratory portion of the flow curve (that part that is below the baseline) helps to determine if adequate time is present for exhalation. If the curve does not return to baseline, there is an inadequate time for exhalation and some auto-PEEP (positive end-expiratory pressure) is present. Section A indicates some clinical reasons for this problem and suggests some interactions that might remedy the situation.

2. *Does shape of inspiratory curve match that selected on the ventilator?* If the patient is on a decelerating ramp-style flow pattern, the inspiratory portion of that flow curve should resemble that shape (a rise to the preset peak flow rate and a gradual linear descent to baseline). If the shape is different from that preset shape, it means that the set peak flow rate is inadequate and patient is attempting to draw additional flow. Section B offers some suggestions for correcting this problem.

3. *Is expiratory flow curve not "square"?* Although grammatically incorrect, it allows for the algorithm to continue in a downward fashion. If the expiratory flow curve is square in shape, it means that there is a fixed maximum amount of flow that can go through the system. As Section C outlines, this is typically a result of a fixed airway obstruction, which in a mechanically ventilated patient is usually the result of an inappropriately sized artificial airway or a blocked heat and moisture exchanger (HME)/filter.

4. *Is the "trigger" (flow or pressure) matched with an immediate rise in flow? Does the pressure drop (flow change) match the sensitivity?* This question requires that the display be changed to allow for both the pressure-versus-time and flow-versus-time waveforms to be simultaneously displayed. The waveforms are then evaluated to verify that the triggering mechanism (changes in pressure or flow) are matched by an immediate initiation of the breath (that is, flow being delivered to the patient). Section D identifies causes and solutions for this problem.

5. *Does baseline PEEP match the ventilator setting? Does the tidal volume waveform return to baseline?* The first question requires analysis of the pressure versus time graphic. The second requires analysis of the volume versus time graphic. Both identify problems with ventilator circuit leaks, and Section E helps the user to correct the problems.

6. *Does the peak of the tidal volume graphic match the ventilator setting?* This question is similar to the previous one but identifies problems with the inspiratory breath being delivered. Section E is used to identify and correct problems.

7. *Does the pressure volume (PV) loop look "ideal"?* This step requires that the user change the graphical display to show a pressure-volume loop. An "ideal" waveform is one which shows a gradual rise in pressure to the peak pressure (that is, delivered tidal volume) and then a gradual return to baseline. It has a characteristic shape like that of a football with the origin being zero on the pressure and volume scales. As Section F outlines, any alteration from that "ideal" (especially over time) indicates a change in the compliance or resistance of the patient's lungs.

Evaluation of how each breath is being delivered and the response of the patient to mechanical ventilation may lead to early recognition of potentially hazardous situations.

If each of the questions are answered "Yes," the patient-ventilator interface has been evaluated and the settings are appropriate for that patient at that point in time.

Waveform analysis augments care

Graphical analysis is a component of ventilation that allows the bedside clinician to determine if the ventilator is properly set for the needs of the patient or if there has been a change in the patient's condition that warrants some sort of intervention. Although physiological parameters (arterial blood gas values, pulse oximetry, capnography, blood pressure) may give an indication that something is wrong, evaluation of how each breath is being delivered and the response of the patient to mechanical ventilation may lead to early recognition of potentially hazardous situations.

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ADDITIONAL READING

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