BEDSIDE ASSESSMENT OF THE MECHANICALLY VENTILATED PATIENT I:

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Mechanical ventilation is the most common intervention in all of Critical Care and the implementation of it has blossomed in an exponential fashion. This can be attributed in large part to advances in medical and surgical therapeutics, the expansion of Critical Care as a required discipline and the continuing growth and evolution of evidence based Respiratory Therapy.

The management of the patient receiving mechanical ventilation calls for an experienced and practiced hand. There is no substitute or replacement for the informed, competent and compassionate Respiratory Therapist at the bedside and our profession must remain the vanguard of current thought and practice in all facets of it. It is essential that every patient being mechanically ventilated be assessed on a continuing basis. It is also essential that the information gleaned from patient assessments be clinically applied in the form of evolving treatment and care plans.

My intention is to briefly comment on those aspects of the assessment of the mechanically ventilated patient that are indispensable both in their clinical utility and significance to patient care. I must apologize as there is inadequate space to give every aspect of the assessment process fair and complete treatment.

Our profession must remain the vanguard of current thought and practice in all facets of mechanical ventilation.

Classic assessment technique begins with an observation of the patient-ventilator system. Observations start with the patient and progress towards the mechanical ventilator. Use your eyes and hands to inspect the artificial airway for signs of compromise or excessive dermal pressure on the surrounding tissue. Use your eyes and your hands to palpate and observe air movement. As much as possible palpate for equal and bilateral movement in a descending bi-lateral fashion. Examine the patient-ventilator system for any malfunction and act to correct it.

Auscultation is an essential skill and vital physical assessment practice and the auscultation of the patient restores the art and compassion in the assessment process. Auscultation both connects the therapist and patient and communicates on an intimate level the physical reality of the patient's experience of mechanical ventilation. Auscultation gives the therapists a real time experience of the patient ventilator system and the tidal changes within that system.

Auscultation should be performed with stethoscope placement in a bilateral descending fashion. One must note the phase of the breath, breath type and auditory character of any sound must be noted in some detail. The documentation of the auscultation of the patient requires one to create a narrative depiction of an auditory phenomena knowing that this physical finding may transform on a breath to breath basis.

The purpose of the lungs is gas exchange and the purpose of mechanical ventilation is to facilitate the movement of gas into and out of the lungs for those who are unable to support their metabolic requirements. I am assuming a reasonable familiarity with blood gasses by the reader and will comment on an essential use of the blood gas for assessing mechanically ventilated patients, The PaO2/FiO2 index or, (P/F ratio). The PaO2/FiO2 index quantifies the ratio of arterial oxygen tension to available oxygen concentration. It is an indispensable articulation of the degree compromise of cardiopulmonary function. The PaO2/FiO2 index is also valuable indicie of diffusion capability and a primary tool in assessing the degree of injury to the lung. Low diffusion states will have a low ratio of arterial oxygen in relation to a given FiO2. The PaO2/FiO2 index acts to identify the severity of lung injury. If the PaO2/FiO2 index is < 300 strongly suspect Acute Lung Injury. (ALI). If the PaO2/FiO2 index is < 200 strongly suspect Acute Respiratory Distress Syndrome. (ARDS) The PaO2/FiO2 Ratio is an excellent predictor of mortality and an essential tool in assessing the mechanically ventilated patient.

The measurement of Plateau Pressure (PPLAT) is one of the most indispensable values we can determine. Plateau Pressure (PPLAT) is the pressure measured at the end of inspiration during an inflation hold during volume

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"Don't wait up, honey. My lawyer just informed me I'll be 5 to 10 years late."

targeted ventilation or the pressure at the end of a fully equilibrated breath when pressure cycling is employed.

In all methods of ventilation the inflation hold must be sufficient to allow inspired gas to equilibrate in regions of the lung with incongruous time constants. This inflation hold allows inspired gas to equilibrate in regions of the lung with incongruous time constants. The mindful clinician will note that the equilibration of regional lung units is necessary to create a stable Pplat. A decaying pressure profile is reflective of erratic; non-homogenous regional time constants and tissue viscance.

PPLAT is the pressure required to counterbalance end inspiratory forces and is related to the static end inspiratory elastic recoil pressure of the total respiratory system. Airway pressure measured during an end inspiratory occlusion replicates the elastic threshold stress to the pulmonary system sans the inevitable resistive forces present during active inspiration. PPLAT faithfully approximates alveolar pressure and as such is a very useful clinical assessment tool.

Elevated PPLAT will alert the clinician to increased alveolar pressure. Incremental changes in PPLAT are inversely related to lung compliance. An increase in the plateau pressure signals a fall in the global lung compliance. Indeed, a PPLAT of 35 cmH_2O represents the normal peak alveolar pressure necessary to reach TLC. It has been suggested that PPLAT equal to, or in excess of that needed to reach TLC would facilitate lung injury or impede efforts to ventilate the already hyper-inflated lung.

Plateau pressure is needed to calculate total lung compliance as the relationship between PPLAT and delivered volume. This lung and chest wall compliance is derived in the following manner. $Cl = Vt / (PPLAT - PEEPtot)$. The difference between Peak Airway Pressure and PPLAT is a function of resistive forces in the patient ventilator system. Raw is calculated by looking at the pressure gradient between the peak airway pressure and the plateau divided by the flow. $Raw = PAP - PPLAT / Flow$ *(L/sec.)*

In the context of global lung assessment it is important that we remain cognizant of the reality that variations in Pplat may be present throughout the lung field. Although we must be aware in a conceptual sense of the very regional nature of Pplat, we must treat the lung globally and fashion a ventilation strategy aimed toward producing the lowest possible Pplat.

The calculation of the pulmonary time constant is essential in determining the tidal cycle indispensably important for avoiding dynamic hyperinflation and ventilator induced or associated injury. The Pulmonary Time Constant (TC, Kt), is the product of the airways resistance times the static lung compliance in seconds that will allow for 63% of transferred volume to equilibrate. The time constant will fluctuate in response to changes in resistance and compliance. Time constants may vary regionally.

Gas moves into and out of the lung at a rate and in a fashion that is conditioned by the collective impedance of individual lung units. Lung units with high compliance will have a longer time constant; as will lung units with high airways resistance. Conversely, lung units with low compliance and low airways resistance will have a shorter time constant. The time constant of any individual lung unit may alter with the phase of ventilation and will vary with changes in the patient-ventilator system. The time necessary for the lungs to passively fill 63% during pressure controlled ventilation with a rectangular pressure waveform. Three to five time constants are required for adequate pressure equilibration within the patient-ventilator system. Think regionally and treat globally.

The Rapid Shallow Breathing Index (RSBI), is an extremely reliable predictor of a patient's potential for

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success in the weaning process. The clinician evaluates the patient's breathing patt

ern by analyzing the relationship linking breathing frequency and average tidal volume. The RSBI is an accurate forecaster of the patient's ability to perform endurance related work and assume the work of breathing when extubated.

The RSBI is calculated as the spontaneous frequency divided by the average spontaneous tidal volume in Liters, (f/VT). The patient is evaluated while breathing spontaneously without inspiratory adjuncts such as PSV. An index of less than 100 is a predictor of weaning success while an index of greater than 100 suggests probable weaning failure.

The current and informed caregiver will know that the gold standard for predicting weaning success in the Spontaneous Breathing Trial or, (SBT). The SBT is performed by allowing the patient to breathe with a minimal level of Pressure Support or flow-by while monitoring their Rapid Shallow Breathing Index, Work of Breathing and hemodynamic parameters. A successful SBT of 30-120 minutes indicates a patient's potential to maintain adequate ventilation when extubated.

Peak Airway Pressure, (PAP/PIP), is the maximum airway pressure recorded during an inspiratory cycle. This maximum or extreme pressure is usually actualized at the end of inspiration. This pressure reflects the collective result of machine and patient variables and is dynamic in character. The extreme pressure at the end of volume delivery is subject to an extensive number of variables and has limited clinical utility in and of itself. Mean Airway Pressure is a much better assessment tool.

Mean Airway Pressure, (mPAW), is the average airway pressure during one complete ventilatory cycle or the area under the pressure-time curve for one breathing cycle divided by cycle time. The mean airway pressure (mPAW) recorded under passive conditions is the only indicator of the mean alveolar pressure. mPAW is directly related to the mechanisms that enhance ventilation and stabilize the lung field. mPAW is directly related to PEEP and influenced by PAP, inspiratory time and inspiratory flow.

The Pressure Volume curve is an essential tool in evaluating the mechanically ventilated patient. However, this most indispensable of assessment methods requires specialized knowledge and instrumentation. The P-V is of such importance it bears special mention. The PV curve is a composite of information from numerous lung units whose contours are fashioned by the pressure-volume relationships of units at discrete points of distension. There are three different zones of interest over the volume-pressure, (V-P) curve: the first at low lung volumes is a Lower Inflection Point, (LIP), is detected, the second where the V-P curve is linear, and the third where the V-P curve becomes flatter because of the reduction of static compliance at high lung volumes; the Deflection Point or Upper Inflection Point, (UIP).

The LIP is thought to correspond to the opening pressure of most of the small airways, which were collapsed during the previous deflation and progressively recruited during the initial part of the current inflation. In mechanically ventilated patients, the V-P curves of the respiratory system are very useful because their computation can help the clinician to set the appropriate PEEP and Vt on the ventilator in patients with ARDS. PEEP should be maintained to surpass the lower inflection point of the inspiratory PV curve when high end-inspiratory (plateau) pressures are in use. Some suggest that an expiratory PV curve has more theoretical interest as a means of setting PEEP.

The linear part of the V-P curve is the part with maximal compliance of the respiratory system. The UIP is usually thought of as the point at which the air-filled lung units become overdistended and the potential for alveolar stretch and injury is greatest.

The inflation V-P curve may be used to quantify the alveolar recruitment achieved with PEEP. It has been demonstrated that alveolar reopening continues on the linear part of the V-P curve. The UIP may indicate that recruitment has ceased during inflation, and does not necessarily indicate only overdistention. Be mindful that alveolar recruitment and derecruitment are continuous processes occurring along the entire inspiratory and expiratory V-P curves.

The continuous assessment process is an essential standard for the proficient care of our mechanically ventilated patient population. Vigilant assessment will enhance patient safety, clinical efficacy and expedite liberation from mechanical ventilation. In addition to facilitating the weaning process competent assessment will act to prevent Ventilator Associated or Induced Lung Injury and decrease incidence of Ventilator Associated Pneumonia.

Perhaps the least discussed and most important aspect of the assessment process lies in the connection we as clinicians make with our patients. I t has been documented elsewhere that patients who are "touched" with greater frequency have greater outcomes. This connection on a very human level is essential for both patient and caregiver. **The stated intent of our endeavor is two-fold, to assuage suffering and to heal the patient. It is to those intentions and to those ends that we must focus our attention in the form of advanced assessment skills.**