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Troubleshooting of Nursing Practice for Mechanically Ventilated Patients

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***Abstract*: In a wide variety of settings, nurses are increasingly likely to care for patients on mechanical ventilators. Let's assume you're one of them. What do you need to know to plan your shift? Which patient assessment parameters are crucial? What evidence-based practice guidelines should you follow? To troubleshoot problems with mechanical ventilation (MV) means to respond urgently and appropriately to signs of respiratory distress and/or ventilator malfunction, and to correct the cause of the problem while maintaining ventilation and adequate oxygenation. For general information about patient monitoring during mechanical ventilation, see Nursing Practice & Skill…Mechanical Ventilation in the Adult: Monitoring, Nursing Practice & Skill…Mechanical Ventilation in Children: Monitoring and Nursing Practice & Skill…Mechanical Ventilation in the Neonate: Monitoring**

***Keywords:* Mechanical Ventilator, Nursing Practice, Troubleshooting.**

Abbreviations:

ETT	Endotracheal Tube	ACLS	Advanced Cardiovascular Life Support
MV	Mechanical Ventilator	ARDS	Acute respiratory distress syndrome
Pplat	limiting plateau pressure	ABCs	Airway, Breathing, and Circulation
VILI	Ventilator-Induced Lung Injury	BLS	Basic Life Support

1. INTRODUCTION

Mechanical ventilation is a cornerstone in the management of patients with acute respiratory distress syndrome (ARDS) [1]. We now know that mechanical ventilation per se can aggravate lung injury, a process referred to as ventilator-induced lung injury (VILI), through several mechanisms including volutrauma, barotrauma and biotrauma. Dynamic lung distension and repeated opening and closing of recruitable lung units are considered the two main mechanisms contributing to lung injury. The lung protective ventilation strategy using low tidal volume and limiting plateau pressure (Pplat) has been proven to improve survival in patients with ARDS in a large randomized controlled study and was confirmed in a meta-analysis[2]. Current research still suggests that further reducing ventilator-associated or -induced lung injury is the main avenue to further reduce mortality in this syndrome. A mechanical ventilator is a highly complex device equipped with alarms (e.g., high-pressure, low-pressure, disconnection) that alert the clinician when a problem is affecting the normal functioning of the ventilator. While not all alarms indicate a serious or persistent problem, the patient's condition must be assessed immediately and the cause of the sounding of an alarm promptly investigated to maintain patient safety and prevent life-threatening respiratory compromise[3].

Troubleshooting potential problems with MV involves understanding the potential causes of these alarms, discerning potential causes and their severity, and responding accordingly. In addition, troubleshooting involves responding to problems that directly involve the patient (e.g., pneumothorax, biting on the endotracheal tube [ETT], self-extubation), and making sure that the patient receives adequate ventilation until the problem is resolved[4].

MV is used most frequently in the ICU and less frequently in other settings (e.g., long-term care facility or in the home). Nurses, respiratory therapists, and physicians collaborate to troubleshoot and correct problems with the ventilator or patient. Assistive healthcare personnel can contribute to this process by alerting a nearby clinician if a ventilator alarm sounds or if the patient appears to be in distress. The desired outcome when troubleshooting problems with MV is to rapidly identify and remedy the problem, while providing adequate ventilation and maintaining oxygenation until MV can resume. Mechanically ventilated patients are intubated and often sedated and cannot vocalize issues affecting their ventilation. Intensive monitoring of the patient and of alarms that are triggered by the mechanical ventilator is crucial for proper functioning of the device and continued respiratory support[5].

2. FACTS AND FIGURES

Prone positioning during MV requires a team of highly trained, experienced healthcare clinicians to monitor for and rapidly respond to signs of airway compromise in patients who are unable to self-report. In a recent meta-analysis, prone positioning was found to significantly improve mortality in mechanically ventilated patients with acute respiratory distress syndrome (ARDS) but increase risk for serious airway problems[6]. Adverse events associated with prone positioning included unplanned extubation, ETT obstruction, and displacement of the ETT into the main bronchus. Muscle weakness and symptomatic aspiration are two conditions associated with mechanical ventilation over a longer period of time. A study found that muscle weakness was a predictor of aspiration and found that a manual muscle test could help identify patients at risk. Investigators of a study in Iran found that the use of nature-based sounds for ventilator-assisted patients decreased anxiety and promoted relaxation. In patients who were sedated it led to a deeper level of sedation and was found to be a safe complementary treatment that could be applied by clinical nurses[1].

3. KNOWLEDGE OF INDICATIONS FOR AND IMPORTANCE OF TROUBLESHOOTING PROBLEMS WITH MECHANICAL VENTILATION

•See What is the Desired Outcome of Troubleshooting Problems with Mechanical Ventilation, and Why is Troubleshooting Problems with Mechanical Ventilation Important?, above ›Competence in physical assessment skills and in basic life support (BLS) and advanced cardiovascular life support (ACLS) techniques[7].

•Assessment of the patient is an essential part of troubleshooting. When responding to alarms or other signs of ventilatory compromise, patient assessment should be the first measure taken. The clinician should focus on the patient's ABCs(Airway, Breathing, and Circulation) while troubleshooting[2].

•For detailed information about the assessment of mechanically ventilated patients, see Nursing Practice & Skill … Mechanical Ventilation: Patient Assessment ›Knowledge of the basic principles of mechanical ventilation, modes of operation, and common terms[8].

•MV is delivered using one of two control variables: Volume-Controlled(VC), based on tidal volume (TV, i.e., the total amount of air delivered during inspiration) and Pressure-Controlled (PC), based upon peak inspiratory pressure (PIP, i.e., the maximum pressure achieved during inspiration) –Whether volume-controlled ventilation or pressure-controlled ventilation is used is largely dependent upon the equipment that is available, the patient's condition, and clinician preference. Pressure-controlled ventilation is currently used more frequently than volume-controlled ventilation in adults because it allows the tidal volumes to vary based upon changes in the patient's lung compliance, which reduces the risk of excessively high airway pressures that can lead to pulmonary injury[9].

•Terminology used to refer to how breathing is triggered and controlled include: –Mandatory – refers to the delivery of mechanical breaths that are controlled solely by the mechanical ventilator –Assisted – refers to breaths that are triggered by the patient but controlled by the ventilator –Supported – refers to breaths that are triggered by the patient but controlled and supported (e.g., with additional pressure) by the ventilator –Spontaneous – refers to breaths that are initiated and controlled by the patient without any assistance from the ventilator[3].

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•The three basic methods of MV are continuous mandatory ventilation (CMV), assist-control (A/C), and intermittent mandatory ventilation (IMV). Any of these modes can be delivered using VC or PC –Continuous mandatory ventilation (CMV): in this mode, an automatic mechanical breath is delivered at a preset volume/ pressure irrespective of the patient's breathing patterns. This is appropriate for patients who are chemically paralyzed, apneic, or undergoing general anesthesia –Assist-control (A/C): in this mode, a mechanical breath is delivered at the present volume/pressure when the patient takes a spontaneous breath. If a spontaneous breath is not taken, the ventilator will deliver an automatic breath at the preset settings –Intermittent mandatory ventilation (IMV): in this mode a preset number of mechanical breaths are synchronized with the patient's spontaneous breaths and delivered at the preset volume/pressure[10].

•Prescribers generally indicate the ventilator mode by writing first the control variable (PC or VC) followed by the mode. For example, PC-CMV indicates that the patient is to receive pressure-controlled continuous mandatory ventilation Additional MV settings include: –Rate: This refers to the respiratory rate, which may be programmed by the rate/timing of inspiration (I), expiration (E), and/or the ratio of the two (I/E) –Positive end-expiratory pressure (PEEP): This refers to airway pressure that is applied at the end of expiration but before inspiration, in order to keep the alveoli open and permit improved oxygenation. PEEP is measured by noting the airway pressure reading at the end of expiration. Prescribed therapeutic levels range between 10–35 cm H20 –Sigh: This refers to a large mechanical breath that is programmed to occur periodically, and it mimics the physiologic sigh that would naturally occur in a spontaneously breathing individual –Pressure support: This refers to supplemental inspiratory pressure that can be used with any mode of MV. Adding pressure support improves tidal volumes in patients who have weak respiratory muscles and who cannot draw in a deep enough breath on their own. Prescribed therapeutic levels range been 5–30 cm H20 ›Familiarity with the common ventilator alarms and their potential causes[11].

•MV alarms signal that there is a problem with the pressure, volume, or rate of air being delivered to the patient. High-pressure and low-pressure alarms have different common causes and remedies; most commonly, alarms sound due to issues with the ventilator tubing (e.g., disconnection) or ETT (e.g., air leak):

- ❖ The first step in responding to a ventilator alarm is to check the patient and, if the patient is in respiratory distress, manually ventilate the patient — then, once the patient is stable, troubleshoot the alarm. Common ventilator alarms include: –High pressure alarm – indicates high resistance to lung inflation and results from any situation that increases pressure in the ventilator tubing, including coughing or laughing, obstructed ETT (e.g., from biting ETT, due to excessive secretions, or due to position of the patient's head/neck), bearing down, agitation/anxiety, initiating respirations out of sync with the ventilator, or bronchospasm. The high-pressure alarm is typically set at 10–15 cm H20 higher than the peak airway pressure. It may be necessary to increase the high pressure alarm limit (as ordered) when the high pressure alarm is triggered by decreased lung compliance –Low pressure alarm/low-exhaled tidal volume alarm –results from any situation that lowers pressure in the ventilator tubing (indicating no resistance to lung inflation), such as accidental extubation, disconnection of the ventilator tubing from the ETT, open tubing ports (e.g., nebulizer ports), or insufficient ETT cuff inflation which can allow air to leak out from around the ETT. It may also be necessary to increase the low pressure alarm limit (as ordered) when the low pressure alarm is triggered by the patient having higher than expected inspiratory effort –High-respiratory rate alarm can occur if the patient is agitated, in pain, inadequately tolerating the MV, or in respiratory distress (e.g., due to excessive secretions) –Apnea alarm–this alarm signals after a preset period of time passes without the patient initiating a breath. It can indicate true apnea or poor inspiratory effort, or can be due to the apnea alarm interval being set for too short a duration (i.e., the patient is initiating breaths at a slower rate than what is programmed into the MV) –Circuit disconnection – this alarm indicates that either the ETT has become disconnected from the MV tubing, or the tubing has become disconnected from the MV[13].
- ❖ Preliminary steps that should be performed before troubleshooting problems with MV include the following: •When MV is first initiated and at the start of each nursing shift, –review the treating clinician's orders for MV –review the patient's medical history/medical record for any allergies (e.g., to latex, medications, or other substances); use alternative materials, as appropriate –perform a physical examination upon receipt of the patient and repeat the examination at least every 1–2 hours during the course of the nursing shift to evaluate the patient's physical condition and connection to the ventilator –verify the ETT is positioned correctly within the trachea (e.g., as confirmed by X-ray) and properly secured –confirm that the patient is sedated and/or restrained, as prescribed/ordered –verify that the

ventilator set-up, including electrical supply and circuitry, is intact –confirm the ventilator/oxygen settings (e.g., mode, respiratory rate, oxygen concentration [FiO2]) are as prescribed –confirm all ventilator alarms are set to "on," and/or programmed according to facility protocols or physician's orders (e.g., respiratory rate alarm settings) •Gather supplies that may be used during troubleshooting: –Gloves (nonsterile and sterile); additional personal protective equipment (PPE; e.g., gown, mask) may be required based on anticipated exposure to body fluids –Bag-valve-mask device for patient resuscitation –Stethoscope and equipment for assessment of vital signs[14].

–Intubation kit, including spare ETT in size appropriate for patient –Cardiopulmonary (EKG/intra-arterial pressure/capnography [EtCO2]/partial pressure [PO2]) monitors –Endotracheal suction apparatus connected to a suction source –Syringe (for deflating/inflating the endotracheal cuff) –Prescribed sedation, restraints, bite block[5].

4. HOW TO TROUBLESHOOT PROBLEMS WITH MECHANICAL VENTILATION

- Perform hand hygiene and apply nonsterile gloves. When performing endotracheal suctioning, use aseptic technique, including use of sterile gloves and other appropriate personal protective equipment (PPE)[15].

- Report immediately to the patient's bedside in response to generated ventilator alarms or clinical signs of patient distress[1].

- Assess the patient's ABCs (i.e., Airway, Breathing, and Circulation) •Check the positioning of the ETT and its connection to the mechanical ventilator tubing •Assess the patient's ventilation – check for equal chest movement. If chest movement is not visualized, auscultate the patient's bilateral lung sounds –If the patient is not being ventilated, call for assistance, disconnect him/her from the mechanical ventilator, and manually resuscitate the patient using a bag-valve-mask device •Evaluate the patient's cardiopulmonary status by checking EKG/intra-arterial pressure/EtCO2/PO2 monitors. This will help determine whether hemodynamic deterioration is the problem ›Once the patient is deemed stable and if an alarm is still sounding, troubleshoot the alarm •In response to a high-pressure alarm, which indicates blockage of the airway/tubing, –check again for equal, bilateral chest movement and breath sounds and check EtCO2 monitor. If abnormalities are found, verify that the airway is patent; the quickest way to do this is to disconnect the patient from the ventilator and manually resuscitate the patient using a bag mask -At worst, a high-pressure alarm can indicate the patient has a tension pneumothorax[16].

- If this occurs, assist with completion of a chest X-ray and placement of a chest tube –evaluate whether the ETT is blocked by secretions; suction the patient to clear secretions from the airway –check whether the patient is biting on the ETT. If so, utilize a bite block and/or administer additional sedation, as prescribed –inspect the ventilator tubing for condensation; clear the condensation into the collection chamber –evaluate whether the patient may have been coughing -Coughing is the most common reason that the high-pressure alarm is generated. If coughing triggers the alarm, the alarm will clear itself after several breaths •In response to a low-pressure or low-exhaled tidal volume alarm, which indicates tubing disconnection or air leak, –verify that the ventilator tubing is intact and that the connections are tight; re-connect and tighten tubing at connections and drainage and access points –check inflation of the endotracheal cuff; re-inflate the cuff, if necessary –verify correct ETT placement and reposition if needed; in case of extubation or displacement, ventilate the patient manually and notify the treating physician immediately •In response to a high-respiratory rate alarm, –evaluate the patient for anxiety, pain, respiratory distress (using method described above), and confusion/agitation; administer anxiolytic, analgesia, and/or sedative, as prescribed, and provide verbal reassurance to the patient –evaluate the ventilator tubing for kinks or accumulated water, which can trigger high-respiratory rate alarms as the water pulses through the tubing; clear condensed water and remove kinks, as needed •Take the following measures in response to an apnea alarm: –Check first that the tubing has not been disconnected from the patient[9].

- This is the most common reason for an apnea alarm. Reconnect the patient to the ventilator, if this is the case –If the apnea alarm has been triggered because the patient has extubated him- or herself, call for assistance, disconnect the patient from the ventilator and begin manual resuscitation –If the apnea alarm has been triggered because the patient is not breathing, call for assistance, disconnect the patient from the ventilator, and begin manual resuscitation ›Once the problem is identified and remedied, reassess respiratory status, level of consciousness/sedation, and comfort level ›Discard used procedure materials and PPE; perform hand hygiene[6].

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❖ Update the patient's plan of care, as appropriate, and document MV troubleshooting in the patient's medical record, including the following information: •Date and time that the problem occurred •The nature of the problem (e.g., high-pressure alarm, tubing disconnection) •How the problem was remedied •The patient's condition prior to and after performing interventions •Patient/family member education, including topics presented, response to education provided/discussed, plan for follow-up education, and details regarding any barriers to communication and/or techniques that promoted successful communication[17].

4.1 Other Tests, Treatments, or Procedures That May be Necessary Before or After Troubleshooting Problems with Mechanical Ventilation

›Chest X-ray may be performed to identify problems with placement of the ETT, to identify pneumothorax, and for verification of chest tube placement[12].

›The mechanically ventilated patient will require hourly reassessment of his/her respiratory and neurological status and evaluation of the mechanical ventilator settings/alarms[3].

4.2 What to Expect After Troubleshooting Problems with Mechanical Ventilation

›The clinician responds urgently and appropriately to ventilator alarms and signs and symptoms of patient distress[1].

›The clinician employs measures to correct problems with MV and implements manual resuscitation until the problem can be corrected[17].

5. CONCLUSION

Troubleshooting potential problems with MV involves understanding the potential causes of these alarms, discerning potential causes and their severity, and responding accordingly. In addition, troubleshooting involves responding to problems that directly involve the patient (e.g., pneumothorax, biting on the endotracheal tube [ETT], self-extubation), and making sure that the patient receives adequate ventilation until the problem is resolved.

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