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Adequate Supply Of Artificial Ventilation Equipment To Hospitals: Risks For Patients

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Abstract

Background: Providing respiratory support to patients in intensive care units is an extremely important measure in the provision of primary and highly specialized medical care.

Objective: Despite improved medical care and the development of new medical technologies, a number of factors remain increasing the risk of respiratory failure.

Method: The authors have analyzed factors that have an influence on the patients' respiratory support provision. And have indicated risks to the patients which appear in less present of the specialized equipment in hospitals of the entire world.

Results: Defective or outdated ventilators, ventilator-associated pneumonia, oxygen station malfunctions, emergencies during the transportation of patients pose a significant danger to patients in need of respiratory support. Many old hospitals need to be repaired, the oxygen stations to be improved, and new emergency plans to be developed to eliminate the risks of sudden power losses or shutdowns of medical air stations.

Conclusions: A number of hospitals around the world need better technical and material support. The authors have grouped and presented these factors in order to minimize them and eliminate in the daily practice of the medical worker.

Keywords: respiratory support, Intensive care unit (ICU), ventilated patient, respiratory equipment.

1. Introduction

Numerous epidemiological studies like by Mehta et al. estimated that in the United States, approximately 310 persons per 100,000 adult population undergo invasive ventilation for nonsurgical indications. Patients requiring invasive mechanical ventilation present 2.8% of hospital admissions which costs 12% of hospital outlays at $27 billion per year [1-2]. The main indications for mechanical ventilation applying are:

(1) airway protection for a patient with a reduced level of consciousness (head trauma, stroke, drug overdose, anesthesia, etc);

(2) hypercapnic respiratory failure due to airway, chest wall, or respiratory muscle diseases;

(3) hypoxemic respiratory failure;

(4) circulatory failure in which sedation and mechanical ventilation can decrease the oxygen cost of breathing.

Mechanical ventilation is part of a global strategy and not a single treatment: sedation management, etiologic treatment, physiotherapy, and prevention of muscle loss are all important considerations in the ventilated patient [3].

1.1. Intensive Care Unit (ICU) Respiratory Equipment [4-5].

- Medical gas pipeline systems – serving for central distribution of the gases inside the hospitals;
- Small liquid Oxygen containers – mainly used for patient's transportation;
- Suction equipment – used for mechanical aspiration of the gases or liquids by vacuum;
- Oxygen concentrators – applying when central pipeline systems usage is impossible;
- Suction (vacuum equipment);
- Mechanical ventilators – invasive and noninvasive;
- Humidification equipment – using for heating and hydration of the gas substance;
- Anesthesia ventilators and vaporizers (using by anesthesia machines);
- Face masks, supraglottic airway devices (combitube, laryngeal tube, pharyngeal tube);
- Laryngoscopes;
- Tracheal tubes;
- Lung isolation devices (double-lumen endotracheal tubes, bronchial blockers);
- Devices for difficult airway management (gum elastic bougie, McCoy laryngoscope, videolaryngoscope, retrograde intubation kit, fibre-optic bronchoscope, Bullard laryngoscope);

Every hospital containing ICU must have options of:

- Gas monitoring;
- Pulse Oximetry monitoring and alarm devices;
- Temperature monitoring;
- Noninvasive blood pressure monitoring;
- Neuromuscular transmission monitoring;

The **main purpose** of given article is to show potential causes affecting the safety of patients with respiratory support.

2. Material and Methods

We have analyzed present literature data to create main hospital needs in the ICU equipment, and form the basic problems in safety using respiratory support for the patients in the Vietnam hospitals.

3. Results and Discussion

Patients receiving respiratory support in intensive care units in hospitals may be at significant risk if the medical support chain is disrupted. The main factors that may affect the quality of respiratory care for patients in the hospital include:

(1) Insufficient and outdated mechanical ventilation devices;

(2) Malfunction of the medical gas supply system and insufficient awareness of the medical staff of the intensive care units;

(3) Lack of necessary ICU equipment;

(4) Inability to provide respiratory support during in-hospital and in-hospital transportation;

(5) Insufficiency of portable artificial ventilation devices;

(6) Nosocomial infections.

3.1. Mechanical ventilation

Important part of intensive care of critical patients are mechanical ventilators. These devices are designed to move breathable air into and out of the lungs, to provide breathing for a patient who is physically unable to breathe, or breathing insufficiently. These ventilators blow the air into the patient’s lungs through a tube. Mechanical ventilation is divided into invasive or noninvasive ventilation. Invasive ventilation requires endotracheal intubation when the tube is inserted inside the patient’s airway (trachea) through the mouth or nose or tracheostomy when the tube is inserted through a hole made into the trachea. Noninvasive mechanical ventilators come with masks and can be used at home.

3.2. Kind of non-invasive ventilation:

- Continuous positive airway pressure (CPAP): delivers constant and steady air pressure;
- Autotitrating (adjustable) positive airway pressure (APAP): changes air pressure according to the breathing pattern;
- Bilevel positive airway pressure (BiPAP): delivers air with different pressures for inhalation and exhalation.

Positive pressure mechanical ventilators have evolved over the last several decades from simple high pressure gas regulators to sophisticated microprocessor systems controlling many aspects of breath delivery, inspiratory/expiratory timing, and expiratory pressure [6].

Mechanical ventilation is an essential component in the delivery of modern critical care, peri-operative practice and transfer medicine. Ventilators are mandatory in hospital based environments and are ubiquitous in pre-hospital settings. Although safe and reliable, modern devices remain hampered by high costs, reliance on inconvenient consumables such as compressed gas supplies, and practical inefficiencies such as size and complexity [7]. Hand-delivered positive-pressure ventilation systems such as bag-valve masks are commonly used for short-term ventilation but prevent the operator from simultaneously performing other crucial clinical interventions. As imprecise techniques, they also potentially expose the patient to greater risk from volutrauma, barotrauma and hyperventilation [8].

Managing of medical devices is a comprehensive and very demanding task especially in very complex healthcare institutions such as hospitals or clinical centers. Good management strategies should ensure effective, accurate, safe and equal service to all patients. All medical equipment has life-expectancy after which performance deteriorates and periodical check-ups are of great importance. International guidelines define how healthcare institutions should perform. Modern devices are equipped with user interfaces that present data analysis, smart alarm systems and other functions. Safety and effectiveness of medical electrical equipment is defined by international standards. Although medical equipment failure is one of the top ten causes of sentinel event registered by The Joint Commission (TJC), preventive maintenance is in many occasions excessive and inefficient. An alternative methodology, the so-called evidence-based maintenance (EBM), focused on constantly improving the effectiveness of the maintenance processes, a negative feedback amplifier method. Supporters of this method point out how similar devices have very different maintenance intervals recommended by the manufacturers, which has led to the question of the accuracy and validity of these recommendations [9-11].

Nowadays we use ventilators of the 4th generation, they are available worldwide. This is the current generation of ICU ventilators, which are the most complex and versatile of any mechanical ventilators ever manufactured. In this era there has clearly been a marked increase in the number of ventilators, of all possible types. There are a number of what have been referred to as sub-acute ventilators, as well as transport/home-care ventilator. The single feature that distinguishes this generation is the plethora of ventilation modes available. In addition, many of these new modes are based on closed-loop control. The question that we all should be asking manufacturers regarding these new modes is. The questions every hospital should ask manufacturer before buying a mechanical ventilator are about new ventilation mode is useful are:

- Does it make ventilation safer?
- Does it decrease the likelihood of ventilator-induced lung injury or hemodynamic compromise?
- Does it more effectively ventilate or oxygenate the patient?
- Does it wean the patient from ventilatory support faster?
- Does it improve patient-ventilator synchrony?

If the answer to each of those questions is no, then the mode is essentially useless. The clinician enters the patient's ideal body weight, desired minute volume, and maximum airway pressure, and the ventilator determines the respiratory rate and tidal volume combination that results in the least work of breathing. This pattern is established by the ventilator automatically adjusting the ventilating pressure and respiratory rate. All of the ventilators of this generation are easily upgradable, include waveforms as a basic operating feature, and provide extensive monitoring. Each of them provides monitoring data of 20 to 40 individual variables. Many provide multiple screens of data presentation. Almost every possible patient and ventilator variable is displayed. Trending data are also available on most of these units.

Some of these ventilators include specific management/assessment packages. Some allow the clinician to program the performance of a pressure-volume loop. Others have programs that make it easy to perform recruitment maneuvers or decremental PEEP trials. Others have options that facilitate assessment for weaning and performance of weaning trials, whereas others allow for measurement of esophageal pressure and functional residual capacity. The current generation of ICU ventilators is far ahead of the ICU ventilators we used in the 1960s or 1970s. Considering how much change has occurred in ICU ventilators over the last 50 years, one can speculate on the future of ICU ventilators [12].

3.4. Complications of mechanical ventilation [13]**:**

- Complications during intubation
- Ventilator-associated lung injury (VALI)
- Barotrauma
- Volutrauma
- Oxygen toxicity
- Ventilator-associated pneumonia
- Cardiovascular reaction.

3.5. Intra- and inter-hospital ventilation equipment

Positive-pressure ventilation of critically ill patients during intra- or inter-hospital transport carries potential patient risk. Guidelines recommend the presence of both bag-valve mask systems and mechanical ventilators during transport of ventilated patients, but generally support the belief that mechanical ventilators are superior to manual resuscitators. Mechanical ventilators compared to a self-inflating bagger device during in-hospital transport of intubated children found more stable PetCO2 values. Manual resuscitators, in comparison, are readily available, inexpensive, familiar to anesthesiologists, and contain fewer internal sources of mechanical failure. The 2 types of manual resuscitators common in clinical settings are self-inflating and flow-inflating resuscitators. Flow-inflating resuscitators using manometry were superior to self-inflating resuscitators without a manometer in achieving targeted ventilator parameters. The initial decision to exclude a pressure manometer within the self-inflating resuscitator arm was based on its absence in common practice. The ubiquity of manual resuscitation devices in acute care and the paucity of supportive data warrant further study. Positive-pressure ventilation delivery of predetermined ventilation goals between self-inflating resuscitator and the flow-inflating resuscitator both equipped with manometers and 3 models of mechanical ventilators. Mechanical ventilators provide most accurate and consistent positive-pressure ventilation delivery compared to manual resuscitators and. Flow-inflating resuscitators with manometry are superior to self-inflating resuscitators with manometry to accurately and consistently deliver positive-pressure ventilation [14-18].

3.6. Medical Air systems

Medical gases are nowadays being used for a number of diverse clinical applications and its piped delivery is a landmark achievement in the field of patient care. Patient safety is of paramount importance in the design, installation, commissioning, and operation of medical gas pipeline systems (MGPS). The system has to be operational round the clock, with practically zero downtime and its failure can be fatal if not restored at the earliest. There is a lack of awareness among the clinicians regarding the medico-legal aspect involved with the MGPS. It is a highly technical field; hence, an in-depth knowledge is a must to ensure safety with the system. A survey by the Anesthesia Patient Safety Foundation showed a significant knowledge deficit among anesthesiologists regarding the medical gas pipeline systems [19-20].

The core of the entire system is the manifold room which should be manned round the clock with trained personnel. It should have a suitable acoustic enclosure with 100% generator backup and fire security. The location should be marked clearly for ease of identification in the event of an emergency. Continuous supply of oxygen is the primary requisite of any medical unit. There should be three independent supply sources. Primary, secondary, and a reserve source adequate to meet the demand in the event of primary and secondary supply failure. The manifold room should have 2 banks of D-type cylinders, each holding a minimum of 2 days consumption, attached to a fully automatic changeover control panel. Three-day consumption should be kept in reserve, as a contingency plan. Cylinders should be tested by manufacturers at intervals of 5 years [21]. Liquid oxygen is an economical and convenient form of oxygen storage. VIE should be installed in a high security and fire safe zone after taking regulatory approval. Excessive pressure can cause damage to equipment and barotrauma for patients. Only small quantity of mechanical ventilators has reducers for damage prevention.

Compressed air used both as a driving force for equipment such as pneumatic drills (surgical air) or as an inhalational gas (medical air). The medical air quality should meet the standards laid by the European Pharmacopoeia [22], restricting the carbon monoxide level to 5 ml/m3. Integral dryers, filters, and dew point monitor control the humidity to its allowable limit of 67 ml/m^3.

Copper seamless pipes with flux-less silver brazing are used which should be as per ASTM standard and Lloyd's certification. They are intercepted by the area valve service units (AVSUs) and area alarm panels (AAPs) [23]**.** AVSUs are placed in each clinical sector, to cutoff the gas delivery to the area beyond it during maintenance or to handle emergency. AAPs display the line pressures and have audiovisual alerts. All pipelines should be coded with coloured bands put at intervals of every 3 m.

Outlet Points

These are the final delivery points which are colour coded, incorporating either the diameter index safety system or are of the quick connect type. Indigenous arrangement – all critical areas should have bulk oxygen cylinders, fitted with a double-stage regulator, tubing, and an adaptor. In case of manifold failure, the AVSU of the area is closed. The pipeline beyond it can now be fed with oxygen from this cylinder, by connecting the adaptor to any oxygen outlet point within the territory. Crisis due of vacuum pipeline failure can be tided over with portable electrical suction units.

Safety can be ensured only when there is a proper upkeep and maintenance of the system. This can be ensured by:

- Formulating Standard Operating Procedures (SOP's)
- Maintaining logbooks
- Keeping all the equipment under Annual Maintenance Contract/ Comprehensive Maintenance Contract (AMC/CAMC), allotted to the original supplier of the Equipment or to vendors with minimum 3-year experience in the field;
- Preventive maintenance of equipment and leak test of pipeline should be ensured on quarterly basis;
- 24 h manning by trained personnel;
- Periodic training of manifold personnel;
- Regular inspection of the pipelines, particularly after Public Works Department (PWD) work of every area;
- Daily checking of contingency plan;

- Mock drills of pipeline failure, fire, and explosion should be regularly conducted [24].

3.7. Prevention of nosocomial infections

Hospital acquired infections (HAIs) is a major safety concern for both health care providers and the patients. Considering morbidity, mortality, increased length of stay and the cost, efforts should be made to make the hospitals as safe as possible by preventing such infections [25].

Ventilator-associated pneumonia (VAP) is one of the most commonly encountered hospital-acquired infections seen in the critical care setting and can be linked to several adverse clinical outcomes. Defined by the United States Centers for Disease Control and Prevention as pneumonia occurring 48 h after the initiation of mechanical ventilation, VAP is associated with increased rates of multidrug-resistant infections, increased antibiotic use, prolonged mechanical ventilation time, increased ICU length of stay, and increased hospital length of stay [26-27].

Steps towards VAP development prevention [28]:

- Minimize ventilator exposure
- Regular oral hygiene care
- Correct subglottic suction procedures
- Optimal positioning and mobility maintaining
- Adequate stuffing

4. Conclusions

To improve the work of intensive care units in Vietnam hospitals and reduce the risks of poor respiratory support in patients, it is necessary to provide modern artificial ventilation with turbines, to establish strict control over oxygen stations. It is also necessary to equip the intensive care unit with oxygen panels, to follow strict rules for the spread of nosocomial infections. Vietnam hospitals, as all over the world, must be provided with ventilators and portable oxygen cylinders. Such measures will minimize the risks of failed oxygen support in hospitals.

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