Abstract of the thesis entitled  

The Use of Humidification System to Reduce the Work of Breathing  
in Mechanical Ventilated Patients  

Submitted by  

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for the Degree of Master of Nursing  

at The University of Hong Kong  

in July 2013  

Critically ill patients in an intensive care unit (ICU) often require mechanical ventilation (MV). Humidification systems are essential devices for MV which replace the natural heat and moisture exchange process of inspired gases. A heat and moisture exchanger (HME) is commonly used for the humidification of MV patients in ICU. In contrast, a heated humidifier (HH) that is a more complicated device is used only for prolonged MV patients because of its higher cost and nurse workload. However, HME may increase the breathing workload of patients, thereby inflicting damage to their respiratory function, especially among respiratory failure patients. However, there was no evidence-based guideline that instructs nurses on choosing humidification devices in ICU.
This dissertation aimed to 1) evaluate the current evidence and formulate evidence-based guideline in selecting a humidification device for mechanically ventilated acute respiratory distress syndrome (ARDS) patients in reducing the risks of breathing workload; 2) assess its implementation potential, as well as its feasibility and transferability; and 3) develop implementation strategies and evaluation plans for the use of this device in an adult ICU.

Three electronic databases, namely, Proquest, Ovid, and Google Scholar, were searched for randomized controlled trials (RCTs) of humidification systems for MV. Eight articles were retrieved. Their reference lists were read and found two additional RCT. Four high-quality RCT showed that HH increased the breathing workload more than HME. Several studies showed that HME has potential drawbacks of significantly increase airway resistance, minute ventilation, CO$_2$ retention, and respiratory discomfort. However, studies showed that no significant difference of ventilator-associated pneumonia (VAP) rate between HME and HH. The initial application of HME is safer and less costly. However, prolonged use of HME in ARDS patients may induce further workload on the respiratory system and worsen treatment progress.

An evidence-based clinical guideline in choosing the humidification system was formulated and assessed using the appraisalal instruments of Scottish Intercollegiate
Guideline Network. It is deemed to be transferable with patient characteristics, clinical situation, and organizational infrastructure similar to studies evaluated the suggested innovation. Feasibility was also assessed and is considered to be high. The setup and running cost per year were HKD17450 and HKD6600. Although the humidification system had no actual cost reduction, non-material benefits such as prevention of tube blockage, reduction in breathing workload, and respiratory discomfort were more important than the cost.

An implementation plan including a one-month communication plan with stakeholders and one-month pilot testing were developed. The evaluation of the guideline will last for 10 months. The effectiveness of the innovation will be determined by the reduction in breathing workload, cost and benefit ratio, and staff satisfaction level.
The Use of Humidification System to Reduce the Work of Breathing in Mechanical Ventilated Patients

by

Cheung Wai Ki

A dissertation submitted in partial fulfillment of the requirements for the Master of Nursing at The University of Hong Kong.

July 2013
Declaration

I declare that this dissertation represents my own work, except where due
acknowledgement is made, and that it has not been previously included in a thesis,
dissertation or report submitted to this University or to any other institution for a
degree, diploma or other qualifications.

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Cheung Wai Ki

July 2013
Acknowledgement

I would like to take this opportunity to express my sincere appreciation to my supervisor, Dr. Daniel Yee-Tak Fong for his enlightenment, supervision, and great patience for my entire project in these two years. He always gives me extremely useful guidance and support when I'm lost in this journey. I cannot finish it without him. Also, I would also like to thank you all of my families and friends especially my AICU potatoes who always give me energy and faith to overcome the difficulties throughout the whole process.

At last but not least, I am very touched to finish this dissertation which I thought I'll give up in the middle. I'm proud to be a student in the Master of Nursing in HKU.

It is a valuable memory and must be a great chapter in my life.
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Chapter 1:

Introduction

1.1 Background

Acute respiratory failure patients such as acute respiratory distress syndrome (ARDS) patients often require mechanical ventilation (MV) support and admission in the intensive care unit (ICU) when the condition deteriorates. However, MV is also a risk factor for the development or worsening of ARDS. In particular, humidification system, one of the essential devices, may increase the breathing workload as demonstrated in several studies. However, the negative impact of the humidification device on the respiratory function has often been underestimated.

The use of MV with an artificial airway bypassed the upper airway which cannot contribute to the natural heat and the moisture exchange process of inspired gases. Inadequate humidification may lead to respiratory heat loss, airway obstruction from thick secretions, and impairment of the mucociliary escalator. Therefore, adequate inspired gas humidification is necessary during invasive MV to prevent mucosal injury and ventilator-associated pneumonia (VAP). To avoid these potentially serious complications, the use of heated water humidification system (HH) and heat and
moisture exchangers (HME) for humidification of inspiratory gases is an essential practice for patients receiving mechanical ventilation.

Artificial humidification of mechanical gases can either be active or passive. HH is a kind of active humidifier wherein the inspired gas will pass across a heated water bath, producing heat and water vapor from water to inspiratory gases at near body temperature and humidity. However, this humidification system has disadvantages, which include high maintenance costs, production of circuit tubing condensate serving as a source of lung infection, and increased care provider workloads. To avoid the problem associated with the use of HH, HME was developed to serve the similar function of HH. HME, known as artificial noses, has a passive humidifier that traps heat and humidity from the patient’s exhaled gas and return some to the patient on subsequent inhalation. Generally, HME has the advantage of simpler circuit maintenance because of its passive operation, lower maintenance workload, lower cost, and lack of condensate as compared with HH. On the other hand, HME has a potential drawback such as increased circuitry dead space, airway resistance, and breathing workload.

1.2 Affirming the needs

We consider the local setting of an AICU in a local public hospital in Hong Kong.
In current clinical practice for the AICU, around half of the clinical admissions required MV support. MV patients have significantly higher mortality rate compared with non-MV patients. Patient receives MV for various reasons such as for postoperative paralysis following surgery, protection of airway after resuscitation, and poor lung function, which is one of the most common indication for MV support. Surgical patients are usually on MV for 2 days, whereas respiratory failure patients generally require longer duration ventilator support lasting for around one week and may extended up to 2 months. When a patient is intubated and mechanically ventilated, HME is used initially for all medical or surgical patients needing MV for humidification. HME is the most frequent used humidification device because it is cost effective and reduces nursing workload. The device is recommended to be changed daily or whenever it is fully soaked with condensate. HH is recommended for use only to patients receiving mechanical ventilation for more than 14 days.

Although many studies have compared the efficacy of HME and HH in terms of humidifying ventilation gases and preventing VAP, some studies suggested that HME has lower maintenance cost, and is more convenient to use. However, several issues concerning airway humidification and the use of HME are still under debate including the exact duration of HME use before its replacement, the potential drawback such as the increased airway resistance and respiratory effort, and the appropriate duration of
mechanical ventilation with HME. Campbell et al. (2000) showed that breathing workload increased by 66% when switching from HH to HME. On the other hand, ARDS patients, a significant portion of all ICU patients, usually have longer duration of MV, and have difficulty weaning of ventilator when compared with “healthy lung” patients. Unfortunately, while ARDS patients contribute to a higher mortality rate as their lung function vary every moment and commonly show fatigue during inhalation especially when the HME was soak full with condensate, clinicians do not consider HH as their first choice in protecting their lung from additional workload due to the humidification device. Furthermore, even if many of the health care providers are not familiar with the humidification system as well as their detailed advantages and disadvantages, they only blindly follow the traditional practice.

Early provision of HH among ARDS patients, may protect their respiratory function from adding extra workload on their breathing, and thereby may improve their treatment progress. Unfortunately, no comprehensive guideline or protocol is available to define the use of humidification system in different types of patient providing optimal result. Further, the benefits of early HH provision among ARDS patients in shortening their length of MV duration, and in lowering their mortality rates have not yet been evaluated. Which is the best choice of humidification system for those ARDS patient? How does it affect the breathing workload during mechanical
ventilation? Many nursing research works were done to seek for the best clinical practice to improve the quality of care in these critically ill-patients. A comprehensive evidence-based guideline in choosing humidification system is necessary to protect the fragile ARDS patients, and to improve their treatment progress.

### 1.3 Objectives and significance

Based on the above clinical situation, the objectives of this dissertation are:

1. To evaluate the current evidence on the effects of humidification system on the work of breathing during mechanical ventilation;
2. To develop an evidence-based protocol in choosing the appropriate humidification devices for those ARDS MV patients;
3. To assess the implementation potential of the clinical guideline to reduce respiratory effort among the ARSD MV patients;
4. To assess the feasibility and transferability of the innovation; and
5. To formulate an implementation plan in choosing the most appropriate humidification device, and an evaluation plan to gauge its effectiveness.

This dissertation will formulate evidence-based guideline in reducing the risks of increased breathing workload by choosing an appropriate humidification device,
balancing the cost, and the needs of the ARDS patients. Given that the invasive
ventilation support are common in ICU setting, a comprehensive evidence-based
guideline is important in providing high quality of care for all mechanically ventilated
patients. With early application of HH on those respiratory failure patients are
essential to decrease the work of breathing and the length of ICU stay will be shorten
with improving weaning progress, subsequently the length of hospital stay will be
shorten.
Chapter 2: 
Critical Appraisal

2.1 Search and appraisal strategies

2.1.1 Identification of studies

To retrieve the research studies related to the selection of the humidification device for the MV patient, the literature searching process began from March 15, 2012 to September 24, 2012. The searching keywords were "Heat and moisture exchanger", "heated humidifier", "work of breathing", "airway resistance", "mechanical ventilation", and "randomized control trial". Three electronic bibliographical databases were used including Proquest, Ovid, and Google Scholar. Systematic review, meta-analysis, and randomized control trial were screened. The titles and abstracts of the potential study were reviewed, and the reference lists were carefully screened for further potential studies.

2.1.2 Inclusion Criteria

To extract the relevant studies from databases, criteria were set up to select the appropriate paper:

1) Published in either English or Chinese;
2) Target groups are limited to the adult ICU patients;

3) Mechanically ventilated patients since only few studies focused on the ARDS or chronic obstructive pulmonary disease patients; however, studies with ARDS patients as their target group were preferred; and

4) Randomized controlled trial (RCT)

2.1.3 Exclusion criteria:

1. Conducted outside the ICU setting;

2. Examined on pediatric patient; and

3. Non-invasive mechanically ventilated patient. Studies regarding the humidification system on non-invasive MVs (without an artificial airway like endotracheal tube (ETT) or tracheostomy) like BiPAP or CPAP will not be considered as eligible articles because those patients still remain an upper airway functioning as a normal humidification system, the results conducted in those studies may vary from those studies with invasive MV patients.

2.1.4 Data Extraction

Data from several studies were summarized into a table of evidence (Appendix 2). The author, published year, study type, patient characteristics, sample size, study
intervention, the focus comparison, length of follow up, outcome measurement, and the effect size of the study were analyzed. The interventions were on the use of HME and HH among MV patients. Most papers were comparing the effect of different humidification devices on the airflow of the MV on the patients’ physiological changes. The outcome measurements are blood gas result, humidity value, airflow resistance, physiological dead space, and breathing workload.

2.1.5 Appraisal strategy

The methodology used to grade the articles included is designed by the Scottish Intercollegiate Guideline Network (SIGN, 2006). It is a guideline involving checklist and methodology developed to critically appraise the quality of a research study. It is based on the following areas to identify the quality of the study:

1. Study focus;
2. Involvement of randomization;
3. Concealment method;
4. Blinding procedure;
5. Baseline difference between the intervention and control groups;
6. Reliability of the outcomes measurement;
7. Dropout rate;
8. Intention-to-treat analysis; and

9. Multiple centers involved

2.2 Results

2.2.1 Search results

The search strategy retrieved 852 citations, 36 articles from Proquest, 24 articles from Ovid, and 792 articles from Google Scholar. After screening of the titles and abstracts, 33 articles were identified as the potential relevant studies. Applying the inclusion and exclusion criteria, and eliminating duplicated studies, eight articles were retrieved from the database. Their reference lists were carefully screened for potential relevant studies, two of the studies satisfied the inclusion and exclusion criteria, and therefore, were retrieved from the related literature's references list as well. These studies were analyzed, and the research results were summarized.

2.2.2 Study characteristics

All studies included in this dissertation were all primary studies conducted in western countries. No local study was found. They were single center studies and investigated in adult medical and surgical ICUs. Their study measured airway
resistance, dead space volume, CO₂ level, and work of breathing. Only four studies reported ethical approvals.

2.2.3 Quality appraisal

All of the studies stated clear about their study focus with adequate description of their objective, intervention, and the outcome prediction. It can be easily identify in the outline and abstract of the article.

Six of the retrieved studies are RCTs. Lacking description of randomization method is a common limitation of the studies. All of the RCTs only mentioned about involvement of randomization; however, the details about the method used were insufficient. Four retrieved papers claiming to be RCTs satisfied all the inclusion criteria; however, no randomization details were found throughout the entire study. Actually, these studies were case control studies.

Among the selected studies, only Marin et al. (1998), which uses opaque sealed envelope method, have mentioned about the concealment method. The rest of the studies did not mention any concealment method.

None of the retrieved studies could remain blind to the entire participant. Five out of 10 studies have mentioned about the blinding issue in their paper. One of the studies, Ziad et al. (2001), the clinicians was notice about their study target after they
are randomly allocated into the group. The other 4 studies reported that blinding is not necessary for their study. The authors explained that most of the intervention of the study examined different kinds of humidification device on the MV patient then obtain the lab result and calculate the effect size and significance. Since the intervention required the patient basic respiration, the blinding procedure seems did not affect significantly on the result obtained. In observational study on the routine clinical practice, having consent is unnecessary.

Overall study showed no significant different on their baseline characteristics. Campbell et al. (2000) and Iotti et al. (1996) have reported the only difference is the intervention under investigation. Ziad et al. (2001), Marin et al. (1998), Jaber et al. (2004) and Prat et al. (2002) studies listed out the information in detail with statically analyzed table and result showed no significant difference between the target and control group, their baseline characteristics were clearly stated in the article.

All of the studies have clearly identified the outcome measurement. The procedure, specific equipment, measurement calculations, biological and physiological term, and definition were described in detail. Three studies' protocols were approved by French Intensive Care Society and the other one was approved by the Washington University School of Medicine Human Studies Committee. There is no measurement instrument has tested for reliability as all of the measurement
strategy was based on the observation of the routine care.

Not all of the studies reported about the dropout rate of their target group. The patients were not dropped out from the study rather being excluded. In Girault et al. (2003) study, the patients were excluded out because of the condition changed that could not tolerate the entire intervention, Marin et al. (1998) patients were transferred out with MV. In Ziad et al. (2001) and Jaber et al. (2004) study, the patients were early extubated, or their ventilation time was less than the study minimum requirement.

Intention to treat analyses is done to avoid the effects of crossover and drop-out, which may break the randomization to the treatment groups in a study. For those studies that the entire participant completed the analysis without dropped out the study, all subjects were analyzed as in the allocated group. The intention to treat was used in primary data analysis in Girault et al. (2003), Marin et al. (1998), Ziad et al. (2001), and Jaber et al. (2004), however, the dropped out data were not involved in the analysis.

All of the retrieved studies are single center design. They were all conducted at western country, none of the local study was found. Three studies were conducted from the medical intensive care unit and seven studies were from mixed surgical and medical intensive care unit.
The levels of evidence were ranked based on the criteria suggested from Scottish Intercollegiate Guideline Network 2011. From all of the retrieved study, there are two studies ranked have the highest level of evidence 1++, 2 studies were ranked as 1+, 2 studies were ranked as 1- and four studies were ranked as 2++.

One of the patterns about the sample size was noted. The study target focused on the ARDS patients, the sample sizes were relatively smaller when compared with those RCTs that only focused on the MV patients. Given that many of the mechanically ventilated ARDS patients were clinically unstable and were not suitable for the intervention, the sample size was limited. In contrast, Ziad et.al. (2001) and Marin et.al. (1998) only targeted to the MV patients, and generally had larger sample size. Other than their advantage in sample size, they were ranked as a high quality study (1++) as they have reached most of the criteria of well-designed RCTs. Their intervention procedure and measurement method were reported clearly and their study outcome were statistically analyzed with low risk of bias.

Jean et al. (1999) had assessments made by independent observers, and there could be worry of inter-rater reliability. In Campbell et al. (2000), their study was done comprehensively with detailed explanation of the similarity and the discrepancy with others' findings. It achieved most of the grading criteria, however, a relatively small sample size was the major limitation in this paper. This affected the overall
quality of the paper, thus, it was ranked as 1+.

Two of the RCTs, Iotti et al. (1996) and Girault et al. (2003) were ranked as 1-. The reason of the slightly lower grade were because their relatively small sample size which are only 10 and 11. The sample size is an important element of the empirical study to represent their studied population. Although the rationale of small target group was explained as above paragraph, the statistical power was weaken by their small sample size. Four studies claimed as RCT, but they did not mention the randomization method. Their objectives, study designs, baseline characteristics, statistical analyses were reported in detail. The study target group of Prat et al. (2002), Moran et al. (2006), and Prin et al. (2002) focused on the ARDS patient. Their outcome measurements were clearly identified with comprehensive analysis of the findings and most of the inclusion criteria were matched. However, lack of randomization is the major limitation of these studies. Therefore, they were ranked as 1--.

2.3 Summary and synthesis

2.3.1 Work of breathing

The use of HME was reported to have increased the work of breathing in five studies, and also increased of dead space directly related to increase airway resistance
in four studies. Dead space and resistance of HME are larger than HH. The minute
ventilation in Campbell et al. (2000) study increased with responded to increase in
resistance from using HH to HME to HMEF, the WOB increased form 13.6±8.6 (HH)
to 19.2±9.1 (HME) to 22.3±9.9 (HMEF), p<0.05. This result corresponded with Iotti
et al. (1996) study which conducted the finding with increase expiratory resistance by
30%, the inspiratory WOB increase 60% respectively. Increase dead spaces add an
extra workload to respiratory work.

Moran et al. (2006) also found that there were strong relationship between the
dead space volume, airway resistance, and the airway pressure. A chain reaction were
noted when the dead space volume decrease, the other two will decrease respectively.
Further, the impact on the respiratory compliance was also noted in their paper. They
demonstrated that the decrease in dead space volume and airflow resistance was
correlated with an increase in respiratory compliance. The respiratory system
compliance increased when switching from HME (35±12 ml/cmH₂O) to HH (42±15
ml/cmH₂O), \( p = 0.001 \). Increase in compliance can achieve an optimum therapeutic
effect with the lowest support. Hence, this improvement can diminish the mechanical
load and reduce the ventilator requirement which minimize the tidal volume,
subsequently avoid over ventilation. These prevent the potential harmful ventilator
associated complication such as barotraumas due to over ventilation, thus, enhanced
the weaning progress.

Six of the studies' target group are ARDS patient or patient who fail to wean of the ventilator as poor lung function. The other studies did not limit on the type of patient. Even in the “healthy lung”, those studies like Jaber et al. (2004)’s and Jean et al. (1999) still suggested that HME may contribute on increase work of breathing. While an additional resistance put on ARDS patient, HME may bring further workload on their “weak lung” and worsening their treatment progress.

2.3.2 CO₂ retention

Artificial airway dead space increased is related to the PaCO₂ increase. Four studies suggested that the use of HME may increase CO₂ retention and respiratory acidosis. Prat et al. (2002) noted a significant decrease in PaCO₂ when switching from the highest dead space volume device (80.3±20 mmHg) to lowest system (63.6±13 mmHg) ($p < 0.05$). They concluded that the PaCO₂ decreased is directly proportional to the instrumental dead space volume reduction. Moran et al. (2006) and Prin et al. (2002) also found that reduction in dead space volume in ARDS patients significantly decreased PaCO₂ levels and Girault et al. (2003) also showed that change in humidification system was contributed in correct of acidosis as humidification instrument was strongly related to the change of PaCO₂ and pH value. They also
observed that a significant respiratory discomfort when using HME when comparing with HH during pressure support ventilation. Campbell et al. (2000) also suggested that the respiratory muscle fatigue can negatively affect the weaning progress. Because the increase in respiratory rate and using accessory muscles or increase in ventilator requirement to compensate for CO₂ clearance. These physiologic effects may result in a feeling of respiratory discomfort for patients.

When comparing the findings conducted by the retrieved paper, the effect size of PaCO₂ and pH are different. Some of them provided a more significant result while some were smaller or even statistically not significant. Campbell et al. (2000) have the most significant findings, followed by Moran et al. (2006), Prat et al (2002). Girault et al. (2003)’s study has the less significant result, on the other hand, Iotti et al. (1996) showed there are no significant different in the use of HME and HH in terms of the PaCO₂ and pH level. With the analysis of different aspect of those findings, some resonate can be made. Firstly, time is correlated with change in PaCO2 and pH value. Campbell et al. (2000)’s study have the procedure lasted for 60mins which is the longest intervention time whereas Girault et al. (2003)’s study only lasted for 20 min, it was corresponded with the effect size. The decrease of the effect size were noted when a decrease in intervention duration. However, Iotti et al. (1996)’s study was lasted for 25 min. which longer than Girault et al. (2003)’s study (20 min), but still
cannot provide a significant result. Their target group are chronic respiratory failure
patients while Iotti et al. (1996)’s target group are patient with MV and not affected by
respiratory failure. Respiratory failure patients are more sensitive to the change in
airflow resistance. The use of HME in ARDS patient may result in an additional
increase in CO₂ level and more acidosis.

Secondly, the mode of ventilation support may play an important aspect in
providing a significant effect size. The pressure support ventilation (PSV) could mask
the effect size of the PaCO₂ and pH level. Campbell et al. (2000) demonstrated that
increase in the airflow pressure provide additional minute ventilation which can
overcome the increased dead space resistance, subsequently the elevated CO₂ can be
compensated. And extra 10 cmH₂O pressure support were needed to eliminate the
increased WOB resulted by the increased HME dead space. Similar findings were also
showed in Girault et al. (2003), study. Furthermore, as I mentioned in above
paragraph, an extra respiratory discomfort was noted when using HME, and they
reported that this was markedly influenced by the type of the humidification system in
the respiratory failure patients. In addition, the compensatory mechanism resulted
after the increase in ventilator requirement in pressure support mode.
2.3.3 Reduction of ETT patency

Four studies mentioned that HME is safe for short term MV. For a short term MV (3–4 days), there is no significant difference in ETT patency. Prolonged use of HME (9–10 days) has progressive reduction of ETT patency compared with the use of HH. The inhaled gas should be warmed between 25° and 30° and should be saturated with water to 100%. The performance of HME is in the lower part of the range. Jean et al. (1999) reported that, the absolute humidity provided by most of the HMEs models were only around 25 mgH₂O/L which is below the minimum requirement of the International Standards Organization recommendation of 30 mgH₂O/L. Adequate humidity can help the endotracheal clearance by stimulating the mucus secretion subsequently increase the coughing effort. Under moist of the inspiration air has been responsible for server airway damage like endotracheal occlusion as the inadequate humidity from the inspiratory air thickened the bronchial secretions, the inner wall of the ETT can gradually obstruct the lumen of the ETT.

Moreover, Marin et. al. (1998) also pointed out that if the patients with copious bronchial secretion there are increasing risk of induce HME occlusion as the filter of the HME may fully soak with the sputum that blockage the lumen. While ARDS patients are usually associated with more sputum production as the symptom of the inflammation of alveoli, HME may not be suitable for high sputum productive patient.
2.3.4 Ventilator associated pneumonia (VAP)

Both Ziad et al. (2001) and Marin et al. (1998) reported that there was no significant difference in term of the VAP rate between the use of HME or HH, while the other study did not show any information about VAP. The subjects recruited in both of the studies did not focus on long term MV. Ziad et al. (2001) excluded the patients if their MV duration was less than 48 hr, whereas Marin et al. (1998) had no limitation of the duration of the ventilator time. This dissertation focuses on ARDS patient who often requires relatively longer MV support. There is insufficient research done on the ARDS patient in the use of humidification system on incident of VAP, thus, the findings of these studies may not suitable to apply on the long term MV patients.

Based on the above studies, HME have potential drawback as it may significantly increase airway resistance, minute ventilation, CO₂ retention, and respiratory discomfort. Studies showed that no significant difference in VAP rate between HME and HH; however, they ignored the MV duration which may affect the result. The effect size of the PaCO₂ and pH values can be affected with different
intervention time and different ventilator mode. Further, HME affects not only ARDS patients but also patients with normal respiratory function. Initial application of HME is safer and more economical. Combining all the factors, patient respiratory workload would increased. The use of HME among ARDS patient may bring further workload on their respiratory system, and may worsen their treatment progress. However, several issues concerning airway humidification and the use of HME are still under debate. HH should be used as soon as possible to prevent further damage of their weak lung. It may shorten the duration of MV, and may improve weaning progress. When choosing an artificial nose for ARDS and long term ventilated patients, clinicians should not solely based on their evaluation on cost-effectiveness, but most especially on the function of the HME and on the patient's disease characteristic.
Chapter 3
Translation and Application

3.1 Implementation potential

From the previous chapters, the systematic review of the studies demonstrated that the implementation of active humidification system on patients with ARDS may decrease breathing effort. Following this, we will evaluate the transferability and feasibility of this intervention in the AICU of public hospital in Hong Kong. An evidence-based clinical guideline is formulated based on the searched findings, feasibility, and cost-benefit ratio which will suggest to the health care provider to improve quality care.

3.1.1 Transferability of the findings

To determine the transferability of the findings of the reviewed studies into our clinical setting, the characteristics of target audience between the target setting and the reviewed studies should be compared.

In the reviewed studies, the target populations were mechanically ventilated patients with medical and/or surgical problems in AICU. Five studies were conducted in the medical ICU, two were in surgical, and three were in mix AICUs. All
participants in the reviewed studies were adult patients who required MVs for various reasons. Five studies focused on the ARDS patient as their target group, which is similar with the target population in the current study focus (Iotti et al, 1996; Girault et al. 2003; Prat et al, 2002; Moran et al, 2006; Prin et al, 2002). Also the target setting is also a medical and surgical AICU which is similar to the reviewed studies. The suggested innovation can be beneficial to health care providers by setting a clear guideline on choosing a suitable humidification system to avoid further damage of their critically ill patients.

The philosophy of care of using suitable humidification system on MV patients is to improve their quality of care. Especially for those who are critically ill and medically dependent, providing a holistic care that minimizes any potential harmful aspects from the patient is essential. According to the mission and vision of Hospital Authority 2012, consistently offering best possible patient centered care is the first priority of all health care professionals. Promotion of evidence-based practices, building critical thinking, and multidimensional consideration are fundamental in improving quality of nursing care. This new innovation meets the emphasis of patient-centered care.

In the target setting, an average of 800 new patients requiring mechanical ventilation was admitted to ICU per year. Of this number, 60% were classified under
surgical specialties, 30% were medical patients, around 10% were considered to belong to other specialties. Although no official statistics were reported, approximately one fourth of the total was diagnosed with ARDS and required MV. Medical patients such as those afflicted with pneumonia, acute pulmonary edema, and sepsis accounted for the largest proportion of the ARDS cases, whereas the other specialty patients such as those who experienced trauma, drowning, burning, aspiration, and fluid overload after massive blood transfusion and during resuscitation were likewise counted as ARDS cases. These patients generally required MV and admission to ICU. Thus, there would be at least 200 ICU patients who benefited from the implementation of the guideline each year.

A two-week training program is needed to introduce the aims and guideline. The program is relatively short because both active and passive humidification systems are available in the target setting, and the staff is familiar with these devices. Sufficient time will be provided to pilot the program and in familiarization with the innovation to eliminate the uncomfortable feeling caused by the change. A total of 11 months will be earmarked for implementing and evaluating the entire program.

To conclude, the characteristics and study focus demonstrated in the reviewed studies were similar with the target setting. Therefore, there is high chance to adapt the guideline for choosing humidification system to the local setting.
3.1.2 Feasibility

After assessing the transferability from the reviewed studies, feasibility is another important issue that should be considered before implementing a new innovation.

The staff compliance and attitude toward the changes are crucial. In the proposed hospital, physicians do not have any preference with regard to the type of humidification system. Generally, the decision was determined by the nurses. Thus, nurses have high autonomy on making the decision in this aspect. However, people might hesitate when facing change. The main concern of implementing the new innovation is the extra workload on the nursing staff, particularly for those assigned to ICU patients because they have to contend with different monitoring equipment, tubing, and infusion drugs. The use of active humidification system may increase the nursing workload because of the time needed to change the condensation chamber. Moreover, the system occupies an extra space in the setting. However, to protect the patients from further damage on their injured lungs, the increase in the load seems unavoidable. Nevertheless, the nurse to patient ratio in ICU is 1:1; thus, there is adequate manpower for frequent monitoring of the device systems. Consequently, extra work is acceptable in an intensive care unit.

Obtaining support from the administration and stakeholders is important. The
The proposed target hospital has links with a major university that encourages research and evidence-based practices. The clinical practices are reviewed frequently by doctors and nurse specialists. Utilizing research findings in nursing practices are encouraged. With the consensus from the stakeholders, acquisition of sufficient equipment and facilities can be supported. Sponsorship can be obtained from the department of intensive care unit for the additional purchase of the hearted humidification system. This system is needed as the currently used humidification devices are mainly HME and the number of HHs is not enough to provide the modified treatment in the new innovation.

Another issue to consider is the availability of tools for evaluating the innovation. A research team including doctors and nurses will be formed to collect the data and provide opinions regarding the treatment plan. Patient's length of MV, airway pressure, blood gas CO₂ level and pH value, oxygen consumption, sputum character, and chest X-ray reports will be obtained daily. These data can be acquired easily from patients’ medical records.

### 3.1.3 Cost-benefit ratio of the innovation

To assess the cost and benefit ratio of the innovation, systematical calculation and comparison of the benefits and costs of the project have to be considered. The
potential risk of the patient will be a concern in the process of implementing the new innovation, and the potential benefit should be analyzed.

The proposed interventions are setting up an evidence-based guideline for choosing which humidification system is suitable for MV patients and suggesting HH that should be used in ARDS patient. When using HH, the potential risk of electrical shock caused by the leakage of the water from the humidifier exists. However, there are no accidents have been reported either in the local setting and the reviewed studies. On the other hand, increased stress due to the change in the current practice and the time consumed for emptying the condensate from the water trapper is one of non-materials costs. Introducing a new practice may bring additional stress; however, it will be minimized after the training and pilot period.

According to the information provided by the ward manager of the target ICU, each HH system cost approximately HKD$600. There are 3 HH systems in the target setting. Additional two systems are required to carry out the intervention which cost HKD$1,200. After calculating the set up and the training costs of the innovation, a total of HKD$17450 is required for preparing the intervention and the running cost per year is approximately HKD$6600. Details of the cost calculation are shown in the Appendix 4.

According to Jean et al. (2005), the daily cost of providing humidification using
HME and HH per patient is $9.2 and $23, respectively, inclusive of material and the manpower costs. Thus, the daily cost of using HH is higher than that of HME on each ARDS patient by HKD$13.8. Approximately, there are 200 ARDS patients admitted in the target hospital per year who meet the inclusion criteria of the new intervention and thus, are potential candidates. Based on the results of Jean et al. (2005), an additional spending of (HKD$13.8 X 200) = HKD$2,760 per year is required when using HH instead of HME. However, there are no statistically significant differences in the hospital length of stay and the duration of MV while using HME or HH (Marin et al., 1998). Therefore, this money will be spent during the implementation of the new innovation annually.

Although there is no actual reduction of the cost of the humidification system, non-material benefits have been reported by the reviewed studies. Moran et al. (2006), Campbell et al. (2000), Iotti et al. (1996), and Prat et al. (2002) observed that using HH can reduce the breathing workload by providing lower dead-space resistance, which significantly associated with the decrease of PaCO₂ levels. Likewise, they observed significant reduction in respiratory discomfort and muscle fatigue when using HME compared with HH during pressure support ventilation. Jaber et al. (2004) have suggested that prolonged use of HME leads to higher progressive reduction of ETT patency compared with the use of HH. Marin et al. (1998) have pointed out that
copious bronchial secretion may increase the risk of lumen blockage by the fully soaked HME filter. Furthermore, HME may not suitable for higher sputum producing patients such as ARDS patients. Based on the above reasons, HH was suggested.

After considering different disciplines as well as the absence of actual reduction in the cost of the humidification system, the benefits of implementing the intervention are considered more important than the potential risks and cost.

3.2 Evidence-based protocol

After identifying the transferability, feasibility, and cost-benefit ratio in the previous section, an evidence-based guideline that adheres to the systematic review mentioned above should be developed. The methodology used to grade the reviewed articles was designed by the Scottish Intercollegiate Guideline Network (SIGN, 2012), and the recommendation was graded based on the Grades of Recommendation. Two of the reviewed studies were classified as those that belong to the highest level 1++, (Ziad et al., 2001; Marin et al., 1998), two were ranked 1+, (Campbell et al., 2000; Jean et al., 1999), three were graded 1-, (Iotti et al., 1996; Jaber et al., 2004; Girault et al., 2003), and three were ranked 2++, (Prat et al., 2002; Moran et al., 2006; Prin et al., 2002).

The evidence-based guideline for choosing humidification system for
mechanically ventilated ARDS patients is attached in Appendix 6.
Chapter 4
Implementation Plan

4.1 Communication plan

To implement the evidence-based guideline in the target setting successfully, an implementation plan comprising a communication plan with the stakeholders and a pilot study plan should be developed to facilitate the new innovation implementation process.

4.1.1 Stakeholders

Stakeholders are people who are affected or may be affected by the implementation of an innovation. Identifying the stakeholders and obtaining their support are essential for the promotion of the new innovation and reduction of friction during adaptation to the new innovation.

The key stakeholders in the implementation of the new protocol on using active humidification system to reduce breathing effort in AICU patient with acute respiratory distress symptom (ARDS) are the administrators, physicians, and nurses. The administrators include the chief of service (COS), consultant, department operation manager (DOM), nursing consultant (NC), and the ward manager of the
AICU. They are in-charge of the department and responsible for the approval of the new innovation and in providing the necessary resources for the development and implementation of the new clinical guideline. The frontline nurses including advanced practice nurses (APN) and registered nurses (RN) are key stakeholders as well. The RNs are responsible for administrating the new humidification protocol and assessing the patient condition after applying the new guideline. The APNs are responsible for monitoring the progress, handling potential problems, and evaluating and providing training as well as supervising the nurses on the use of the new guideline.

4.1.2 Communication process

The communication process is divided into three stages, namely, the initiating, guiding, and sustaining stages.

To initiate the communication process, the innovation proposer approaches the senior frontline nurse staff, which includes nursing officers, advanced practice nurses, and nursing specialists. An informal discussion will be held. The existing problems of mechanically ventilated ARDS patients in relation to the humidification system and the proposed interventions will be discussed. An informal discussion of the influence of breathing effort on the humidification system and the problems of ARDS patients will be conducted. Their comments and suggestions on the new evidence-based
guideline will be obtained.

After collecting the opinions from the experienced senior staff, the approval and the essential resources from the administrators, including DOM and COS have to be obtained. A formal presentation will be held, wherein evidence obtained from the reviewed research studies and the transferability and implementation potential of the innovation will be presented. The significance and needs of the changing current practice will be presented as well. The benefits of the new intervention to the patient and the expected outcome will be clearly reported. The cost-benefit ratio will be highlighted in the preliminary budget plan as well as the required resources and manpower. The benefits that would be gained in terms of cost and patients’ benefit when using the new protocol will be illustrated. A comprehensive written proposal for the evidence-based guideline will be provided. Further meetings with the administrators will be arranged as required to update the intervention progress and identify any barriers that oppose the new guideline. Modification on the innovation will be made according to their suggestions.

After obtaining the approval from the administrators, an operation team, which includes one NC, two APNs, and 5 senior nurses, will be formed. The team acts as the trainer, supervisor, and auditor of the new intervention. The members of the team are responsible for implementing the guideline, carrying out a pilot test, modifying, and
evaluating the effectiveness of the innovation. In the first two weeks, regular meetings will be held to establish the program details and set up the new protocol, training program, pilot test, timeframe, and the evaluation plan. The operation team will also maintain active communication with the administrators to obtain resources and advice on implementing the innovation.

In the third and fourth weeks, the new humidification guideline will be introduced to the AICU nurses who are the core users of the intervention. The information will be delivered via internal email, daily handover time, and posting updated information on staff notice board. Moreover, the protocol will be placed at the bedside for reference. Five training sessions will be conducted to ensure that all of the frontline nurses acknowledge the new protocol. All suggestions and opinions will be welcomed and will be discussed during operation team meetings.

During the implementation of the guideline, the operation team members will be available in every duty shift to monitor compliance and immediately clarify any uncertainty from the user. They are required to demonstrate the proper use of the new protocol, ensure that the nurses are familiar with the procedure, provide continuous support, and address the difficulties of the frontline staff. The patient's condition and vital signs will be documented by the ICU nurse as previously practiced. The immediate feedback on the program will be collected and uncertainty during
implementation from the frontline nurses will be clarified by the operation team members in every shift. Establishing adequate communication will allow early identification of resistance or problems, which are essential in promoting the new protocol.

Finally, to determine the feasibility of the guideline, a pilot test will be conducted during the sustaining stage. The intervention progress will be monitored by the operation team, and comments and feedback will be obtained. After the evaluation and the adjustments, the new protocol will be implemented. The guideline will be included into the orientation program for the new staff training. The clinical data related to the use of the active humidification system in ARDS patient will be collected and analyzed. The changes on the clinical and financial aspects will be presented to the stakeholders.

4.2 Pilot testing plan

A pilot study is a small-scale preliminary study conducted to refine the research plan. It is a rehearsal of the full program, which allows the determination of the feasibility, cost, adverse events, and acceptability as well as the prediction of an appropriate sample size before the implementation of the research project. The pilot test will be conducted by the operation team within the estimated time of two months.
4.2.1 Subject enrollment strategies

The target participants in the pilot test will be the patients that were considered based on the inclusion and exclusion criteria. Convenient sampling method will be used to recruit the eligible patients. All enrolled patients will be assessed by the operation team. The pilot test involving 20 ARDS patients with invasive mechanical ventilation in AICU will be performed. The members of the operation team will be invited to design the enrollment logistics and the enrolled participants will be screened by the operation team. Nurses will be expected to follow the proposed guideline and provide nursing care to the target patients.

4.2.2 Staff training

The pilot test will aim to evaluate the details of the protocol including staff training session, proposed guideline, staff acceptance, patient outcome, and the evaluation method. Nurses will be invited to participate in the training session before implementing the evidence-based guideline. The new guideline details including the significance of change, research findings, procedures, and the expected outcome will be clearly presented. Proper use of the new protocol will be demonstrated. Although there are no additional skills required by the new protocol, a refresher session on the use of the active humidification system will
be included to minimize doubts.

4.2.3 Data collection

Patient characteristics including age and gender, diagnosis, reason for mechanical ventilation, mode of ventilation, blood gas result, humidity value, physiological dead space, and duration of mechanical ventilation will be collected. Airflow resistance and work of breathing will be calculated and analyzed. Undesirable results, even those collected after the implementation of the new protocol will be documented in detail and reported to the program supervisor immediately. The time required for data collection, data entry, and analysis process will be tested. The cost of the pilot test will be measured to estimate the budget of the intervention. The data obtained will be computerized and discussed during the evaluation.

To collect user feedback specifically comments and suggestions, a questionnaire will be distributed to the participating staff. The satisfaction level of the staff will be measured.

4.2.4 Evaluation of the pilot testing

Collected data will be evaluated in the weekly program meeting. The problem tackled during implementation will be discussed. The success of the proposed intervention is exemplified mainly by the reduction in the breathing effort of the
mechanically ventilated ARDS patient. The information obtained including those obtained from the questionnaire answered by the user and the suggestions from the stakeholders will be discussed after the pilot test is completed. The humidification protocol will be modified and finalized into a more feasible guideline after the pilot test.

4.3 Evaluation plan

In assessing the efficacy of the humidification protocol on the mechanical ventilation, an evaluation is crucial. It can help determine whether the new protocol can achieve the project objectives and assess the feasibility of the implementation in the target setting. The potential benefits can be identified by comparing the pre- and post-implementation outcome differences. The evidence-based information from the evaluation can assist the stakeholders in deciding on the worthiness and on their support to the new clinical guideline protocol.

4.3.1 Outcomes

The outcomes of implementing the humidification protocol will be categorized into patient, healthcare provider, and organization outcomes. The outcomes form the essential criteria in determining the success of the proposed evidence-based guideline.
4.3.1.1 Patient outcomes

According to the reviewed studies, HME has a potential drawback as shown by the significant increase in airway resistance, minute ventilation, CO₂ retention, and respiratory discomfort. The use of HH on the ARDS patient facilitated less breathing effort compared with the use of HME on the same type of patient. Therefore, breathing workload of the mechanically ventilated ARDS patients is considered as the primary outcome. The data was obtained by calculating the airflow resistance, dead space volume, and the level of mechanical ventilation support of the patient.

CO₂ level is the secondary outcome. Artificial airway dead space increase is related to the increase in blood CO₂ concentration, which will be reflected in the PaCO₂ level in the laboratory test. Increase in CO₂ retention is an undesired outcome of mechanical ventilation that causes respiratory acidosis. The PaCO₂ decrease is directly proportional to the instrumental dead space volume reduction Moran et al. (2006). Girault et al. (2003) also showed that a change in the humidification system contributed to the correction of acidosis as the humidification instrument was strongly related to the change of PaCO₂ and pH values. By measuring the PaCO₂ level in the patient blood test, the benefit of applying the new protocol can be shown. Thus, it can be considered as an effective innovation.
The secondary outcome includes airflow humidity. Adequate humidity can help the endotracheal clearance by stimulating the coughing effort. Moist inspiration air can cause endotracheal occlusion through the gradual obstruction created by the thickened bronchial secretions on the lumen of the ETT. Therefore, measurement of airflow humidity is important in preventing ETT occlusion.

4.3.1.2 Healthcare provider outcomes

Staff satisfaction is important in the successful initiation and sustained implementation of a new innovation. To measure the healthcare provider outcome, the participant's satisfaction level on the new innovation will be evaluated. The satisfactory level toward the program training session and the proposed guideline are considered as primary outcomes. The participants will be invited to complete a self-reported questionnaire to assess their satisfaction level. The degree of satisfaction will be measured by the score rate ranging from 1 to 4: very dissatisfied (1), dissatisfied (2), satisfied (3), and very satisfied (4). This measurement provides the users an opportunity to express their opinions freely and helps to increase the acceptability of the protocol by solving the difficulties raised by the staff. The questionnaires are attached in Appendices 7 and 8.
4.3.1.3 System outcome

Cost effectiveness is considered as the system outcome. It is an essential issue in the administrators' aspect to determine the new innovation is worthwhile to implement. The costs related to the instrument, nursing manpower, set up, and maintenance are the key parameters to be monitored.

4.3.2 Nature and number of clients to be involved

Characteristics of the target population recruited for the evaluation of protocol are based on the inclusion and exclusion criteria of the evidence-based guideline mentioned previously. Population will be composed of mechanically ventilated patients in AICU including medical and surgical patients. Patients diagnosed with ARDS will be eligible to receive the intervention. However, pediatric patients and non-invasive MV patients will be excluded. Upper airways of non-invasive MV patients are functioning as a normal humidification system. Thus, the results may vary from those obtained from invasive MV patients. Pediatric patient will be excluded because the target setting of the protocol is focused on adult ICU patients. Moreover, patients who are planning to undergo extubation within 24 h will be excluded as well.

Convenience sampling will be used during the 10-month implementation period
for recruiting target patients. All recruited patients will be assessed by the program supervisor and followed up by the operational team until discharge to the general ward.

The expected primary outcome of the proposed innovation is the reduction of the work of breathing of mechanically ventilated ARDS patient by using the active humidification system. For comparison of breathing with the use of the new protocol, t-test will be used and the results will be presented as mean +/- standard error of the mean (SEM). A free online computer program will be used to calculate the sample size (Lenth, 2006-9). The reviewed studies revealed that the minimum reduction of the breathing effort is 40%. With a power of 80% at a statistical significance level of 5%, the anticipated reduction rate is 40% and the attrition rate is 10%, whereas the estimated sample size is 156.

**4.3.3 Timing and frequency of taking measurements**

Different types of the outcome have different timing and frequency for the method of measurement. Patients' outcome are demographic data, diagnosis, and clinical parameters. The information will be documented by the case nurse as previously practices. During the implementation period, the patient's vital signs and ventilator parameters will be documented on an hourly basis and the airflow humidity
will be measured every 4 hours until weaning off from the ventilator. The patient's blood test, WBC count, and chest X-ray will be performed at least daily as generally done. The operation team will collect the data weekly until the termination of the mechanical ventilator. Any interruption and abnormality that occurs will be recorded in detail and reported to the program coordinator. A monthly program meeting will be held for the evaluation and modification of the protocol. The questionnaire on the new protocol, which aims to assess the satisfaction level, will be completed by the nurse in the last month of the implementation period. Moreover, the set up, training, and running costs as well as resource allocation will be evaluated in the monthly meeting. All expenditures will be obtained and evaluated after the entire program has been completed.

4.3.4 Analysis of data

The patient characteristics, demographic data, and diagnosis will be summarized by descriptive statistics. A t-test for testing one proportion will be used to determine whether a 40% mean reduction of the breathing effort can be achieved after implementing the new innovation.

For the data that include satisfaction level on the training session and evidence-based guideline as well as the acceptability of the protocol, a 95% confident
interval rating score will be reported. Qualitative data obtained such as opinions on the program will be grouped into themes and the different perceptions of the opinion will be analyzed and reported.

Recording of the expenditures of the program will be computerized. A comparison with the previous expenditures before the application of the guideline will be performed. According to the ward manager of the target setting, the daily cost of providing humidification using HME and HH per patient is $10 and $24, respectively, including material and manpower costs. Therefore, there will be an additional expenditure of $14 per patient when using HH instead of HME.

4.3.5 Determining protocol effectiveness

The effectiveness of a new innovation should be determined before it is applied to the clinical setting. The humidification protocol will be considered as effective if the primary outcome of achieving 60% reduction in breathing effort after implementing the new innovation is attained. From the findings of the reviewed studies, the average reduction of the PaCO₂ level is approximately 10% when using the HH instead of HME. Thus, a 10% decrease in the PaCO₂ level is considered as effective.

The healthcare provider outcomes, satisfaction level of the training arrangement,
implementation process, and acceptability of the innovation are important in determining the effectiveness. Achieving 95% attendance in the training session and 80% completion rate of the questionnaire are considered as evidence of effectiveness.

Although no actual reduction of the cost of the humidification system exists for the organization outcome, non-material benefits are reported by the reviewed studies. The reduction of the breathing effort and the PaCO2 level can facilitate the treatment progress. Thus, these benefit the weaning progress and reduce the length of stay in ICU. Despite the additional expenditure when using HH instead of HME, long-term benefits and adherence to patient’s interest outweigh the potential risks and cost.
# Appendices

## Appendix 1

### Searching Results

<table>
<thead>
<tr>
<th>Search terms</th>
<th>Database searched</th>
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<tr>
<td></td>
<td>Proquest</td>
<td>Ovid</td>
<td>Google Scholar</td>
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<tr>
<td>1 +2+3+4+5+6</td>
<td>36</td>
<td>24</td>
<td>792</td>
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<td>Potentially relevant studies after screening of the abstract, without previous database(s) duplication</td>
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<td>3</td>
<td>6</td>
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<tr>
<td>Hand searching articles from reference lists</td>
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<td>2</td>
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<tr>
<td>Final analyzed studies</td>
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</table>
## Appendix 2
### Table of evidences

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Study type</th>
<th>Patient characteristics</th>
<th>Interventions</th>
<th>Comparison</th>
<th>Length of follow up</th>
<th>Outcome measures</th>
<th>Effect size</th>
</tr>
</thead>
</table>
| Jean (1999)   | RCT (1+)   | 45 medical ICU patients undergoing MV for respiratory insufficiency of various etiology and severity - mean age 42 years - mean weight 66 kg (rang: 46 to 99) | Humidification with HME (n=25) | Humidification with HH (n=20) | N/A | 1) absolute humidity  
2) relative humidity  
3) Tracheal temperature | 1) 25.1±1.6 (HME), 34.3±1.3 (HH), p<0.01  
2) 88.4±6.1 (HME), 99.9±0.4 (HH), p<0.05  
3) 32.1±0.9 (HME), 34.8±0.7 (HH), p<0.001 |
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<tr>
<th>Author (Year)</th>
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<th>Effect size</th>
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<tbody>
<tr>
<td>Campbell (2000)</td>
<td>RCT (1+)</td>
<td>26 surgical ICU patient with MV Group 1: patients were recovering from acute lung injury (ALI) and spontaneous breathing with ventilator Group 2: patients were pharmacologically paralyzed with controlled MV for OT</td>
<td>The patients were recovering from ALI and MV with 3 types of humidification system: HH, HHME, HME (n=15)</td>
<td>The patients were paralyzed and MV with 3 types of humidification system: HH, HHME, HME (n=11)</td>
<td>N/A</td>
<td>1) Frequency (breaths/min) 2) Tidal volume (mL) 3) Minute volume (L/min) 4) oxygen consumption 5) carbon dioxide production. 6) dead space volume 7) work of breathing (j/min)</td>
<td>1) 22.1± 6.6(HH), 24.5 ±6.9(HHME), 27.7±7.4(HME), HH vs HMR, p&lt;0.05 2) 411± 61, 400±52, 428±67, HME vs HHME, p&lt;0.05 3) 9.1±3.5, 9.9±3.6, 11.7±4.2 HH vs HME, p&lt;0.05 4) 30.3±6.8, 33.7±7.4, 39.0±8.6 HH vs HME, p&lt;0.05 5) 34.9±6.9, 38.4±6.4, 45.2±7.6, HH vs HME, p&lt;0.05 6) 59±13, 62±13, 68±11, HH vs HME, p&lt;0.05 7) 13.6±8.6 (HH), 19.2±9.1 (HME), 22.3±9.9 (HMEF), p&lt;0.05</td>
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<tr>
<td>Author (year)</td>
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<td>Interventions</td>
<td>Comparison</td>
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<tr>
<td>Iotti, (1997)</td>
<td>RCT (1-)</td>
<td>-Require MV -not affected by COPD -All patients are awake and free from pathological or pharmacological central neural depression -respiratory center function was normal -7 patients were tracheotomized and 3 orally intubated -4 females, 6 males -mean age 58±14 years old</td>
<td>1) MV with HME 2) MV with hygroscopic heat and moisture exchanger and mechanical filter (HMEF) (n=10)</td>
<td>MV with HH (n=10)</td>
<td>N/A</td>
<td>1) Total minute volume 2) Inspiratory work of breathing 3) Pressure support ventilation level above PEEP 4) Physiological dead space 5) Airway resistance</td>
<td>1) 10.6±2.3 l/ml (HH), 10.9±1.6 l/min (HME), 11.9±1.6 l/min (HMEF) p&lt;0.01 2) 13.6±8.6 joule/min (HH), 19.2±9.1 joule/min (HME), 22.3±9.9 joule/min (HMEF), p&lt;0.05 3) 12.8±6.4 cmH₂O (HH), 14.8±5.4 cmH₂O (HME), 17.6±5.6 cmH₂O (HMEF), p&lt;0.001 4) 195±99ml (HH), 227±78ml (HME), 256±72ml (HMEF), p&lt;0.0001 5) 10.4±4.1cmH₂O/l per s (HH), 12±4.6 cmH₂O/l per s (HME), 13.6±5.4 cmH₂O/l per s (HMEF), p&lt;0.001</td>
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<tr>
<td>Author (Year)</td>
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</table>
| Girault (2003) | RCT (1-)  | -chronic respiratory failure patients with MV  
-male: 8  
-female: 3 | MV with HME for 20 mins at two different PSV levels, (HME-7, HME-15) (n=11) | MV with HH for 20 mins at two different PSV levels, (HH-7, HH-15) (n=11) | 5 days | 1) flow rate  
2) minute ventilation  
3) PEEP  
4) PaCO₂  
5) pH  
6) total inspiratory work of breathing | 1) 28±7, 29±7, 26±7, 28±7, p: NS  
2) 12.4±3.5, 13.4±3.5, 12.9±2.9, 13.9±3.6, p=0.005  
3) 4.5±3.1, 6.5±3.8, 4.9±3.3, 5.6±4.2, p=0.032  
4) 7.0±1.5, 8.5±2.7, 6.5±1.7, 8.4±2.5, p=0.025  
5) 7.35±0.05, 7.30±0.09, 7.38±0.06, 7.29±0.09, p=0.020  
6) 1.35±0.80, 1.71±0.97, 0.93±0.84, 1.40±89, p<0.05 |
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<tr>
<th>Author (Year)</th>
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<th>Effect size</th>
</tr>
</thead>
</table>
| Ziad (2001)  | RCT (1++)  | -Require MV for more than 48hrs  
in medical/surgical ICU  
-age 46.9±19.9 | MV with HME (n=123) | MV with HH (n=120) | 1 years | 1) Incidence of VAP  
2) Amount of isolated pathogens  
3) mortality rates | 1) VAP occurred 11.4% in HME group, 15.8% in HH group, p=0.3  
2) Pathogens free: 67.5% in HME group, 50% in HH group, p=0.006  
3) Mortality rate: 32.5% in HME, 25% in HH, p=0.2 |
<table>
<thead>
<tr>
<th>Author (Year)</th>
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<th>Length of follow up</th>
<th>Outcome measures</th>
<th>Effect size</th>
</tr>
</thead>
</table>
| Marin (1998) | RCT (1++)  | Require MV in the medical/ surgical ICU  
- The mean age: 58.4±17.0 (range, 18 to 95)  
- Male: 173  
- Female: 137 | MV with HME (n=163) | MV with HH (n=147) | 4 months | 1) Incidence of VAP  
2) Length of hospitalization and intensive care  
3) The no. of acquired organ system derangements  
4) Duration of MV  
5) Hospital mortality | 1) VAP occurred 15 (9.2%) in HME, 15 (10.2%) in HH, p=0.766  
2) 5.7±5.7 in HME, 5.3±5.5 in HH, p=0.65  
3) 1.5±1.3 in HME, 1.6±1.3 in HH, p=0.561  
4) 4.6±5.8 in HME, 3.7±4.1 in HH, p=0.092  
5) 40(24.5%) in HME, 39(26.5%) in HH, p=0.688 |
<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Study type</th>
<th>Patient characteristics</th>
<th>Interventions</th>
<th>Comparison</th>
<th>Length of follow up</th>
<th>Outcome measures</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaber (2004)</td>
<td>RCT (1-)</td>
<td>60 patients who stayed in the medical ICU over a 10-months period required continuous MV for more than 48 hrs. All patients are orally intubated</td>
<td>MV with an HH with a dual heated-wire circuit. (n=26)</td>
<td>MV with HME, HMEs were replaced every 48 h as recommended. (n=34)</td>
<td>5 month</td>
<td>1) ETT diameters 2) ETT volume 3) ETT resistance</td>
<td>1) 8.0 ± 0.3, 7.9 ± 0.3; p=0.55 2) -5.1 ± 2.5, -3.3 ± 2.9%; p=0.008 3) 8.4 ± 12.2, 19.4 ± 17.7; p=0.001</td>
</tr>
<tr>
<td>Author (Year)</td>
<td>Study type</td>
<td>Patient characteristics</td>
<td>Interventions</td>
<td>Comparison</td>
<td>Length of follow up</td>
<td>Outcome measures</td>
<td>Effect size</td>
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<tr>
<td>Prat (2003)</td>
<td>RCT (1--)</td>
<td>10 ARDS patients, with hypercapnia (PaCO2&gt;60 mmHg) patients are MV using a low tidal volume (mean tidal volume below 8 ml/kg of ideal body weight), and already had an indwelling radial artery catheter</td>
<td>MV with the following humidification system: 1) HME (internal volume=45 ml) with CSS (DSh=70 ml) 2) HME (internal volume=25 ml) with CSS (DSh=50 ml) 3) HH with CSS (DSh=25 ml) 4) HH alone (DSh=0 ml) (n=10)</td>
<td>MV with HME (internal volume=95 ml) with a tracheal closed-suction system (CSS) (internal volume=25 ml; total DSh=120 ml) (n=10)</td>
<td>N/A</td>
<td>1) tidal volume (VT) 1) respiratory rate (RR) 2) extrinsic positive end-expiratory pressure (PEEPe) 3) end-expiratory pressure (PEEPi) 4) intrinsic positive end-expiratory pressure (PEEPi) 5) plateau pressure (Pplat) 6) pH 7) PaCO₂ 8) PaO₂/FiO₂ 9) SaO₂ 10) Heart rate (HR) 11) Mean arterial pressure (MAP)</td>
<td>From high resistance to low resistance 1) pH: 7.18±0.08, 7.22±0.09, 7.24±0.09, 7.26±0.08, 7.28±0.08, p&lt;0.05 2) PaCO₂ (mmHg): 80.3±20, 73.7±16, 70.1±16, 65.6±13, 63.6±13, p &lt;0.05 3) The other parameters are not significant</td>
</tr>
<tr>
<td>Author (year)</td>
<td>Study type</td>
<td>Patient characteristics</td>
<td>Interventions</td>
<td>Comparison</td>
<td>Length of follow up</td>
<td>Outcome measures</td>
<td>Effect size</td>
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</tr>
<tr>
<td>Morán (2006)</td>
<td>RCT (1--)</td>
<td>1) 17 ALI/ARDS patients with mechanical ventilated in the ICU. 2) 10 men and 7 women 3) mean age: 62 ± 15 years (range 25–81 years old) 4) Sedation was achieved with titrated IV infusion of propofol, midazolam and opiates, alone or in combination regimens</td>
<td>1) MV with HH; 2) Using the same HH, tidal volume (Vt) was decreased until basal PaCO2 levels were reached. FiO2, respiratory rate and PEEP were kept unchanged. (n=17)</td>
<td>MV with HME (n=17)</td>
<td>N/A</td>
<td>1) PaCO2 (mmHg) 2) pH 3) Physiologic dead space (Vdphys) (ml) 4) Peak airway pressure (Ppeak) (cmH2O) 5) Plateau airway pressure (Pplat) (cmH2O) 6) Total airway resistance (cmH2O/l/seg) 7) Tidal volume (Vt) (ml/kg1) 8) Respiratory system compliance (Crs) (ml/cmH2O)</td>
<td>1) PaCO2: 46 ± 9, 40 ± 8, 45 ± 9, p &lt; 0.001 2) pH: 7.34 ± 0.10, 7.39 ± 0.11, 7.33 ± 0.10, p &lt; 0.001 3) Vd phys: 352 ± 63, 310 ± 74, 269 ± 80, p &lt; 0.001 4) Ppeak: 36 ± 8, 34 ± 7, 29 ± 8, p &lt; 0.001 5) Pplat: 25 ± 6, 25 ± 6, 21 ± 6, p &lt; 0.001 6) Total airway resistance: 12.8 ± 5.4, 11.7 ± 4.2, p = 0.049 7) Vt: 7.3 ± 1.1, 7.3 ± 1.1, 6.1 ± 1.3, p &lt; 0.001 8) Crs: 35 ± 12, 35 ± 12, 42 ± 15, p = 0.001</td>
</tr>
<tr>
<td>Author (year)</td>
<td>Study type</td>
<td>Patient characteristics</td>
<td>Interventions</td>
<td>Comparison</td>
<td>Length of follow up</td>
<td>Outcome measures</td>
<td>Effect size</td>
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<tr>
<td>Prin (2002)</td>
<td>RCT (1--)</td>
<td>- 11 ARDS patients require MV - 5 females, 6 males - mean age 50±17 years</td>
<td>Patients were MV with HME (n=11)</td>
<td>Patients were MV with HH (n=11)</td>
<td>1 year</td>
<td>1) PaO2 (mmHg) 2) SaO2 (%) 3) PaCO2 (mmHg) 4) pH 5) Pplateau (cmH2O) 6) PEEPi (cmH2O)</td>
<td>1) 69±15, 65±10, p=NS 2) 88±7, 89±5, p=NS 3) 67±9, 56±6, p=0.003 4) 7.20±0.11, 7.26±0.06, p=0.005 5) 27±4, 27±4, p=NS 6) 2±1.5, 2±1.5, p=NS</td>
</tr>
</tbody>
</table>
## Appendix 3

### Critical appraisal for the retrieved RCTs

<table>
<thead>
<tr>
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<tr>
<td><strong>Internal validity</strong></td>
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</tr>
<tr>
<td>1.1 The study addresses an appropriate and clearly focused question.</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
</tr>
<tr>
<td>1.2 The assignment of subjects to treatment groups is randomised</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Poorly addressed</td>
<td>Well covered</td>
<td>Not addressed</td>
<td>Not addressed</td>
<td>Not addressed</td>
<td>Not addressed</td>
</tr>
<tr>
<td>1.3 An adequate concealment method is used</td>
<td>Not addressed</td>
<td>Not addressed</td>
<td>Not addressed</td>
<td>Not addressed</td>
<td>Not addressed</td>
<td>Well covered</td>
<td>Not addressed</td>
<td>Not addressed</td>
<td>Not addressed</td>
<td>Not addressed</td>
</tr>
<tr>
<td>1.4 Subjects and investigators are kept ‘blind’ about treatment allocation</td>
<td>Adequately addressed</td>
<td>Not blinded</td>
<td>Not blinded</td>
<td>Not blinded</td>
<td>Adequately addressed</td>
<td>Not addressed</td>
<td>Not blinded</td>
<td>Not addressed</td>
<td>Not blinded</td>
<td>Not addressed</td>
</tr>
<tr>
<td>1.5 The treatment and control groups are similar at the start of the trial</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Poorly addressed</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
</tr>
<tr>
<td>1.6 The only difference between groups is the treatment under investigation</td>
<td>Poorly addressed</td>
<td>Well covered</td>
<td>Adequately addressed</td>
<td>Adequately addressed</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Adequately addressed</td>
<td>Adequately addressed</td>
</tr>
<tr>
<td>1.7 All relevant outcomes are measured in a standard, valid and</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
<td>Well covered</td>
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<td>Well covered</td>
</tr>
</tbody>
</table>
1.8 What percentage of the individuals or clusters recruited into each treatment arm of the study dropped out before the study was completed?

<table>
<thead>
<tr>
<th></th>
<th>Not addressed</th>
<th>Not addressed</th>
<th>Not addressed</th>
<th>Total dropped out rate is 26.6%</th>
<th>39.4% in HME group dropped out; 38.4% in HH group dropped out; total dropout rate is 39%</th>
<th>23.5% in HME group dropped out; 29% in HH group dropped out; total dropout rate is 26.8%</th>
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<th>Not addressed</th>
</tr>
</thead>
</table>

1.9 All the subjects are analysed in the groups to which they were randomly allocated (often referred to as intention to treat analysis)

<table>
<thead>
<tr>
<th></th>
<th>Well covered</th>
<th>Well covered</th>
<th>Well covered</th>
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<th>Well covered</th>
<th>Well covered</th>
<th>Well covered</th>
<th>Well covered</th>
</tr>
</thead>
</table>

1.10 Where the study is carried out at more than one site, results are comparable for all sites

<table>
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<tr>
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Level of evidence 1+ 1+ 1- 1- 1++ 1++ 1- 1- 1- 1-
Appendix 4  
Cost of setting up innovation

Staff training

<table>
<thead>
<tr>
<th>Staff</th>
<th>Time</th>
<th>Cost (HK$)</th>
<th>Total cost (HK$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 coordinated nurses</td>
<td>1 teaching hour</td>
<td>$250/hr</td>
<td>$1250</td>
</tr>
<tr>
<td>70 nurses</td>
<td>1 training hour</td>
<td>$200/hr</td>
<td>$14000</td>
</tr>
<tr>
<td><strong>Total staff training cost</strong></td>
<td></td>
<td></td>
<td><strong>$15250</strong></td>
</tr>
</tbody>
</table>

Materials

<table>
<thead>
<tr>
<th>Material cost</th>
<th>Items</th>
<th>Cost (HK$)</th>
<th>Total cost (HK$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heated Humidifier</td>
<td>2</td>
<td>$600/each</td>
<td>$1200</td>
</tr>
<tr>
<td>Photocopies notes/guideline</td>
<td></td>
<td></td>
<td>$500</td>
</tr>
<tr>
<td>Stationery</td>
<td></td>
<td></td>
<td>$200</td>
</tr>
<tr>
<td><strong>Total material cost</strong></td>
<td></td>
<td></td>
<td><strong>$2200</strong></td>
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</tbody>
</table>

**Total set up cost of the innovation is $15250 + $2200 = $17450**

Appendix 5  
Running cost per year

<table>
<thead>
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<th>Material maintenance cost</th>
<th>Items</th>
<th>Cost (HK$)</th>
<th>Total cost (HK$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance cost of Heated Humidifier</td>
<td>5</td>
<td>$500/each</td>
<td>$2500</td>
</tr>
<tr>
<td>70 Staff refreshment training</td>
<td>0.5 training hour</td>
<td>$200/hr</td>
<td>$3500</td>
</tr>
<tr>
<td>Photocopies notes/guideline</td>
<td></td>
<td></td>
<td>$500</td>
</tr>
<tr>
<td>Stationery</td>
<td></td>
<td></td>
<td>$100</td>
</tr>
<tr>
<td><strong>Total running cost</strong></td>
<td></td>
<td></td>
<td><strong>$6600</strong></td>
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</table>
Appendix 6

An Evidence-Based Guideline

Evidence Based Clinical Guideline for choosing humidification system for mechanical ventilated acute respiratory distress syndrome (ARDS) patients aimed at the reduction of the work of breathing in adult intensive care unit (AICU)

Introduction

Patients suffering from acute respiratory failure such as acute respiratory distress symptom (ARDS) generally require mechanical ventilation (MV) support. Likewise, these patients are admitted to intensive care unit (ICU) when their conditions deteriorate. However, MV may constitute a risk factor in the development, or the worsening of ARDS. The humidification system, one of the essential devices, may increase the work of breathing as demonstrated in several studies. Heat and moisture exchanger (HME) is used initially for all medical or surgical patients who require MV for humidification. However, several studies have shown that HME has potential drawbacks because of the significant increase in airway resistance, minute ventilation, CO₂ retention, and respiratory discomfort (Campbell et al., 2000; Jean et al., 1999; Girault et al., 2003; Moran et al., 2006; Prin et al., 2002). The use of HME in ARDS patient may bring further work load on their respiratory system and worsen their
treatment progress. HH has been recommended for immediate use to prevent further
damage of their weak lungs. (Jaber et al., 2004; Iotti et al., 1996; Prat et al., 2002)

This guideline is formulated according to the evidence from the reviewed studies
and aims to reduce the risks of increased work of breathing by choosing the
appropriate humidification device. The methodology used to grade the articles was
designed by the Scottish Intercollegiate Guideline Network (SIGN).

**Objectives**

1. To provide recommendation based on current evidence for choosing
   humidification device to reduce respiratory effort among the ARDS ventilated
   patient;

2. To promote better patient outcomes in terms of preventing further damage to
   their injured lungs;

To shorten duration of use of mechanical ventilator

**Target Population**

The target population will be mechanically ventilated patients in AICU including
medical and surgical patients. Patients diagnosed with ARDS will be eligible to
receive the intervention. However, pediatric and non-invasive mechanically ventilated
patients will be excluded.

**Target Users of the Guideline**

This guideline is intended for nurses working in AICU where the guideline will be implemented.

**Recommendations**

**Recommendation 1:**

*HH should be used for humidification system for the ARDS patient requiring long-term MV. (Grade of recommendation: A)*

Evidence:

Marin et al., 1998 (1++) recommended switching from an HME to heated water humidification on or within day 7 of the use of mechanical ventilation to maximize patient safety. During prolonged MV (after 9 or 10 days), the patency of artificial airways can be affected by the type of airway humidification. Thus, HH should be the technique of choice for adequate humidification. For short periods of MV, HME may be used safely (Jaber et al., 2004, 1-).
Recommendation 2:

When choosing artificial nose, low-volume and low-resistance devices should be used. (Grade of recommendation: A)

Evidence:

Passive humidifiers with high dead space may negatively impact the respiratory function of spontaneously breathing patients or the CO₂ retention in paralyzed patients. When choosing a passive humidifier, the device with the smallest dead space, but could meet the desired moisture output requirements, should be selected (Campbell et al., 2000, 1+). Artificial noses (HME) may cause a clinically significant loss in the efficiency of ventilatory support. This loss results from increased inspiratory resistance, increased dead space ventilation, and increased dynamic hyperinflation. Therefore, artificial noses should be carefully evaluated based on resistance and volume (Iotti et al., 1996, 1-).

Recommendation 3:

HH should be used for the patients with copious bronchial secretion to avoid blockage of the HME lumen. (Grade of recommendation: A)

Evidence:

Changing HMEs when these become visibly soiled and switching to heated-water
humidification in the presence of copious or thick secretions will help to avoid such complications as suggested by our study results (Marin et al., 1998 1++). Jean et al. [1999 (1+)] reported that the use of HME produces a significantly higher endotracheal diameter reduction compared with the use of HH.

**Recommendation 4:**

The temperature of the HH should be set at 40 °C to provide a 37 °C gas temperature and 100% relative humidity to the patient. (Grade of recommendation: B)

**Evidence:**

The 40 °C setting of the HH ensures a 37 °C gas temperature when the gas reaches the patient because cooling occurs across the 8 cm to 10 cm flexible catheter mount and in the 6 cm of the protruding ETT (Jaber et al., 2004, 1-). The normal breathing of the gas that reaches the alveoli should have a humidity of 100% humidity and temperature of 37 °C (Prin et al., 2002, 2++).  

**Recommendation 5:**

HME should not be used in difficult or potentially difficult to wean patients.  
(Grade of recommendation: B)
Evidence:

Increased dead spaces when using HME add an extra workload to respiratory work (Campbell et al., 2000, 1+). The use of HMEF is associated with an increase in total inspiratory work by approximately 60% of the value observed in the control condition. On the other hand, airway resistance increased only by 30% (Iotti et al., 1996, 1-). The use of HME with pressure support ventilation in respiratory failure patients may induce inspiratory workload, increase in ventilatory requirements, impairment in gas exchange with ventilatory acidosis, and respiratory discomfort. The use of HME should not be recommended in difficult or potentially difficult to wean patients with chronic respiratory failure (Girault et al., 2003, 1-).
References


Marin H. Kollef, Steven D. Shapiro, Vanessa B., Patricia S., Benjamin V. H., Ellen T., Donna P., *A randomized clinical trial comparing an extended-use hygroscopic*
condenser humidifier with heated-water humidification in mechanically ventilated patients. Chest 1998;113;759-767.

Appendix 7
Satisfaction Questionnaire for the Training Session

Please “tick” the following
very dissatisfied (1), dissatisfied (2), satisfied (3) and very satisfied (4)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<tbody>
<tr>
<td>1</td>
<td>Content of training session are relevance</td>
<td></td>
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<tr>
<td>2</td>
<td>Content of training session are valuable</td>
<td></td>
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<tr>
<td>3</td>
<td>Duration of training session</td>
<td></td>
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<tr>
<td>4</td>
<td>Skills of speaker in training session</td>
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<tr>
<td>5</td>
<td>Self competent to use the humidification guideline after training</td>
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Other comment:
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_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
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Date of completion: _____________________
Name: ________________________________
Title: ________________________________
Appendix 8  
Satisfaction Questionnaire for using Evidence-Based Humidification Guideline

Please “tick” the following: very dissatisfied (1), dissatisfied (2), satisfied (3) and very satisfied (4)

<table>
<thead>
<tr>
<th></th>
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<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Content of guideline</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Clearness of guideline</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>3</td>
<td>Guideline is user-friendly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Resource(s) and material(s) provided</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Support and help given when necessary</td>
<td></td>
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</tr>
<tr>
<td>6</td>
<td>Workload after implementing innovated guideline</td>
<td></td>
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</tr>
<tr>
<td>7</td>
<td>Beneficence to patients after implementing guideline</td>
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<td></td>
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</tbody>
</table>

Other comment:

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
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_____________________________________________________________________

Date of completion: _____________________  
Name: ________________________________  
Title: ________________________________
### Timeline of the Implementation & Evaluation Plans of the Study

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Months</th>
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<tr>
<td>Identify problem</td>
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<tr>
<td>Undertake a systematic review</td>
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</tr>
<tr>
<td>Develop an outline &amp; preliminary thoughts about the overall study</td>
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<tr>
<td>Discuss with the senior frontline nurses for opinion</td>
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</tr>
<tr>
<td>Communicate with Administrators</td>
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<tr>
<td>Building a operation team</td>
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<tr>
<td>Obtaining funds</td>
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</tr>
<tr>
<td>Modification of the guideline, setting up innovation program</td>
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<tr>
<td>Staff training session</td>
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<tr>
<td>Pilot testing</td>
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<tr>
<td>Pilot test evaluation, modifications on the guideline</td>
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<tr>
<td>Implementing new guideline</td>
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<td>Data collection</td>
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<td>Evaluation</td>
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<td>Data analysis</td>
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<tr>
<td>Writing a report of the study</td>
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</table>
References


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