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Mini-Symposium: Ventilation Strategies in the Paediatric Intensive Care Unit

Ventilator Associated Pneumonia in Children

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EDUCATIONAL AIMS

The reader will come to appreciate that ventilator associated pneumonia:

- Is the second most common acquired infection in ventilated children
- Is associated with significant morbidity and mortality
- Contributes significantly to increase in health care burden and costs

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SUMMARY

Ventilator associated pneumonia (VAP) is a common complication in mechanically ventilated children and adults. There remains much controversy in the literature over the definition, treatment and prevention of VAP. The incidence of VAP is variable, depending on the definition used and can effect up to 12% of ventilated children. For the prevention and reduction of the incidence of VAP, ventilation care bundles are suggested, which include vigorous hand hygiene, head elevation and use of non-invasive ventilation strategies. Diagnosis is mainly based on the clinical presentation with a lung infection occurring after 48 hours of mechanical ventilation requiring a change in ventilator settings (mainly increased oxygen requirement, a positive culture of a specimen taken preferentially using a sterile sampling technique either using a bronchoscope or a blind lavage of the airways). A new infiltrate on a chest X ray supports the diagnosis of VAP. For the treatment of VAP, initial broad-spectrum antibiotics should be used followed by a specific antibiotic therapy with a narrow target once the bacterium is confirmed.

INTRODUCTION

After blood stream infections [1], Ventilator Associated Pneumonia (VAP) is the second most frequently occurring nosocomial infection in Paediatric Intensive Care Unit (PICU), accounting for up to 20% of all such infections [1,2]. VAP not only contributes to prolonged hospital length of stay and increased cost, but also to mortality and morbidity [3,4]. In a retrospective study of paediatric cardiothoracic surgical patients, VAP was associated with an additional 3.7 days of mechanical ventilation with an estimated cost of U$11,897 per episode [5]. Moreover, for each day spent in the paediatric cardiac intensive care unit as a newborn, the full scale IQ of a patient at 8 years of age falls by 1.4 points, and mathematical achievement by 1.6 points [6]. The accumulated socioeconomic cost for treatment of VAP therefore far exceeds the expenses associated with prevention of VAP, and highlights the importance of instituting preventative measures to reduce the risk of VAP [7,8]. There have been increasing numbers of publications in recent years addressing the need for instituting a set of key evidence-based interventions to combat this preventable hospital acquired infection (HAI) [9]. This review explores the issues surrounding the definition of VAP including recommendations on how to address the problem and how to measure success in the reduction of VAP in your own institution using strategic guidelines.

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PATHOGENESIS OF VAP

The origin and pathogenesis of VAP remains unclear. Most likely, VAP is the result of micro-aspirations rather than blood stream associated infiltrates of the lung. Entry of bacteria to the lung may be facilitated directly through the endotracheal tube (ETT) during disconnection from the ventilator circuit. Most of the bacteria found in the endotracheal aspirates of patients suffering from VAP are also found in the naso-oropharynx and even in gastric secretions [10]. Therefore, the current literature has emphasised the role of strategies to prevent VAP.

VAP DIAGNOSIS

VAP diagnosis has proven to be challenging. Universally accepted criteria are yet to be determined [4]. To date, there is only one uniform VAP and surveillance definition which was published and developed by the US Centres for Disease Control and Prevention (CDC), reflecting the difficulty in making an accurate and timely diagnosis of VAP [11,12]. There are multiple variables, including non-invasive and invasive diagnostic strategies, and so each guideline and study needs to be carefully reviewed. The reader must consider how the diagnosis of VAP was made, as very different outcomes may be reported depending on the definitions used.

The most commonly accepted definition of VAP is of a pneumonia occurring after the patient has been intubated and received mechanical ventilation. Although no minimum period has been determined before the infection is termed ventilator-associated, it is generally accepted that this should be more than 48 hours [13]. The initial diagnosis is based on clinical suspicion and the presence of at least one of the following on two or more serial chest radiographs: new or progressive radiographic infiltrates, consolidation, cavitation, and pneumatocoeles in an infant $\leq$ 1 year old. Additionally, the standard diagnostic criteria include at least two or three (applicable only for the under 12 year olds) of the following: fever of >38 °C or hypothermia of <36.5 °C; change in sputum volume or character or increased suctioning requirement; new onset or worsening cough or dyspnoea or tachypnoea or apnoea; rales or bronchial breath sounds or wheezing or rhonchi.

A worsening of gas exchange after a period of stability or improvement on the ventilator is used as another criteria (eg, oxygen desaturations, increased oxygen requirements or increased ventilator demands), and bradycardia or tachycardia in the $\leq$1 year age group. Serum biomarkers such as C-reactive Protein (CRP) or procalcitonin (PCT) may also contribute to narrow the diagnostic margin [14]. The debate to include cultures of endotracheal secretions remains open. The risk is that a positive result may represent colonization rather than true infection, potentially leading to inappropriate use of antibiotics.

The clinical criteria on their own have very limited diagnostic value [15]. Many of the signs and symptoms such as purulent secretions and increased suctioning requirements are routinely present in patients receiving prolonged mechanical ventilation or in those with tracheobronchitis. Chest X-Ray changes can be as a result of oedema, atelectasis or haemorrhage. Other signs such as fever, leucocytosis, apnoea and tachycardia are non-specific which can occur in other concurrent morbidities [16]. Moreover, the lack of specific definitions of components of the clinical definitions such as worsening gas exchange, increased oxygen requirements, and increased ventilator settings may contribute to VAP definitions being applied inconsistently [1].

Some clinicians argue that diagnostic criteria should include more invasive methods such as quantitative cultures of lower respiratory tract secretions [11,17]. However, the precise role of diagnostic testing including quantitative cultures in general as well as the use of bronchoscopic versus non-bronchoscopic (NB) methods such as blind bronchial sampling (BBS) or protected specimen brush (PSB) remain controversial [Table 1]. Bronchoscopic techniques allow for the direct visualisation of the lower airways to aid sampling directly at the site of inflammation. The non-bronchoscopic bronchoalveolar lavage (NB-BAL) is performed by placing a suction catheter into the endotracheal tube until resistance is met and then lavaging and suctioning back a small amount of sterile normal saline from the lower airway. The bronchoscopic diagnostic methods are not routinely used because of the technical difficulties and complications that could arise such as relative hypoxemia during the procedure despite high inspired oxygen content leading to a mild increase in $PaCO_2$ and elevation of intracranial pressure in patients with a closed head injury [17]. On the other hand, non-bronchoscopic techniques are less invasive and less costly. These 'blind' sampling procedures do less to compromise gas exchange during the procedure [13], allowing samples to be obtained successfully from patients with small endotracheal tubes. They can be performed by non-physician clinicians [18,19].

Compounding factors that contribute to the significant variability in incidence of VAP include the use of different "gold standards" for diagnosing VAP, the use of different cut off thresholds for quantitative cultures, differences in equipment and protocols, differences in population study and the use of antibiotics. These factors all contribute to the difficulty in study comparison and limited the generalisability of these results [15]. Differences in study methodology and patient characteristics can also influence the reported incidences of VAP [20]. Additionally, differences in surveillance methods across study institutions also introduce variability into the reported incidence of VAP. Since VAP is a hospital acquired infection, preventative strategies should be implemented in bundles and not in isolation of each individual preventive measure.

PREVENTION

Numerous interventions have been studied and shown to decrease the incidence of VAP in the adult ICU setting [13]. However, little research has investigated the effects of these VAP bundles among ventilated paediatric patients [Table 2].

The most common interventions used in the paediatric setting include hand hygiene, mouth care with antiseptic solution and elevating the head of the bed by 30-45°. Other interventions used include changing ventilator circuit only when needing to, drain ventilator condensate away from patient ETT frequently, minimising ventilation days by adopting sedation holidays and weaning protocols, ETT cuff pressure maintenance, preference for orotracheal intubation over nasotracheal intubation, monitoring of gastric residuals to prevent aspiration and in-line suctioning [21,22].

HAND HYGIENE

Hand hygiene remains the primary measure to reduce health care-associated infection. It is estimated that over 30% of healthcare associated infections are preventable by hand hygiene [23]. Its importance warranted international attention, supported by the World Health Organisation (WHO), to highlight the critical role of hand hygiene in order to control the spread of health care-associated infections and multi-resistant pathogens (WHO, 2005). Similarly, the incorporation of hand hygiene into the VAP bundle was recommended and multiple studies have since demonstrated that hand hygiene adherence is a significant component of strategies to reduce VAP [7,24]. Rello et al. found that hand hygiene before manipulating airways had more impact on improving outcomes (VAP rate, ICU length of stay and days of

Table 1
Numerous studies have demonstrated a significant degree of variability in sensitivity, specificity, and positive and negative predictive values when it comes to bronchoscopic diagnostic method. These are presented in the table below:

Turton (2008) [16])	Reviewed 23 studies evaluating the accuracy of bronchoscopic BAL in diagnosing VAP. (n= 957 patients).	• Sensitivity ranged from 42 to 93% with a mean of 73%. Clinical implication is that BAL cultures are not diagnostic for pneumonia in almost one fourth of cases. • Specificity ranged from 45 to 100% with a mean of 82%. This means that the diagnosis is incorrect in about 20% of cases.
Chastre & Fagon (2002) [10]	Reviewed 18 studies that evaluated the bronchoscopically directed PSB technique for diagnosing VAP. A total of 795 critically ill patients were included in the analysis.	Sensitivity 89% Specificity 94%
Chastre et al., (1995) [10]	Compared PSB and BAL to the "gold standard" of histologic findings and quantitative tissue cultures from the same areas of the lungs of patients in their terminal phase of their illness (who had not developed pneumonia before the terminal phase of their illness). 20 ventilated patients were included in this study. Antibiotics had not been added or changed in the 3 days prior to sampling.	• PSB had a sensitivity of 82%, specificity of 77%, positive predictive value of 74%, and negative predictive value of 85%. • BAL had a sensitivity of 91%, specificity of 78%, positive predictive value of 83%, and negative predictive value of 87%. • Quantitative tissue cultures: the presence of $\geq$ 5% intracellular organisms had a sensitivity of 91%, specificity of 89%, positive predictive value of 91%, and negative predictive value of 89%.
Gauvin et al., (2003) [58]	Expert panel was used as the reference standard. They were given clinical, radiographic and microbiologic data but were blinded to the BAL results. Of 30 patients, 10 were diagnosed with VAP and 9 were diagnosed with ventilator-associated tracheitis by an expert panel.	• Intracellular bacteria and gram stain from BAL were specific (95% and 81% respectively) but not sensitive (30% and 50% respectively) for the diagnosis of paediatric VAP. • Clinical criteria and endotracheal cultures were sensitive (100% and 90% respectively) but not specific (15% and 40% respectively). • A bacterial index of $>$ 5 had the highest correlation with the reference standard. A sensitivity of 78%, specificity of 86%, a positive predictive value of 70% and a negative predictive value of 90%. This is the most reliable method for diagnosing VAP in mechanically ventilated children.
Labenne et la., (1999) [59]	Investigated the sensitivity and specificity of PSB and BAL in PICU patients with suspected VAP. The gold standards used by those investigators were a positive pleural fluid culture, computed tomography scan with pulmonary abscesses, histopathological evidence, positive lung biopsy ($> 10^4$ CFU/gram), the same bacteria isolated in blood and endotracheal aspirate without another source, or clinical diagnosis using CDC guidelines established independently by two investigators blinded to PSB/BAL culture results. Of 103 patients, 29 were diagnosed with VAP.	• The sensitivity and specificity for BAL fluid culture were 72% and 88% respectively. • The intracellular bacteria and BAL combined had sensitivity and specificity of 79% and 88% respectively. • Use of PSB culture results in combination with intracellular bacteria and BAL further increased the sensitivity and specificity to 90% and 88% respectively. • Their conclusion was a combined diagnostic approach was superior to either one alone.

mechanical ventilation) than other variables [7]. Similarly, Koff et al. instituted a novel multimodal system designed to improve hand hygiene by ICU providers [24]. They found an increased compliance to hand hygiene resulted in a significant reduction of VAP incidence. There is no doubt that hand hygiene compliance is imperative, but the compliance rate amongst attending healthcare professionals remains low. Therefore, strict hand hygiene guidelines need to be reinforced in the clinical setting.

ROUTE OF ENDOTRACHEAL INTUBATION

In a retrospective chart review, the occurrence of sinusitis in a paediatric population was recently investigated [25]. Out of a total of 596 ventilated children having computer tomography (CT) imaging of the head, 44.3% had radiological evidence of sinusitis without clinical sinus disease. However, no significant difference was found in the frequency of sinusitis when comparing oral and nasal tubes. In addition, Amantéa et al. (2004) performed a study on 50 spontaneously breathing, mechanically ventilated, supine children with uncuffed endotracheal tubes (ETT) [26]. Potential aspiration was assessed by instilling $\leq$1 ml of Evans blue dye into the oropharynx and then evaluating the ETT secretions. They found that children with orotracheal tubes had a higher prevalence of aspiration compared with nasotracheally intubated children (37.1% vs. 6.7%) and recommended the use of the nasotracheal route for intubation. This recommendation however is in contrast with a previous prevention strategy suggested by Muscedere et al. [21,22].

CUFFED ENDOTRACHEAL TUBES AND CUFF PRESSURE CHECKS

The use of cuffed ETTs could potentially decrease risk of aspiration, reduce the need to change ill-fitting tracheal tubes, alter fresh gas flow consumption resulting from excessive leak and lower the usage of over-sized uncuffed tubes, the main cause of subglottic stenosis [27]. In another study comparing cuffed to uncuffed ETTs, a total of 2246 children from birth to 5 years who weighed at least 3 kg from 24 European paediatric anaesthesia centres were studied [28]. It was found that post extubation stridor rates were similar in both groups [28]. Tracheal tube exchange rate was considerably lower in the cuffed tube group with only 2.1% compared to 30.8% in the uncuffed groups. Considering micro-aspiration of contaminated oral secretions is one of the mechanisms leading to VAP, the use of cuffed ETTs may be beneficial in VAP prevention as the superior tracheal seal may decrease the incidence of micro-aspiration. A larger randomised trial is desirable to confirm this finding. In the interim it would seem reasonable to use a cuffed ETT with regular cuff pressure monitoring.

FREQUENCY OF VENTILATOR CIRCUIT CHANGES

Several RCTs were conducted to investigate the frequency of changes to humidified circuitry. This included 2-day versus 7-day intervals [29], 3 day versus 7 day intervals [30]), 7-day versus no change [31] and a prospective study of 2 day versus 7-day and 30 day intervals [32]. All these studies supported the hypothesis that there was no increased incidence of VAP when the frequency

Table 2
What key interventions have been used for paediatric VAP bundle?

Reference	VAP bundle implemented	Outcomes
Brierley, et al. (2012) [60]	• Head up tilt (target 45°, but achieved 20-30°) • Mouth care with oral antiseptic every 4 hourly OR 12 hourly toothbrush • Clean suctioning practice • Gastric ulcer prophylaxis: Ranitidine • Chest X-Ray interpretation (Physio to complete) • Documentation to be completed 4 hourly • Indication of VAP compliance – to be documented each shift	Pre- bundle VAP is 5.6/1000 ventilator days. Post bundle VAP is 0/1000 ventilator days over 12 month period.
Bigham, et al. (2009) [61]	Prevention of bacterial colonisation of oropharynx, stomach & sinuses • Change ventilator circuits and in-line suction catheters only when visibly soiled • Drain condensate from ventilator circuit at least every 2-4 hours (use heated wire circuits to reduce rainout) • Store oral suction devices (when not in use) in non-sealed plastic bag at the bedside; rinse after use • Hand hygiene before and after contact with ventilator circuit • When soiling from respiratory secretions is anticipated, wear gown before providing care to patient • Follow unit mouth care policy every 2-4 hours Prevention of aspiration of contaminated secretions • Elevate HOB 30-45°, unless contraindicated and by written order • Always drain ventilator circuit before repositioning patient • When possible, for children > 12 years old, use endotracheal tube with dorsal lumen above endotracheal cuff to help suction secretions above the cuff	The VAP rate was reduced from 5.6 to 0.3 infections per 1000 ventilator days after bundle implementation
Rosenthal, et al. (2012) [8] Countries involved include: Colombia India Philippines El Salvador Turkey	• Adherence to hand hygiene guidelines • Semi-recumbent position 30-45° • Daily assessment to wean and use of weaning protocols • Use of non-invasive ventilation whenever possible, minimising the duration of ventilation • Preference of orotracheal intubation over nasotracheal intubation • Maintenance of endotracheal cuff pressure of at least 20 cm H_2O • Removal of condensate from ventilator circuits, keeping the ventilator closed during condensate removal • Changing of the ventilator circuit only when visibly soiled or malfunctioning • Avoidance of gastric over distension • Avoidance of histamine-receptor 2-blocking agents and proton pump inhibitors • Use of sterile water to rinse reusable respiratory equipment	VAP rate was 11.7/1000 ventilator days during baseline period and 8.1/1000 ventilator days during the intervention period (31% reduction in VAP rate).

of ventilator circuit changes was reduced. Cost considerations clearly favour less frequent changes.

SUCTIONING TECHNIQUES AND EQUIPMENT

Maintenance of aseptic techniques when performing endotracheal suctioning is essential to prevent contamination of the airways [33]. There are very few studies that have addressed suctioning techniques and the prevention of infection. A systematic review of suctioning in adults with an artificial airway recommended an aseptic technique be maintained throughout the whole procedure [34]. The importance of an aseptic technique is further highlighted by a study performed by Sole et al. (2002) to evaluate the proportion of suctioning devices colonised with pathogenic bacteria and to correlate the bacteria found on respiratory equipment with those found in patient's mouth and sputum [35]. Those investigators found that within 24 hours of changing to new suctioning equipment, 94% of tonsil suction tubing, 83% of in-line suction tubing and 61% of distal suction connectors were colonised with pathogenic bacteria similar to those found in the patient's oropharynx and sputum.

Several studies have been conducted comparing open versus closed suction systems and VAP incidence. A closed suction system was introduced to address some of the complications associated with the traditional open system suctioning procedure, including environmental contamination, cross infection, hypoxia and alveolar de-recruitment. Multiple trials have found no difference in VAP incidence utilising either suctioning system [36,37].

The use of normal saline instillation (NSI) prior to endotracheal suctioning has been practised widely in intensive care units to assist with eliciting cough, and the dilution and removal of thick secretions. It has been argued that NSI could increase the incidence of VAP because it dislodges more viable bacterial colonies from the endotracheal tube to the lower respiratory tract than the insertion of a suctioning catheter without saline instillation. Interestingly, Caruso et al. (2009) found a decrease in the incidence of culture proven VAP with the instillation of isotonic saline before tracheal suctioning in their randomised clinical trial of 262 patients utilising a closed suctioning system [38].

SEMI-RECUMBENT POSITIONING

Positioning of intubated patients is believed to be a significant element in VAP prevention. The 30-45° semi-recumbent or head of bed elevation has been widely recommended in the literature [39] and endorsed by the US Centres for Disease and Prevention (CDC) as one of the most simple and effective strategy in VAP prevention [11]. A clinical randomised cross over trial demonstrated greater aspiration of gastric contents to the airways when patients were kept in the supine position despite inflation of the endotracheal tube cuff [40]. Additionally, the length of time spent in this position was proportionate to an increased aspirated content. The semi-recumbent position of patients has been effective in preventing aspiration of the gastric contents [41]. A few years later, another randomised trial demonstrated that semi-recumbent position is more effective in reducing VAP incidence than the supine position [42].

However, recently some investigators have questioned whether this position is optimal for VAP prevention [43]. Panigada et al. argued that in the semi-recumbent position, gravitational forces will facilitate contaminated subglottic secretions travelling across the tracheal cuff, entering the lower respiratory tract especially during suctioning because of the pressure drop within the respiratory system [44]. At the same time, lower respiratory tract secretions cannot be cleared out of the trachea, except during suctioning. This claim was supported by an animal study which showed that gravitational forces influenced tracheal mucus clearance following tracheal intubation [45]. When the trachea is oriented above horizontal (as in the semi-recumbent position in the human), a flow of mucus from the proximal trachea toward the lungs is highly associated with bacterial colonisation of the lungs and pneumonia. Whereas, when the trachea is oriented even slightly below horizontal, mucus always moved toward the glottis and lungs remained free from bacterial colonisation [43]. In another study, comparing patients placed in the lateral horizontal position compared to patients in semi-recumbent position, it was demonstrated that the incidence of aspiration of gastric contents was similar in both positions [46]. In addition, the lateral position did not cause any adverse events. Currently, a multinational trial is undergoing to corroborate the benefit of lateral Trendelenburg versus semi recumbent body position in intubated patients with relation to the incidence of VAP.

ORAL HYGIENE

Poor oral hygiene has been identified as having a strong association with VAP [47,48]. Bacterial plaque can build on teeth within 72 hours after cessation of an adequate oral hygiene regime. In addition, the formation of an oral biofilm on the non-shedding surfaces of teeth serves as a susceptible medium for colonization by respiratory pathogens [47,49]. Many of these pathogenic bacteria can migrate into the lung directly via the open route provided by the presence of an endotracheal tube (ETT) which increases the risk of VAP.

A comprehensive oral hygiene program in acute care settings is essential to prevent VAP and has been recommended by the CDC [11]. In a systematic review of oral assessment instruments, out of fifty-four different instruments only four were identified for use in children and young people [50]. The review identified the Oral Assessment Guide [OAG] developed by Eilers et al. (1998) for use in the care of children and young people with cancer to be the most appropriate and clinically useful instrument for optimising oral hygiene in the intensive care setting [51]. Excellent inter-rater agreement between clinical nurses was demonstrated and it was preferred over other instruments. The OAG was also found to be clinically useful for assessment, documentation and communication on oral changes, effective in detecting changes in oral status and useful in guiding nursing interventions.

Traditionally, foam swabs dipped in tap water or mouthwash had been used extensively in critical care settings to provide oral care for those who are receiving mechanical ventilation [52]. There has been substantial research dedicated to comparing the efficacy of foam swabs with a toothbrush in their ability to remove dental plaque and debris to maintain oral health. Foam swabs were less effective in comparison to tooth brushing in plaque removal [53]. The use of a small, soft toothbrush is the recommended tool in most literature for providing oral hygiene for mechanically ventilated patients [47]. Tap water is used in many critical care units for providing oral care. Researchers had noted that potentially pathogenic bacteria were present in the water supply of health care facilities and stated that tap water should not be used as a mouth rinse for critically ill patients since it can be a source of nosocomial infections [54].

Oral decontamination with chlorhexidine (CHX) has also been suggested to decrease the incidence of VAP in studies [55]. CHX has the ability to maintain oral health by suppressing overgrowth of gram-positive and gram-negative bacteria as well as yeast, without causing increased resistance of oral bacteria. Subsequently, it is often used to reduce dental plaque as well as preventing gum disease such as gingivitis. Hence, the risks of exposing the lungs to pathogenic bacteria can be reduced when micro-aspiration of oral secretions occur around the endotracheal tube.

Recommendations to reduce the risk of VAP:

- **Strict hand hygiene guideline is to be employed in the clinical setting.**
- **Orotracheal vs. nasotracheal intubation route in paediatric population requires further study before recommendation can be made in respect to VAP prevention.**
- **Ventilator circuit change is only warranted if the circuit become visibly soiled or malfunctions.**
- **Adopt aseptic technique when performing endotracheal tube suctioning. Suctioning equipment may benefit from changing every 24 hour. Rinse out Yankeur sucker and suction tubing with water after each use.**
- **Comprehensive oral hygiene program incorporating chlorhexidine use, tooth brushing and sterile water are to be adopted for all mechanically intubated children.**

TREATMENT

Once VAP has been diagnosed, timely antibiotic treatment should be initiated. A number of studies have demonstrated that delays in the administration of effective treatment are associated with increased morbidity, costs of care and mortality [56]. There are commonly multiple organisms involved in VAP and during early onset VAP; bacteria such as *Staphylococcus Aureus*, *Streptococcus pneumoniae* and *Haemophilus influenzae* are frequently cultured [23]. Enteric gram-negative bacilli are occasionally observed. In late onset VAP more nosocomial bacteria are found that are often multi-resistant to antibiotics. These include *Pseudomonas aeruginosa, Acinobacter sp, Stenotrophomonas maltophilia* and enteric gram-negative bacilli including *Enterobacter sp., Klebsiella sp. and Citrobacter sp.* Each hospital and paediatric intensive care unit needs collaboration with infection control (IC) guidelines in the treatment of VAP to contain the spread of multi-resistant bacteria. The duration of antibiotic treatment remains controversial but it seems that a shorter duration of administration is sufficient [57]. A short and pragmatic approach is given in Figure 1.

SUMMARY

There is no gold standard for diagnosing VAP, in either the adult or paediatric intensive care setting, but it is accepted that VAP contributes to a significant increase in health care costs. The emphasis in each individual unit should be to prevent VAP using simple measures as high hand hygiene standards. Early antibiotic treatment seems to be the key for successful treatment and reduction of associated co-morbidities.

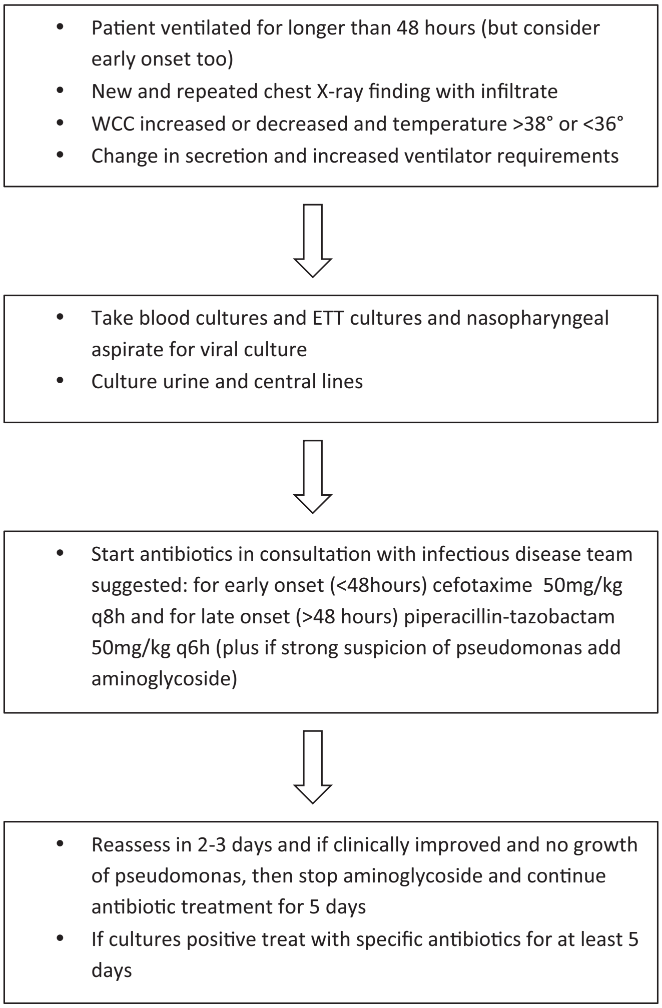

Figure 1. Suggested approach to diagnose and treat VAP.

FUTURE RESEARCH DIRECTIONS

- Like many infection control bundles there is a need for controlled studies to investigate VAP bundles in paediatrics
- Implementation of guideline directed prevention of VAP
- Role of antibiotics in prevention of VAP
- Address the problem of VAP in multi centre studies

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