Association among duration of mechanical ventilation, cuff material of endotracheal tube, and postoperative nosocomial pneumonia in cardiac surgical patients: A prospective study

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Objectives: Postoperative pulmonary complications are a burden for high-risk surgical patients with a risk of aspiration of subglottic secretions along the polyvinyl chloride cuff. The introduction of a polyurethane cuff diminishes secretion leakage with a decreased rate of pneumonia. The aim of the current analysis was to determine the time at which a polyurethane cuffed endotracheal tube might be advantageous to prevent aspiration in a setting of high-risk surgical patients.

Methods: The present investigation is based on published data obtained in postoperative cardiac surgical patients undergoing operation from 2006 to 2007. Cuff pressure was kept between 20 and 26 cmH2O intraoperatively and in the intensive care unit. The current post hoc analysis determines (1) the discriminatory cutoff value of intubation duration for predicting postoperative pneumonia and (2) the potential factors associated with prolonged intubation.

Results: Forty-three patients (32%) were diagnosed with early postoperative pneumonia. Receiver operating characteristics analysis revealed a cutoff value of 16.6 hours for the duration of mechanical ventilation to discriminate patients with postoperative pneumonia. A stepwise binary logistic regression analysis revealed that a polyvinyl chloride cuff was associated with a 10-fold increased risk for prolonged intubation.

Conclusions: The current analyses provide evidence that among cardiac surgical patients, mechanical ventilation more than 16.6 hours is associated with an increased likelihood of postoperative pneumonia. (J Thorac Cardiovasc Surg 2014;148:1622-7)

Postoperative pulmonary infections are a major cause of prolonged hospital care, particularly in high-risk surgical patients.[1-3] Accumulation of secretions in the subglottic area has been described as a major cause. Leakage of secretions along an inadequately sealing cuff and little channels, due to the physical characteristics of a polyvinyl chloride (PVC) cuff, could cause postoperative pneumonia.[4-6] Indeed, microaspiration has been associated with ventilator-associated tracheobronchitis and pneumonia.[7,8] In this respect, evident preventive intraoperative measures comprise adequate cuff pressure and sealing optimization of the endotracheal cuff.

During the past years, there has been considerable progress by optimizing the cuff material altering from PVC to polyurethane (PU).[9-11] The physical characteristics of PU allow the formation of smaller channels, considerably improving sealing capacity and preventing descent of subglottic secretions into the trachea. Poelaert and colleagues[11] have demonstrated a significant decline in the occurrence rate of pneumonia.

Knowledge of the time frame when a PU-cuffed endotracheal tube (ET) becomes beneficial would be important for anesthesiologists and critical care physicians. Therefore, the aim of the current analysis was to determine the time point before which a PU cuffed ET might become advantageous to prevent aspiration in a setting of high-risk surgical patients. Therefore, we used data from our previously published randomized, controlled trial comparing PVC with PU cuffed ETs.[11] More specifically, the objectives of the current post hoc analysis were as follows: (1) to determine the discriminatory cutoff value of duration of intubation predicting postoperative nosocomial pneumonia and (2) to determine which factors are associated with prolonged duration of intubation.

METHODS

The current post hoc analysis is based on a series of patients (undergoing operation in 2006-2007) who were enrolled in a previously published randomized, controlled trial studying the effects of cuff material (PVC vs PU cuffed tubes) on the incidence of early postoperative pneumonia after major heart surgery.[11] The investigation was approved by the ethics committee at Ghent University Hospital (2005/098), and all patients provided written consent to participate in the study.

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Abbreviations and Acronyms

ET = endotracheal tube
euroSCORE = European System for Cardiac Operative Risk Evaluation
ICU = intensive care unit
IV = intravenously
PU = polyurethane
PVC = polyvinyl chloride
ROC = receiver operating characteristic

The study design of the randomized, controlled trial comparing PVC with PU cuffed tubes has been reported.[11] Briefly, all patients undergoing scheduled, urgent, or emergency major heart surgery—coronary revascularization, valve surgery, or combined surgical interventions—were included. Patients with previous (<1 month) or current antibiotic treatment were excluded. Therefore, all patients with endocarditis were not included.

All enrolled patients underwent cardiac surgery after intubation randomly with a high-volume, low-pressure PVC barrel-shaped cuffed (Malinckrodt Inc, Hazelwood, Mo) or PU barrel-shaped cuffed (Sealguard; Covidien, Mansfield, Mass) ET at induction of the anesthetic. The choice of tube used was governed by a randomization list. The anesthesiologist was the sole caregiver aware of which tube was placed into the trachea. Both the PVC and the PU cuffed ET looked similar once the patient was intubated. Therefore, none of the involved caregivers could discern the different tubes. According to countrywide accepted current guidelines, female patients received an ET with an 8.0-mm internal diameter and male patients received an ET with a 9.0-mm internal diameter. After intubation, the cuff was inflated until cuff pressures were between 20 and 26 cmH2O, which were assessed intermittently throughout the procedure and in the postoperative setting.

Induction of anesthesia was performed with sufentanil administered intravenously (IV) (3 $\mu g \cdot kg^{-1}$) and propofol administered IV (2 $mg \cdot kg^{-1}$), in addition to cis-atracurium (induction bolus IV 0.1 $mg \cdot kg^{-1}$, after which a continuous infusion of 0.1 $mg \cdot kg^{-1} \cdot h^{-1}$ was administered). Antibiotic prophylaxis was obtained with cefazolin 2 g/8 hours administered IV for 24 hours.

Postoperatively, patients were transferred to an 8-bed postsurgical intensive care unit (ICU). Sedation consisted of propofol 0.5 to 2 $mg \cdot kg^{-1} \cdot h^{-1}$ administered IV, as reported previously by our research group.[12] Cuff pressure was assessed on arrival and further evaluated at 4-hour intervals. Cuff pressure was kept between 20 and 26 cmH2O. Ranitidine (50 mg IV 3 times per day), nitroglycerin (0.25-1.0 $\mu g \cdot kg^{-1} \cdot min^{-1}$), cefazolin 100 $mg \cdot kg^{-1} \cdot d^{-1}$ (3 times per day), and inotropic drugs, when necessary, were administered. Weaning and extubation criteria consisted of cardiorespiratory stability, with adequate gas exchange, including an arterial oxygen tension greater than 70 mm Hg (with inspired oxygen fraction <0.6, positive end-expiratory pressure <6 cmH2O, and peak inspiratory pressure <21 cmH2O), pH greater than 7.32, and chest tube drainage less than 1 $mL \cdot kg^{-1} \cdot h^{-1}$ for a minimum of 2 consecutive hours. In addition, any neurologic deficit was absent. Aspiration of oropharyngeal secretions was performed every 2 hours until extubation.

Bacteriological samples were taken routinely on arrival to the ICU. Furthermore, recruiting with a peak inspiratory pressure of 35 cmH2O and 5 cmH2O positive end-expiratory pressure was performed starting immediately postoperatively and subsequently every 2 hours, the last time just before extubation.

All other interventions and therapies were started and continued at the discretion of the attending anesthesiologist and surgical team. In all patients, routine blood samples including blood gases were assessed every 4 hours for the first 8 hours postoperatively, and later every 8 hours. A control chest x-ray was taken postoperatively whenever it was found necessary by the attending intensive care physician and in any case the morning after operation. The European System for Cardiac Operative Risk Evaluation (euroSCORE) was calculated and chest x-rays were evaluated by an independent investigator.

Diagnosis of postoperative nosocomial pneumonia was defined before the onset of the study. In our patient population, because microbial pathogens other than commensal flora are rarely isolated in this setting of early postoperative pneumonia, we aimed for higher specificity of the clinical diagnosis requiring that all Johanson criteria[13] and 2 additional criteria be fulfilled.[14] Thus, postoperative nosocomial pneumonia was defined as the presence of a new or evolving infiltrate on chest x-ray within 7 days after surgery, in conjunction with the presence of the Johanson criteria[13]: temperature greater than 38.2°C, leukocytosis greater than 12,000 cells/mm^3, and presence of purulent sputum or endotracheal aspirate.

Additional criteria were an increase in C-reactive protein for at least 2 consecutive days after surgery and a deterioration of at least 20% of the ratio of arterial oxygen tension to the inspired oxygen fraction. After admission to the ICU, patients were screened daily for postoperative nosocomial pneumonia by the attending ICU physician, who was blinded to the ET allocation. Diagnosis of pneumonia was made during the stay in the ICU by the same staff intensive care physician.

Statistical Analysis

The diagnosis of the presence of postoperative pneumonia based on the duration of ventilation was explored using receiver operating characteristic (ROC) curves. By using the duration of ventilation of each patient, we calculated the ROC including area under the curve, specificities, sensitivities, and Youden's index J, which was obtained from the following formula[15]: J = specificity + sensitivity − 1. The maximal value of Youden's index J corresponds to the optimal cutoff value for duration of ventilation to separate patients with and without postoperative pneumonia.

Next, patients were stratified into 2 distinct groups according to the optimal cutoff value for duration of ventilation as obtained from the maximal value of Youden's index J. For each group of interest, continuous data were summarized as median, indicating both 25th and 75th percentiles, and categoric data as the number of cases with percentage. Univariate between-group differences were analyzed by independent samples Mann–Whitney *U* tests for continuous data and the Fisher exact or chi-square tests for categoric data. Statistical significance was specified as a 2-tailed type I error (*P* value) set below the 5% level ($\alpha < .05$).

A multivariate (binary logistic regression) analysis was carried out to assess independent risk factors for a mechanical ventilation duration in excess of the cutoff value (outcome variable). In this multivariate analysis, all variables with a *P* value less than .15 in the univariate analysis were considered to have a plausible relationship with prolonged mechanical ventilation and were included in the adjusted equation model.

Variables were excluded stepwise if the *P* value was greater than .15 in the adjusted equation. The euroSCORE remained included irrespective of its associated *P* value because of its overall evaluation potential because this variable encompasses various physiologic variables. Adjusted odds ratios and 95% confidence intervals were calculated. All analyses were performed using SPSS version 20.0 (IBM, Chicago, Ill).

RESULTS

Overall, 136 patients were enrolled. Two patients died of refractory cardiogenic shock during surgery and were excluded from further analysis.[11] The patient characteristics have been reported. Forty-three patients (32%) were diagnosed with early postoperative pneumonia. The current post hoc ROC analysis revealed an area under the curve of

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