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# Impact of polyurethane on variations in tracheal cuff pressure in critically ill patients: a prospective observational study

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**Abstract** *Objective:* To determine the impact of polyurethane (PU) on variations in cuff pressure ($P_{cuff}$) in intubated critically ill patients. *Methods:* Prospective observational before-after study performed in a ten-bed ICU. Cuff pressure was continuously recorded for 24 h in 76 intubated patients, including 26 with polyvinyl chloride (PVC), 22 with cylindrical polyurethane (CPU), and 28 with tapered polyurethane (TPU)-cuffed tracheal tubes. $P_{cuff}$ was manually adjusted every 8 h by nurses and was maintained around 25 cm$H_2O$. Time spent with cuff underinflation and overinflation was continuously measured. In addition, pepsin, a proxy for microaspiration of gastric contents, was quantitatively measured in tracheal secretions at the end of recording period. *Results:* A total of 1,824 h of continuous recording of cuff pressure was analyzed. Patient characteristics were similar in the three groups. No significant difference was found in percentage of time spent with underinflation (mean ± SD, 26 ± 22, 28 ± 12, 30 ± 13% in PVC, CPU, and TPU groups, respectively) and overinflation [median (IQR), 7 (2–14), 6 (3–14), 11% (5–20)] among the three groups. However, a significant difference was found in the coefficient of variation of $P_{cuff}$ (mean ± SD, 82 ± 48, 92 ± 47, 135 ± 67, $p = 0.002$). While the coefficient of $P_{cuff}$ variation was significantly ($p < 0.017$) higher in the TPU compared to CPU and PVC groups, no significant difference was found between the CPU and PVC groups. The pepsin level was significantly different among the three groups (408 ± 282, 217 ± 159, 178 ± 126 ng/ml; $p < 0.001$). In fact, the pepsin level was significantly lower in the CPU and TPU groups compared with the PVC group. *Conclusion:* PU does not impact variations in $P_{cuff}$ in critically ill patients.

**Keywords** Polyurethane · Cuff pressure · Microaspiration · Intubation · Pepsin · Complications

## Abbreviations

| | |
|---|---|
| CPU | Cylindrical polyurethane |
| ICU | Intensive care unit |
| PVC | Polyvinyl chloride |
| PU | Polyurethane |
| TPU | Tapered polyurethane |
| VAP | Ventilator-associated pneumonia |

## Introduction

Tracheal intubation is a procedure commonly performed in the intensive care unit (ICU) [1, 2]. The tracheal tube cuff has two main functions: ensuring airtightness and protecting the lower airway from the aspiration of contaminated oropharyngeal secretions. Based on recent recommendations, cuff pressure should be maintained around 25 $cmH_2O$ in critically ill intubated and mechanically ventilated patients [3]. However, despite manual checking of tracheal cuff pressure, patients intubated with polyvinyl chloride (PVC)-cuffed tubes spend a large amount of time with underinflation or overinflation of the tracheal cuff [4, 5]. Overinflation and underinflation of the tracheal cuff are associated with subsequent complications such as tracheal stenosis, tracheomalacia, and microaspiration [6–10]. Several factors related to cuff properties and the patient can play a role in aspiration around the tracheal tube cuff. As for cuff properties, internal pressure, resting diameter, material, and shape are the most important factors. As for the patient, viscosity of oropharyngeal secretions, tracheal diameter, hydrostatic pressure above the cuff, and airway pressure are all factors that may facilitate or impede aspiration [11].

Recently, polyurethane (PU)-cuffed tracheal tubes have been commercialized. These tubes have been shown to decrease leakage of oropharyngeal secretions [12, 13]. The PU cuff has a thinner wall (7 μm vs. the more typical 50 μm) and creates a better tracheal seal at generally accepted safe cuff inflation pressures via the creation of smaller channels that impede drainage of oropharyngeal secretions below the tracheal tube cuff. However, to our knowledge, no study has evaluated the impact of polyurethane on variations in tracheal cuff pressure [14]. Because of the thickness, lower resistance, and resting volume of polyurethane cuffs, cuff pressure variations are expected to be greater in these cuffs. However, risk factors for cuff underinflation and overinflation, such as duration of intubation, tracheal suctioning, cough, changes in position, and patient-ventilator asynchrony are common in all intubated ICU patients.

Therefore, we hypothesized that variations in cuff pressure would be similar in patients intubated with PU-cuffed tracheal tubes compared to patients intubated with PVC-cuffed tracheal tubes, and that microaspiration would be less frequent in patients intubated with PU-cuffed tracheal tubes compared to patients intubated with PVC-cuffed tracheal tubes. The primary objective of this study was to determine the impact of the cuff material (PU versus PVC) on variations in cuff pressure. Secondary objectives included investigating: (1) the impact of cuff shape (standard, cylindrical, or tapered) on variations in cuff pressure; (2) the impact of material and shape of the tracheal cuff on microaspiration of gastric contents as quantitatively measured by the pepsin level in tracheal secretions. Some of the results of this study were presented in part at the American Society of Critical Care Medicine's 39th Congress [15].

## Patients and methods

This prospective observational study was performed in a ten-bed ICU during an 18-month period. No informed consent was required by the local Institutional Review Board because of the noninterventional design of the study. Patients or next of kin were informed of their inclusion in this study and could refuse to participate. All patients requiring a first intubation in the ICU were eligible for this study. The only exclusion criterion was intubation before ICU admission.

During the first period of 6 months, patients were intubated with PVC-cuffed tracheal tubes. During the second and third periods of 6 months, patients were intubated with cylindrical polyurethane (CPU) and tapered polyurethane (TPU)-cuffed tracheal tubes, respectively. When several patients were eligible the same day, the patient with the longest duration of mechanical ventilation was included first.

### Cuff pressure recording and pepsin measurement

In all patients, cuff pressure and airway pressure were continuously recorded at a digitizing frequency of 100 Hz for 24 h (Physiotrace®, CHRU, Lille, France) [16]. To maintain cuff pressure around 25 $cmH_2O$, nurses manually checked the cuff pressure with a manometer (Rusch, Kernen, Germany) just before starting the recording and every 8 h thereafter.

In all patients, tracheal suctioning was performed at the end of the recording period in order to determine the pepsin level in tracheal secretions. Tracheal aspirates were stored at −20°C. Quantitative pepsin measurement was performed by an ELISA technique [17]. The pepsin level was considered as positive at 200 ng/ml. Physicians who performed pepsin measurements were blinded to study group assignment.

### Study population

All study patients received enteral nutrition according to a written protocol. Sucralfate was used to prevent stress ulcer prophylaxis. Proton pump inhibitors were used to treat documented esophagitis or gastric ulcer. Continuous subglottic suctioning was not utilized. The ventilator circuit was not changed routinely. In all patients a heat-moisture exchanger was positioned between the Y piece

**Table 1** Characteristics of tracheal tubes used in study patients

| Tube tested | Manufacturer | Cuff material/shape | ID of the tube | OD of the tube | Outer cuff diameter |
|---|---|---|---|---|---|
| Hi-Lo Lanz | Mallinckrodt Medical, Athlone, Ireland | PVC/standard | 7 | 9.4 | 23 |
| | | | 7.5 | 10.2 | 24 |
| | | | 8 | 10.9 | 25 |
| Microcuff | Kimberly-Clark, Zaventem, Belgium | PU/cylindrical | 7 | 9.3 | 22 |
| | | | 7.5 | 10 | 22 |
| | | | 8 | 10.7 | 26 |
| Tapered seal guard | Covidien, Athlone, Ireland | PU/tapered | 7 | 9.6 | 19–26 |
| | | | 7.5 | 10.6 | 20–27 |
| | | | 8 | 11.6 | 21–28 |

*ID* internal diameter, *OD* outer diameter, *PVC* polyvinyl chloride, *PU* polyurethane

and the patient; the heat-moisture exchangers were changed every 48 h or more frequently if visibly soiled. Patients were kept in a semirecumbent position during most of their period of mechanical ventilation. Sedation was based on a written protocol including remifentanil and midazolam. Ramsay score was used to evaluate consciousness [18]. The target Ramsay score was determined by the physicians. The bedside nurse adjusted sedative infusion to obtain target sedation level. In all patients, tracheal suctioning was routinely performed by nurses using an open tracheal suction system. This procedure was performed eight times daily or more if clinically indicated. Quantitative tracheal aspirate was performed after intubation, and weekly thereafter. Tracheal tube size was chosen following the Higenbottam-Payne equation [19]. All tracheal tubes used in this study were high volume and low pressure; other characteristics of tracheal tubes are presented in Table 1 and Fig. 1.

## Definitions

All data were prospectively collected. Normal cuff pressure was defined as cuff pressure 20–30 $cmH_2O$.

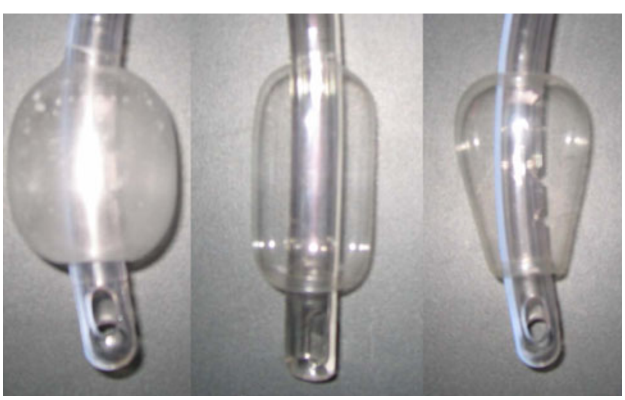

**Fig. 1** Cuff shape of tracheal tubes used in study patients. From *left* to *right*: polyvinyl chloride, cylindrical polyurethane, and tapered polyurethane cuffs

Overinflation and underinflation of the tracheal cuff were defined as cuff pressure >30 $cmH_2O$ and <20 $cmH_2O$, respectively. In all patients, the time spent with normal cuff pressure, overinflation, and underinflation of the tracheal cuff was measured using continuous recording data. The coefficient of variation of cuff pressure was calculated for each hour of cuff recording, using highest, lowest, and mean cuff pressure: (highest − mean) + (mean − lowest)/2. The coefficient of cuff pressure variation for the total recording period was defined as the mean of cuff pressure variation for all the 1-h periods in each patient. The definition of ventilator-associated pneumonia (VAP) included the presence of new or progressive radiographic infiltrate associated with two of the three following criteria: (1) temperature >38.5°C or <36.5°C, (2) leukocyte count >10,000/µl or <1,500/µl, and (3) purulent tracheal aspirate. In addition, a positive ($\geq 10^6$ cfu/ml) tracheal aspirate culture was required [3]. VAP episodes were identified by prospective surveillance of nosocomial infections. Tracheobronchial colonization was defined as positive tracheal aspirate without clinical signs of VAP.

## Statistical analysis

SPSS software (SPSS, Chicago, IL) was used for data analysis. All $p$ values were two-tailed. Differences were considered significant if $p < 0.05$. Categorical variables were described as frequencies (%). The distribution of continuous variables was tested for normality. Normally distributed and skewed continuous variables were described as mean ± SD and median (interquartile range), respectively. $\chi^2$ test and one-way ANOVA were used to compare qualitative and continuous variables among the three groups. If a significant difference was found among the three groups, further analyses were performed between each two groups. Appropriate corrections (Bonferoni) were made for multiple comparisons.

Please see ESM for additional details on methods.

## Results

Seventy-six consecutive patients were eligible and were all included in this study. Twenty-six, 22, and 28 patients were included in the PVC, CPU, and TPU groups, respectively (Fig. 2). No significant difference was found in patient characteristics at ICU admission (Table 2) or during ICU stay (Table 3).

Mean cuff pressure was similar in the three groups. The rate of patients with cuff underinflation was significantly different among the three groups. No significant difference was found in time spent with cuff underinflation. The rate of patients with overinflation and duration of overinflation of the tracheal cuff were similar in the three groups. The coefficient of cuff pressure variation was significantly ($p = 0.002$) different among the three groups (Table 4). The coefficient of cuff pressure variation was significantly higher in the TPU group compared with the PVC ($p = 0.001$) and CPU ($p = 0.016$) groups. No significant difference ($p = 0.47$) was found in the coefficient of cuff pressure variation between the PVC and CPU groups.

A significant difference was found in pepsin levels among the three groups (Table 4). The pepsin level was significantly lower in the CPU and TPU groups compared with the PVC group ($p = 0.007$, $p < 0.001$, respectively). The rate of patients with pepsin >200 ng/ml was significantly lower in the CPU and TPU groups compared with the PVC group [OR (95% CI) = 0.2 (0.1–0.5), $p = 0.008$; 0.2 (0.1–0.7), $p = 0.013$, respectively]. The rate of patients with pepsin >300 ng/ml was significantly lower in the CPU and TPU groups compared with the PVC group [OR (95% CI) = 0.2 (0.1–0.6), $p = 0.009$; 0.2 (0.1–0.6); $p = 0.005$, respectively]. The pepsin level, rate of patients with pepsin >200 ng/ml, and patients with pepsin >300 ng/ml were similar in the CPU and TPU groups ($p > 0.3$, for all comparisons). Please see ESM for additional results.

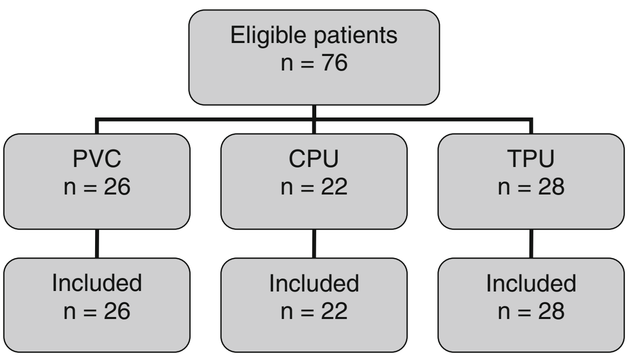


**Fig. 2** Study *flowchart*. PVC: polyvinyl chloride, CPU: cylindrical polyurethane, TPU: tapered polyurethane

## Discussion

The main results of our study are that PU does not impact variations in tracheal cuff pressure in critically ill patients. Tapered cuffs are associated with an increased coefficient of variation in cuff pressure compared with cylindrical and standard cuffs. Microaspiration of gastric contents is less frequent in patients intubated with PU-cuffed tubes compared with patients intubated with PVC-cuffed tubes. No significant difference was found in the pepsin level between patients intubated with CPU and TPU-cuffed tracheal tubes.

**Table 2** Patient characteristics at ICU admission

| | PVC cuff $n = 26$ | CPU cuff $n = 22$ | TPU cuff $n = 28$ | $p$ value |
|---|---|---|---|---|
| Age | 64 ± 13 | 62 ± 14 | 60 ± 16 | 0.648 |
| Male gender | 15 (57) | 13 (59) | 20 (71) | 0.519 |
| SAPS II, median (IQR) | 50 (44–61) | 50 (43–77) | 48 (33–56) | 0.138 |
| LOD score | 6 ± 3 | 6 ± 3 | 6 ± 2 | 0.827 |
| McCabe score | | | | 0.783 |
| Nonfatal underlying disease | 19 (73) | 17 (77) | 18 (64) | |
| Ultimately fatal underlying disease | 6 (23) | 4 (18) | 7 (25) | |
| Rapidly fatal underlying disease | 1 (3) | 1 (4) | 3 (10) | |
| Comorbidities | | | | |
| Diabetes | 3 (11) | 4 (18) | 5 (17) | 0.764 |
| COPD | 11 (42) | 4 (18) | 9 (32) | 0.200 |
| Chronic heart failure | 4 (15) | 2 (9) | 2 (7) | 0.595 |
| Gastroesophageal reflux | 1 (3) | 1 (4) | 3 (10) | 0.537 |
| Category of admission | | | | 0.708 |
| Medical | 23 (88) | 18 (81) | 25 (89) | |
| Surgical | 3 (11) | 4 (18) | 3 (10) | |

Data are $N$ (%) or mean ± SD, unless otherwise specified
*PVC* polyvinyl chloride, *CPU* cylindrical polyurethane, *TPU* tapered polyurethane, *IQR* interquartile range, *SAPS* simplified acute physiology score, *LOD* logistic organ dysfunction, *COPD* chronic obstructive pulmonary disease

**Table 3** Patient characteristics during ICU stay

| | PVC cuff $n = 26$ | CPU cuff $n = 22$ | TPU cuff $n = 28$ | $p$ value |
|---|---|---|---|---|
| At the day of cuff pressure recording | | | | |
| Duration of prior intubation, median (IQR), day | 2 (1–3) | 2 (1–4) | 2 (2–3) | 0.201 |
| Size of tracheal tube | 7.7 ± 0.3 | 7.7 ± 0.3 | 7.6 ± 0.3 | 0.875 |
| LOD score | 4.5 ± 2 | 4.7 ± 3 | 4.8 ± 3 | 0.922 |
| Quantity of enteral nutrition during cuff pressure recording, ml | 653 ± 240 | 571 ± 267 | 772 ± 261 | 0.193 |
| Vomiting | 3 (11) | 2 (9) | 4 (14) | 0.851 |
| Prokinetic drugs | 2 (7) | 2 (9) | 3 (10) | 0.929 |
| Proton pump inhibitor use | 6 (23) | 5 (22) | 7 (25) | 0.843 |
| Sedation | 17 (65) | 15 (68) | 16 (57) | 0.694 |
| Ramsay score | 3 ± 0.6 | 3.3 ± 0.6 | 3.4 ± 1.1 | 0.490 |
| Paralytic agent use | 3 (11) | 1 (4) | 7 (25) | 0.109 |
| Residual gastric volume, ml/day | 120 ± 30 | 138 ± 25 | 131 ± 27 | 0.851 |
| Ventilatory mode | | | | 0.665 |
| ACV | 21 (80) | 20 (90) | 23 (82) | |
| BPPV | 1 (3) | 1 (4) | 0 (0) | |
| PSV | 4 (15) | 1 (4) | 5 (17) | |
| Mean airway pressure | 14 ± 5 | 15 ± 4 | 15 ± 4 | 0.442 |
| Peak airway pressure | 31 ± 8 | 34 ± 7 | 35 ± 9 | 0.152 |
| Positive end expiratory pressure | 6 ± 3 | 7 ± 4 | 6 ± 3 | 0.635 |
| Number of tracheal suctionings/24 h | 8 ± 1 | 8 ± 1 | 8 ± 1 | >0.999 |
| During ICU stay | | | | |
| Tracheobronchial colonization | 10 (38) | 6 (27) | 7 (25) | 0.525 |
| Incidence rate of VAP, no. of episodes/1,000 MV-days | 18 | 13 | 12 | 0.082 |
| MV duration, median (IQR), day | 13 (6–30) | 16 (8–37) | 23 (11–41) | 0.075 |
| Length of ICU stay, median (IQR), day | 14 (10–33) | 26 (13–40) | 24 (12–60) | 0.229 |
| ICU mortality | 9 (34) | 8 (36) | 9 (32) | 0.951 |

Data are *N* (%) or mean ± SD, unless otherwise specified
*PVC* polyvinyl chloride, *CPU* cylindrical polyurethane, *TPU* tapered polyurethane, *IQR* interquartile range, *LOD* logistic organ dysfunction, *ACV* assist-control ventilation, *BPPV* bilevel positive pressure ventilation, *PSV* pressure support ventilation, *VAP* ventilator-associated pneumonia, *MV* mechanical ventilation, *ICU* intensive care unit

**Table 4** Cuff pressure and pepsin level in study patients

| | PVC cuff $n = 26$ | CPU cuff $n = 22$ | TPU cuff $n = 28$ | $p$ value |
|---|---|---|---|---|
| Cuff pressure, $cmH_2O$ | 24 ± 5 | 23 ± 2 | 24 ± 3 | 0.771 |
| Cuff pressure 20–30 $cmH_2O$ | 26 (100) | 22 (100) | 28 (100) | – |
| Duration, min | 881 ± 335 | 893 ± 190 | 789 ± 206 | 0.277 |
| % of time | 61 ± 23 | 62 ± 13 | 55 ± 14 | |
| Cuff pressure <20 $cmH_2O$ | 22 (84) | 22 (100) | 28 (100) | 0.017 |
| Duration, min | 384 ± 329 | 404 ± 176 | 433 ± 193 | 0.764 |
| % of time | 26 ± 22 | 28 ± 12 | 30 ± 13 | |
| Cuff pressure <15 $cmH_2O$ | 18 (69) | 16 (72) | 22 (78) | 0.733 |
| Duration, min, median (IQR) | 44 (3–60) | 18 (0–112) | 89 (26–136) | 0.367 |
| % of time | 3 (2–4) | 1 (0–8) | 6 (1–9) | |
| Cuff pressure >30 $cmH_2O$ | 24 (92) | 22 (100) | 28 (100) | 0.139 |
| Duration, min, median (IQR) | 101 (23–209) | 93 (43–214) | 164 (77–289) | 0.868 |
| % of time | 7 (2–14) | 6 (3–14) | 11 (5–20) | |
| Coefficient of variation of cuff pressure | 82 ± 48 | 92 ± 47 | 135 ± 67 | 0.002 |
| Pepsin level, ng/ml | 408 ± 282 | 217 ± 159 | 178 ± 126 | <0.001 |
| Patients with pepsin >200 ng/ml | 18 (69) | 6 (27) | 9 (32) | 0.004 |
| Patients with pepsin >300 ng/ml | 16 (61) | 5 (22) | 6 (21) | 0.003 |

Data are *N* (%) or mean ± SD, unless otherwise specified
*PVC* polyvinyl chloride, *CPU* cylindrical polyurethane, *TPU* tapered polyurethane, *IQR* interquartile range

Previous studies demonstrated that variations in cuff pressure occur frequently in patients intubated with PVC-cuffed tracheal tubes [4, 20–22]. In a prospective observational cohort study [21], continuous recording of cuff pressure was performed for 8 h in 101 patients intubated with PVC-cuffed tracheal tubes. Only 18% of study patients spent 100% of the recording time with normal cuff pressure. In addition, 33% of study patients developed underinflation or overinflation for more than 30 min. No modifiable risk factor for underinflation or overinflation could be identified. Our results are in line with previous observations that cuff pressure is highly variable over time. Cuff underinflation might increase microaspiration and lead subsequent VAP, whereas cuff overinflation is associated with increased risk for tracheal ischemia. Therefore, continuous control of cuff pressure could reduce complications related to underinflation and overinflation of tracheal cuff.

However, two recent studies, performed in patients and animals intubated with PVC-cuffed tracheal tubes, did not find a reduction in complication rate with continuous regulation compared to manual control of cuff pressure. Valencia et al. [23] performed a randomized unblinded study to determine the impact of automatic control of cuff pressure on VAP rate. Patients were randomized to receive continuous regulation of the cuff pressure with an automatic device ($n = 73$) or routine care of the cuff pressure (control group, $n = 69$). No significant difference was found in the VAP rate between the two groups. However, a recent study demonstrated that automated cuff pressure controllers with rapid pressure correction interfere with the self-sealing mechanism of high-volume, low-pressure PVC-cuffed tracheal tubes and reduce their sealing characteristics [24]. Our group performed a randomized unblinded animal study to determine the impact of continuous regulation of cuff pressure on ischemic tracheal lesions [5]. Twelve piglets were intubated and mechanically ventilated for 48 h. Animals were randomized to manual control of the tracheal cuff pressure ($n = 6$) or to continuous control of the tracheal cuff pressure using a pneumatic device ($n = 6$). Hyperinflation of the tracheal cuff was performed in order to mimic high-pressure periods observed in intubated critically ill patients. Although the pneumatic device provided effective continuous control of cuff pressure, no significant difference was found in tracheal mucosal lesions between the two groups. However, animals were intubated for only 48 h. Further studies should determine the impact of continuous control of cuff pressure on complication incidence in patients intubated with PVC and PU-cuffed tracheal tubes.

Tapered cuffs were associated with significantly higher coefficients of variation of cuff pressure compared with cylindrical and standard cuffs. This result could be explained by the different cuff shape. However, the higher coefficient of variation of cuff pressure observed in TPU-cuffed tubes did not result in a higher incidence of microaspiration. In fact, microaspiration was significantly less frequent in the TPU group compared with the PVC group. In addition, no significant difference was found in microaspiration between the TPU and CPU groups. The tapered cuff represents a new strategy to reduce leakage around the tracheal cuff. The tapered cuff design ensures that there is always a "sealing zone" where the outer cuff diameter corresponds to the internal tracheal diameter.

Our results suggest that microaspiration occurs less frequently in patients intubated with PU-cuffed tracheal tubes compared with those intubated with PVC-cuffed tracheal tubes. Previous in vitro and in vivo studies found similar results [12, 13]. However, our study is the first to use quantitative pepsin measurement in tracheal secretions to quantify microaspiration in critically ill patients. Lucangelo et al. [13] performed a randomized unblinded study to determine the impact of positive end expiratory pressure on microaspiration. Patients were intubated with PVC-cuffed ($n = 20$) or PU-cuffed ($n = 20$) tracheal tubes. Bronchoscopy verified whether the Evans blue leaked around the cuff. The authors found that 5 $cmH_2O$ positive end expiratory pressure was effective in delaying the passage of fluid around the cuffs of tracheal tubes. In addition, leakage, diagnosed by Evans blue, was significantly less frequent in the PU group compared with the PVC group. However, Evans blue only allowed qualitative assessment of leakage. In addition, no information could be provided on cuff pressure in the study by Lucangelo and colleagues. Our data suggest that the reduced leakage found in PU groups compared with PVC group could not be explained by variations in cuff pressure. The creation of smaller channels that impede drainage of oropharyngeal secretions below the tracheal tube cuff is probably the main mechanism in reducing microaspiration in patients intubated with PU-cuffed tracheal tubes [12]. A recent in vitro study suggested that microaspiration occurs during tracheal suctioning [25]. Cuff pressure decreases during tracheal suctioning. However, microaspiration is mainly caused by the negative pressure used to perform tracheal suctioning. Microaspiration of gastric contents and oropharyngeal secretions is an important risk factor for VAP [26–28]. Two recent randomized studies found lower nosocomial pneumonia rates in patients intubated with PU-cuffed tracheal tubes [29, 30].

Our study has some limitations. This study was observational and performed in a single center. Therefore, further randomized multicenter studies are needed to confirm these results. Because of the small number of included patients, no definite conclusion could be drawn on the relationship between PU and tracheobronchial colonization or VAP. However, this was clearly not the objective of our study. Further, percentage of time spent in a semirecumbent position was not measured. Supine position was identified as a risk factor for aspiration of gastric content and VAP [31]. However, microaspiration of gastric contents was a secondary outcome, and it is unlikely that time spent in a semirecumbent position influenced our primary outcome, which is variations in cuff pressure. Pepsin measurement in the tracheal aspirate did not allow quantifying aspiration of oropharyngeal secretions other than gastric content. The role of the stomach in the pathogenesis of VAP is still a matter of debate. However, the results of a recent large study suggest that aspiration of gastric content plays an important role in VAP pathophysiology [26]. Another limitation of this study is that cuff pressure was recorded during only 24 h, which represents less than one tenth of the total duration of mechanical ventilation, resulting in a possible selection bias. However, recording cuff pressure during the total duration of mechanical ventilation is difficult in a large cohort of patients. In addition, variations of cuff pressure are common during a 24-h period, and risk factors for underinflation and overinflation of the tracheal cuff are frequently identified during such a period. Finally, quantitative pepsin was only performed once per patient. Therefore, no comparison of pepsin levels during mechanical ventilation could be performed.

We conclude that PU does not impact variations in cuff pressure in critically ill patients. Tapered cuffs are associated with an increased coefficient of variation in cuff pressure compared with cylindrical and standard cuffs. Microaspiration of gastric contents is less frequent in patients intubated with PU-cuffed (either cylindrical or tapered) tubes compared with patients intubated with PVC-cuffed tubes.

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**Conflict of interest statement** S. Nseir: Covidien, other authors: none

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