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Comparative Effectiveness of Standard Endotracheal Tubes vs. Endotracheal Tubes With Continuous Subglottic Suctioning On Ventilator-Associated Pneumonia Rates

Executive Summary

- Ventilator-associated pneumonia (VAP) accounts for the majority of nosocomial pneumonias, which may increase intensive care and prolonged hospital stays.
- Endotracheal tubes allowing continuous subglottic suctioning may reduce VAP; however, they are more expensive than standard endotracheal tubes not allowing continuous suctioning.
- The objective of this study was to measure the comparative costs associated with continuous subglottic suctioning endotracheal tubes (CSS-ETT) versus standard endotracheal tubes (S-ETT) among intubated patients and whether cost differential is offset by the occurrence of VAP in patients receiving either type of intubation.
- A retrospective chart review was conducted for 154 intubated adult patients (77=S-ETT; 77=CSS-ETT).
- The S-ETT group had one case of VAP; the CSS-ETT group had none. The mean total hospital charges were higher for the S-ETT group ($103,600; CSS-ETT= $88,500) ($p$=0.3).
- Although the average number of intubation days and ICU days were greater for the CSS-ETT group, there were no cases of VAP compared to the S-ETT group.
- Based upon the one S-ETT VAP case and the VAP attributable costs, it is cost effective to use the CSS-ETT.

VENTILATOR-ASSOCIATED pneumonia (VAP) accounts for 90% of all nosocomial pneumonias in the mechanically ventilated population (Caffery & Antle, 2004; Grap & Munro, 2004). The incidence of VAP can occur in up to 65% of all ventilated patients depending on risk factors with an associated crude mortality rate of 24%-50% (Grap & Munro, 2004).

When a patient is mechanically ventilated, the endotracheal tube (ETT) bypasses the natural cough mechanism which helps to avoid aspiration of upper-airway secretions. These secretions then pool above the ETT cuff and eventually can cause microaspiration and pneumonia (DePew & McCarthy, 2007). Microaspiration has been estimated to occur in 20%-40% of mechanically ventilated patients. Guidelines were released by the Centers for Disease Control and Prevention (CDC) in 2003 to assist health care workers in preventing the incidence of VAP (CDC, 2003). These guidelines have placed the use of endotracheal tubes with subglottic suctioning as a category II recommendation, which is defined as "suggested for implementation and supported by suggestive clinical or epidemiologic studies or by strong theoretical rationale." Subglottic suctioning allows for continuous removal of contaminated oral secretions

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above the endotracheal tube cuff.

In 2005, the hospital in which this research was conducted implemented a ventilator care bundle that incorporated many CDC recommendations for the reduction of VAP. Use of the continuous subglottic suctioning endotracheal tube (CSS-ET) was considered; however, the hospital's acquisition charge was a higher cost than the standard endotracheal tube (S-ETT) ($1.62=S-ETT; $13.05=CSS-ETT). Because of this cost differential, many hospitals do not provide CSS-ETT for all patients undergoing intubation, despite the average cost of VAP, estimated at $57,000 per occurrence (Cocanour et al., 2005). Others have estimated the attributable cost of VAP to be approximately $12,000 (Warren et al., 2003). The excess costs per patient makes VAP a target for intervention strategies.

The National Nosocomial Infection Surveillance (NNIS) System Report is used to monitor the occurrence of VAP across the nation (NNIS, 2004). The NNIS rates are pooled means and percentiles of the distribution of ventilator utilization ratios by intensive care unit (ICU) type and size. At our hospital, the combined medical-surgical ICU external benchmark was set using the NNIS at or below 5.1, which is within the 50th percentile of like units in the NNIS report. In the design phase of this research study, the hospital VAP rates ranged from 3.3 to 12.3 quarterly.

The objective of this study was to compare the incidence and the attributable costs of care among ICU patients receiving continuous CSS-ETT versus S-ETT. From an evidence-based practice perspective, the results of this study can be considered by hospitals who are evaluating the purchase of CSS-ETTs for all patients with an anticipated intubation of greater than 48 hours.

The hypothesis of this study was that CSS-ETT is a cost-effective alternative to S-ETT, despite its higher unit cost, based on its index of performance in minimizing the risk of VAP, a costly healthcare outcome associated with intubation.

Methods

This research was approved by an institutional review board. The research was conducted in accordance with the ethical standards set forth in the Helsinki Declaration of 1975. The study was conducted at a 155-bed community hospital with a combined 11-bed medical and surgical ICU.

Retrospective chart review was used to collect study data on 154 intubated patients (77=S-ETT; 77=CSS-ETT) hospitalized over a 23-month period between 2005 and 2007. The S-ETT and the CSS-ETT patients were intubated according to the American Heart Association practice guidelines for Advance Cardiac Life Support and the hospital's standard operating procedure (SOP). The hospital modified the SOP to include the use of CSS-ETTs. During 2005 through 2007, we selected two groups of intubated patients (n=77 per group) according to whether they received CSS-ETT or S-ETT tubes. These two groups were sequential. The CSS-ETT group was selected as the first 77 patients intubated after the hospital's SOP was modified in June 2005. The S-ETT group was selected as the last 77 patients intubated before the SOP modification to include the use of CSS-ETT. The period of selection for each group was approximately 13 months. The hospital intubates on average 222 patients annually. Health care provider types responsible for intubating patients and for direct patient care were consistent before and after SOP modification, and thus were consistent for both study groups.

In this study all patients were 18 years of age or older and intubated either in the hospital or in the field by emergency medical technicians (EMTs) or paramedics. Data for patients were not included in this study if the patient was ventilated by a tracheostomy or intubated for less than 48 hours.

Patient demographics and risk factors for VAP were documented from medical records, as was length of stay, intubation-related factors, medications administered, tube feeding related factors, and extubation-related factors. Documented risk factors included primary admitting diagnosis, previous potential exposure to hospital-acquired pneumonia, and the Acute Physiology and Chronic Health Evaluation (APACHE) II score, a severity of disease classification system (Knaus, Draper, Wagner, & Zimmerman, 1985). Intubation-related factors included intubation days, intubation attempts, occurrence of vomiting with intubation, witnessed aspiration during intubation, hospital location of intubation, intubating professional type, and positive sputum culture within 24 hours post-intubation. For a sputum culture to be considered positive, the following criteria were met: collection within 24 hours post-intubation, gram stain criteria (white blood cells >25 and epithelials <10 straight count per lower power field), and gram stain positive. Diagnosis of VAP was based on the CDC diagnostic criteria (CDC, 2003).

Administration of the following medications was documented: antibiotics, antifungals, antivirals, sedatives, anesthetics, muscle relaxants, paralytics, steroids, chemotherapeutic agents, stress ulcer prophylactics, and nebulizer treatments. Tube feeding related factors were type of enteral tube used, type of feedings administered, frequency of feedings and those held for high residuals, and witnessed regurgitation of tube feeding. Lastly, extubation-related data documented included number of weaning trials, reason for extubation, and disposition at 48 hours post-extubation.

Using the assumption that approximately 29% of patients undergoing intubation experience

nosocomial-acquired pneumonia, the sample size of 154 patients (77 in each group, subglottic versus usual care endotracheal intubation), at 95% confidence and 80% power, was derived. This sample size would optimize the ability to see a significant difference in VAP among intubated patients with S-ETT versus CSS-ETT.

Frequencies and means were used to describe the demographic, risk factor, extubation, and intubation data. To analyze continuous outcomes, t-tests and Mann-Whitney tests were used to determine any statistical difference between the S-ETT and CSS-ETT groups. To compare the two groups by categorical factors, Chi-Square and Fisher Exact tests were incorporated. To adjust for inflated Type I errors due to multiple comparisons, a Bonferonni adjustment was incorporated where needed. Significance levels for all tests were at an alpha level of 0.05. SAS (version 9.1.3; SAS Institute, Inc., Cary, NC) for Windows was the statistical analysis software used in this study.

To estimate the associated charges for each group, S-ETT and CSS-ETT, ten patients were randomly selected from each group. The VAP attributable charges were derived from these patient's hospital medical bills for all care received for the following three periods of time: total days of ICU stay, total days of intubation, and total days of hospital stay. These periods of time were all measured in full days. The VAP attributable costs were applicable from the date of diagnosis of VAP through hospital discharge. Hospital medical bill charges were per those in the hospital accounting database. The hospital acquisition charges used for the tubes compared in this study were $1.62 (S-ETT) and $13.05 (CSS-ETT).

Results

One incident of VAP occurred in this study and it was in the S-ETT group (1.3%).

Table 1.
Patient Demographics and Risk Factors

Demographics	Endotracheal Tube Type (N=154)		
	S-ETT (N=77)	CSS-ETT (n=77)	*p* Value
Average age in years (std)	66.7 (14.2)	61.6 (15.7)	0.032†
Gender (%)			
Male	42 (54.5%)	41 (53.2%)	0.850
Female	35 (45.5%)	36 (46.8%)	
Race/Ethnicity (%)			
African American	11 (14.3%)	11 (14.3%)	0.865
Asian	1 (1.3%)	3 (3.9%)	
Caucasian	59 (76.6%)	56 (72.7%)	
Hispanic	4 (5.2%)	4 (5.2%)	
Other	2 (2.6%)	3 (3.9%)	
ICU admitting diagnosis (%)*			
Cardiac	33 (42.9%)	30 (40%)	0.618
Drug/alcohol/overdose	6 (7.8%)	8 (10.4%)	0.565
Gastrointestinal	9 (11.7%)	13 (16.9%)	0.490
Neurological	13 (16.9%)	13 (16.9%)	0.888
Oncology	2 (2.6%)	2 (2.6%)	0.725
Postoperative	2 (2.6%)	5 (6.5%)	0.258
Pulmonary	61 (79.2%)	75 (97.4%)	0.0003†±
Renal	4 (5.2%)	3 (3.9%)	0.653
Sepsis	6 (7.8%)	6 (7.8%)	0.838
Trauma	0	1 (1.3%)	0.332
Average total number ICU days (std)	9.4 (10.8)	11.3 (10.1)	0.381
Average total number hospital days (std)	18.4 (17.6)	17.8 (13.9)	0.866

* Patients had more than one admitting diagnosis, non-mutually exclusive categories.
† $p < 0.05$
± Statistically significant after Bonferonni adjustment.

The groups were comparable with respect to demographics (see Table 1). The mean age for the study population was 64.2 years, with a greater proportion of the sample being male (53.9%). Average patient age was 5.1 years less in the CSS-ETT group (p=0.032). For both groups, the most frequent ICU admitting diagnoses were pulmonary and cardiac related. Average ICU days were 1.9 days shorter for the S-ETT group than for the CSS-ETT group. Average total days of ICU stay was 0.6 days shorter for the CSS-ETT group.

The analysis of risk factors for VAP is provided in Table 2. APACHE II scores on the first 24 hours of intubation were significantly different between the two groups with the S-ETT group having higher scores (S-ETT=27.4, range 6-49; CSS-ETT=23.5, range 10-35). There were two other risk

Table 2.
Potential Risk Factors for Ventilator-Associated Pneumonia

Risk Factors	Endotracheal Tube Type (N=154)		
	S-ETT (N=77)*	CSS-ETT (n=77)*	*p* Value
Average APACHE II score (std)	27.4 (7.9)	23.5 (5.4)	0.001†
>2 days hospitalization in past 90 days (%)	30 (39.0%)	22 (28.6%)	0.174
Nursing home or long-term care facility resident in past 90 days (%)	8 (10.4%)	9 (11.7%)	0.761
Home nursing care in past 30 days (%)	3 (3.9%)	1 (1.3%)	0.327
Hemodialysis in past 30 days (%)	5 (6.5%)	3 (3.9%)	0.464
Presence of infection upon hospital admission (%)	27 (35.1%)	18 (23.4%)	0.112
Witnessed aspiration prior to intubation (%)	12 (15.6%)	2 (2.6%)	0.005†±
Abdominal or thoracic surgery on this admission (%)	5 (6.5%)	3 (3.9%)	0.464
Immunosuppressive illness (%)	4 (5.2%)	4 (5.2%)	0.803
Smoking within the past year (%)	19 (24.7%)	22 (28.6%)	0.580
Neurologic deficit or impaired sensorium (%)	17 (22.1%)	13 (16.9%)	0.416
Antibiotic use within the past 14 days (%)	23 (29.9%)	10 (13%)	0.011†±
Chronic renal failure (%)	8 (10.4%)	10 (13%)	0.605
Chronic obstructive pulmonary disease (%)	26 (33.8%)	20 (26%)	0.292
Current alcohol abuse (%)	12 (15.6%)	10 (13%)	0.634
Chronic steroid use (%)	9 (11.7%)	9 (11.7%)	0.867
Presence of pneumonia on initial chest X-ray (%)	30 (39%)	34 (44.2%)	0.513

* Does not sum to 100%, non-mutually exclusive categories.
† $p<0.05$
± Statistically significant after Bonferonni adjustment.

factors for development of VAP that were statistically significant between the groups. There was a higher rate of witnessed aspiration prior to intubation in the S-ETT group (15.6), compared to the 2.6% in the CSS-ETT group ($p=0.005$). Antibiotic use within the 14 days prior to intubation was higher in the S-ETT group (29.9%) than in the CSS-ETT group (13.0%) ($p=0.011$).

Average total intubation days were significantly higher for the CSS-ETT group (7.9 days) than for the S-ETT group (5.5 days) (see Table 3). The differences in ET tube sizes used between the groups were not considered clinically relevant.

The extubation factors analyzed are provided in Table 4. For both groups, the primary reason for extubation was planned. At 48 hours post-intubation, more S-ETT patients (74%) than CSS-ETT patients (49.4%) remained hospitalized ($p<0.05$).

The analysis regarding medications administered and tube feedings did not demonstrate clinically relevant findings.

The observed mean charges for total days of hospital stay were $103,600 for the S-ETT group and $88,500 for the CSS-ETT group ($p=0.3$), a savings of approximately $15,000 (see Table 5). The mean charges for total days of ICU stay for the S-ETT group were $72,982 and $81,498 for the CSS-ETT group. However, when the mean charge per ICU day was measured, CSS-ETT patients were $10,859 per ICU day, compared to $15,890 per ICU day for the S-ETT group. The CSS-ETT group patients appeared to require more days of ICU care compared to S-ETT, with their care charge on average being $5,031 less per day.

Based upon the total charges for the one VAP case in this study, the acquisition charge for the endotracheal tubes, and an average number of 222 patients ventilated in the ICU annually where the research was conducted, the cost-effectiveness analysis demonstrates that in terms of total costs of care and cost associated with ICU care, the CSS-ETT enhanced option is cost effective, and may diminish the risk of VAP. There is plausible biologic evidence to sustain the expectation of cost effectiveness of CSS-ETT, and our own empirical observations suggest CSS-ETT is tied to no cases of VAP. Therefore, we conclude based on this study limited by the number of adverse outcomes

Table 3.
Intubation Factors

Intubation Factors	Endotracheal Tube Type (N=154)		
	S-ETT (N=77)	CSS-ETT (n=77)	*p* Value
Average total number intubation days (std)	5.5 (4.26)	7.9 (6.03)	0.008†
Average number intubation attempts (std)	1.1 (0.4)	1.2 (0.6)	0.362†
Occurrence of vomiting with intubation (%)	3 (3.90%)	0	0.102
Witnessed aspiration during intubation (%)	2 (2.6%)	1 (1.3%)	0.999
Location of intubation (%)			
Out of hospital in field	5 (6.5%)	4 (5.2%)	0.687
In hospital	72 (93.5%)	73 (94.8%)	
Intubating professional type (%)			
EMT/paramedic	6 (7.8%)	4 (5.2%)	0.506
Physician in hospital	71 (92.2%)	73 (94.8%)	
Endotracheal tube size (%)			
6.5 cm	3 (3.9%)	1 (1.3%)	0.327
7.0 cm	10 (13%)	17 (22.1%)	0.138
7.5 cm	44 (57.1%)	26 (33.8%)	0.004†±
8.0 cm	20 (26%)	33 (42.9%)	0.028†±
Positive sputum culture within 24 hours post-intubation (%)	18 (23.8%)	9 (11.69%)	0.089

† $p<0.05$
± Statistically significant after Bonferonni adjustment.

Table 4.
Extubation Factors

Extubation Factors	Endotracheal Tube Type (N=154)		
	S-ETT (N=77)	CSS-ETT (n=77)	*p* Value
Average number weaning trials attempted (range)	1.1 (1-2)	1.2 (1-3)	0.249
Reason for extubation (%)			
Planned extubation	58 (75.3%)	49 (63.6%)	0.117
Unplanned extubation/Self-extubation	3 (3.9%)	0	0.102
Terminal weaning	9 (11.7%)	12 (15.6%)	0.479
Tracheostomy	3 (2.6%)	10 (7.8%)	0.045†
Death	2 (2.6%)	6 (7.8%)	0.157
Transferred	2 (2.6%)	0	0.198
Disposition at 48 hours post-extubation (%)			
Remains hospitalized	57 (74%)	38 (49.4%)	0.002†±
Discharged to home	0	7 (9.1%)	0.006†±
Transferred to another acute care facility	3 (3.9%)	3 (3.9%)	0.773
Transferred to rehab facility	1 (1.3 %)	5 (6.5%)	0.107
Died	16 (20.8%)	24 (31.2%)	0.143

† $p<0.05$
± Statistically significant after Bonferonni adjustment.

Table 5.
VAP Associated Charges by Study Group

	S-ETT	CSS-ETT	Difference
Mean total charges	$103,594	$88,498	$15,096
Mean ICU charges	$72,982	$81,450	$ (8,468)
Mean charge per day	$8,157	$9,248	$ (1,091)
Mean charge per ICU day	$15,890	$10,859	$5,031

observed (one case of VAP) that CSS-ETT is associated with lower average and per diem costs of care, and may be associated with a lower risk of VAP.

Discussion

Although the average number of total days of intubation and total days of ICU stay were greater for the CSS-ETT group, there were no cases of VAP in the CSS-ETT group compared to one VAP in the S-ETT group.

Regarding the overall S-ETT and CSS-ETT study groups, 14 of the 17 VAP risk factors were not significantly different between the groups. Of those three factors that were significantly different (APACHE II score, witnessed aspiration prior to intubation, and antibiotic use within 14 days of intubation), the 3.9 point difference in the mean APACHE II score between the groups (S-ETT=27.4; CSS-ETT=23.5) was both statistically and clinically significant, as mortality rates increase with increasing scores. The one VAP case in this study (S-ETT group) was negative for these three risk factors. The APACHE II score was below the average S-ETT group score and only one risk factor for VAP was positive.

From an operational viewpoint, based on the results of this study, the use of the more expensive CSS-ETT in mid-size hospitals could be considered as a practice change or modification to SOP. Careful consideration should be given in the SOP delineating placement of the CSS-ETT to control access of the CSS-ETT and by whom. For example, the CSS-ETT could be included in airway boxes and on crash carts. The CSS-ETTs could also be provided to EMTs who serve the hospital. While it is impossible to determine if a patient will require mechanical ventilation for more than 48 hours, these points of entry may be most practical to capture the population of long-term ventilator patients including those with primary respiratory and cardiac ICU admitting diagnoses. It would be recommended due to the higher acquisition cost for the CSS-ETT that these tubes not be used in operating rooms and surgical areas due to an expected lower volume of patients requiring longer-term ventilation.

This study represents VAP results in a general 155-bed community hospital with an 11-bed medical-surgical ICU. A limitation of this study is that these results may not be applicable to other types of hospitals.

Time, cost, and other constraints prevented the use of random assignment for this study; followup studies may allow for this desirable methodological approach. Another limitation of this study is that indirect costs were not quantifiable due to the nature of retrospective data obtained for this study. However, it is assumed indirect costs would not vary between the groups. We further acknowledge that not all billing records could be extracted due to budget and time constraints; we were able to sample such records and recorded the experience of ten randomly selected patients from each group. Nonetheless, there are no known reasons for systematic differences in patient billing records sampled from those not sampled, and certainly with respect to demographic and medical history characteristics that might bias the results reported.

Conclusion

From the evidence-based practice perspective the results of this study can be used to support the purchase of the more expensive CSS-ETT for use in patients who are expected to have an endotracheal tube in place for at least 48 hours.

Our comparison suggested that CSS-ETT is a cost-effective alternative to S-ETT equipment used in patient intubation. When we measure average and per diem costs of care associated with both modes of intubation, we observed lower costs associated with CSS-ETT. Clearly additional assessments are needed to confirm and substantiate our findings; but in the absence of evidence to the contrary, the additional costs associated with CSS-ETT intubations are balanced by lower average and per diem costs of care. CSS-ETT intubations were also associated with no incidence of VAP, a potentially costly outcome whose avoidance is clearly warranted by cost and patient health risk factors. **$**

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