Use of endotracheal tubes with subglottic secretion drainage reduces ventilator-associated pneumonia in trauma patients

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BACKGROUND: Patients sustaining traumatic injuries have a higher incidence of ventilator-associated pneumonia (VAP) compared with other critically ill patient populations. Previous studies of patients with predominantly medical diagnoses and use of endotracheal tubes allowing subglottic secretion drainage (ETT-SSD) have shown significant reduction in VAP rates. We hypothesized that the use of ETT-SSD would reduce VAP in trauma patients.

METHODS: A retrospective review from 2010 to 2014 of adult trauma patients orotracheally intubated for more than 48 hours was performed at a Level 1 trauma center. Patients were compared based on standard endotracheal tube (ETT) versus ETT-SSD for the primary outcome VAP per 1,000 ventilator days. The diagnosis of VAP was made by quantitative bronchoalveolar lavage cultures as defined by Centers for Disease Control and Prevention criteria. Patients with ETT-SSD were matched to patients with ETT based on age group, sex, mechanism of injury, head and chest Abbreviated Injury Scale (AIS) score, and Injury Severity Score (ISS).

RESULTS: Of 1,135 patients included in the study, 667 patients had ETT and 468 had ETT-SSD. Groups did not differ by demographics, mechanism of injury, Glasgow Coma Scale (GCS) score, alcohol intoxication, or ISS. Patients with ETT-SSD had significantly higher head AIS score but lower chest AIS score. In matched cohorts, ETT-SSD had a lower VAP rate (5.7 vs. 9.3 for ETT, $p = 0.03$), decreased ventilator days (12 vs. 14, $p = 0.04$), and decreased intensive care unit length of stay (13 days vs. 16 days, $p = 0.003$).

CONCLUSION: After controlling for confounding factors, ETT-SSD decreased VAP rate, ventilator days, and intensive care unit length of stay in trauma patients. In this high-risk patient population, we recommend routine use of ETT-SSD to decrease VAP. (*J Trauma Acute Care Surg.* 2016; 80: 218–222. Copyright © 2016 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic/care management study, level III.

KEY WORDS: Subglottic suction; endotracheal tube; ventilator-associated pneumonia.

Ventilator-associated pneumonia (VAP) is a common complication in patients who are endotracheally intubated and is defined as pneumonia arising in a patient intubated for greater than 48 hours.[1,2] Patients experiencing traumatic injuries have a higher incidence of VAP compared with other critically ill patient populations.[3] In the 2012 National Healthcare Safety Network report, the mean VAP rate (number of VAP per 1,000 ventilator days) for trauma patients was 3.6, compared with only 1.0 for medical patients and 2.2 for general surgical patients.[4] In addition, trauma patients intubated in the prehospital setting or emergency department may have even higher rates of pneumonia.[5] VAP is associated with increased risk of sepsis and death, and previous studies have emphasized the importance of prevention initiatives.[6]

VAP is thought to be caused by pooling of oral secretions above the endotracheal tube (ETT) cuff and subsequent microaspiration of these secretions.[7–9] Pooling of secretions can be reduced by the use of ETTs equipped with subglottic suction. These specialized ETTs have a separate suction port that allows suctioning below the glottis and above the ETT cuff. Previous studies involving primarily medical patients, including multiple randomized controlled trials, have shown significant reduction in VAP rates in patients intubated with endotracheal tubes with subglottic secretion drainage (ETT-SSD).[10–15] Despite these purported benefits, these tubes are not widely used and have not been studied in traumatically injured patients; therefore, applicability to the traumatically injured population is unknown. We hypothesized that the use of ETT-SSD would reduce VAP in trauma patients, who are inherently high risk for VAP.

PATIENTS AND METHODS

Adult trauma patients admitted to Community Regional Medical Center, a 650-bed, American College of Surgeons–verified Level 1 trauma center in Fresno, California, were retrospectively reviewed from 2010 to 2014. Patients were identified from the trauma registry and included if they were 14 years or older, were orotracheally intubated for more than 48 hours, and had complete medical records. Patients were excluded if they were intubated at a referring hospital or had an early death (<48 hours). Data collected included demographics, mechanism of injury (blunt vs. penetrating), Glasgow Coma Scale (GCS) score, Injury Severity Score (ISS), organ system Abbreviated Injury Scale (AIS) score, VAP, ventilator days, tracheostomy, intensive care unit (ICU) length of stay (LOS), and mortality. The primary outcome was VAP rate, which was

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TABLE 1. Baseline Characteristics

	ETT (n = 667)	ETT-SSD (n = 468)	*p*
Male sex	516 (77%)	368 (79%)	0.61
Age, mean (SD)	44 (20)	45 (20)	0.42
Blunt mechanism	559 (84%)	409 (87%)	0.09
Initial GCS score, mean (SD)	10 (5)	10 (5)	0.82
BAL ≥ 0.08	162 (25%)	112 (24%)	0.76
ISS, mean (SD)	24 (12)	25 (13)	0.68
Head AIS score ≥ 3	350 (52%)	316 (68%)	<0.001
Chest AIS score ≥ 3	311 (47%)	188 (40%)	0.03

BAL, blood alcohol level.

calculated as number of VAP episodes / number of ventilator days × 1,000; secondary outcomes included ICU LOS, ventilator days, and mortality.

ETT-SSDs were not used in our facility before 2011. A trial period took place from February 2011 through March 2012, during >which time all patients intubated in the emergency department used ETT-SSD. After this trial period, standard use of ETT-SSD was implemented, although patients intubated in the operating suite or in the prehospital setting generally had ETT. In patients with ETT-SSD, subglottic drainage at 120 mm Hg was used for intermittent durations of 10 seconds every 20 seconds to minimize tracheal mucosal damage. All patients received the recommended National Healthcare Safety Network ventilator bundle for infection prevention, including semirecumbent positioning (unless contraindicated), stress ulcer and deep vein thrombosis prophylaxis, oral decontamination every 4 hours, and sedation interruptions for readiness to wean assessments. Cuff pressures on both types of endotracheal tubes were maintained between 25 cm H_2O and 30 cm H_2O. Closed suction with Ballard catheters was used, and ventilator circuits were changed only if visibly soiled.

The diagnosis of VAP was made using Centers for Disease Control and Prevention criteria. Centers for Disease Control and Prevention defines VAP as a period of at least 2 days of baseline stability on the ventilator followed by a period of worsening oxygenation (as evidenced by a requirement for increased fraction of inspired oxygen or positive end-expiratory pressure) and positive respiratory cultures.[2] Quantitative bronchoalveolar lavage cultures were obtained by blind bronchial suctioning or endoscopic-directed sampling. Cultures were considered positive if the organism grew greater than or equal to 100,000 colony-forming units.

Statistical analysis was performed by comparing ETT versus ETT-SSD groups. Data were analyzed using χ^2 analysis, independent and paired *t* tests, and binary logistic regression to control for confounding variables. To further reinforce the validity of the results, patients who had ETT-SSD were matched 1:1 to patients with ETT based on age group (14–35, 36–55, 56–75, and >75 years), sex, mechanism of injury, head and chest AIS group (<3 or ≥3), and ISS group (<15, 15–25, >25). Thirty-four patients (7%) could not be adequately matched and were excluded. These groups were then also compared for primary and secondary outcomes. Statistical analyses were performed using the SPSS software version 23.0 (IBM, Armonk, NY), and significance was attributed to a $p < 0.05$. The study was approved by the institutional review boards of Community Medical Centers and the University of California, San Francisco–Fresno.

RESULTS

During the study period, 2,261 patients were identified from the trauma registry as requiring orotracheal intubation. Patients were excluded because of the following: age of less than 14 years (n = 37), intubation at a referring facility (n = 216), or duration of intubation of less than 48 hours (includes early deaths, n = 873). Of the remaining 1,135 patients meeting inclusion criteria, 667 patients had ETT and 468 had ETT-SSD.

After introduction of the ETT-SSD in February 2011, there were no differences in the proportion of ETT versus ETT-SSD used at our facility during the trial period (ETT, 132; ETT-SSD, 135) or following routine ETT-SSD use (ETT, 311; ETT-SSD, 333). These similar proportions are a result of many patients undergoing intubation in the prehospital setting or operative suite, where ETT-SSDs were unavailable. Compliance with ventilator bundle components has been tracked since 2012 and was greater than 97% with no significant variation over time.

Patients were severely injured with a mean ISS of 24. Baseline characteristics were similar between groups, including demographics, mechanism of injury, GCS score, proportion with alcohol intoxication, and ISS (Table 1). The percentage of patients who had a VAP was lower in the ETT-SSD group and approached significance (ETT at 10% vs. ETT-SSD at 7%, $p = 0.059$; Table 2); however, the ETT-SSD group had a higher percentage of patients with severe head injury (AIS score ≥ 3, $p < 0.001$) and a lower rate of severe chest injury (AIS score ≥ 3, $p = 0.031$). With the use of binary logistic regression to control for these confounding variables, ETT-SSD was highly significant for reduction of VAP (odds ratio, 0.6; 95% confidence interval, 0.4–0.9; $p = 0.027$). Similarly, the VAP rate decreased from 7.8 in the ETT group to 5.5 in the ETT-SSD group ($p = 0.036$). Mortality seemed to be higher in the ETT-SSD group on initial analysis, but after controlling for other factors, head AIS score of 3 or greater was the only significant predictor of mortality ($p < 0.001$). In the matched cohorts, the ETT-SSD group continued to have a lower VAP rate (Table 3). In addition, the cohort of patients with ETT-SSD had fewer ventilator days (12 vs. 14, $p = 0.04$) and decreased ICU LOS (13 days vs. 16 days, $p = 0.003$) compared with the patients who had ETT.

DISCUSSION

As trauma care has improved in recent decades, early death from hemorrhage has decreased. Unfortunately, this has

TABLE 2. Outcomes

	ETT (n = 667)	ETT-SSD (n = 468)	*p*
VAP	67 (10%)	32 (7%)	0.06
Ventilator days/patient, mean (SD), d	12.8 (11.2)	12.5 (11.6)	0.69
VAP rate	7.8	5.5	0.09
Tracheostomy	214 (32%)	166 (35%)	0.23
ICU LOS, mean (SD), d	13 (12)	14 (13)	0.16
Mortality	122 (18%)	110 (24%)	0.032

TABLE 3. Outcomes in Matched Cohorts

	ETT (n = 434)	ETT-SSD (n = 434)	*p*
VAP	57 (13%)	31 (7%)	0.003
Ventilator Days/patient, mean (SD), d	14 (12)	12 (12)	0.04
VAP rate	9.3	5.7	0.03
Tracheostomy	165 (38%)	149 (34%)	0.26
ICU LOS, mean (SD), d	16 (14)	13 (12)	0.003
Mortality	84 (19%)	96 (22%)	0.32

led to a subsequent increase in the proportion of delayed morbidity and mortality due to multisystem organ failure.[16] Often, multisystem organ failure is incited by nosocomial infection, such as pneumonia.[17] Trauma patients are at particularly high risk for nosocomial pneumonia and VAP. This is likely attributable to a combination of factors, including aspiration in patients with altered level of consciousness, proinflammatory response, and immunosuppression due to blood product administration.[18,19] Thus, improvement in trauma care must incorporate strategies to reduce VAP to reduce late morbidity and mortality.

One potential strategy to decrease VAP is the use of endotracheal tubes with subglottic secretion drainage. Continuous aspiration of subglottic secretions with ETT-SSD was recommended as early as 2005 by the American Thoracic Society and the Infectious Diseases Society of America.[20] In addition, in a recent meta-analysis of more than 2,400 critically ill patients randomized to ETT or ETT-SSD, the overall risk ratio for VAP with ETT-SSD was markedly reduced at 0.55 (95% confidence interval, 0.46–0.66; $p < 0.00001$).[8] Despite this evidence and the previous recommendations, the use of ETT-SSD has not become standard practice.

The current study is the first to validate the results of previous studies investigating ETT-SSD use in the group of patients at highest risk for VAP, those with traumatic injuries. Our results affirm those of previously published studies that the use of ETT-SSD decreases VAP rate, ventilator days, and ICU LOS. Although the initial cohorts did not show a statistically significant decrease in VAP, the baseline characteristics between groups were different. After controlling for these differences, both with binary logistic regression as well as matched cohorts, ETT-SSD was found to have lower VAP rate.

The timing of tracheostomy, if required, is a potential confounding factor in the development of VAP. However, the number of patients who went on to require tracheostomy was not different between groups, in either the unadjusted comparisons (Table 2) or the matched cohorts (Table 3). In those patients who had both a tracheostomy and a VAP, there was no difference between ETT and ETT-SSD groups in VAP rate or timing, making it unlikely that this is truly a confounding factor.

There are very few disadvantages to the use of ETT-SSD. Implementation of ETT-SSD requires only a change in the available equipment. Intubation techniques and ventilator management strategies need not change. An additional suction system is required, but no other changes are needed from nursing or respiratory care services, so the overall impact on workflow is negligible. One of the primary arguments against the use of the ETT-SSD has been the additional cost. The cost of ETT-SSD ($10–$30) is approximately 15 times that of ETT ($1–$2).[21,22] However, since each episode of VAP costs an estimated $10,000 to $60,000,[23] the routine use of ETT-SSD has been shown not only to be cost-effective but also to produce significant savings.[21,24] Another argument against ETT-SSD is the potential for tracheal mucosal injury, but this has not been problematic when intermittent suction is used, as was done in our protocols.[22]

The current study is limited by the retrospective design. Selection bias may play a role, as sicker patients may be more likely to be intubated in the prehospital setting with ETT. However, the baseline characteristics do not demonstrate an easily discernable difference, and the ETT groups also included patients intubated in the operative suite, who may not be as severely injured since they are usually intubated under more controlled circumstances. ICU and ventilator protocols were not different between groups. During the study period, no significant changes in critical care faculty, ventilator management strategies, or other ICU protocols occurred. The proportion of patients receiving ETT versus ETT-SSD also remained stable over time. Comparison of matched cohorts should also minimize selection bias.

In conclusion, the current study validates the reduction of VAP with the use of ETT-SSD in traumatically injured patients, as seen in previous studies of critically ill patients. In addition, ICU LOS and ventilator days were also reduced. We therefore recommend that ETT-SSD be used in all critically ill trauma patients requiring intubation.

AUTHORSHIP

J.L.H. contributed to the conceptual design, data analysis, and manuscript preparation. W.L.V. contributed to the conceptual design, data collection, data analysis, and manuscript review. R.C.D. contributed to the conceptual design, data analysis, manuscript review, and statistical analysis. J.W.D. and K.L.K. contributed to the conceptual design and manuscript review.

DISCLOSURE

Mallinckrodt provided 100 free subglottic suction endotracheal tubes to our hospital before initiation of this research study. No incentive was provided to study their use or influence the results.

REFERENCES

1. Chastre J, Fagon JY. Ventilator-associated pneumonia. *Am J Respir Crit Care Med*. 2002;165(7):867–903.
2. Center for Disease Control and Prevention. Available at: http://www.cdc.gov/nhsn/PDFs/pscManual/10-VAE_FINAL.pdf. Accessed December 16, 2015.
3. Cook A, Norwood S, Berne J. Ventilator-associated pneumonia is more common and of less consequence in trauma patients compared with other critically ill patients. *J Trauma*. 2010;69(5):1083–1091.
4. Dudeck MA, Weiner LM, Allen-Bridson K, Malpiedi PJ, Peterson KD, Pollock DA, Sievert DM, Edwards JR. National Healthcare Safety Network (NHSN) report, data summary for 2012, device-associated module. *Am J Infect Control*. 2013;41(12):1148–1166.
5. Eckert MJ, Davis KA, Reed RL 2nd, Esposito TJ, Santaniello JM, Poulakidas S, Gamelli RL, Luchette FA. Ventilator-associated pneumonia, like real estate: location really matters. *J Trauma*. 2006;60(1):104–110; discussion 110.
6. Bottiggi AJ, White KD, Bernard AC, Davenport DL. Impact of device-associated infection on trauma patient outcomes at a major trauma center. *Surg Infect (Larchmt)*. 2015;16(3):276–280.
7. Suys E, Nieboer K, Stiers W, De Regt J, Huyghens L, Spapen H. Intermittent subglottic secretion drainage may cause tracheal damage in patients with few oropharyngeal secretions. *Intensive Crit Care Nurs*. 2013;29(6):317–320.

8. Muscedere J, Rewa O, McKechnie K, Jiang X, Laporta D, Heyland DK. Subglottic secretion drainage for the prevention of ventilator-associated pneumonia: a systematic review and meta-analysis. *Crit Care Med*. 2011; 39(8):1985–1991.
9. Bouza E, Pérez MJ, Muñoz P, Rincón C, Barrio JM, Hortal J. Continuous aspiration of subglottic secretions in the prevention of ventilator-associated pneumonia in the postoperative period of major heart surgery. *Chest*. 2008; 134(5):938–946.
10. Cook D, De Jonghe B, Brochard L, Brun-Buisson C. Influence of airway management on ventilator-associated pneumonia: evidence from randomized trials. *JAMA*. 1998;279(10):781–787.
11. Damas P, Frippiat F, Ancion A, Canivet JL, Lambermont B, Layios N, Massion P, Morimont P, Nys M, Piret S, Lancellotti P, Wiesen P, D'orio V, Samalea N, Ledoux D. Prevention of ventilator-associated pneumonia and ventilator-associated conditions: a randomized controlled trial with subglottic secretion suctioning. *Crit Care Med*. 2015;43(1):22–30.
12. Pérez Granda MJ, Barrio JM, Hortal J, Muñoz P, Rincón C, Bouza E. Routine aspiration of subglottic secretions after major heart surgery: impact on the incidence of ventilator-associated pneumonia. *J Hosp Infect*. 2013;85(4):312–315.
13. Smulders K, van der Hoeven H, Weers-Pothoff I, Vandenbroucke-Grauls C. A randomized clinical trial of intermittent subglottic secretion drainage in patients receiving mechanical ventilation. *Chest*. 2002;121(3):858–862.
14. Mahul P, Auboyer C, Jospe R, Ros A, Guerin C, el Khouri Z, Galliez M, Dumont A, Gaudin O. Prevention of nosocomial pneumonia in intubated patients: respective role of mechanical subglottic secretions drainage and stress ulcer prophylaxis. *Intensive Care Med*. 1992;18(1):20–25.
15. Kollef MH, Skubas NJ, Sundt TM. A randomized clinical trial of continuous aspiration of subglottic secretions in cardiac surgery patients. *Chest*. 1999; 116(5):1339–1346.
16. Acosta JA, Yang JC, Winchell RJ, Simons RK, Fortlage DA, Hollingsworth-Fridlund P, Hoyt DB. Lethal injuries and time to death in a level I trauma center. *J Am Coll Surg*. 1998;186(5):528–533.
17. Minei JP, Cuschieri J, Sperry J, Moore EE, West MA, Harbrecht BG, O'Keefe GE, Cohen MJ, Moldawer LL, Tompkins RG, et al. The changing pattern and implications of multiple organ failure after blunt injury with hemorrhagic shock. *Crit Care Med*. 2012;40(4):1129–1135.
18. Hyllienmark P, Brattström O, Larsson E, Martling CR, Petersson J, Oldner A. High incidence of post-injury pneumonia in intensive care-treated trauma patients. *Acta Anaesthesiol Scand*. 2013;57(7):848–854.
19. Giannoudis PV. Current concepts of the inflammatory response after major trauma: an update. *Injury*. 2003;34(6):397–404.
20. American Thoracic Society; Infectious Diseases Society of America. Guidelines for the management of adults with hospital-acquired, ventilator-associated, and healthcare-associated pneumonia. *Am J Respir Crit Care Med*. 2005;171(4):388–416.
21. Shorr AF, O'Malley PG. Continuous subglottic suctioning for the prevention of ventilator-associated pneumonia: potential economic implications. *Chest*. 2001;119(1):228–235.
22. Haas CF, Eakin RM, Konkle MA, Blank R. Endotracheal tubes: old and new. *Respir Care*. 2014;59(6):933–952.
23. Branch-Elliman W, Wright SB, Howell MD. Determining the ideal strategy for ventilator-associated pneumonia prevention. Cost-benefit analysis. *Am J Respir Crit Care Med*. 2015;192(1):57–63.
24. Hallais C, Merle V, Guitard PG, Moreau A, Josset V, Thillard D, Haghighat S, Veber B, Czernichow P. Is continuous subglottic suctioning cost-effective for the prevention of ventilator-associated pneumonia? *Infect Control Hosp Epidemiol*. 2011;32(2):131–135.

DISCUSSION

Dr. Andrew J. Kerwin (Jacksonville, Florida): I want to congratulate the authors on an extremely well-written manuscript. Both the conceptual design and the data analysis are well done. The manuscript is succinct and easy to read. I highly recommend that you do read it.

I do have some comments and some questions for the authors.

In the manuscript, the authors validate that there are significant benefits to the use of endotracheal tubes with subglottic secretion drainage in terms of reduced incidence of ventilator-associated pneumonia, intensive care unit length of stay, and ventilator days. At our institution, we added this to our ventilator bundle as well. And after reading the manuscript it seems that we all should be doing this.

So I noticed that this began as a trial and then became standard practice after March 2012. Were there enough data at that point to convince your hospital that this should now become the standard practice? Or was there something else in there that made this standard practice?

Since the tubes with subglottic secretion drainage are considerably more costly, was it difficult to convince your hospital to make this a standard? How should other hospitals go about making this change if they are not already using these tubes?

I noticed that this is a critically-injured patient population with a high number of ventilator days. Do you know how many patients went on to have a tracheostomy? And if so, did you have any tracheostomy tubes with subglottic secretion drainage? If not, were the tracheostomy patients excluded from the data analysis?

I think there is some potential for selection bias as the most critically-injured patients were likely to be intubated in the pre-hospital setting and did not receive the tube with subglottic secretion drainage. These patients seemed like they would be the most likely ones to benefit from this tube. Did you ever change any of these field tubes out for the tube with subglottic secretion drainage?

Given the benefits that you and others have shown should we make this part of our practice if we judge that the patient will likely need to remain intubated for more than 48 hours? Or should every patient get intubated with a tube with subglottic secretion drainage?

Finally, you noted that all of the other components of the ventilator bundle were used during the study. Do you have any data on compliance with the bundle elements?

And what mode of ventilation do you typically use for your patients? Did your approach to vent management change at all during this study period, as this could be a potential confounding factor?

Again, I thank you for the privilege of the podium and I congratulate the authors on a well-written manuscript and a very nice presentation.

Dr. John Hall (Hilton Head Island, South Carolina): Dr. Hubbard, that was very well done and I agree with you. We had our ICU use it a long time ago, but I do have a question on your bias.

Your standard tubes, I seem to understand, were inserted either in the pre-hospital setting or in the OR. Prehospital are notoriously dirty and in the OR we have all seen the anesthesiologists, at times, place the tube on the chest before they insert it so the insertion is contaminated. Did you look back at your data and compare your ICU data from now versus when you were doing them before to see if there were any change with clean vs dirty insertions?

Dr. Ajai K. Malhotra (Burlington, Vermont): I enjoyed the presentation. One question was already asked because it is a selection bias from prehospital folks.

The second is that if you look at the national nosocomial data every year, or every two or three years, whenever they present it, the VAP rates have been slowing coming down. Since your study is a temporal study with pre and post, what about just a natural decrease in VAP rates?

Dr. Jenifer L. Hubbard (Fresno, California): Dr. Kerwin, thank you for your comments and insightful questions. I am also grateful for receiving your questions ahead of time.

We did initially trial the subglottic secretion drainage tubes. As I mentioned, we used 100 patients. We looked at our data at that point and we felt that it did have improved VAP rates but did not reach statistical significance.

The way we convinced our hospital to implement these was based on prior data, as I mentioned, with the multiple, randomized, controlled trials.

As far as the cost, yes, these tubes are more expensive. They are somewhere in the $10 to $20 range as opposed to $1 to $2 for a standard endotracheal tube; however, the cost of VAP, which can be $20,000 to $40,000 per episode is completely offsetting of that. And in fact these tubes have been shown to be cost-effective in prior studies so that was able to convince our hospital.

With regard to tracheostomies, I unfortunately do not have data on how many patients went on to require tracheostomies. But I think, like mortality, that is a measure that is, has a lot of confounding variables, especially head injuries.

We do not currently use tracheostomies with subglottic secretion drainage. We did look into that. We only had one patient in this trial period that had a VAP after tracheostomy tube placement, and so far we haven't felt that it was going to be that beneficial, but certainly something we will be keeping an eye on.

This addresses a couple of the questions—as far as tubes in the prehospital setting, certainly those patients could be more severely injured. It's a less controlled setting and probably dirty. But I think this is offset by that same group also includes patients in the operating room. I don't know about that being more dirty. I think that the ED is probably dirtier than the OR and that tube gets tossed around a lot, too, I think.

So we did have approximately equal numbers of patients in that group that were either intubated in the pre-hospital setting in the OR so those do offset a little bit. Certainly, there is some selection bias there but that's why we went on to do the matched cohort groups, to try and minimize that selection bias.

We do not routinely change out endotracheal tubes, the standard tubes for the subglottic secretion drainage tube. If we extubate or have to change the tube for another reason then we would certainly use the subglottic secretion drainage group.

Finally, as far as the ventilator bundles, we do have a very good compliance. We looked at our compliance with all of the other components of the ventilator bundles and we have upwards of 90% compliance, and in some categories even 100% compliance. Our approach to ventilator management has not changed over the time periods in the study. We typically use PRVC, or PC-VVG is the other name for it. And if the patients have worsening oxygenation or need rescue therapy then we go on to use APRV.

Dr. Hall, I think I addressed it a little bit as far as being selection bias in the field versus the ED. We have not looked at our ventilator-associated pneumonia rates pre-trial versus this trial.

This study wasn't exactly longitudinal as during the different times frames there were still about equal numbers in both groups. We didn't stop using standard ET tubes after 2012, they just weren't used in those specific settings.