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The Role of Subglottic Secretion Drainage in VAP Prevention: ICU Experience with an Automated Intermittent Subglottic Secretion Drainage System

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Abstract

The most difficult and challenging cases in the ICU involve long periods of mechanical ventilation which are associated with a high risk of ventilator-associated pneumonia (VAP). Patients with VAP face prolonged hospital stays and significantly increased risk of mortality. Efforts to prevent VAP have included selective oral decontamination (SOD), elevation of head rest and subglottic suctioning of secretions.

This paper describes a new approach that combines the use of tracheal and endotracheal tubes containing ballooned cuffs and integrated suction ports, with the use of an automated intermittent subglottic secretion aspiration system, in an 18-bed ICU in Hamburg, Germany. The author provides an overview of the cases of 16 patients on the automated devices visited during a single day on unit rounds, as well as a description of an additional, and particularly challenging, paradigmatic case. The cases are intended as a "snapshot" of clinical experience gained with the system in over 4 years and in approximately 500 patients.

Keywords: Ventilators, Mechanical, Pneumonia, Respiratory Tract Infections, Ventilator Associated Pneumonia (VAP), Ventilator Associated Events (VAE), Subglottic Secretion Drainage (SSD), Automated Intermittent Subglottic Aspiration

Introduction

Ventilator-associated pneumonia (VAP) is the most common and serious type of hospital-acquired infection (HAI) in the ICU. The reported incidence varies in different studies on the subject which is in part due to complexity, and differences in the applied criteria such as epidemiological variables, diagnostic tests, use of antimicrobials, and other management strategies. A large current observational study in 27 ICUs of 9 European countries found 18.3 episodes of VAP per 1000 ventilator-days and an increase in mortality of 6% as well as an increase of duration of ventilation and length of stay.[1] VAP continues to be a serious problem, despite progress in the understanding of its origins, and improvements in treatment protocols.

The 18-bed ICU unit at Asklepios Klinik Barmbek in Hamburg specializes in weaning long-term ventilated patients from the ventilator. The patients treated are almost exclusively referrals from mainly surgical ICUs in the Hamburg area and at the time of transfer in general have been ventilated for about 20 days. The average length of stay is 34 days and at any time point about 90% are invasively ventilated, and 90% of those have a tracheal cannula. This specialized weaning unit was created in 2008 and expanded thereafter. Subglottic suctioning and selective oral decontamination (SOD) were not practiced until 2012 when the decision was made to implement a VAP prevention bundle, based on several observations in this cohort of long-term ventilated patients. In about half of the patients we saw what was described as "hypersalivation." These patients always had a lot of saliva in the mouth, and the tissue surrounding the tracheostoma was always wet and patients required a higher frequency of endotracheal (bronchial) suctioning. In addition, some of these patients had subfebrile temperatures that we could not find a reason for, and the rate of purulent bronchial secretions was deemed elevated. Further observations of these patients for several minutes revealed that swallowing was not present. We therefore concluded that their problem was a deficit in swallowing rather than hypersalivation.

We looked at the published evidence for measures to reduce VAP and found that all proven interventions had something to do with reducing the likelihood of pathogens passing from the upper gastrointestinal tract to the lung, first noting a more than 50% reduction in VAP when postpyloric feeding was compared with the conventional gastric feeding.[2] We also noted that at the gastric level, avoiding the use of proton pump inhibitors, which elevate the gastric pH and thus favor bacterial survival, can reduce VAP by more than 50%.[3] Looking at the next level in the supposed pathway, the oropharynx, we reviewed a large meta-analysis showing a 44% reduction of VAP when using selective oral decontamination.[4]

We then turned to evidence involving the last step in the pathway, which is the prevention of oropharyngeal and subglottic secretions from entering the lower respiratory tract via the outside of the cuff. A study comparing intermittent vs. continuous control of ballooned cuff pressure showed a 44% VAP reduction when continuous cuff pressure was used.[5] A current meta-analysis of 17 studies including 3369 patients noted a 0.58 relative risk for VAP using subglottic suction.[6] Looking on these results together it seems obvious that there is a common mechanism as all these interventions hinder the ascension of pathogens from the gastrointestinal tract to the lung. This is in accordance with the observation that the rate of VAP is not reduced when a closed suction system is used.[7]

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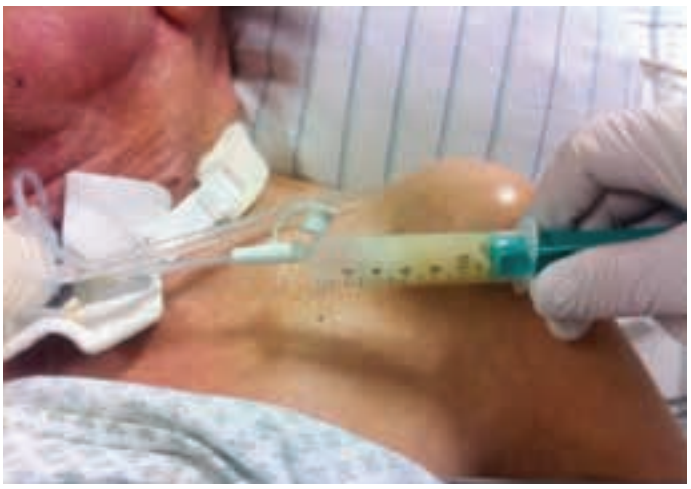
The hypothesis of VAP being a consequence of the movement of pathogens from the gastrointestinal tract to the lung is strengthened by a study from Johannesburg published in 1999.[8] Researchers in the Johannesburg study looked for the time course of the appearance of pathogens in the oropharynx, stomach, lower respiratory tract, and inside the endotracheal tube, every 6 hours after intubation. After the first 12 hours following intubation, gram positive pathogens, especially Staphylococcus, appeared in the pharynx. After about 1.5 days, gram negative pathogens, for example Klebsiella, Pseudomonas, E. coli, Proteus, Enterobacter, and Enterococcus appeared about simultaneously in the stomach and in the oropharynx. After about 3 days, they appeared in the lower respiratory tract, and only after that appeared on the inside of the cannula. This sequence of events strengthens the hypothesis that the pathogens that cause VAP reach the lung traveling with contaminated oral secretions via the outside of the cannula passing the cuff of the endotracheal tube rather than being introduced by the staff through the lumen of the tube.

Based on our review of the evidence, we decided that our VAP prevention bundle should include:

- a preference for postpyloric feeding and PEG/PEJ thus avoiding nasogastric tubes
- systematic use of SOD
- continuous cuff pressure control, and
- subglottic suctioning

The introduction of SOD did not pose any problems while the introduction of continuous cuff pressure control was not possible for economic reasons.

Figure 1. Manual suctioning using a syringe. Similar to that used in the French study protocol[9] for SSD.



The practical problems with subglottic suctioning became evident when looking closely at a randomized controlled SSD study conducted in France.[9] The study included 333 adult patients in 4 centers and yielded similar results as the above cited meta-analysis, reducing the relative risk of VAP to 0.55. The protocol called for manual suctioning hourly with a 10 ml syringe, and called for the recording of the amount of secretions removed. Actual suctioning took place at approximately 90-minute intervals. The volume of secretions on average was 14 ml per day with a span of 8-22 ml, with a minimal value of 0 and a maximum value of 197 ml. The suctioning of every patient at least every 90 minutes consumes a lot of manpower and represents a great challenge to ICU staff. With only 6 nurses per shift on our 18-bed unit, hourly manual suctioning would not have been possible (see Fig 1).

In reviews of the SSD literature, both wall suction regulators and manual syringes had been shown to exert more force on the airways than recommended by guidelines.[10] In addition, prior experience on our own unit where various brands of wall suction had been evaluated for use in SSD, the wall suction proved insufficient for controlling negative pressures and suction time intervals, and unsuitable for removing the different types and volumes of secretions among our patients. Therefore we began using an automated subglottic secretion drainage device immediately when we introduced our VAP prevention bundle.

> "…prior experience on our own unit where various brands of wall suction had been evaluated for use in SSD, the wall suction proved insufficient for controlling negative pressures and suction time intervals, and unsuitable for removing different types and volumes of secretions…"

Figure 2. Automated Intermittent Subglottic Secretion Aspiration System.

October 2014 Unit Rounds Snapshot

During a single day in October of 2014, each patient on our 18-bed unit was visited during rounds, with the goal of creating a snapshot of our challenging patient population to serve as a basis for discussing the lessons learned in our efforts to prevent VAP using the automated aspiration system. On that day, 16 devices were available and utilized in the treatment of the patients described in Table 1.

Table 1 shows the patient characteristics (where captured and recorded) for all 16 patients on the automated aspiration device. The cases are typical of cases on the unit at any given time. Disease categories documented included cardiovascular, respiratory, neurologic, gastrointestinal, metabolic, and oncologic. Sepsis, organ failure, and severe CIP were noted. The pathogens documented, many drug resistant, are those frequently associated with VAP. Large amounts of secretions, of varying viscosities, were removed daily. Dysphagia was noted in the majority of the patients.

Table 1. Automated Subglottic Aspiration System Patients

Pt	M/F	Age	Condition	Pathogen(s)	Secretion/Daily	Other Observations
01	M	63	Coronary artery bypass OP. Cerebeller infarction	Morganella morgagnii	100 ml mucopurulent (fecal smell)	Delirium Dysphagia
02	M	85	Valve replacement. CHF. Diabetes	E.coli. Morganella morgagnii. Stenotrophomonas	150-250 mucopurulent	Delirium Dysphagia
03	M	67	55 day post esophagectomy for cancer. COPD		400 ml watery	Gastric regurgitation
04	M	74	Coronary artery bypass OP with aortic valve replacement. Acute persistent renal failure. Severe critical illness polyneuropathy. Slow recovery due to axonal type		150 ml mucopurulent. 1400 ml total collected within a few days	Dysphagia Depression
05	M	83	29 days post emergency coronary artery bypass OP. Severe critical illness polyneuropathy		250-350 ml mucopurulent	
06	F	79	48 hours post intubation for AECOPD	Stenotrophomonas maltohilia	50 ml mucopurulent. 600 ml total collected within a few days	Dysphagia Anxiety disorder
07	F	63	Intubated for pneumonia. MS for 20 years		400-600 ml watery	Dysphagia
08	M	75	AECOPD	Enterobacter. Serratia	50-100 ml Mucoid, hemorrhagic secretions	Delirium Dysphagia
09	M	75	AECOPD. ICU weakness. CIP. CIM.	E.coli. Pseudomonas. Klebsiella. Multi resistant against 3-4 major antibiotic classes.	500-1000 ml watery	Severe dysphagia
10	M	71	92 days post ARDS, following spondylodiscitis with sepsis and fibrotic lung	Enterococcus resistant to 4 major antibiotic classes		De-cannulated but later died not wanting further treatment
11	M	66	37 days post pneumonia. Sepsis. Multiple organ failure. Severe weakness		50-100 ml mucopurulent	Delirium Dysphagia
12	F	82	Valve replacement for endocarditis. ICU acquired weakness	Multi-resistant Klebsiella and E. coli	50 ml Mucoid, hemorrhagic secretions	Delirium
13	F	73	32 days post op for aortic dissection	Stenotrophomonas in sputum. Non-invasive ventilation		
14	F	69	AECOPD. Extreme weakness	Very resistant MRSA and Enterococcus	50-150 ml mucopurulent	Dysphagia
15	F	48	123 days post pulmonary embolism. Slightly obese	Klebsiella in sputum on non-invasive ventilation		
16	M	67	26 days intubated for pneumonia and AECOPD	Klebsiella oxytoca	500 ml watery	Dysphagia Delirium

Two Patient Populations

From clinical experience we make a distinction between two patient populations. Group 1 has massive aspiration of a saliva-type fluid. From the subglottic port we remove 400-1000 ml of secretions per day and we adjust the settings of the automated aspiration device to a rather low pressure because the fluid is not very viscous. We also use a very short interval of 5 minutes because the watery fluid can microaspirate and pass the ballooned cuff quickly. You can appreciate the practical impossibility of using manual suction when such frequent suctioning is needed. Group 2 patients have a small-to-medium amount of thick, mucopurulent secretions, in the range of 20-200 ml per day. We adjust the parameters of the automated device differently, using higher negative pressures because the secretions are viscous, with longer intervals to allow accumulation of the secretions on top of the ballooned cuff. This approach facilitates the suctioning of the fluids, while avoiding inadvertent suctioning of the tracheal wall.

Secretions in Group 2 seem to develop primarily in the space between the vocal cords and the cuff. This space is around 20 ml and in normal life it is ventilated all the time, passing some 15 liters of air every minute. When a cuff is in place, this space is no longer ventilated but the mucous membranes continue to produce mucus that then accumulates on top of the cuff. There is no effective barrier to oropharynx pathogens passing into this space and inoculating the above mentioned mucus.

> "Group 1 [patient population] has massive aspiration of saliva-type fluid [400-1000 ml per day]....Group 2 patients have a small-to-medium amount of thick, mucopurulent secretions [20-200 ml per day]."

As the temperature in this space is 37°C, and because there is no ventilation, conditions are very favorable for bacterial growth. The mucus then turns to a purulent and highly infectious material. It is of critical importance to prevent this from entering the lung. Regular suctioning above the cuff is therefore warranted.

Negative pressure settings for the automated intermittent aspiration system range from -60 to -300 mbar (-45 to -225 mmHg). Suction interval settings range from 10-60 seconds (ON), and from 3-60 minutes (OFF). SSD guidelines from the AARC recommend the use of negatives pressures from -80 to -150mmHg.[11]

A Paradigmatic Case

A 58-year-old man was initially admitted to another hospital with decompensated heart failure. He was known to have insufficiency of the aortic and mitral valves. On holiday, he had hiked in the mountains and overstressed his capacity. They tried to recompensate him medically, but after that failed, an emergency double valve replacement was done and the patient's condition further deteriorated and remained critical. He had severe shock (cardiogenic or septic), and developed renal failure and subileus. A pneumothorax occurred. Nonetheless, he began to improve soon after the operation.

He was extubated on Day 6 post op and put on non-invasive ventilation. Dysphagia became apparent on Day 6 post-extubation, and on the 10th day post-extubation the patient was reintubated. On the 12th day they performed a tracheotomy. A pericardial effusion was drained. He had atrial fibrillation and a catheter-associated infection with E. faecium.

When we first saw the patient on our unit he had a very reduced vigilance and an extremely pronounced muscle weakness such that he was almost tetraplegic. He appeared to be hyperventilating. He had a fever and his CIP was very strong. As the tracheotomy was performed only a few days prior to his transfer to our unit and the cannula used had no port for subglottic suctioning for the first 4 days of his stay we could not perform subglottic suctioning. In this period we had to suction frequently endotracheally and from the mouth as there were large amounts of saliva type secretions. These procedures were very unpleasant to this patient.

On his 4th day on our unit, we successfully put in a tracheal cannula with a subglottic port, and using the automated device suctioned a large amount of secretions. The frequency of endobronchial suctioning and suctioning from the mouth required was immediately reduced. Almost 900 ml of secretions per day were being removed subglottically. Very little endobronchial secretions remained. By the 5th day we could already start with short intervals of spontaneous breathing and by Day 6 the use of a speaking valve was possible. Day 7 there was still a large amount of subglottic secretions, and some dysphagia persisted, but he no longer required ventilation. By Day 14, only 50 ml a day were being removed subglottically. On Day 18, we were able to remove the tracheal cannula and discharge him.

The case is typical in that patients frequently respond very positively after having large volumes of secretions removed by the device that previously would have descended into the lungs. The case seemed special, and somewhat atypical, from

Figure 3. Example of watery secretions collected (400-600ml daily) – Pat. # 7 in Table 1.

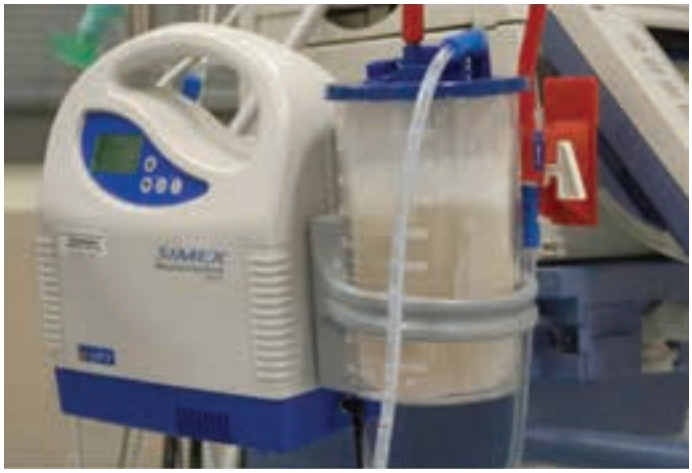


Figure 4. Example of watery secretions collected (500-1000ml daily) – Pat. # 9 in Table 1.

Figure 5. Example of mucopurulent secretions collected (150-250ml daily) – Pat. # 2 in Table 1.

the standpoint of the dramatically short time that was required for the patient to recover from his serious and threatening conditions. His problem, and the reason why he could not be weaned before we started subglottic suctioning was the huge amount of secretions that were passing to his lungs due to a severe dysphagia caused by his critical illness polyneuropathy.

The Practical Application of Subglottic Secretion Drainage

Since 2012 we have used a bundle of measures for the prevention of VAP. When patients are admitted, we change as soon as possible to a cannula with a subglottic port and start automated intermittent suctioning. We do selective oral decontamination (SOD) on all patients using polyhexanide.

We do FEES (fiberoptic endoscopic evaluation of swallowing) on all patients before oral feeding. If we find a relevant amount of dysphagia, we insert a PEG (percutaneous endoscopic gastrostomy tube) and if there is regurgitation we proceed to postpyloric feeding. We start training with a speaking valve early when the patients are still dependent on the ventilator. Even if we know a patient is dysphagic, we start to put him on the speaking valve for periods of 15 minutes to re-ventilate the subglottic space which helps to reconstitute its sensitivity and the swallowing reflex. All patients receive specialized logopedic training and repeat FEES evaluations to see if the training is working. When we start feeding, we color the food with methylene blue in order to see whether there is still aspiration. We also engage head-of-bed elevation, and emphasize early mobilization. We do not use PPI treatment because it has been shown that reducing the acidity of the stomach allows gastrointestinal pathogens to pass into the oropharynx.

As a common initial setting for the automated device, we frequently use -200 mbar (-150 mmHg), with a suction time of 20 seconds and a pause between suctioning of 5 minutes. Manual aspiration has to be done every 8 hours because the machine cannot replace the nurse or doctor or the respiratory therapist—it is a means to help in their work. The responsibility is still with the human being.

Discussion

Our experience with the benefits of subglottic suctioning are in accordance with the large body of evidence for its use that has prompted the German commission for hospital hygiene and infection prevention at the Robert Koch Institute, an organization with similarities to the US CDC, to recommend its use. The KRINKO[12] recommendations issued in 2013 call for the use of an endotracheal tube with a subglottic port for suctioning if the time of ventilation is expected to be greater than 72 hours. In addition, consideration of the exchange of a conventional endotracheal tube to one with an integrated subglottic suctioning port is recommended if the benefits are deemed to outweigh the risks of the procedure. The category of the recommendation is 1A, the highest possible.[12]

Even though the benefits of SSD for patients are undisputable, its use is not as widespread as it should be. It is our belief that this stems from the practical problems with instituting its use in a hospital environment where nursing time is an issue. With the use of an automated system this problem has been overcome in our institution. Our guidelines call for manual suctioning only every 8 hours which proved to be practical. An observation in our unit is that the amount of secretions we are able to suction subglottically using an automated system substantially exceed the amount of secretions collected cited in publications. Our explanation is that in the intervals of 90 minutes and more for manual suctioning a substantial amount of these secretions bypass the cuff while the automated system is able to suction every five minutes when necessary to collect the secretions. An additional benefit of the automated subglottic aspiration system is that it is less traumatic to the tracheal wall. Syringes have been shown to create a vacuum equal to a negative of 1000 mbar (-750 mmHg), while the negative pressure created by the automated pump is strictly limited to -300 mbar (-225 mmHg). Automated subglottic aspiration results in less manipulation of infectious material because the material is contained, and greatly reduces the amount of manpower that was previously devoted to suctioning. In an era of growing concern with antibiotic resistant bacterial infections in hospitals, subglottic suctioning provides a means to reduce bacterial infections in a very vulnerable patient population. A recent study showed that subglottic secretion drainage and continuous control of ballooned cuff pressure, implemented together, save health care costs. Thus, the costs of the interventions should no longer be an issue.[13] Looking on VAP as an evitable hazard to our patients, we should consider all efforts to prevent VAP an obligation to all medical institutions.

"An observation in our unit is that the amount of secretions we are able to suction subglottically using an automated system substantially exceed the amounts of secretions collected cited in publications."

From our experience we therefore strongly recommend the use of subglottic suctioning at least in the here-reported population of long-term ventilated patients. We believe automated intermittent subglottic aspiration offers the means to overcome the practical problems associated with implementing subglottic suctioning.

"Thus, the costs of the interventions should no longer be an issue. Looking on VAP as an evitable hazard to our patients, we should consider all efforts to prevent VAP an obligation to all medical institutions."

Conclusion

Automated intermittent subglottic suctioning in our experience offers a lower rate of VAP than manual and other methods, less endotracheal (bronchial) suctioning, less atelectasis, easier use of a speaking valve, shortened ICU stays, and lowers staff burden. Further studies and clinical evaluation of automated SSD are warranted.

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