



Prevention of Ventilator-Associated Pneumonia in the Calgary Health Region: A Canadian Success Story!

Rosmin Esmail, Greg Duchscherer, Jennifer Giesbrecht, Jennifer King, Pamela Ritchie and Dan Zuege
– for the Ventilator Associated Pneumonia Team*

Abstract

This article describes the experiences of a Canadian multidisciplinary critical care team striving to reduce the incidence of ventilator-associated pneumonia (VAP). Several interventions, including a VAP bundle, were used and applied across a health region. Our regional VAP rate has seen a steady decline over the past 12 months and has been largely under our goal of 9.8 cases per 1,000 ventilator-days. The team's success in lowering VAP has provided the momentum for sustained improvement, which has spread to other areas.

Ventilator-associated pneumonia (VAP) is a leading cause of morbidity and mortality among hospitalized patients. VAP develops in 10–20% of mechanically ventilated patients, with those acquiring VAP experiencing greater attributable mortality and longer lengths of stay in intensive care units (ICUs) (Keith et al. 2004; Safdar et al. 2005; US Centers for Disease Control and Prevention 2005).

The Calgary Health Region (CHR) provides healthcare services to 1.2 million residents in Southern Alberta and

tertiary services for 1.3 million residents of Alberta and British Columbia. The Department of Critical Care Medicine has three adult multi-system ICUs, admitting over 3,000 patients per year to 38 ICU beds. In recent years, our infection control-based VAP surveillance system discovered a significant incidence of VAP in our regional ICUs. From 1998 to 2002, CHR's rate of VAP was 19 cases per 1,000 ventilator-days. Paralleling published observations from other centres, patients acquiring VAP in the CHR had significantly longer ICU stays, contributing to suboptimal resource use. Accordingly, the department elected to focus on the prevention of VAP.

This focus began in 2002 in conjunction with our participation in the Institute for Healthcare Improvement's Project Impact, with a focus on the ventilator bundle. Joining the Canadian Collaborative on Improving Patient Care and Safety in the ICU (www.improvementassociates.com) in 2004 allowed us to further benefit from the sharing of practice and experience by introducing additional change concepts including the VAP bundle.

This “ideas at work” case study is unique in that it provides a Canadian context, makes use of a modified bundle focused exclusively on measures linked to the prevention of VAP and exemplifies strategies for VAP prevention as applied across a health region rather than an individual hospital.

Definition and VAP Surveillance

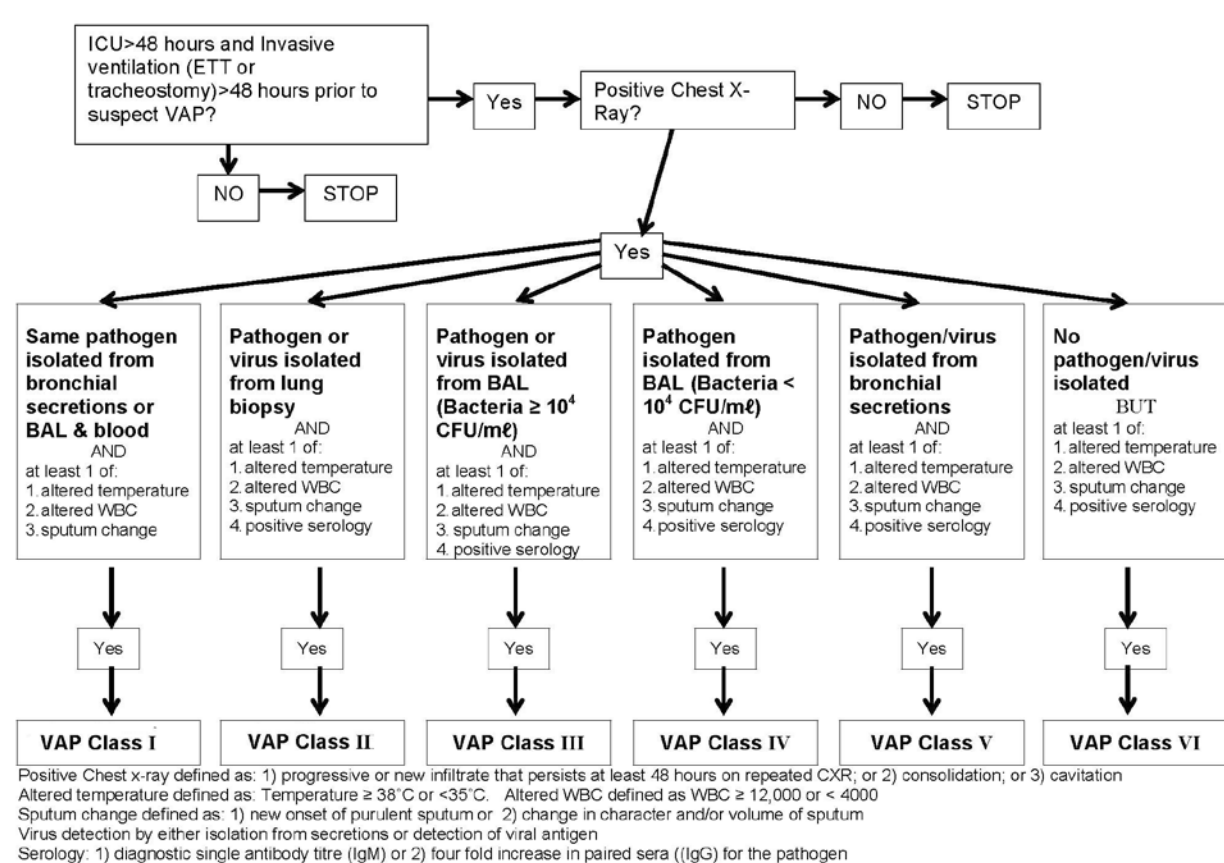
The definition of VAP varies among healthcare institutions, surveillance bodies and published guidelines. The Canadian ICU Collaborative and the Canadian Safer Healthcare Now! Campaign (<http://www.saferhealthcarenow.ca>) define VAP as “a pneumonia occurring in patients requiring a device intermittently or continuously to assist respiration through a tracheostomy or endotracheal tube. Further, the device must have been in place within the 48-hour period before onset of infection and for at least two consecutive days” (Safer Healthcare Now! Campaign 2007). The surveillance definition of pneumonia itself is based on the combination of new radiographic densities and supportive clinical signs (Safer Healthcare Now! Campaign 2007). The number of cases of VAP is usually referenced to the number of ventilator-days to yield a rate. The best approach for obtaining supportive microbiological data for VAP remains controversial, with recent randomized trials demonstrating equivalency in important clinical outcomes with invasive and non-invasive approaches (Canadian Critical Care Trials Group 2006). Although a diagnosis of VAP is commonly associated

with the growth of a pathogen, this is not always the case (Lambotte et al. 2002). Accordingly, most contemporary definitions of VAP do not depend on adjuvant microbiological data.

CHR uses a similar definition of VAP that further classifies cases of VAP based on the strength of any additional microbiological data (Figure 1) to better understand patterns of diagnosis over time. Though surveillance definitions for VAP clearly contribute to a more objective diagnosis, ultimately there remain significant subjective components to the diagnosis, including the interpretation of chest radiographic and clinical data in patients who frequently have multiple nidi of inflammation. Critical to surveillance as it applies to quality improvement is internal consistency in definition and classification so that performance can be reliably compared over time without the bias of changing definitions.

Surveillance for VAP is accomplished by infection control practitioners (ICPs) conducting standardized surveillance in the three multidisciplinary ICUs. The surveillance system is illustrated in Figure 2. Case finding is accomplished using microbiology-based triggers via daily automated downloads from

Figure 1. Classification of ventilator-associated pneumonia



Calgary Laboratory Services that indicate whenever a respiratory specimen of any kind has been received on a patient from one of the ICUs. Given that our routine practice does not include the performance of any surveillance respiratory cultures, the assumption with this kind of case finding is that the performance of a respiratory culture indicates some clinical suspicion for respiratory infection. Secondary triggers for case finding include verbal or written reports of a suspected VAP from the ICU medical staff.

Using an electronic bedside charting system, Quantitative Sentinel, the ICPs determine if the patient initially meets the case definition for VAP; that is, the patient has been in the ICU and mechanically ventilated continuously for at least 48 hours and has at least one clinical sign of an infection, such as altered temperature, white blood cell count or sputum (see Figure 1). The ICP then marks in the Quantitative Sentinel system that a VAP is suspected; this triggers the creation of a chart in a web-based VAP surveillance system, which forms part of our critical care data warehouse and reporting system.

The VAP surveillance system, through interfaces with various other databases, collates in a single record chest radiographic, microbiology (sputum, bronchoscopy and blood specimens), demographical, clinical and antibiotic data. Automatically populated fields facilitate the review from any network computer and decrease data-entry errors. ICPs review in a single record the above data and decide if the case definition is met. Ambiguous cases undergo review by a multidisciplinary group.

The key advantages of this system are (1) efficiency – given that all relevant data are collated into a single record; (2) accuracy – given that the system helps to ensure that data are complete

and builds in some error checking; and (3) the ability to easily create and share real-time reports and graphs. The web-based application has reduced the amount of time ICPs dedicate to VAP surveillance by minimizing the time spent on chart review, contributing to a more sustainable system over the long term.

Quality Improvement Initiatives and VAP Background

There have been numerous articles published describing quality improvement methodologies associated with decreasing the rate of VAP (American Health Consultants 2003; Berriel-Cass et al. 2006; Cocanour et al. 2006; Fox 2006; Goeschel et al. 2006; Keith et al. 2004; Misset et al. 2004; Murray and Goodyear-Bruch 2007; Resar et al. 2005; Simmons-Trau et al. 2004; Youngquist et al. 2007). All of these studies have been conducted in the United States and illustrate that by implementing a quality improvement program, including use of a ventilator bundle and education strategies, VAP rates decrease substantially.

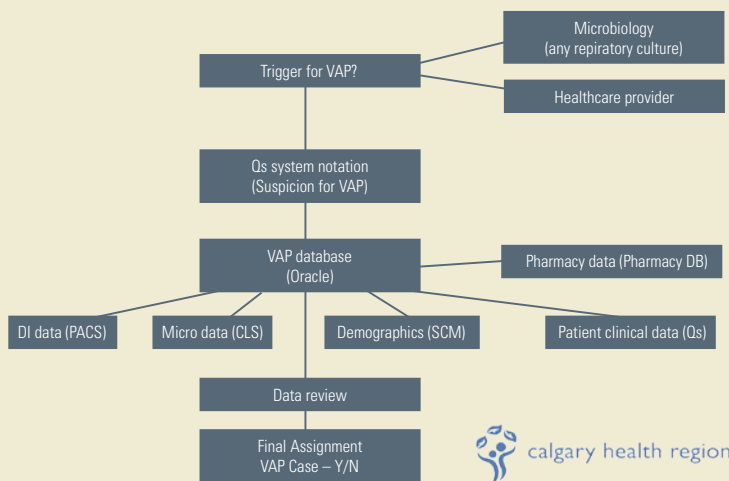
The traditional ventilator bundle, as popularized by the Institute for Healthcare Improvement, consists of (1) elevation of the head of the bed to 30–45 degrees, (2) daily “sedation vacation” and daily assessment of readiness to extubate, (3) peptic ulcer disease prophylaxis and (4) deep venous thrombosis prophylaxis (unless contraindicated) (Institute for Healthcare Improvement 2006). The Canadian Safer Healthcare Now! Campaign in 2005 advocated for a modified prevention bundle via the inclusion of two additional practices that were alluded to in the clinical practice guidelines for the prevention of VAP published by the Canadian Critical Care Society and the Canadian Critical Care Trials Group (Dodek et al. 2004):

(1) elevation of the head of the bed to 30–45 degrees, (2) daily sedation vacation and daily assessment of readiness to extubate, (3) preferential use of oral versus nasal tubes for access to the trachea or stomach and (4) use of EVAC tubes for the drainage of subglottic secretions. Though prophylaxis against peptic ulcer disease and deep venous thrombosis are desirable practices in mechanically ventilated patients, they are not directly related to VAP prevention (Safer Healthcare Now! Campaign 2007).

Team Formation and Objectives

A regional multidisciplinary team was created to work on VAP prevention in conjunction with the Canadian ICU Collaborative in May 2004. Its membership included intensivists, registered nurses, respiratory therapists, infection prevention and control practitioners, physiotherapists, a respiratory therapy

Figure 2. VAP surveillance system



CLS = Calgary lab services; DB = Database; DI = Diagnostic imaging; PACS = Picture archiving and communications system; Qs = Quantitative Sentinel system; SCM = Sunrise clinical manager; VAP = ventilator-associated pneumonia.

manager, an intensivist with infectious disease training, an information technology manager and a quality improvement and patient safety leader. An intensivist and a respiratory therapy clinical development leader co-chaired the team. Membership was distributed across the three ICUs.

The overall aim was to reduce the impact of VAP in all multi-system ICUs within the CHR; specifically, within one year, to reduce the incidence of VAP across all units by 25% and to ensure that >90% of ventilated patients have all four components of the VAP bundle applied (where appropriate).

Interventions and Change Concepts

The Department of Critical Care Medicine first focused on the prevention of VAP in early 1998 with a systematic review of the literature and the establishment of new and modification of existing policies, procedures and guidelines related to various aspects for care of the ventilated patient in ICU. In November 2002, the ventilator bundle was initiated based on an involvement with the Institute for Healthcare Improvement's Project Impact.

In September 2004, the VAP committee instituted a new VAP bundle to replace the ventilator bundle. The new bundle included head-of-the-bed elevation >30

Table 1. Change concepts and ideas tested and implemented by regional and site-based teams

Change Concept*	Ideas Tested, Implemented, Spread
Develop operational definitions	<ul style="list-style-type: none"> Standard and consistent Calgary Health Region definition for VAP developed, adapted from those of CDC
Use proper measurements	<ul style="list-style-type: none"> Tracking of VAP through sustainable surveillance database VAP bundle compliance tracked through monthly audits done on 10% of ventilated patients at each site
Apply best science	<ul style="list-style-type: none"> VAP bundle components tested and implemented Audit additional components: PUD, DVT, hand hygiene, oral care EVAC tube use and function and readiness for extubation assessed on daily rounds Hallway huddles focusing on HOB and patient positioning Online quizzes, VAP discussions at site quality committee meetings, "safety snippets" posted on departmental website
Use checklists	<ul style="list-style-type: none"> Use of VAP bundle audit sheets
Create a culture of collaboration and teamwork	<ul style="list-style-type: none"> Establish multidisciplinary teams Engaged RRT to share responsibility of VAP bundle audits
Standardize care	<ul style="list-style-type: none"> Implementation of sedation scoring system and practice guideline for sedation Implementation of a weaning protocol including daily spontaneous breathing trials
Establish reliable processes	<ul style="list-style-type: none"> Charting of HOB position in the clinical record q1h by nursing RRTs documenting HOB q2h and reporting HOB on daily rounds Charting frequency of oral care When audits are conducted, families are told what is being done to prevent VAP
Design systems to avoid mistakes	<ul style="list-style-type: none"> Signs for HOB >30 degrees HOB alarm on all new total care and sport beds
Give people access to information	<ul style="list-style-type: none"> VAP rates and bundle compliance posted on website, in department newsletter and on bulletin boards VAP project reviewed at Quality and Safety Council and site quality committees Communication of the cost of a VAP Review a VAP case at meeting Reported on VAP project and outcomes to the regional board Regional newspaper articles Posters on HOB and hand hygiene in family room
Develop alliances, co-operative relations	<ul style="list-style-type: none"> Regional implementation of EVAC tubes (critical care, emergency, code carts, ambulance and air rescue organizations) Co-operation with OR for postoperative ICU patients to have EVAC tubes inserted selectively Change to minimum pressure rather than volume technique for EVAC tube cuffs Linkage with Cardiac Sciences to spread VAP bundle to CVICU
Reassess current paradigms – change target or set points	<ul style="list-style-type: none"> Poster on VAP-free days at one site Downward adjustment of goal once it has been reached by another 25%

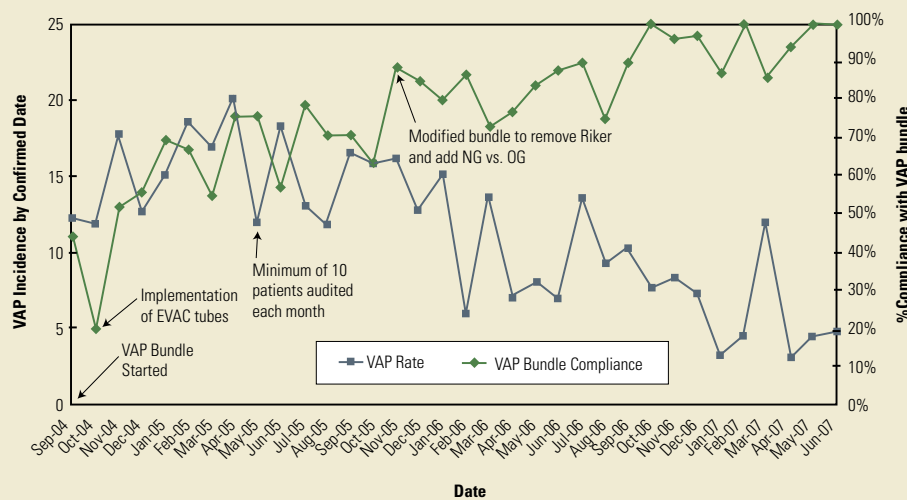
CDC = US Centers for Disease Control and Prevention; CVICU = Cardiovascular Intensive Care Unit; DVT = deep venous thrombosis; HOB = head of the bed (elevation); ICU = Intensive Care Unit; OR = operating room; PUD = peptic ulcer disease; RRT = rapid response team; RT = respiratory therapist; VAP = ventilator-associated pneumonia.

*Data from Couves and Harris (2007).

degrees, daily assessment for spontaneous breathing trial, preferential use of an oral gastric tube, preferential use of an endotracheal tube (ETT) – which allows for continuous aspiration of subglottic secretions (CASS) – and use of the Riker sedation scale. The revised bundle was introduced because it was felt that the new care practices were more directly related to the prevention of VAP; also, our department was influenced by its involvement in the Canadian ICU Collaborative.

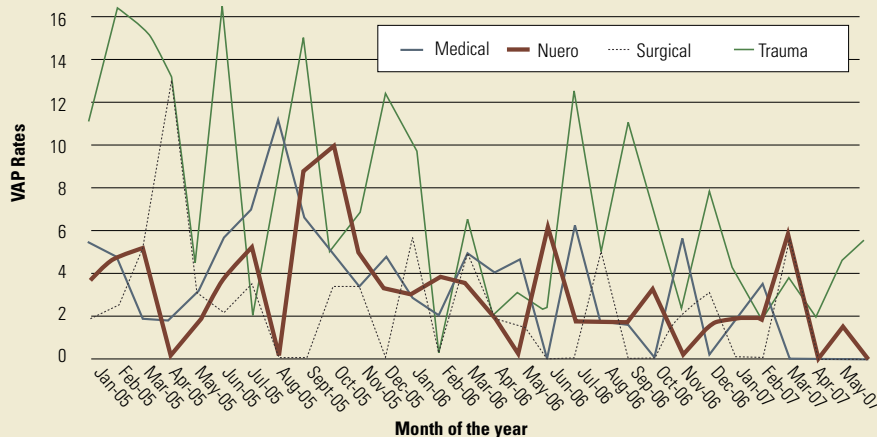
One of the most significant and widespread changes that the team spearheaded was the region-wide introduction of EVAC tubes ... if the region were to prevent just one case of VAP, this cost savings would cover the entire cost for the change to EVAC tubes.

Figure 3. Incidence of VAP* and compliance with VAP bundle† over time



NG = nasogastric; OG = orogastric; VAP = ventilator-associated pneumonia.
 *VAP cases/1,000 ventilator-days.
 †Percentage of audits compliant with all four bundle components.

Figure 4. Incidence of VAP* over time by admitting medical category†



VAP = ventilator-associated pneumonia.
 *VAP cases/1,000 ventilator-days.
 †Medical category is assigned on admission to the Intensive Care Unit based on the diagnosis most responsible for the admission.

One of the most significant and widespread changes that the team spearheaded was the region-wide introduction of ETTs that allow for CASS (or EVAC ETTs). In October 2004, all areas in all three adult sites in Calgary, except for the operating room, converted to exclusive use of EVAC ETTs. The business case for this change was based on the premise that if the region were to prevent just one case of VAP, this cost savings would cover the entire cost for the change to EVAC tubes. (In CHR, the acquisition of VAP increases ICU length of stay by about 10 days. At approximately \$3,000 per ICU-day, this added “cost” to the system is roughly \$30,000 for a single case of VAP. The yearly additive cost to change over to EVAC ETTs was approximately \$16,000 per year [based on yearly utilization data provided by our purchasing and supply department given that the EVAC ETT costs about three times that of a standard ETT].) To gain support from the various stakeholders (ICU, emergency department, anesthesia, purchasing and supply management etc.), committee members met with key clinical, medical and administrative leaders in each area. Within the following year, this initia-

tive was also spread to our ground ambulance system in Calgary and to the air rescue system in Southern Alberta.

In November 2005, the assessment of the use of the Riker sedation scale was removed from the bundle audit form as it was felt that compliance with this assessment alone did not directly relate to the potential for developing VAP. Rather, the department developed and instituted a sedation protocol and a sedation vacation procedure to be used in conjunction with the assessment for readiness to extubate.

Other initiatives implemented but not directly related to the VAP bundle included those on hand hygiene and the implementation of appropriate equipment cleaning guidelines. Though hand hygiene may be less formally evidence based, it is considered a core quality improvement initiative within our region and department for which ongoing measurement, feedback and action are undertaken.

The team tested, implemented and is continuing to work on numerous interventions, change concepts and ideas using the improvement model and plan-do-study-act cycles (Langley et al. 1996). Table 1 describes the change concepts and ideas that we have tested to support changes to clinical processes.

Our regional VAP rate has seen a steady decline over the past 12 months and has been largely under our goal of 9.8 cases per 1,000 ventilator-days since August 2006.

Measures and Results

The team used several measures to determine if changes were leading to improvement. The key outcome measure was the incidence of VAP as expressed by the number of VAPs per 1,000 ventilator-days. The key process measures were the overall compliance with the VAP bundle and compliance with the individual bundle components. The auditing process for measurement of the compliance with the VAP bundle consisted of bedside reviews of a minimum of 10 selected ventilated patients per month; this number needed to account for at least 10% of the total ventilation-days at each unit.

Our regional VAP rate (Figure 3) has seen a steady decline over the past 12 months and has been largely under our goal of 9.8 cases per 1,000 ventilator-days since August 2006. Figure 4 demonstrates the variation in VAP incidence across patient admission categories and a general decline in VAP incidence across all groups. Concurrently, a gradual improvement in regional

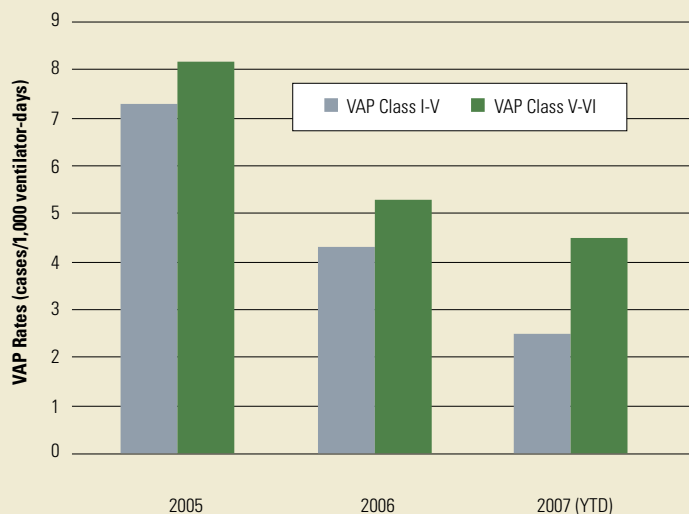
compliance with the VAP bundle, largely meeting or exceeding our goal of 90% compliance for all components for the past 10 months (see Figure 3), has occurred. This is inversely related to due reduction in our VAP rate.

Figure 5 demonstrates that VAP rates fell in both higher- and lower-class categories of VAP per the classification scheme of Figure 1. This data, though reassuring, must be interpreted with caution given the likely shift in utilization toward less invasive diagnostic techniques to gain supportive microbiological data over time reflecting evolving trial data (Canadian Critical Care Trials Group 2006).

The variability of VAP when measured monthly is well demonstrated in Figures 3 and 4. Recognizing this variability, our quality improvement teams do not typically react to what is perceived as normal random variation. However, whenever there is a signal suggestive of a special cause for a change in rates, the site quality committees initiate a process-based analysis in an attempt to isolate causes for unusual or uncontrolled variation. (*Special cause variation* is defined as a single data point beyond the upper or lower control limits or 99.7% probability limits [three standard deviations from the mean], or a run of five or more consecutive data points on one side of the mean.) The learnings from these analyses are used as teaching points for staff and ask the question, is there anything that can be done to address this special cause?

For many of our staff, it is more intuitive to show our VAP data in terms of the number of cases each month or the days between VAP cases rather than an overall rate, primarily because

Figure 5. Incidence of VAP* over time by VAP diagnostic classification†



VAP = ventilator-associated pneumonia.
 *VAP cases/1,000 ventilator-days.
 †See Figure 1. VAP diagnostic classes I-IV and V and VI are grouped separately.

of the variability of the data and the difficulty interpreting a number expressed as cases per 1,000 ventilator-days. More importantly, Figures 3 and 4 indicate that, regardless of the way the data are expressed, overall our VAP rates have decreased over time, which is our ultimate goal.

Given the achievement of our initial goal of reducing the incidence of VAP across all units by 25%, the team in September 2007 reviewed its charter and reset the goal to reduce the incidence of VAP by another 25% by March 2008. Therefore, our regional goal has been reduced from 9.8 to 7.4 cases per 1,000 ventilator-days.

The support and lessons gained from each of the national collaborative ventures we have been a part of have been invaluable.

Key Learnings and Challenges

Support and Leadership

The VAP team is fortunate to be led and sponsored by those with expertise and who genuinely value the importance of VAP prevention. Through this commitment, these values are subsequently passed on to each multidisciplinary team and staff member. Similarly, the moral, financial and human resource supports from departmental and regional levels to pursue this initiative have been critical. The support and lessons gained from each of the national collaborative ventures we have been a part of have been invaluable.

Multidisciplinary Participation

When appropriate, families have been involved in the audit process. In most cases, family members have valued the opportunity to be integrated into the care process. For example, families often commented that they enjoyed checking the elevation of the head of the bed each time they entered the room and felt as though they were helping the staff by doing so.

Education

Throughout the implementation of the VAP bundle, the department has been challenged to revise and update clinical care to establish new care values and norms. Transmission of the importance of the VAP bundle to staff was accomplished through hallway huddles and brief group education sessions held within proximity to patient beds. The strongest correlate of staff acceptance of the VAP bundle seemed to be educational strategies that incorporated rationale in addition to process.

Sustainable Reliable Measurement

The ability to measure our VAP rates in a sustainable fashion is

crucial. To help accomplish this, our VAP surveillance system builds in efficiencies. Maintenance of internal consistency for the definition and classification of VAP is crucial to allow for reliable comparisons of performance over time without the bias of changing definitions.

Local Oversight and Responsibility

It was difficult to oversee and put into action VAP-prevention strategies across a health region via a high-level regional team alone. The creation of unit-based teams charged with local VAP oversight and implementation was an important evolution, allowing quality-of-care processes to have oversight as close to the bedside as possible.

Persistence

The observed decreases in VAP incidence occurred only after many months of sustained application of VAP-prevention strategies, as reflected in our VAP bundle compliance.

Challenges

There were two key areas of challenge during the implementation of the VAP bundle. Concerns related to the EVAC ETTs include that a percentage of patients have secretions too thick to effectively be evacuated and that the EVAC suction lines produce sounds that can mimic a cuff leak. As well, the radiopaque line within the EVAC tube is interrupted by the Murphy eye on the end of the ETT, thereby making the radiographic assessment of exact ETT depth more challenging. Staffing levels in the ICU continue to pose major challenges and have been linked to increases in VAP (Hugonnet et al. 2007). This issue will continue to require specific attention by the department in the coming years.

Conclusion

The implementation of the VAP bundle, with the goal to apply it on every patient every time, has contributed to a decrease in VAP rates for CHR. Participation in both the Canadian ICU Collaborative and Safer Healthcare Now! Campaign has clearly been of benefit in the development and implementation of our change concepts, in particular the bundle concept. In our experience, keys to achieving sustained improvement include persistence, oversight and responsibility placed as close to the bedside as possible; a sustainable and reliable VAP surveillance system; implementation of several change concepts as bundled interventions; and regular performance measurement, feedback and action to drive improvement. Next steps are to hold and extend our gains in our ICUs and to spread VAP prevention to other areas, including the Cardiovascular ICU. We also look forward to continued participation with national collaboratives. **HQ**

About the Authors

Rosmin Esmail, MSc, was previously the quality improvement and patient safety leader for the Department of Critical Care Medicine, Calgary Health Region, Calgary, Alberta. She is now the director of quality, safety and risk management for the BC Cancer Agency, Vancouver, British Columbia. She can be contacted at 604-877-6198, by fax at 604-877-6292 or by e-mail at resmail@bccancer.bc.ca.

Greg Duchscherer, RRT, is a clinical development leader, Respiratory Services, Calgary Health Region.

Jennifer Giesbrecht, RN, is the assistant patient care manager, Intensive Care Unit, Foothills Medical Center, Calgary Health Region.

Jennifer King, RN, is the assistant patient care manager, Intensive Care Unit, Rockyview General Hospital, Calgary Health Region.

Pamela Ritchie, RN, is an infection prevention and control practitioner, Rockyview General Hospital, Calgary Health Region.

Dan Zuege, MD, is the site medical director of the Intensive Care Unit, Peter Lougheed Hospital, Calgary Health Region.

*Acknowledgements

Special thanks to the contribution of the additional current and past members of the CHR Ventilator-Associated Pneumonia Regional Team: Dr. Paul Boiteau, Dr. Paul Boucher, Dr. Chip Doig, Dr. Terry Hulme, Patty Infusino, Dr. Kevin Laupland, Kathy LeBlanc, Marlene Montgomery, Reza Shahpori, Lydia Shewchuk, Jan Stoesz, Peggy Tan, Jim Winnick and past members Lorraine Blaich, Marg White and Hilary Gray.

References

American Health Consultants. 2003. "Ventilator Education Program Reduces VAP." *Healthcare Benchmarks and Quality Improvement* 10(2): 17-9.

Berriell-Cass, D., F.W. Adkins, P. Jones and M.G. Fakih. 2006. "Eliminating Nosocomial Infections at Ascension Health." *Journal on Quality and Patient Safety* 32(11): 612-20.

Canadian Critical Care Trials Group. 2006. "A Randomized Trial of Diagnostic Techniques for Ventilator-Associated Pneumonia." *New England Journal of Medicine* 355: 2619-30.

Cocanour, C.S., M. Peninger, B.D. Domonoske, T. Li, B. Wright, A. Valdivia and K.M. Luther. 2006. "Decreasing Ventilator-Associated Pneumonia in a Trauma ICU." *Journal of Trauma Injury, Infection and Critical Care* 61(1): 122-30.

Couves, L. and B. Harris. 2007. *Improving Patient Care and Safety in the ICU: Improvement Guide*. Edmonton, AB: Improvement Associates Ltd.

Dodek, P., S. Keenan, D. Cook, D. Heyland, M. Jacka, L. Hand, J. Muscedere, D. Foster, N. Mehta, R. Hall and C. Brun-Buisson, for the Canadian Critical Care Trials Group and the Canadian Critical Care Society. 2004. "Evidence-Based Clinical Practice Guideline for the Prevention of Ventilator Associated Pneumonia." *Annals of Internal Medicine* 141: 305-13.

Fox, M.Y. 2006. "Toward a Zero VAP Rate. Personal and Team Approaches in the ICU." *Critical Care Nursing Quarterly* 29(2): 108-14.

Goeschel, C.A., A. Bourgault, M. Palleschi, P. Posa, D. Harrison, L.L. Tacia, M.A. Adamczyk, D. Falkenberg, L. Barbret, P. Clark, K. Heck, M. O'Neil, V. Pitts, K. Schumacher, D. Sidor, M. Thompson, E. Wahl and D.M. Bosen. 2006. "Nursing Lessons from the MHA Keystone ICU Project: Developing and Implementing an Innovative Approach to Patient Safety." *Critical Care Nursing Clinics of North America* 18(4): 481-92.

Hugonnet, S., I. Uckay and D. Pittet. 2007. "Staffing Level: A Determinant of Late-Onset Ventilator-Associated Pneumonia." *Critical Care* 11: R80. Retrieved August 16, 2007. <<http://ccforum.com/content/11/4/R80>>.

Institute for Healthcare Improvement. 2006. "Getting Started Kit: Prevent Ventilator-Associated Pneumonia How-to Guide." *Critical Care Nursing Quarterly* 29(2): 157-73.

Keith, D.D., K.M. Garrett, G. Hickox, B. Echols and E. Comeau. 2004. "Ventilator-Associated Pneumonia: Improved Clinical Outcomes." *Journal of Nursing Care Quality* 19(4): 328-33.

Lambotte, O., J.F. Timsit, M. Garrouste-Orgeas, B. Misset, A. Benali and J. Carlet. 2002. "The Significance of Distal Bronchial Samples with Commensals in Ventilator-Associated Pneumonia." *Chest* 122(4): 1389-99.

Langley, J.G., K.M. Nolan, T.W. Nolan, C.L. Norman and L.P. Pronovost. 1996. *The Improvement Guideline: A Practical Approach to Enhancing Organizational Performance*. New York: Jossey-Bass.

Misset, B., J.F. Timsit, M.F. Dumay, M. Garrouste, A. Chalfine, I. Flouriot, F. Goldstein and J. Carlet. 2004. "A Continuous Quality-Improvement Program Reduces Nosocomial Infection Rates in the ICU." *Intensive Care Medicine* 30(3): 395-400.

Murray, T. and C. Goodyear-Bruch. 2007. "Ventilator-Associated Pneumonia Improvement Program." *AACN Advanced Critical Care* 18(2): 190-9.

Resar, R., P. Pronovost, C. Haraden, T. Simmonds, T. Rainey and T. Nolan. 2005. "Using a Bundle Approach to Improve Ventilator Care Processes and Reduce Ventilator-Associated Pneumonia." *Journal on Quality and Patient Safety* 31(5): 243-8.

Safdar, N., C. DeZfulian, H. Collard, and S. Saint 2005. "Clinical and Economic Consequences of Ventilator-Associated Pneumonia: A Systematic Review." *Critical Care Medicine* 33(10): 2184-93.

Safer Healthcare Now! Campaign. 2007. *Getting Started Kit: Prevention of Ventilator-Associated Pneumonia in Adults How-to Guide*. Institute for Healthcare Improvement and Safer Healthcare Now! Campaign. Retrieved August 2, 2007. <<http://www.saferhealthcarenow.ca/Default.aspx?folderId=82&contentId=180>>.

Simmons-Trau, D., P. Cenek, J. Counterman, D. Hockenbury and L. Litwiller. 2004. "Reducing VAP with 6 Sigma." *Nursing Management* 35(6): 41-5.

US Centers for Disease Control and Prevention. 2005. *An Overview of Ventilator Associated Pneumonia*. Atlanta, GA: Department of Health and Human Services, Division of Healthcare Quality Promotion. Retrieved August 2007. <http://www.cdc.gov/ncidod/dhqp/dpac_ventilate_data.html>.

Youngquist, P., M. Carroll, M. Farber, D. Macy, P. Madrid, J. Ronning and A. Susag. 2007. "Implementing a Ventilator Bundle in a Community Hospital." *Joint Commission Journal on Quality and Patient Safety* 33(4): 219-25.