MESSAGE FROM THE EDITOR-IN-CHIEF / MESSAGE DU RÉDACTEUR EN CHEF

Respiratory therapists in the health system: Defining and building our role / Les thérapeutes respiratoires au sein du système de santé : définir et bâtir notre rôle

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Staffing patterns of respiratory therapists in critical care units of Canadian teaching hospitals

Impact of interprofessional education on noninvasive ventilation in a tertiary neonatal intensive care unit

Home mechanical ventilation: A retrospective review of safety incidents using the World Health Organization International Patient Safety Event classification
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MESSAGE FROM THE EDITOR-IN-CHIEF / MESSAGE DU RÉDACTEUR EN CHEF

Respiratory therapists in the health system: Defining and building our role / Les thérapeutes respiratoires au sein du système de santé : définir et bâtir notre rôle

Jason W Nickerson

EDITORIAL

Making a difference: More than just respiratory care

Alisha Nelson

ORIGINAL ARTICLES

Staffing patterns of respiratory therapists in critical care units of Canadian teaching hospitals

Andrew J West, Jason Nickerson, Gene Breau, Puck Mai, Christina Dolgowicz

Previous studies have shown that staffing levels of health care providers, especially physicians and nurses, can directly affect the quality of patient care and the risk for adverse events. However, although registered respiratory therapists (RTs) are an integral part of multidisciplinary care for critically ill, mechanically ventilated patients and, therefore, an important determinant of patient outcomes, there is a gap in the literature describing the impact or optimal levels of RT service in this context. Accordingly, this observational study investigated RT staffing ratios in primary teaching hospitals of Canadian medical schools.

Impact of interprofessional education on noninvasive ventilation in a tertiary neonatal intensive care unit

Debra Paterson, Sandesh Shivananda, Salhab El Helou, Christoph Fusch, Amit Mukerji

Efforts to reduce ventilation-induced lung injury has prompted advances in technology and the emergence of new methods of noninvasive ventilation (NIV). Consequently, this has necessitated the education of front-line health care professionals about the indications, mechanics and limitations of each NIV mode. This cross-sectional, single-centre study investigated the impact of a hands-on interprofessional NIV workshop for all health care disciplines at Canadian tertiary level facility.

Home mechanical ventilation: A retrospective review of safety incidents using the World Health Organization International Patient Safety Event classification

Lily Yang, Mika Nonoyama, Regina Pizzuti, Philip Bwititi, George John

Home mechanical ventilation (HMV) has become a principal of care for individuals with amyotrophic lateral sclerosis, spinal cord injury, chronic obstructive pulmonary disease and Duchenne muscular dystrophy, among many other conditions. Advances in HMV technology and its greater availability has improved patient mobility and quality of life for many patients. However, there is limited information about the safety of HMV in these medically fragile patients in the community. After defining the risks HMV patients encounter, this retrospective observational review of on-call logs, which includes four call examples, investigated incidents of patient harm over a one-year period in Ontario.

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MESSAGE FROM THE EDITOR-IN-CHIEF /
MESSAGE DU RÉDACTEUR EN CHEF

Respiratory therapists in the health system: Defining and building our role

The past months have brought several important developments in Canadian health policy. Perhaps the most contentious has been the passage of Bill C-14 on the provision of medical assistance in dying, which received royal ascent on June 17, 2016. The bill was the result of consultations with numerous stakeholders across the country in response to the Carter v. Canada case, in which the Supreme Court of Canada struck down the provision in the criminal code that prohibited assisting someone in ending his or her life, and gave Canadian adults the right to a doctor’s help in dying under certain circumstances. At the time of publication, at least one Canadian has already launched a legal challenge to the provisions of Bill C-14, and regulatory bodies continue to work to understand the implications for health professions other than physicians. Despite the legislation having been approved, it appears that many questions remain.

This is but one example of public policy innovation that will push the boundaries of how we, as respiratory therapists, see ourselves within Canada’s health care systems. Other legislative changes are coming or likely, and will raise major questions for our profession as clinicians, advocates and educators: what role should respiratory therapists play in educating patients on reducing the harms of cannabis use, particularly if smoked, when Canada legalizes non-medical use? If Canada moves forward with a national pharmacare strategy, how can we best ensure that our patients’ needs for respiratory medicines are met? What approaches to innovation should the federal government take to stimulate new advances in respiratory therapy and respiratory science and ensure that biomedical innovations are available, accessible and affordable for our patients?

To answer these questions, we need to not only understand our strengths and play to them, but to understand where the future of Canada’s health care lies and strategize on how to propel our profession to be there in ways that matter.

This may take many forms, ranging from a degree-as-entry-to-practice, to stimulating more research led by respiratory therapists with graduate-level training in research methods, and ensuring that we have a seat at the table where important legislative and regulatory changes are made outside of our profession. However, to do so, we need to understand our impact, the needs of our patients, and how we can best meet them.

Over the past several years, the Journal has strived to meet this challenge, publishing articles that explore the role of respiratory therapists in research and the barriers to engaging in more rigorous research work, homecare in respiratory therapy, the ratio of respiratory practitioners in research work, homecare in respiratory therapy, the ratio of respiratory practitioners in research and the barriers to engaging in more rigorous research work, homecare in respiratory therapy, the ratio of respiratory practitioners in research and the barriers to engaging in more rigorous research work, homecare

Les thérapeutes respiratoires au sein du système de santé : définir et bâtir notre rôle

Les politiques canadiennes en matière de santé ont subi des changements importants ces derniers mois. La plus controversée est probablement l’adoption du projet de loi C-14 sur l’aide médicale à mourir, qui a reçu la sanction royale le 17 juin 2016. Ce projet de loi déoulait de consultations avec de nombreux intervenants du pays, dans la foulée de la cause Carter c. Canada, où la Cour suprême du Canada a invalidé les dispositions du Code criminel qui interdisaient d’aider une personne à mettre fin à ses jours et, dans certaines situations, a donné aux adultes canadiens le droit d’obtenir l’aide d’un médecin pour mourir. Au moment de la publication, au moins un Canadien a déjà déposé une contestation judiciaire à l’égard des dispositions de cette loi, et les organismes de réglementation continuent leur travail afin d’en comprendre les répercussions pour les professionnels de la santé qui ne sont pas médecins. En effet, malgré l’adoption de la loi, de nombreuses questions demeurent en suspens.

Ce n’est là qu’un exemple de nouvelles politiques publiques qui repousseront les limites de la perception que nous, les thérapeutes respiratoires, avons de nous-mêmes au sein du système de santé canadien. D’autres modifications législatives s’annoncent ou pourraient survenir et souleveront d’importantes questions pour les cliniciens, les promoteurs de la santé et les éducateurs de notre profession : Quel rôle les thérapeutes respiratoires devraient-ils jouer pour apprendre aux patients à réduire les dommages causés par l’utilisation du cannabis, particulièrement sous sa forme fumée, lorsque le Canada légalisera l’utilisation à des fins non médicales? Si le Canada adopte une stratégie nationale d’assurance médicaments, comment pourrons-nous le mieux nous assurer de respecter les besoins de nos patients sur le plan de la médecine respiratoire? Quelles approches à l’innovation le gouvernement fédéral doit-il adopter pour stimuler de nouveaux progrès en thérapie respiratoire et en sciences de l’appareil respiratoire et pour s’assurer que les innovations biomédicales soient offertes, accessibles et abordables pour les patients?

Pour répondre à ces questions, nous devons non seulement comprendre nos forces et les exploiter, mais nous devons également comprendre où se trouve l’avenir du système de santé canadien et formuler des stratégies pour mettre notre profession de l’avant afin qu’elle fasse sa part.

Ces mesures peuvent prendre diverses formes, qu’il s’agisse de la nécessité d’un diplôme pour exercer, de l’encouragement des recherches menées par des thérapeutes respiratoires détenant une formation de deuxième cycle en méthodologie de la recherche ou de
therapists to critically ill ventilated patients and many others. This work lays a foundation on which we must continue to build, but also presents a challenge to translate this knowledge into action at the bedside and at the legislative table.

Collectively, we are at the beginning phases of understanding and articulating our role and our impact in a more refined way, and we must continue to build on this. While the role of the Journal is to publish rigorous works that get to the heart of these issues, the role of the profession is to take these works and debate and discuss them, and to implement them and ensure maximum impact. This should not be an idle or passive process, it must be active and responsive to the changing needs of our patients and the landscape of health care in Canada. To do this effectively, however, we must first understand ourselves and clearly articulate where we need to be to continue to be the advocates and clinicians that our patients need.

Jason W Nickerson RRT FCSRT PhD, Editor-in-Chief

notre présence et participation aux pourparlers lors d’importants changements aux lois et à la réglementation non liés à notre profession. Cependant, pour ce faire, nous devons comprendre quelles sont nos répercussions, les besoins de nos patients et les secteurs où nous sommes les plus efficaces.

Ensemble, nous commençons à approfondir et à structurer notre rôle et nos répercussions et nous devons continuer à les étoffer. Le rôle du Journal consiste à publier des articles rigoureux qui vont au cœur de ces questions, mais celui de la profession consiste à en discuter et à en débattre et à nous assurer qu’ils auront le plus d’effets possible. Ce ne devrait pas être un processus vain ni passif, mais bien actif et souple adapté aux besoins évolutifs de nos patients et au paysage de la santé du Canada. Cependant, pour y parvenir en toute efficacité, nous devons d’abord comprendre qui nous sommes et établir clairement notre position pour continuer d’être les promoteurs de la santé et les cliniciens dont nos patients ont besoin.

Jason W Nickerson RRT, FCSRT, Ph. D., rédacteur en chef
Our practice as registered respiratory therapists is heavily guided by evidence-based medicine, scientific studies and professional practice standards. However, our practice can also be shaped by inspiring stories. Dr Remen writes in her book, Kitchen Table Wisdom, “Life is the ultimate teacher, but it is usually through experience and not scientific research that we discover its deepest lessons” (1).

Brianna was a 17-year-old girl facing the end of her life – misdiagnosed, and then re-diagnosed with a fatal spinal cord tumour – within a six-month timeframe. Her biggest wishes after dealing with all of her medical issues, which left her paralyzed and attached to a ventilator 24 h per day, were simple: to go home and to graduate from high school. Unfortunately, this was not possible, but it inspired one of our pediatricians to facilitate a meeting among health care providers to brainstorm ideas to optimize Brianna’s stay in hospital.

After this meeting, the BC Children’s Hospital pediatric intensive care unit worked together to help Brianna and her family create memories outside of the hospital environment. To do this, Brianna and her family required resources: namely, a nurse and respiratory therapist at all times, which led to our increased involvement outside of regular working hours, including outings to concerts, botanical gardens and local amusement fairs. Our team also supplied health care providers in her home on a few occasions, which enabled her to be a part of family celebrations, anniversary parties and birthdays.

One of Brianna’s major accomplishments was finishing high school. Through determination, she did this by using sip and puff technology and an iPad from her hospital bed. We had decided to celebrate her graduation ceremony at the hospital because we were not sure she would make it to her own ceremony in a month’s time. In the matter of a couple of weeks we had different speakers, graduation programs, her high school diploma released from the province, a flash mob routine, a food committee, a decoration committee and, to top it off, a red carpet for Brianna to wheel across as she received her diploma. In the end, Brianna did make it to her high school graduation ceremony, where she received a standing ovation from a full theatre as she was wheeled across the stage by her father. She passed away shortly after this graduation ceremony, in the comfort of her own home.

Respiratory therapists see many traumatizing events, including deaths and devastated family members. To say that we are never affected by any of this is to say that we are not human. This separation of emotion can lead to a career of dissatisfaction, feeling undervalued, unmotivated and numb. According to the Cancer Nursing Journal (2):

Compassion fatigue leaves a heavy toll on nurses as they experience continued loss of patients. Many nurses go about their days experiencing increased stress with little understanding as to what is happening to them until they become ill, numb, or despondent “… some nurses make the ultimate sacrifice of leaving the profession when they no longer feel they are making a difference.

This statement could be applied to any health care provider, including respiratory therapists.

Although therapists can practice self-care, including yoga, leading an active lifestyle, and debriefing after a tragic event, it is important to grieve the loss of life. Dr Remen writes:

In my experience, burnout only really begins to heal when people learn how to grieve… Grieving is not meant to be of help to any particular patient. You grieve because it’s of help to you. “On to the next” is a denial of common humanity… it is a rejection of wholeness, of human connection that is fundamental (1).

Dehumanizing patients can hurt not only the patients and families we care for, but also ourselves.

It is important to consider our role as respiratory therapists, including being part of an end-of-life situation. In some cases, not only do we have to tend to our patient’s medical needs, but also their emotional, social and spiritual needs, and the needs of a family facing the end of someone’s life. We have to be very flexible and open minded, and sometimes do things outside of our general role as respiratory therapists, including stepping outside of our comfort zone to comfort a family member.

The experience of working with Brianna made it clear that excellent patient care cannot be given alone. The World Health Organization definition of pediatric palliative care states:

Effective palliative care requires a broad multidisciplinary approach that includes the family and makes use of available community resources; it can be successfully implemented even if resources are limited (3).

Indeed, “it takes a village” (4) that understands and respects each other’s roles, that has leadership and that allows individuals on the team to speak up when something needs to be said.

In a recent editorial published in the Journal (5), “Patient and family centered care in respiratory therapy: A fundamental right!,” Buell and Menard argue that:

For RRTs to effectively implement the patient and family centered approach, there must be a shift in practice from the traditional hierarchical relationship toward a focus on creating an equal partnership among all health care providers involved with the patient and family.

Throughout Brianna’s journey, our little ‘village’ at BC Children’s Hospital consisted of many individuals. Many disciplines worked together to achieve excellent family centered care.

Respiratory therapists, as well as the rest of the health care team, need to work together to leave positive, lasting impressions on the patients and family members. We need to understand that compassion and empathy are equally as important as academic scores and clinical competence. When speaking with Brianna’s family, it was evident that
they had been emotionally affected by negative comments health care providers had made. Although we reminisced about all the amazing things we did with Brianna at the end of her life, we also spoke about specific examples of negative health care provider and family interactions. Brianna’s mother described an example of a nurse in the late afternoon complaining to Brianna that she hadn’t gone for her break yet after Brianna had asked to be changed. This left Brianna apologizing to the nurse, and Brianna’s mother very upset (4). This was followed by many more examples of negative interactions. It should be remembered that what we say and do in front of patients and their family members can affect them long after the episode of care. Dr Remen states that:

Health care professionals are taught that competence and expertise are the two most important and respected qualities in the medical subculture, as well as in our society, but as important as they are, they do not fully sustain us (1).

REFERENCES

BACKGROUND: The optimal level of respiratory therapy staffing in Canadian intensive care units (ICUs) has not been described in the literature. An examination of practice patterns is an essential first step in developing an understanding of the contribution of respiratory therapists (RTs) to both short- and long-term patient outcomes in this context.

OBJECTIVE: To identify the ratio of mechanically ventilated patients to respiratory therapist (Vent:RT) ratio in the ICUs of Canadian teaching hospitals and the factors that influence this ratio.

METHODS: The present observational study investigated all adult ICUs (n=38) of the primary teaching hospital associated with each Canadian medical school. An electronic survey was administered at three intervals over a period of three months to control for seasonal variation. Data collected included the hours worked by all RTs, the number of mechanically ventilated patients receiving care, ICU characteristics and the practice patterns of the RTs. Data were used to calculate the Vent:RT ratio, and repeated measures ANOVA examined for variation between findings of each of the data collection points. Correlation analyses between key variables were performed and identified associations were further explored using the t-test. Approval for the study was granted by the University of Manitoba Research Ethics Board (Winnipeg, Manitoba).

RESULTS: A mean (± SD) Vent:RT ratio of 5.1±±2.818 was determined. Repeated measures ANOVA demonstrated no significant differences between findings of the three data collection points (F [1,17,30,5]=0.695; P=0.492). Several variables were associated with a significant difference in the Vent:RT ratio including ICUs where RTs intubated (4.05±2.89 versus 6.97±2.85; t[17,6]=−2.64; P=0.02), neurological ICUs (4.04±2.76 versus 6.40±3.35; t[30]=−2.092; P=0.04) and coronary care units (5.72±2.80 versus 3.10±1.88; t[35]=−2.72; P=0.01). Significant differences were also identified in the mean number of RT hours worked in ICUs where RTs intubated (31.40±9.71 versus 60.54±47.20; t[13]=−2.17; P=0.049) and procured arterial blood gases (41.68±10.85 versus 77.33±46.22; t[35]=−2.79; P=0.01).

CONCLUSIONS: The present study is the first to report the Vent:RT ratio and RT practice patterns in Canadian adult ICUs. The results serve as a baseline for comparison of staffing norms and will enlighten future research on the impact of RT staffing and practice patterns on patient outcomes.

Key Words: Critical care; Mechanical ventilator; Patient care; Practice patterns; Respiratory therapy

La dotation en thérapeutes respiratoires dans les unités de soins intensifs des hôpitaux universitaires canadiens

HISTORIQUE : Les publications ne décrivent pas le taux de dotation optimal des thérapeutes respiratoires dans les unités de soins intensifs (USI) canadiennes. À cet égard, il est essentiel de commencer par examiner les profils d’exercice pour comprendre l’apport des thérapeutes respiratoires (TR) aux résultats cliniques des patients à court et à long terme.

OBJECTIF : Déterminer le ratio entre les patients sous ventilation mécanique et les TR (ratio Vent:TR) dans les USI des hôpitaux universitaires canadiens et les facteurs qui influent sur ce ratio.

MÉTHODOLOGIE : La présente étude d’observation a porté sur toutes les USI pour adultes (n=38) de l’hôpital universitaire de soins de première ligne associé à chaque faculté de médecine canadienne. Les chercheurs ont envoyé un sondage virtuel à trois reprises sur une période de trois mois pour contrôler la variation saisonnière. Ils ont recueilli les heures travaillées par tous les TR, le nombre de patients sous ventilation mécanique traités, les caractéristiques des USI et les profils d’exercice des TR. Ils ont utilisé les données pour calculer le ratio Vent:TR et examiné les mesures de variance répétées pour établir la variation entre les observations à chaque moment de la collecte des données. Ils ont effectué des analyses de corrélation entre les principales variables et examiné de manière plus approfondie les associations établies au moyen du test t. Le comité d’éthique de la recherche de l’université du Manitoba, à Winnipeg, a approuvé l’étude.

RÉSULTATS : Un ratio Vent:TR moyen (± ÉT) de 5,1±±2,818 a été établi. Les mesures de variance répétées n’ont démontré aucune différence significative entre les observations à trois moments de la collecte de données (F [1,17,30,5]=0.695; P=0.492). Plusieurs variables s’associaient à une différence importante du ratio Vent:TR, y compris les USI où les TR insèrent les cathéters intra-arteriels (4,05±2,89 par rapport à 6,97±2,85; t[17,6]=−2,64; P=0,02), les USI en neurologie (4,04±2,76 par rapport à 6,40±3,35; t[30]=−2,092; P=0,04) et les unités de soins coronariens (5,72±2,80 par rapport à 3,10±1,88; t[35]=−2,72; P=0,01). Les chercheurs ont également constaté des différences significatives en matière de nombre moyen d’heures-TR travaillées dans les USI où les TR procédaient à des intubations (31,40±9,71 par rapport à 60,54±47,20; t[13]=−2,17; P=0,049) et celles où ils effectuaient des gaz artériaux (41,68±10,85 par rapport à 77,33±46,22; t[35]=−2,79; P=0,01).

CONCLUSIONS : La présente étude est la première à rendre compte du ratio Vent:TR et des profils d’exercice des TR dans les USI pour adultes canadiennes. Les résultats sont un point de départ pour comparer les normes de dotation en personnel et pour éclairer les futures recherches sur les répercussions du nombre de TR et des profils d’exercice sur les résultats cliniques des patients.

Multidisciplinary care teams provide optimal care for mechanically ventilated patients, including registered respiratory therapists (RTs), registered nurses, physicians and health professionals representing several other disciplines. Evidence from epidemiological studies have shown that lower than average staffing levels of health care providers are associated with poor quality of care and increased risk for adverse events in critical care patients and patients on general hospital wards (1-4). While this has been studied extensively to examine nurse to patient ratios and the effects of variable nurse staffing ratios on patient care (3-6), no such figures exist for RTs and, thus, little is known of the effects of variable staffing patterns of RTs on patient outcomes.

Investigations have demonstrated the effectiveness of RT-driven respiratory care in acute care (7-10). One such investigation determined that decreasing costs and increased compliance with established practice guidelines, in the absence of any increase in adverse

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events, was witnessed in RT-driven care when compared with care directed by physicians (11). Similarly, the literature describes the feasibility and effectiveness of implementing non-physician health care professional-driven (typically RT and nurse) weaning strategies for mechanically ventilated patients (12). In Canadian intensive care units (ICUs), RTs are often the primary providers of mechanical ventilation to critically ill patients and, therefore, can be an integral determinant of patient outcomes. While the RT typically undertakes a predominant role in mechanical ventilation management, the literature primarily describes the effectiveness and impact of physician or other health professional's care on ventilated patients' outcomes (1,13). For example, one prospective controlled trial of the impact of mechanical ventilation weaning strategies in ICUs concluded that physician staffing and structured rounds were likely important factors in outcomes as opposed to the type of weaning strategy used (13). Despite the important role of the RT in the ICU, neither the impact of routine RT care nor identification of optimal levels of service in this context has been described in the literature. Because RTs play such a central role in the care of critically ill patients in general, particularly with the provision of mechanical ventilation, further investigation is warranted.

The Canadian Society of Respiratory Therapists (CSRT) has also identified a need for baseline data describing the staffing patterns of RTs in Canada. In the past, it has been articulated by the CSRT membership that such data would be valuable to those who manage health care organizations and respiratory therapy units, and to health care policy and decision makers. As the role of respiratory therapists has continued to expand to include, for example, the insertion of arterial lines, airway management and the management of complex forms of mechanical ventilation, it stands to reason that at some point the ratio of mechanically ventilated patients to RTs (Vent:RT ratio) likely breaches an unsafe threshold, as has been demonstrated for other professions. To achieve this understanding, however, it is essential to understand the current staffing levels and any variation that may exist among institutions. By understanding the current state of RT care, an examination of the effects of variations in staffing patterns and clinical roles can then guide a more robust understanding of the contribution of RTs to both short- and long-term patient outcomes in this environment.

The goal of the present study was to identify the typical Vent:RT ratio in the adult ICUs of Canadian teaching hospitals and the factors that influence this ratio. The results will serve as a platform for identifying potential staffing norms in Canadian ICUs, and will enlighten future research describing the impact of RT staffing and practice patterns on patient outcomes.

**METHODS**

The present observational study systematically identified the typical staffing patterns of the ICUs of Canadian teaching hospitals with respect to numbers of RTs relative to the number of mechanically ventilated patients (i.e., Vent:RT ratio). The study also sought to determine factors relating to the clinical responsibilities and roles of RTs that may influence this ratio. A survey design was used because it is particularly well suited to identify attributes of large populations from a relatively small group of individuals (14). A survey design was also chosen due to its relative cost effectiveness, timeliness and ease of distribution, enabling multicentre sampling and data collection.

Representatives of ICUs of Canadian teaching hospitals were asked to complete an electronic survey. The survey aimed to identify information relating to the number RTs working in each ICU, the number of mechanically ventilated patients receiving care at the time of the response, and descriptive information regarding the ICU including the scope of professional practice of the RTs employed there. Ethics approval for the study was granted by the Human Health Research Ethics Board of the University of Manitoba (Winnipeg, Manitoba), and informed consent was obtained from each site.

**Sampling**

Canada has 17 medical schools accredited by the Association of Faculties of Medicine of Canada (15), all of which are affiliated with at least one major teaching hospital. This was used as a convenient sampling frame because it enables the collection and analysis of data within the context of large Canadian teaching hospitals. Non-teaching hospitals were not evaluated due to the high degree of variability inherent in their contexts and, thus, practice patterns. It was believed that their inclusion would also necessitate a project of significantly larger magnitude than was achievable by the resources available for the present study. This method of sampling provided for a highly representative sample of a clearly definable grouping of institutions whose practices are often used as the benchmarks by other institutions. The selectiveness of the sampling method controlled for over-representation of some geographical locales where there could be a proportionately larger number of sites affiliated with a particular medical school. All participant recruitment was facilitated by the CSRT.

**Inclusion and exclusion criteria**

Recruited participants represented the primary teaching hospitals affiliated with one of 17 Canadian medical schools. Satellite or secondary teaching hospitals were not surveyed. If any ambiguity existed, the largest hospital in the nearest geographical region to the university was included. In the case of hospitals with multiple sites within the same city, all sites with relevant data were included if these sites were served by one fully integrated respiratory therapy department. In the case of hospitals with multiple sites, each with independent respiratory therapy departments, only the site with the largest number of ICU beds was chosen. All adult ICUs of recruited teaching hospitals were included regardless of their areas of specialization (e.g., cardical, medical/surgical, etc.). Any hospital not affiliated with a Canadian medical school was not included.

**Data collection instrument**

A series of three novel questionnaires developed by the researchers were administered to all participants. The number of RTs working and the number of hours worked by each RT, as well as the number of mechanically ventilated patients in each ICU over a specified 24 h period were collected. The survey also collected information relating to the scope of practice of the RTs including typical clinical responsibilities (e.g., endotracheal intubation, intrafacility patient transportation, invasive line insertion or monitoring, etc.) and the characteristics of the ICU (e.g., number of beds, specialty type).

Questions pertaining to staffing levels were based on the number of registered RTs and registry eligible RTs providing direct clinical care within these facilities and units. ‘Registry eligible’ was defined as graduates of an accredited respiratory therapy education program who have not yet attained licensure by the CSRT, or one of the member organizations of the National Alliance of Respiratory Therapy Regulatory Bodies (16). Data were collected based on the number of patients receiving both invasive and noninvasive mechanical ventilation. Student RTs and staff who do not provide direct patient care (e.g., managers) and any ICU not exclusively serving adult patients were excluded from data collection. With respect to questions pertaining to the scope of practice of the RTs, the survey questions were grounded in several key critical care competencies that form part of the National Competency Profile for Canadian RTs (16). No patient-specific information was collected.

**Data collection and analysis**

The survey was administered using an online survey platform (Survey Monkey, USA). Data collection occurred at regular monthly intervals over a period of three months (February, March and April, 2015), for a total of three completed surveys representing each ICU included in the study. The data collection periods were specified by the researchers and, thus, the collected survey data represented the same 24 h period for each ICU. This survey approach enabled better comparison...
of Vent:RT ratios, and provided some limited control for seasonal variability in staffing and patient census that may have had impact on the study findings.

The data were initially analyzed using basic descriptive statistical methods, including key measures of central tendency and measures of dispersion, and graphical analysis of the data to determine its suitability for parametric analyses. The Vent:RT ratio was determined based on the mean number of RTs providing care in each hour compared with the mean number of mechanically ventilated patients in each critical care unit. Such an approach has been used in previous studies to provide nurse-to-patient staffing ratios calculated over a 24 h period using the total number of nurses throughout all shifts in the day, divided by the patient census (17). Data collected in this manner, representing a 24 h period, allows for a common denominator helping to account for the impact of potential variations in staffing patterns that may occur.

Repeated measures ANOVA procedures were performed to examine for variation between the Vent:RT ratio identified at each of the three sampling intervals. The analysis then sought to identify factors that may influence the Vent:RT ratio. Correlation analyses between the professional practice characteristics of the RTs and the mean Vent:RT, and between ICU characteristics and the mean Vent:RT were performed using Pearson’s r. The existence of correlations supported further explorations of these relationships using the paired samples t test. Differences were considered to be statistically significant at P<0.05. All statistical analysis were performed using SPSS version 18.0 (IBM Corporation, USA).

**RESULTS**

The response rate to the survey recruitment initiatives was very good, with 16 of 17 (94%) academic health science centres associated with medical schools participating. A total of 38 teaching hospital ICUs were included in the study, representing the 17 academic health science centres. Individual response rates were higher for the first survey (n=37 [97%]) and dropped somewhat in the second (n=33 [87%]) and third (n=20 [53%]) surveys. The waning response rate over the three survey intervals likely reflected surveyor fatigue. All attempted surveys were fully completed and, thus, none were discarded for incomplete information.

Descriptive analysis of the professional practice characteristics of the RTs working the surveyed ICUs and the characteristics of the ICUs were performed (Table 1). Further exploration of each variable through graphical analysis allowed visual confirmation that the data were normally distributed and, thus, that further parametric analysis was appropriate.

The data were then analyzed to calculate the Vent:RT ratio from data collected at each of the three survey intervals (Table 2). A mean (± SD) Vent:RT of 5.1:1±2.818 was identified from data collected in the first survey, 4.78±1.310 from the second survey, and 5.1:1±2.931 from the third survey. Repeated measures ANOVA procedures were used to examine whether variation between key findings in each of the three surveys existed (Table 3). Analysis using ANOVA necessarily included only intensive care units where data were collected at all three survey intervals. Vent:RT Mechanical ventilator to respiratory therapist (RT) ratio

<table>
<thead>
<tr>
<th>TABLE 1 Baseline sample characteristics (n=38)</th>
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<tbody>
<tr>
<td>Professional practice characteristic of RT</td>
</tr>
<tr>
<td>Performs endotracheal intubation 17 (44.7)</td>
</tr>
<tr>
<td>Insertion of arterial lines 13 (34.2)</td>
</tr>
<tr>
<td>Intrafacility patient transport 35 (92.1)</td>
</tr>
<tr>
<td>Working in multiple intensive care units 13 (34.2)</td>
</tr>
<tr>
<td>Working on general wards 15 (39.5)</td>
</tr>
<tr>
<td>Working in emergency room 10 (26.3)</td>
</tr>
<tr>
<td>Primarily responsible for ABG procurement 12 (31.6)</td>
</tr>
<tr>
<td>Primarily responsible for ABG analysis 25 (65.8)</td>
</tr>
<tr>
<td>Ventilator weaning per protocol 34 (89.5)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of critical care unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical intensive care unit 24 (63.2)</td>
</tr>
<tr>
<td>Surgical intensive care unit 26 (68.4)</td>
</tr>
<tr>
<td>Cardiovascular intensive care unit 14 (36.8)</td>
</tr>
<tr>
<td>Neurological intensive care unit 13 (34.2)</td>
</tr>
<tr>
<td>Coronary care unit 10 (26.3)</td>
</tr>
<tr>
<td>Other intensive care unit type 6 (15.8)</td>
</tr>
<tr>
<td>Intensive care unit beds, mean ± SD 18.21±10.567</td>
</tr>
</tbody>
</table>

Data presented as n (%) of those who responded yes to survey 1, unless otherwise indicated. ABG arterial blood gas; RT Respiratory therapist.

<table>
<thead>
<tr>
<th>TABLE 2 Mechanical ventilator to respiratory therapist (RT) ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1 (n=37) 2 (n=33) 3 (n=20)</td>
</tr>
<tr>
<td>Ventilator to RT ratio 4.78±1.310</td>
</tr>
<tr>
<td>Ventilators per hour 8.79±6.528</td>
</tr>
<tr>
<td>Total number of RT hours worked 49.13±33.45</td>
</tr>
<tr>
<td>RTs on 8 h shift 2.28</td>
</tr>
<tr>
<td>RTs on 10 h shift 0.14</td>
</tr>
<tr>
<td>RTs on 12 h shift 4.50</td>
</tr>
<tr>
<td>RTs on other shift 0.21</td>
</tr>
<tr>
<td>ICU beds* 18.21±10.567</td>
</tr>
</tbody>
</table>

Data presented as mean ± SD or mean number of those who responded yes to survey 1. *Collected as baseline data in survey 1 only. ICU intensive care unit.

<table>
<thead>
<tr>
<th>TABLE 3 Repeated measures ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>Vent:RT</td>
</tr>
<tr>
<td>(n=18)*</td>
</tr>
<tr>
<td>Ventilation, h</td>
</tr>
<tr>
<td>(n=23)*</td>
</tr>
</tbody>
</table>

Data presented as mean ± SD unless otherwise indicated. *Analysis necessarily included only intensive care units where data were collected at all three survey intervals. Vent:RT Mechanical ventilator to respiratory therapist (RT) ratio.
it was not. Several of these variables demonstrated significant mean differences when compared across multiple survey intervals (Table 5). For example, the insertion of arterial lines demonstrated significant between-group differences in the Vent:RT ratio in both survey 2 and 3.

**DISCUSSION**

The Vent:RT ratio

Data were collected at three separate intervals and each measure of the Vent:RT ratio was made using the same sample set. Because no significant differences between the findings of each of the three interval points were identified ($F[1,7,30]=0.695$; $P=0.492$), each measure was, therefore, considered to be representative of the relationship of the Vent:RT ratio. Data from the first survey were, however, characterized by the largest response rate (n=38) (compared with n=33 in survey 2 and n=20 in survey 3) as well as the lowest SD (2.818 compared with 3.108 in survey 2, and 2.931 in survey 3) from among the survey intervals. It was, therefore, determined that from among the three survey intervals that the data collected in the first survey provided the best representation of the Vent:RT ratio. The present study identified that the mean Vent:RT ratio among the ICUs of Canadian teaching hospitals is estimated to be 5:1:1.

The approach to collecting data over separate intervals was intended to account for some degree of seasonal variability and may have, therefore, helped mitigate the impact of phenomenon that could have periodically influenced RT staffing levels in ICUs. It has been well documented that seasonal health patterns, such as influenza, can lead to illness burden, which necessitate critical care intervention including intensive respiratory therapy (18). Shilling et al (19) demonstrated that a variety of factors, such as seasonal influenza, hospital occupancy, weekend admission and nurse staffing levels, each are independently associated with in-hospital mortality. Recognizing these associations, it may, therefore, be important for hospital administrators to consider factors such as seasonally related burden of illness and patient flow when applying these findings.

**Factors that impact the practice patterns of RTs**

A variety of the professional practice-related variables included in the analysis were associated with the Vent:RT ratio. Of the variables analyzed, each can be broadly categorized as either relating to the ICU setting or to the professional scope of practice of the RTs practicing in the ICU environment.

With respect to the ICU setting, it was determined that neurological ICU settings were associated with lower Vent:RT ratios, while coronary care units were associated with an increased ratio. The Vent:RT ratio was not significantly associated with other identified ICU specialty types (medical, surgical, cardiovascular). These findings suggest what many experienced practitioners anecdotally report: that the practice patterns of respiratory therapists are somewhat consistent across ICU settings. However, the strength of the associations between the ratio and a neurological ICU or coronary care unit setting may relate to mechanically ventilated patients tending to exhibit respiratory therapy needs existing at either end of a spectrum of complexity (eg, variations in need for critical intrafacility transportation or for advanced modes of mechanical ventilator).

Additional staffing factors believed to likely contribute to increased workload for RTs were found to be significantly associated with the number of hours worked by RTs. These included ICUs in which RTs worked in other ICUs at the same time, or where RTs were working in an emergency room at the same time. These findings suggest a negative impact on the number of RT working hours in ICUs reporting that RTs also work in other critical care units. In such cases, working in additional critical care units showed a trend toward increased Vent:RT ratios, although these did not reach significant levels. Not surprisingly, the number of ICU beds was also determined to directly correlate with the number of RTs working in the ICUs.

Acuity of care has been a factor that, alongside nurse staffing levels, has been identified in the nursing literature as associated with patient outcomes (20). While the present study did not directly seek correlations between acuity of care and RT staffing levels, the variation between practice settings (as determined by ICU type) suggests that acuity of patient care may be a confounding variable. Based on this understanding, the utilization of RT staffing benchmarks that incorporate measures of patient acuity are suggested.

Several factors relating to the professional scope of practice of Canadian RTs that were anticipated to potentially impact their staffing patterns were also included in the analysis. Of those factors, a variety were found to be significantly associated with either the Vent:RT ratio or to the number of hours worked by RTs in the ICUs surveyed. These factors included RTs who performed intubation, inserted arterial lines, procured or analyzed arterial blood gases or managed ventilators according to a weaning protocol. It was not surprising to the research team that these critical procedural skills were...
TABLE 5  
\textbf{t test for equality of means}

<table>
<thead>
<tr>
<th>RT practices and ICU characteristics</th>
<th>Survey 1 (n=37)</th>
<th>Survey 2 (n=33)</th>
<th>Survey 3 (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RT worked hours</td>
<td>Vent:RT</td>
<td>RT worked hours</td>
</tr>
<tr>
<td>Performs ETT intubation</td>
<td>44.0±38.15</td>
<td>4.4±2.73</td>
<td>42.4±32.73</td>
</tr>
<tr>
<td>Insertion of arterial lines</td>
<td>64.1±39.75</td>
<td>5.69±2.85</td>
<td>48.6±44.70</td>
</tr>
<tr>
<td>Working in multiple ICUs</td>
<td>41.6±35.35</td>
<td>5.05±3.36</td>
<td>51.0±43.97</td>
</tr>
<tr>
<td>Working in emergency room</td>
<td>74.6±39.53</td>
<td>4.9±1.49</td>
<td>32.8±31.75</td>
</tr>
<tr>
<td>Responsible for ABG procurement</td>
<td>52.5±43.44</td>
<td>5.1±2.61</td>
<td>32.2±33.43</td>
</tr>
<tr>
<td>Responsible for ABG analysis</td>
<td>54.6±33.18</td>
<td>4.7±3.27</td>
<td>72.0±33.16</td>
</tr>
<tr>
<td>Neurological ICU</td>
<td>51.19±40.90</td>
<td>4.95±2.66</td>
<td>35.2±33.25</td>
</tr>
<tr>
<td>Coronary care unit</td>
<td>58.8±37.62</td>
<td>5.1±3.37</td>
<td>75.7±36.6*</td>
</tr>
<tr>
<td></td>
<td>41.6±30.85</td>
<td>5.0±3.23</td>
<td>41.1±35.02</td>
</tr>
<tr>
<td></td>
<td>77.3±36.2*</td>
<td>4.9±1.79</td>
<td>54.5±44.37</td>
</tr>
<tr>
<td></td>
<td>40.6±29.61</td>
<td>5.2±3.93</td>
<td>54.4±39.68</td>
</tr>
<tr>
<td></td>
<td>60.0±34.20</td>
<td>4.8±2.09</td>
<td>40.0±36.77</td>
</tr>
<tr>
<td></td>
<td>44.8±32.93</td>
<td>4.8±3.39</td>
<td>44.4±34.73</td>
</tr>
<tr>
<td></td>
<td>68.7±37.33</td>
<td>5.3±1.28</td>
<td>46.5±45.49</td>
</tr>
<tr>
<td></td>
<td>56.5±23.48</td>
<td>5.7±2.80</td>
<td>44.5±38.63</td>
</tr>
<tr>
<td></td>
<td>44.4±26.71</td>
<td>3.1±1.88*</td>
<td>46.8±37.78</td>
</tr>
</tbody>
</table>

\textit{t test for equality of means for all variables found to have statistically significant correlations (bolded values) with ventilator to respiratory therapist (RT) ratio (Vent:RT); or measures of RT worked hours (mean ± SD of those who responded ‘yes’; mean ± SD of those who responded ‘no’). Ventilator weaning per protocol not included in analysis due to insufficient sample size for testing. 'Indicates significant difference (P<0.05 [two-tailed]).' ABG arterial blood gas; ETT Endotracheal tube; ICU intensive care unit

related to RT staffing given the impact each would have on the time demands of practicing RTs.

Part of the rationale for focusing the present study design on one hospital type (ie, teaching hospitals) was due to presumed practice differences between teaching hospitals and nonteaching hospitals. Based on the experiences of the research team in both teaching and nonteaching hospital contexts, it was expected that differences in the proportion of RTs performing many critical skills would exist between these settings. This was hypothesized to relate to an increased access to a broader range of advanced practitioners at teaching hospitals (eg, senior residents or nurse practitioners), and the need for trainees of those professions to access skill development opportunities; thus, potentially limiting RT involvement in some practices. While recognizing this, the proportion of teaching hospital ICUs where RTs routinely engaged in the critical care skills surveyed were lower than anticipated. For example, RTs routinely perform intubation at 45% of the ICUs surveyed, routinely insert arterial lines at 34% and routinely procure arterial blood gases at 32%.

The low proportion of ICUs where critical competencies were performed may, in part, be an indication that the survey used did not capture the full breadth of relevant ICU RT practice-related factors. For example, RT participation in bronchoscopy procedures was not surveyed, although may be more commonplace in teaching hospital contexts. For example, RTs working over a 24 h period. It is worth noting, therefore, that any wide variations in staffing (eg, an ICU that had four RTs working during the day and two RTs working at night) would not have been evident through this analysis. Therefore, when interpreting the results of the present study, the possibility that fluctuations in the ratio may be expected at different points over a 24 h period should be noted.

Exercise caution when generalizing the findings presented in the NCP to particular practice environments. Based on these findings, deeper exploration in the teaching hospital context is encouraged, and comparative inquiry into the range of practices in nonteaching hospital settings is warranted, including any potential variations that may be impacted by other factors such as rurality. Our understanding of these potentially confounding factors will be important for informing future outcomes-oriented research.

\textbf{Limitations}

Because of the preliminary nature of the present study, it was not feasible to examine the contribution of these patterns to patient outcomes. While we recognize the central importance of outcomes health research, the present observational study was believed to be a necessary step in establishing data that will, in turn, support outcome-oriented research. This approach was believed useful in providing valuable data that will serve as a method of benchmarking among comparable organizations.

The sampling framework of the present study has implications for its generalizability to Canadian ICUs. Limiting participant ICUs to those in teaching hospitals associated with medical schools provided a researchable contextual frame, which is commonly used for controlled inquiry within the health care system. Doing so, however, also potentially limited the applicability of these findings because differences in staffing and patient characteristics among smaller community hospitals or nonteaching hospitals in major cities are likely to differ from those encountered in the academic teaching hospitals. Moreover, the sampling framework impacts the ability of these findings to be directly generalized to practice contexts, such as critical care units in small and rural communities, in specialized institutions such as children's hospitals, or for specialty areas not included such as pediatric and neonatal ICUs outside of children's hospitals.

The method used for determining the Vent:RT ratio from the collected data was chosen because it was an achievable and robust approach to examining the practice pattern. The mean Vent:RT ratio was determined based on the mean calculation of the hourly RT hours worked in each ICU, which was derived from the total RT hours worked over a 24 h period. It is worth noting, therefore, that any wide variations in staffing (eg, an ICU that had four RTs working during the day and two RTs working at night) would not have been evident through this analysis. Therefore, when interpreting the results of the present study, the possibility that fluctuations in the ratio may be expected at different points over a 24 h period should be noted.
CONCLUSION
The findings of the present study provide what we believe to be the first reported assessment of RT staffing patterns in Canadian teaching hospital ICUs. Our assessment determined a typical ratio of 5.1 mechanical ventilators to each RT (ie, Vent:RT= 5.1) working in the ICUs of Canadian teaching hospitals. A variety of factors related to both the typical practices of the RTS and the care specialization of the ICU were associated with changes in the Vent:RT ratio. Specifically, decreases in the ratio were associated with ICUs where RTS intubated, procured arterial blood gases, inserted arterial lines and in neurological ICUs. Conversely, coronary care units were associated with an increased Vent:RT ratio.

These results will serve as a platform for identifying potential staffing norms in Canadian ICUs and will inform future research describing the impact of RT staffing and practice patterns on patient outcomes. We believe this is an area of emerging research importance in an evermore outcomes-oriented health care system, and further research is needed to understand the impact and implications of varying Vent:RT ratios on important patient and health systems outcomes. For example, similar to investigations in other disciplines, the impact of variable RT staffing ratios on the length of stay and mortality of mechanical ventilated patients would be useful. Access to the findings of patient outcomes-oriented research in respiratory therapy will be particularly important for health care planners and policy makers.

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DISCLOSURES: The authors have no financial disclosures or conflicts of interest to declare.

REFERENCES
Impact of interprofessional education on noninvasive ventilation in a tertiary neonatal intensive care unit

Debra Paterson RRT, Sandesh Shivananda MD, Salhab El Helou MD, Christoph Fusch MD, Amit Mukerji MD

OBJECTIVE: To evaluate the impact and effectiveness of an experiential interprofessional education workshop on noninvasive ventilation (NIV) in the setting of a neonatal intensive care unit.

METHODS: In the present cross-sectional study, a full-day workshop, consisting of didactic and hands-on components, was developed to assess knowledge and perceptions, and to disseminate the latest evidence and practical aspects of NIV use. All health care professionals (HCPs) were asked to participate. Pre- and post-participation questionnaires and knowledge tests were used to assess the effectiveness of knowledge transfer, and to seek participants’ reflections on the utility of the workshop.

RESULTS: Among 214 participants, 206 (96%) and 195 (91%) completed the pre- and post-participation questionnaires, respectively. The majority agreed (14%) or strongly agreed (75%) that NIV education was important for their role. Participants scored their perceived comfort with NIV following the workshop highly (median 5 [interquartile range (IQR) 1]) on a five-point Likert scale and 96% would recommend it to a colleague. Median knowledge scores on NIV, assessed as percent correct responses, increased from 74% (IQR 16) to 86% (IQR 11) (P<0.05).

CONCLUSIONS: A focused, context-specific workshop helped improve understanding and comfort among HCPs while reducing misconceptions about NIV. Further research to assess optimal delivery of NIV education and impact on patient outcomes is required.

Key words: Health care professional; Interprofessional care; Hands-on workshop

Use of noninvasive ventilation (NIV) has increased in neonatal intensive care units (NICUs) in an effort to reduce ventilation-induced lung injury (1-3). With the advent of new technology, various modes of NIV, such as biphasic continuous positive airway pressure (CPAP), nasal intermittent positive pressure ventilation, noninvasive high-frequency ventilation and high-flow nasal cannula, are now available, along with the traditional mode of nasal CPAP (4). In addition, a variety of different interfaces are also available, resulting in numerous permutations of NIV-interface combinations that a patient can receive at any given time (5-8).

This increased availability of various NIV modes and interfaces necessitates proper education about the mechanics, advantages, indications and limitations of each, based on available evidence. In addition to physicians, there is also the need to educate front-line health care professionals (HCPs) about NIV. In the NICU, registered nurses and/or respiratory therapists play a vital role in the implementation and trouble-shooting of NIV and, as such, their education on the topic is imperative. In addition, in a busy environment such as the NICU, despite provision of health care as a multidisciplinary team, the detailed roles and responsibilities of any one HCP discipline may not be apparent to others. Interprofessional education (IPE) has been shown to improve collegiality and communication among various team members, as well as lead to improved patient outcomes in various other fields (9-11). In fact, the WHO and Institute of Medicine have both endorsed IPE as a key initiative toward improving patient outcomes (12,13). Recognizing this importance of IPE on the relatively new intervention, a hands-on educational workshop for all HCP disciplines was organized at our centre based on the principles of IPE – to learn with, from and one another (14). The objective of the present study was to assess the impact of this workshop in improving caregivers’ knowledge and comfort with NIV.

METHODS

In the present cross-sectional study performed at a tertiary level neonatal intensive care unit in Canada, all HCPs (including registered respiratory therapists, registered nurses, advanced care nurse practitioners and their respective trainees) were invited to participate in an NIV-focused full-day IPE workshop. The workshop was organized at our centre based on the principles of IPE – to learn with, from and one another (14). The objective of the present study was to assess the impact of this workshop in improving caregivers’ knowledge and comfort with NIV.

OBJECTIF : Évaluer les effets et l’efficacité d’un atelier expérimental de formation interprofessionnelle sur la ventilation non invasive (VNI) dans une unité de soins intensifs néonatals.

MÉTHODOLOGIE : Dans la présente étude transversale, les chercheurs ont créé un atelier d’une journée comportant des volets magistraux et pratiques pour évaluer les connaissances et les perceptions et pour faire connaître les données probantes les plus récentes et les aspects pratiques de la VNI. Ils ont invité tous les professionnels de la santé (PfS) à y participer. Ils ont utilisé des questionnaires avant et après la participation et des tests de connaissances pour évaluer l’efficacité de l’application du savoir et pour obtenir les réflexions des participants sur l’utilité de l’atelier.

RÉSULTATS : Parmi les 214 participants, 206 (96 %) et 195 (91 %) ont rempli le questionnaire avant et après la participation, respectivement. La majorité étaient d’accord (14 %) ou tout à fait d’accord (75 %) pour affirmer que la formation sur la VNI était importante dans leur rôle. Les participants avaient une perception élevée de leur aisance à l’égard de la VNI après la formation (médiane 5 [écart interquartile (PIQ) 1]) sur une échelle de Likert de cinq points, et 96 % l’auraient recommandée à un collègue. Les indices de connaissances médians sur la VNI, évalués selon le pourcentage de bonnes réponses, sont passés de 74 % (PIQ 16) à 86 % (PIQ 11) (P<0,05).

CONCLUSIONS : Un atelier ciblé et adapté au milieu a contribué à accroître la compréhension et l’aisance des PfS tout en réduisant les idées fausses quant à la VNI. D’autres recherches s’imposent pour évaluer la prestation optimale de la formation sur la VNI et les effets sur les résultats cliniques des patients.
Table 1: Participant feedback regarding pre- and post-participation surveys

<table>
<thead>
<tr>
<th>HCP category (n1, n2)*</th>
<th>NIV education</th>
<th>Desire to learn more about NIV</th>
<th>Increased comfort with NIV</th>
<th>Recommend to peers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute care nurse practitioners (6, 6)</td>
<td>5 (0)</td>
<td>5 (0)</td>
<td>4.5 (1)</td>
<td>5 (0.75)</td>
</tr>
<tr>
<td>Respiratory therapists (17, 16)</td>
<td>5 (1)</td>
<td>5 (1)</td>
<td>5 (0)</td>
<td>5 (0)</td>
</tr>
<tr>
<td>Registered nurses (139, 134)</td>
<td>5 (0)</td>
<td>5 (1)</td>
<td>5 (1)</td>
<td>5 (1)</td>
</tr>
<tr>
<td>Other HCPs (20, 20)</td>
<td>5 (1)</td>
<td>5 (0.5)</td>
<td>4 (1)</td>
<td>4 (1)</td>
</tr>
<tr>
<td>HCP trainees (24, 19)</td>
<td>5 (1)</td>
<td>5 (0)</td>
<td>4 (1)</td>
<td>5 (1)</td>
</tr>
<tr>
<td>Overall (206, 195)</td>
<td>5 (0)</td>
<td>5 (0)</td>
<td>5 (1)</td>
<td>5 (1)</td>
</tr>
</tbody>
</table>

Data presented as median (interquartile range). *n1 = Number of pre-participation respondents, n2 = number of post-participation respondents. HCP health care provider; NIV noninvasive ventilation

Table 2: Comparison of knowledge and pre- and post-participation surveys

<table>
<thead>
<tr>
<th>HCP category*</th>
<th>Pre (n)</th>
<th>Post (n)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute care nurse practitioners (n=6)</td>
<td>82 (9)</td>
<td>89 (0)</td>
<td>NS</td>
</tr>
<tr>
<td>Respiratory therapists (n=16)</td>
<td>79 (17)</td>
<td>89 (11)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Registered nurses (n=134)</td>
<td>68 (15)</td>
<td>84 (10)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Other HCPs (n=20)</td>
<td>71 (28)</td>
<td>89 (12)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>HCP trainees (n=19)</td>
<td>74 (10)</td>
<td>89 (8)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Overall (n=195)</td>
<td>74 (16)</td>
<td>84 (11)</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

All results expressed as median % (IQR) unless otherwise indicated. *Participants who completed both pre- and post-participation knowledge questionnaires. HCP Health care provider; NS Not significant

A multidisciplinary group of HCPs developed a workshop consisting of didactic sessions, hands-on simulations, and a reflection component. The workshop covered the importance of understanding principles of NIV and the strengths and weaknesses of each modality. The workshop was conducted for three months to enable all HCPs the opportunity to attend as well as limit the number of participants in each workshop to 20 to facilitate opportunity for interdisciplinary discussions and collaborative learning in small groups.

Based on principles of the Kirkpatrick educational framework, this experiential workshop consisted of a didactic component led by the respiratory therapist educator that covered basic pulmonary development and physiology, the rationale for increased NIV use, and the strengths and weaknesses of each modality, as well as a review of available evidence. Furthermore, the role of registered respiratory therapists in providing and maintaining adequate NIV was covered. This included the indications to call the patient's bedside, imparting knowledge on basic trouble-shooting that they do to ensure proper functioning of the equipment and interface, and their thought process leading to decision making regarding escalation and/or weaning from a particular mode of NIV, with a view to increase awareness of the roles of registered respiratory therapists to other HCP disciplines.

In addition to the didactic component, there was a hands-on simulation that included the opportunity to practice placing interfaces correctly on a newborn mannequin, discuss strategies to maintain the desired set NIV pressure and basic trouble-shooting. The hands on session with the interfaces were based on IPE principles whereby HCPs of varying backgrounds (as listed in Tables 1 and 2) had the opportunity to discuss their respective roles and expertise while learning from each other. These sessions allowed time for spontaneous discussions among representatives from varying HCP disciplines in small groups, moderated by the lead respiratory therapist educator (DP) as needed, that were designed to allow for increased awareness and mutual understanding of one another's roles and responsibilities.

A pre- and post-participation questionnaire was given to all participants (Supplementary Files 1 and 2) on the day of the workshop. The pre-participation questionnaire consisted of a knowledge assessment component (consisting of 20 questions and scored as a percentage of correct responses) on basic respiratory physiology and non-invasive ventilation. The second component consisted of participants' opinion, on a modified Likert scale of 1 (strongly disagree) to 5 (strongly agree), regarding importance of understanding principles of NIV and desire to learn more about it. In addition, we inquired about barriers to adequate knowledge and understanding on NIV in free form.

A post-participation survey consisted of the same knowledge assessment questions to assess effectiveness of the workshop on knowledge acquisition, as well as a reflection component (assessed on the same Likert scale) regarding post-participation comfort with NIV, and whether they would recommend this workshop to a colleague. Suggestions to improve practice of NIV at the bedside were also ascertained in free form. All ordinal Likert scale results and quantitative knowledge scores were reported as median (interquartile range). Pre- and post-participation knowledge scores were reported only for participants who completed both and compared using Wilcoxon signed-rank test; P<0.05 was considered to be statistically significant.

The present project was approved by the Hamilton Integrated Research Ethics Board (Hamilton, Ontario), and all data (completed survey questionnaires) were stored in a locked cabinet in the office of one of the authors (AM).

Results

The 214 participants (of 250 eligible HCPs) of the workshop consisted of a variety of HCPs including registered nurses (139 of 180 eligible [77% participation rate]), acute care nurse practitioners (six of 11 eligible [55% participation rate]), respiratory therapists (17 of 22 eligible [77% participation rate]) and HCP trainees. Among the participants, 206 (96%) completed the pre-participation, among whom 195 (91%) also completed the post-participation surveys.

Before participating in the workshop, 88% (n=182) of respondents agreed or strongly agreed that NIV education was important to their profession. Similarly, 93% (n=191) of respondents agreed or strongly agreed that they would like to learn more about NIV, while 2% (n=4) did not answer the question. Details of these results from the Likert scale, subcategorized according to profession, are as shown in Table 1. When asked regarding the best form of education to learn more about NIV, 86% (n=178) favored a combination of didactic and hands-on-learning. Lack of educational materials/sessions, lack of in-servicing and lack of recognition of roles and responsibilities were identified as the top three barriers to adequate knowledge and understanding of NIV.

In the post-participation survey, 90% (n=175) of respondents agreed or strongly agreed that they felt more comfortable in caring for a patient on NIV after participation in the workshop, with 1% (n=2) not responding. Similarly, 96% (n=188) said they would recommend the workshop to a colleague. Details of responses in modified Likert scale are as shown in Table 1. A comparison of pre- and post-participation knowledge assessments showed improvement in knowledge across all professions, as shown in Table 2. Suggestions to improve NIV...
practice were categorized into the following three themes: enhanced team collaboration; education; and minimize excessive patient load. Other comments from the participants are listed in Table 3.

**DISCUSSION**

In the present study, we found that participation in an interprofessional experiential workshop focused on NIV was useful in increasing HCPs’ comfort with the use of this modality as well as increasing their knowledge significantly. It also filled an important knowledge-gap as identified by HCPs themselves, and the vast majority of participants indicated they would recommend such a workshop to their peers. Finally, although not measured as a tangible outcome, this workshop allowed for various HCPs to gain a deeper appreciation of the roles and responsibilities of their colleagues from other disciplines, albeit with a heavy focus on the role of registered respiratory therapists. To our knowledge, the present study was the first to investigate the effectiveness of an IPE-based hands-on workshop on NIV in an NICU.

Interprofessional care models have become increasingly common in various medical fields due to the complexity of patients seen, many of whom require the skills and knowledge of professionals with a wide range of expertise (9,11,16). Such an interprofessional care model is particularly relevant in the intensive care unit setting where some of the most complex and chronic patients with multisystem issues are cared for (17). An effective interprofessional care model requires knowledge, collegiality, mutual respect, open communication and understanding of the roles of all team members, and IPE is an important tool to this end (10,18). However, recent reviews have suggested the need for more research in the field of IPE (19,20) and the current study adds to this growing body of literature in a unique patient care setting.

While there have been no studies investigating the efficacy of ventilation education specifically in the NICU, there are studies evaluating multiprofessional education in adult intensive care units. Guilhermino et al (21) conducted a qualitative survey of 160 nurses in an Australian intensive care unit and found that interactive, practical teaching was perceived to improve transfer of knowledge of ventilation to the everyday work environment. In a separate study, the same group of authors also noted that 63% of respondents reported in a structured survey not having received education about mechanical ventilation before working in intensive care. When asked regarding formats of education, hands-on-practice was perceived to be most effective (22). These results are consistent with our findings whereby the vast majority of participants indicated a desire to learn more about NIV. In addition, a practical and hands-on interactive workshop was the preferred education format according to the majority of our respondents. Results from our study lend support to the efficacy of hands-on workshops in the neonatal setting.

There is a large and continually evolving body of literature on theoretical frameworks of IPE. Recently, the WHO published the “Framework for Action on Interprofessional Education and Collaborative Practice”, in which IPE was deemed to be most effective when principles of adult learning are used, learning methods reflect real world practice and interaction occurs between students (14). Graczyński et al (11) recently introduced the 'Integrated Model for Interprofessional Education', combining concepts of holism, participation and practical education. However, no single IPE model is considered the ‘gold standard’ and profession-specific IPE models need further development and evaluation (19). In addition, the evaluative component of IPE varies widely as reported in a review by Remington et al (9); however, most studies have used a pre- and post-test comparative model that we used in our study. Controlled evaluations using a comparison group may be challenging because the comparison group would need to have similar experience and training for the same duration as participants in IPE.

One of the main strengths of the present study was the large number of participants, and the high rate of participation in the workshop among eligible HCPs. This high rate of participation in the workshop limits selection bias whereby only those HCPs interested in the topic (or those with knowledge of the field) may have participated. In addition, there was a high rate of survey completion among the workshop participants. Finally, the knowledge transfer as a result of the workshop was assessed by participants’ self-reflection in their comfort with the topic, as well as an objective knowledge-based set of questions, which limits measurement bias. However, a number of limitations also warrant acknowledgement. First, this IPE workshop was a one-time intervention and, as such, long-term knowledge retention cannot be evaluated. From the published literature, it remains unclear whether a single IPE session can lead to long-term knowledge retention (9). Second, no patient-centred outcomes were assessed. Objective measures of improvement in patient care were difficult to ascertain in relation to a single intervention, particularly in a setting as complex as the NICU. Audits of practice patterns and assessment of consistency could have been one measure of outcomes, but was outside the scope of the present intervention. Finally, there were no attending physicians who participated and, hence, the interprofessional composition of the NICU was not fully represented.

The success of this single IPE educational workshop on NIV needs to be followed by the development of an ongoing curriculum of educational program that may enhance knowledge retention and sustainability, while ensuring consistency of practice. Such a program needs to be founded on evidence-based theoretical frameworks that have been proven in other fields (11,19) as well as evidence-based evaluation tools as recently proposed by Reeves et al (23). The development of such a curriculum could not only be part of ongoing IPE for HCPs already working in the NICU, but incorporated into the training of prospective HCPs. Furthermore, the educational framework need not only include NIV, but could incorporate other aspects of neonatal care such as sedation/analgesia, weaning of invasive mechanical ventilation and nutritional guidelines, just to name a few. Finally, further research is required to determine the effectiveness of such educational programs on interprofessional collaboration and, ultimately, their effect on efficiency and quality of care as well as patient outcomes in the NICU.

**TABLE 3**

<table>
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<tr>
<th>Participant comments</th>
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<td>What they liked</td>
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<tr>
<td>Suggestions to improve the session</td>
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<td>Suggestions to improve NIV practice</td>
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CPAP Continuous positive airway pressure; NIV Noninvasive ventilation
The focused IPE workshop on NIV described in the present study showed improvement in HCPs knowledge and increased their self-perceived comfort. An evidence-based curriculum on IPE – on NIV and other aspects of neonatal care – may be required as a next step to ensure sustainability and enhance quality of care in an interprofessional care model. Further work is also required in the NICU setting to assess the effectiveness of IPE on HCP collaboration, communication and, ultimately, patient outcomes.

DISCLOSURES: The authors have no financial disclosures or conflicts of interest to declare.

REFERENCES
Home mechanical ventilation: A retrospective review of safety incidents using the World Health Organization International Patient Safety Event classification

Lily Yang MapSc³, Mika Nonoyama RRT PhD², Regina Pizzuti RRT¹, Philip Bwitiiti BSc FIBMS DMLM PhD⁴, George John MPharm Prac¹

BACKGROUND: There is a paucity of patient safety information from the community sector related to the medically fragile population requiring home mechanical ventilation (HMV). To improve safety, the risks HMV patients encounter must first be understood.

OBJECTIVES: To describe patient safety incidents within the HMV population and discuss opportunities for preventing harm.

METHODS: A retrospective observational review of on-call logs from the Ontario Ventilator Equipment Pool (VEP) was conducted. Classification of 248 on-call logs from April 1, 2011 to March 21, 2012 was completed using the standardized tool of the World Health Organization’s (WHO) Patient Safety Taxonomy – International Classification System to quantitatively describe the types of incidents arising. Analysis of data classification was completed using descriptive and nonparametric statistics.

RESULTS: Patient incidents were positive in 188 on-call logs; emerging from these were 227 incident types. Patient incident types included medical device issues (99 device failures, 41 user errors, 12 equipment availability), documentation (20 unavailable labels/prescriptions, four unclear information), clinical processes (16 inadequate treatment or general care) and clinical administration (10 inadequate handover or transfer of care). Patient incidents were associated with mild harm in 87 cases.

CONCLUSIONS: The on-call logs were a good source of quality improvement data to understand harm and patient safety issues emerging in the HMV population. However, establishing a formal incident review and reporting system is required to provide a more comprehensive understanding.

Key Words: Chronic ventilation; Patient safety; Quality improvement; Respiratory incident

Mecanical ventilation may be defined as a life-support system designed to replace or support normal ventilatory lung function (1). The typical individual requiring home mechanical ventilation (HMV) includes those with amyotrophic lateral sclerosis (ALS), central hypoventilation syndrome, chronic obstructive pulmonary disease, kyphoscoliosis, obesity hypoventilation syndrome, spinal cord injury (SCI), Duchenne muscular dystrophy, myopathies and myotonic dystrophy (2). Technology has evolved significantly and, currently, HMV (HMV) includes those with amyotrophic lateral sclerosis (ALS), cervical spinal cord injury (SCI), Duchenne muscular dystrophy, myopathies and myotonic dystrophy (2). Technology has evolved significantly and, currently, HMV is a staple of care for these patients.

The availability of HMV has enabled greater patient freedom and improved quality of life (3). Strategic efforts have come into place in Ontario to support the transition of patients out of the intensive care unit (ICU) into the community while on home mechanical ventilators (4). This, in part, is economically driven (5).

La ventilation mécanique à domicile : une analyse rétrospective des incidents de sécurité au moyen de la Classification internationale pour la sécurité des patients de l'Organisation mondiale de la Santé

HISTORIQUE : Peu d’information sur la sécurité des patients provenant du secteur communautaire porte sur la population fragilisée sous ventilation mécanique à domicile (VMD). Pour améliorer la sécurité, il faut d’abord comprendre les risques que courent ces patients.

OBJECTIFS : Décrire les incidents de sécurité des patients au sein de la population sous VMD et examiner des possibilités de prévenir les dommages.


RÉSULTATS : Les incidents des patients étaient positifs dans 188 des registres d’appel, et 227 types d’incidents en ont émergé. Les types d’incidents des patients incluaient des problèmes avec les dispositifs médicaux (99 défauts de dispositifs, 41 erreurs des utilisateurs, 12 problèmes de disponibilité de l’équipement), la consignation (20 étiquettes ou prescriptions non disponibles, quatre renseignements nébuleux), les processus cliniques (16 traitements ou soins généraux inadéquats) et l’administration clinique (10 transferts de soins inadéquats). Dans 87 cas, les incidents se sont associés à de légers dommages.

CONCLUSIONS : Les registres d’appel étaient une bonne source de données d’amélioration de la qualité pour comprendre les dommages et les problèmes liés à la sécurité des patients émergent au sein de la population sous VMD. Cependant, il faut créer un système officiel d’analyse et de signalisation des incidents pour mieux les comprendre.

Patients residing in Ontario who require HMV are supported for their equipment needs through the Ontario Ventilator Equipment Pool (VEP) (5). Established in 1994, the VEP is a provincial service operated by Kingston General Hospital (Kingston, Ontario) that provides equipment to thousands of clients across Ontario. It is funded by the Ministry of Health and Long-Term Care and is a central provincial depot for respiratory equipment. The VEP loans equipment to eligible individuals of all ages who require these devices at home and who have been approved under the ministry’s Assistive Devices Program. The VEP provides several related services including 24 h telephone technical support seven days per week and educational support. After normal business hours, support is offered through a telephone on-call service staffed by one registered respiratory therapist per shift. The on-call logs generated were the primary records analyzed in the present study.

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Limited information about the safety of ventilated patients in the community exists. There is a paucity of patient safety information from the community sector related to the medically fragile population requiring HMV. To improve safety, therefore, we must first understand the risks HMV patients encounter. The objective of the present study was to describe patient safety incidents within the HMV population and discuss the opportunities for preventing harm.

A Google search of “patient harm while on home mechanical ventilators” yields anecdotal confirmation that harm can occur. Results included a report in 2010 of a National Health Service agency nurse turning off a patient’s ventilator by mistake. The patient with an SCI was left with severe brain damage after the incident (6). Studies show that the relative safety of patients receiving HMV require greater research and investigation due to the number of unknown factors (eg, appropriateness of patient or caregiver training in the community) (2).

The guidelines for transitioning patients from acute care to home established by the Canadian Thoracic Society recognize many of the risks and, in general, these can be grouped as patient medical stability risk, family and other caregiver support risk, equipment and other resource allocation risk (2).

A 1999 study investigated patient safety problems among 3,013,287 general homecare clients (7); the results indicated that 13% had experienced an adverse event. Factors associated with the occurrence of adverse events included (8):

- Complexity of client medical condition
- Client acceptance of care responsibilities
- Failure to identify and control risk
- Delays in implementing services
- Incomplete patient or caregiver education before discharge from acute care
- Equipment management, use or misuse

To understand the generalized risks associated with HMV, it is essential that a common system of measurement be available. A common framework is required to measure the findings arising from the VEP on-call data to compare against findings already found within the literature. One such framework is the World Health Organization’s (WHO) International Classification for Patient Safety (9).

The WHO produced a technical report outlining a conceptual framework that defined and harmonized patient safety concepts into an internationally agreed on classification (9). The intent was that information could be compared, measured and analyzed based on a common taxonomy. Within the framework, 13 incident types were defined and included (9):

1. Clinical administration
2. Clinical process/procedure
3. Documentation
4. Health-associated infection
5. Medication
6. Blood products
7. Nutrition
8. Oxygen/gas/vapour
9. Medical device/equipment
10. Behaviour
11. Patient accidents
12. Infrastructure/building
13. Resource/organization management

| TABLE 1
<table>
<thead>
<tr>
<th>Incident type</th>
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<tbody>
<tr>
<td>1. Clinical administration</td>
</tr>
<tr>
<td>2. Clinical process/procedure</td>
</tr>
<tr>
<td>3. Documentation</td>
</tr>
<tr>
<td>4. Health-associated infection</td>
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<td>12. Infrastructure/building</td>
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<td>13. Resource/organization management</td>
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</tbody>
</table>

Data adapted from reference 9

Study procedures
A retrospective observational review of on-call logs from the Ontario VEP was conducted. Classification of on-call logs from April 1, 2011 to March 21, 2012 was completed using the standardized tool of the WHO’s Patient Safety Taxonomy – International Classification System (9).

The VEP after hours on-call service documents events related to patient problems arising in the evening, overnight and on the weekends. Only logs pertaining to patients requiring HMV were analyzed.

| TABLE 2
<table>
<thead>
<tr>
<th>Degree of harm</th>
</tr>
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<tbody>
<tr>
<td>None – patient outcome is not symptomatic, or no symptoms detected and no treatment is required</td>
</tr>
<tr>
<td>Mild – patient outcome is symptomatic, symptoms are mild, loss of function or harm is minimal or intermediate but short term, and no or minimal intervention (eg, extra observation, investigation, review or minor treatment) is required</td>
</tr>
<tr>
<td>Moderate – patient outcome is symptomatic, requiring intervention (eg, additional operative procedure; additional therapeutic treatment), an increased length of stay, or causing permanent or long-term harm or loss of function</td>
</tr>
<tr>
<td>Severe – patient outcome is symptomatic, requiring life-saving intervention or major surgical/medical intervention, shortening life expectancy or causing major permanent or long-term harm or loss of function</td>
</tr>
<tr>
<td>Death – on balance of probabilities, death was caused or brought forward in the short term by the incident</td>
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Data adapted from reference 9

Analysis
Logs were classified as either positive or negative for the occurrence of a patient safety incident. Positive incidents were assessed using the WHO conceptual framework for International Classification for Patient Safety definitions (9). First, the incidents were categorized into the 13 incident types (Table 1) and the degree of harm (Table 2). Second, the incidents were described according to patient safety definitions (Table 3). In addition, patient characteristics, including diagnosis (from existing VEP records), incident characteristics, incident type and other on-call respiratory therapist (RT) actions, were described. The data were analyzed using nonparametric descriptive statistics including the mean, SD and Mann Whitney U tests to determine significance of age in patients experiencing harm.

The first author (LY) reviewed all on-call data and performed the analysis. An element of judgement was needed to perform the analysis. Assessor qualifications include 15 years working with
patients needing long-term ventilation, 10 years as a VEP on-call therapist, and 10 years working in the field of patient safety and risk including classification of incident types and harm levels based on the WHO framework at two academic health centres in Toronto (Ontario). The present study was approved by Charles Sturt University, School of Biomedical Sciences Ethics in Human Research Committee (Burlington, Ontario) and Queen’s University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board (Kingston, Ontario).

RESULTS

On-call logs were reviewed for the period between April 1, 2011 and March 31, 2012. A total of 268 logs were reviewed. Of these, 248 logs pertained to patients requiring long-term ventilation, either invasively or noninvasively. Twenty logs were removed from the data because they related to nonventilated patients. One hundred eighty-eight of 248 (75.8%) experienced a patient safety incident; 87 (46.3%) of these incidents were associated with mild harm.

Patient characteristics

Patients requiring on-call assistance were male (n=138 [55.6%]) and female (n=110 [44.4%]). The mean (± SD) age of those experiencing any patient safety incident was 57.9±22.8 years (range three to 97 years). The mean age for those experiencing a patient safety incident associated with mild harm was 58.7±22.1 years (range three to 94 years). The mean age for those experiencing no harm was 57.3±23.5 years (range five to 90 years). There was no statistical difference in age between the groups who experienced a patient safety event with or without harm (P=0.99).

The majority of patients requiring the on-call service had a neuromuscular diagnosis including patients with muscular dystrophy, myopathy, SCI and ALS (ALS patients: n=35 [10 invasive ventilation, 25 noninvasive ventilation]). All diagnostic groupings based on the review of incidents from the VEP records are summarized in Table 4.

Incident characteristics

Patient calls emerged from all Ontario Local Health Integration Networks (LHINS) (Table 5), the most frequent being from the South West LHIN (n=26 [13.8%]) and Champlain LHIN (n=26 [13.8%]). Calls originated from three distinct settings including home (n=173 [93.1%]), acute care (n=8 [4.2%]), other (eg, vacation location or unknown (n=3 [1.6%])) and long-term care (n=2 [1.1%]). Callers were primarily relatives (n=82 [43.6%]) (spouses, parents, children) or the patients (n=75 [39.9%]) themselves. The balance of the calls were from regulated health care professionals (n=16 [8.5%]) (registered nurses, registered practical nurses and registered RTs), unregulated health care workers (primarily personal support workers (n=14 [7.4%])) or friends (n=1 [0.5%]).

### TABLE 3
WHO conceptual framework for International Classification for Patient Safety definitions used

| Patient safety incident – an event or circumstance that could have resulted or did result in unnecessary harm to a patient | Contributing factor – a circumstance, action or influence that is thought to have played a part in the origin or development, or to increase the risk of an incident | Patient outcome – is the impact on a patient that is wholly or partially attributable to an incident. Where harm has occurred, the degree of harm is the severity and duration of any harm and any treatment implications that result from the incident | Mitigating factors – actions or circumstances that prevent or moderate the progression of the incident toward harming the patient | Actions taken to reduce risk – steps taken to prevent recurrence of the same or similar patient safety incident and on improving system resilience |

Data adapted from reference 9

### TABLE 4
Patient diagnostic groupings – all incidents (Ontario Ventilator Equipment Pool, 2011/2012) (n=188)

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neuromuscular disorder</td>
<td>83 (44.1)</td>
</tr>
<tr>
<td>Obstructive sleep apnea</td>
<td>28 (14.9)</td>
</tr>
<tr>
<td>Obesity hypoventilation syndrome</td>
<td>24 (12.8)</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>19 (10.1)</td>
</tr>
<tr>
<td>Central respiratory drive depression</td>
<td>17 (9.0)</td>
</tr>
<tr>
<td>Unknown other (information unavailable)</td>
<td>10 (5.3)</td>
</tr>
<tr>
<td>Chest wall deformity</td>
<td>7 (3.7)</td>
</tr>
</tbody>
</table>

Data presented as n (%)

Incident type

Of the 188 on-call logs that were positive for a patient safety incident, where each call could yield more than one incident type (9), 227 different incident types were identified (Table 6). The majority of patient incidents were medical equipment issues (n=164 [72.2%]) including non-invasive and invasive devices (BiPAP™, VPAP™, Trilogy™, LTtV™), adjunctive equipment (masks, circuits) or humidifiers. Documentation incidents (n=25 [11.0%]) included unavailable labels/prescriptions (showing patient ventilator settings) and unclear information (potentially outdated information). Clinical process (n=17 [7.5%]) incidents included inadequate treatment or general care (eg, setting up patients on inappropriate settings. Clinical administration (n=10 [4.4%]) type incidents included inadequate handover or transfer of care issues (eg, patients leaving hospital settings without knowledge of how to use life-support equipment. Behaviour incident types (n=7 [3.1%]) arose from risky patient behaviour (eg, patient choosing to ignore alarms for weeks). Resource incidents (n=3 [1.3%]) were related to organization of community teams and availability or adequacy of policies/guidelines/protocols (eg, health care workers assigned to care for HMV patients without adequate training). One patient accident incident type (n=1 [0.4%]) was recorded as a specific mechanical threat to breathing (eg, malfunction of portable suction device coinciding with blockage of tracheostomy tube).

Patient outcomes

For the 87 incidents found to have mild harm, 115 incident types (Table 7) were associated with these events. Harm occurred because of one or a combination of:

- Delays in therapeutic interventions (n=72 [38%]);
- Inadequate therapeutic intervention (n=45 [24%]);
- No therapeutic intervention (patient refusal to continue using device for prolonged period >48 h) (n=25 [13%]); or
- Potential respiratory failure (n=1 [0.5%]).

 Contributing factors/hazards

Patient safety incidents can have contributing factors that influence the development of the incident or increase the risk (9). These include patient, caregiver, environmental organizational and external factors (9). In the present study, patient (n=61 [34%]) and caregiver (n=58 [32%]) factors were related to cognitive (base knowledge, understanding) and performance (technical error) deficits, as well as behavioural factors (engaging in risky behaviour). Other patient factors were pathophysiological (eg, visual impairments/arthritis/muscle weakness and communication difficulties (eg, language barriers). Environmental factors (remote location) (n=7 [3.9%]), organizational factors (inadequate protocols and policy, organization of teams, organizational culture) (n=30 [16.7%]) and external factors (product, technology, infrastructure and system issues) (n=23 [12.8%]) were also found.

Mitigating factors, and actions to reduce risk and RT actions

The key mitigating factors contributing to reducing the harm potentially resulting from 248 patient safety incidents included patient
Call 2
A 59-year-old man with ALS was set up on noninvasive ventilation. The caller was the patient's daughter. She described a high dependency on the device and, as such, was provided with a back-up power supply (ie, battery). At the time of the call, the patient's home was experiencing a power failure and, at this time, the daughter called to indicate a lack of knowledge on how to attach the noninvasive support device to the battery. Additionally, it was discovered the battery was not charged and, as such, could not be used.

Call 3
A 48-year-old woman with a neuromuscular disorder was on invasive ventilation. Her husband was the primary caregiver along with support from an RT from the local homecare company. The RT was on vacation and the gauge on the ventilator was not moving. The husband, who stated that he could neither read nor write, had difficulty with troubleshooting. He discovered a crack in the swivel with the help of the on-call therapist. He did not have any back-up equipment and stated that the circuit had not been replaced or cleaned since 2007. Duct tape was used to seal the leak in the swivel. The VEP sent replacement tubing the next business day.

Call 4
A 56-year-old woman with advancing ALS was sent home on a new ventilator (Trilogy™) after being set up through a day study at an acute care centre. She was invasively ventilated on the device. The day staff member escorting the patient was provided with training. By the evening, the ventilator began to alarm with a low-pressure alarm. The night care providers (registered practical nurses) were not given training. Written documentation regarding prescription settings, including tracheal cuff volume, were also not provided. The patient and her husband stated that they did not know how to use the device, and the husband was reluctant to offer any help because he was on dialysis and had medical concerns of his own. Attempts to coordinate training for the caregivers were unsuccessful. Subsequent low pressure and low tidal volume alarms continued. Two additional calls to the VEP on-call service were noted over the next few days. By day 7, the caregivers still had not received education. The patient was short of breath. The on-call RT advised the patient to be manually resuscitated and transferred to an emergency room.

**DISCUSSION**
In the present study, a retrospective review of Ontario VEP on-call logs was systematically analyzed. We found 188 positive patient safety...
incidents from 248 on-call records reviewed. Patient incidents were associated with mild harm in 87 cases. Quality improvement opportunity can be obtained through this data source.

### Patient characteristics

We did not find significant differences in age between the groups that did (n=87) and did not (n=99) have mild harm associated with patient safety events (P=0.99). Limited conclusions can be drawn from this but may be reflective of underutilization of the on-call service due to lack of awareness and unrecognized barriers to access for the elderly (11). More research may be warranted with consideration of outreach (11) for this particularly fragile population among an already at-risk group of HMV users.

In the present study, the majority (n=83 [44.1%]) of callers had a neuromuscular diagnostic grouping. Comorbidities could not be determined based on the documentation available. One group of particular concern within the neuromuscular grouping were the ALS patients (n=35 [10 ventilator use, 25 noninvasive ventilation]). In this group, death usually occurs as a result of progressive respiratory muscle involvement, with 50% of patients dying within three years of symptom onset (2). In advancing ALS, the patient becomes more dependent on ventilatory support.

The use of noninvasive ventilation can pose a critical risk for this ALS population. Based on our results, the majority of ALS patients used noninvasive ventilation. It is recognized that choosing noninvasive ventilation for more dependent patients has resulted in sentinel events nationally and internationally (12). Noninvasive bi-level devices are not designed for continuous life-support and should not be used in patients with insufficient respiratory capacity to tolerate brief interruptions in therapy (12).

Currently, there are mitigating strategies and actions to reduce risk for this ALS group. However, there are opportunities to further support this segment of the HMV population. Some of the existing mitigating strategies described in the present study include providing back-up equipment in the home routinely and actions to reduce risk relate to sending replacement equipment (n=82 [17.8%]) immediately when failure occurs. The literature suggests that highly dependent patients could benefit from other strategies such as home surveillance using videophone monitoring and transmission of oximetry to leverage available technology in support of home safety (13).

## TABLE 8

<table>
<thead>
<tr>
<th>Action</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommend alternative interface</td>
<td>14 (3.0)</td>
</tr>
<tr>
<td>Adjust alarms or change settings</td>
<td>17 (3.7)</td>
</tr>
<tr>
<td>Reassurance</td>
<td>28 (6.1)</td>
</tr>
<tr>
<td>Coordination of care</td>
<td>81 (17.6)</td>
</tr>
<tr>
<td>Equipment dispatch</td>
<td>82 (17.8)</td>
</tr>
<tr>
<td>Education</td>
<td>98 (21.3)</td>
</tr>
<tr>
<td>Other clinical advice</td>
<td>140 (30.4)</td>
</tr>
<tr>
<td>Total actions for 248 on-call logs, n</td>
<td>460</td>
</tr>
</tbody>
</table>

### Incident characteristics

Most calls were from patients and their families. This reinforces the importance of patient and family caregiver support. In a risk review of the HMV population, a key part of any home care program is the education of patients, families and caregivers (13). More specifically, this would include competency training on how to operate the ventilator, improving the ability to remedy simple problems and providing the knowledge of when to seek advice (13). Additionally, safety considerations need to evolve with the course of the underlying disease (13).

In this retrospective review, patient (n=61 [34%]) and caregiver (n=58 [32%]) base knowledge and understanding were the largest contributing factors to patient safety incidents. This finding suggests opportunity for improved education in HMV for both patients and caregivers. There is a general lack of resource support for home-ventilated patients and their caregivers (4). Many caregivers are not satisfied with the current education system for HMV (4). They express the need for more information on HMV (ie, related emergency care management and medical techniques) (5). In 2002, a sentinel event alert was released by The Joint Commission in the United States on the prevention of ventilator-related deaths and injuries (14). The Alert reported 23 deaths or injuries related to long-term ventilation (14). Root cause analysis revealed inadequate orientation/training processes to be a contributing factor 87% of the time (14). Our findings support the need for more educational support for patients and caregivers in the home.

With respect to the distribution of on-call service use according to LHIN region, opportunity to make local improvements potentially exist. Due to study time limitations and information availability at the VEP, we were unable to compare on-call service user regional profile to the overall population of VEP patient distribution according to LHIN. Where disproportionate or underutilized service use arise, opportunity for improvement with local prescribing centres could be targeted.

### Incident types

The majority of incidents were equipment related (n=164 [72.2%]). In the present study, incidents were the result of equipment malfunction, user error, lack of equipment availability, inappropriate equipment choice and dislodgement of equipment parts. A review of the Food and Drug Administration (FDA) Manufacturer and User Facility Device Experience (MAUDE) database revealed more than 150 alleged home mechanical ventilator malfunctions or failures in 2010 (15). In our findings, 99 alleged equipment failure or malfunction incidents were isolated. While our findings may appear high, MAUDE is a passive surveillance system and values may be under-reported (15). The FDA MAUDE database noted at least 11 patient deaths related to HMV (15). Of note, in five of the 11 deaths, the ventilator did not alarm (15). While alarm adjustments were required in 3.7% of RT actions in our study, no deaths occurred.

With user errors (n=41 [8.1%]), human factors considerations in the design of home equipment should be encouraged especially with respect to patient and family end users. As noted in the qualitative description
of calls, limitations in functional ability (arthritis, poor vision, muscular weakness) and cognitive ability (literacy) were barriers.

Documentation (n=25 [11%]) was another area for improvement. Patients were frequently unaware of their prescribed ventilator parameters, in part, due to a lack of documentation. In situations of complete equipment malfunction, documentation availability and or patient/family knowledge of required settings is essential in preventing delay of replacement equipment and ensuring effectiveness of replaced devices. Communication is a central theme in patient safety across the health care continuum (14). Findings from this review support the need for more consistent documentation and communication practices. This includes establishing consistent elements for documents across all sites and developing a uniform process for communication of specialized information with referring agencies (16). Documentation access can range from simple labels on a device to more sophisticated electronic linkage of health information to all stakeholders including the patient.

Based on the nature of the on-call logs, equipment type incidents were easily identified and, in fact, occurred most frequently. The more difficult to recognize clinical administration (n=10 [4.4%]) and resource (n=3 [1.3%]) incident types were less likely to be found based on limitations in the context provided by the call logs. However, these events were identified in our study and their existence is supported by the literature. Lang et al (17) described gaps in home safety related to coordination of care, and Van Ineveld et al (16) noted that patient safety is often concerned with failures associated with patient transition. Further interviews with patients and their caregivers could yield a higher incidence of both clinical administration and resource type incidents.

Patient outcome

Medical causes of death or acute hospitalization (ie, moderate and severe harm) in patients on HMV include hypocapnia, hypercapnia, hypoxemia, barotrauma, hemodynamic instability, airway complications, respiratory infection, bronchospasm, exacerbation of underlying disease or deterioration through the natural course of the disease (1). In our findings, only mild adverse events could be identified.

It is unlikely that HMV patients only experience mild harm. One recent publication followed 17 invasively ventilated patients living in a nursing home (18). In this study, one-half of the patients experienced severe incidents. While the on-call logs are a valuable source of quality-improvement data, they were unable to be used to describe situations involving HMV patients experiencing moderate or severe harm. Both moderate and severe harm outcomes were not captured, and likely grossly underestimated because patients presumably went directly to local emergency rooms through paramedic services rather than using the on-call service. Patient outcomes overall were difficult to estimate due to limited patient follow-up. A more formal incident reporting system is required to accomplish this.

Based on the present study and, in concert with the literature, the following recommendations can be made:

1. Develop a standard process, including documentation and education across all prescribing organizations to support the handover and discharge of home-ventilated patients.
2. Enable electronic documentation with shared access among the patient, community caregivers (professional and family), VEP staff, family physicians and prescribing centres (acute/rehab) to support communication across all team members.
3. Improve usability of HMV devices, recognizing limitations of the home setting and the physical limitations of many patients who do not have other caregivers.
4. Investigate the need for interventions, potentially outreach respiratory therapy services linked to expert prescribing Physicians, the VEP, Community Care Access Centre nursing care and home care companies, to support high-risk patients (24 h dependent, elderly, deteriorating conditions).
5. Increase development and application of technology to remotely monitor and support high-risk or fragile patients.
6. Review all VEP patient deaths using the WHO framework and the CPSI incident analysis framework to identify critical incidents and opportunity for improvement.
7. Develop an incident reporting system in the community for patients and caregivers. Analysis of reviews should occur through collective analysis by key stakeholders in partnership with patients and families.

Limitations and next steps

In addition to those already mentioned, there were a number of other limitations to the present study. The on-call logs were used as a proxy to determine the actual number of patient safety incidents. The logs were neither complete patient health records, nor did they constitute an incident recording and management system. The logs were manually recorded and stored, which also led to difficulty in obtaining all call logs in a timely manner. The on-call logs were valuable in furthering the work of understanding the nature of harm for those on HMV in the community. However, as stated, moderate and severe harm was not identified.

Further validation of the findings would include a second reviewer to reanalyze the data. Triangulation of the findings could occur through interviews with on-call staff, patients and their caregivers.

CONCLUSIONS

Patient safety incidents in the HMV population exist but are currently not systematically captured. Strategies to decrease the risks for this population are required if continued efforts to support successful management in the community are to occur. The use of on-call data is valuable to identify some safety improvement opportunity. These opportunities include improved support of patients and caregivers through education, better coordination and documentation, closer examination of subpopulations potentially at higher risk and a formal incident review and reporting system.

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DISCLOSURES: The authors have no financial disclosures or conflicts of interest to declare.

REFERENCES

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**September 3-7, London, United Kingdom:** European Respiratory Society (ERS) International Congress 2016. Contact ERS Headquarters, 4, Avenue Ste-Luce, Lausanne, Switzerland, CH 1003. Telephone 41-21-213-0101, fax 41-21-213-0100, website http://erscongress.org

**January 26-28, Toronto, Ontario:** Better Breathing. Toronto Marriott Downtown Eaton Centre Hotel, 525 Bay Street, Toronto Ontario M5G 2L2. Contact Clarys Tirel, telephone 416-864-9911 ext 226, e-mail ctirel@on.lung.ca, www.betterbreathing.ca

**April 29-May 2, Winnipeg, Manitoba:** Canadian Conference on Medical Education. Contact the Canadian Conference on Medical Education, Ms Chrissy Holloway, Conference Manager, telephone 613-730-0687 ext 240, e-mail cholloway@afmc.ca, website www.mededconference.ca

**April 29-May 2, Vancouver, British Columbia:** Canadian Medical Association (CMA) Annual Meeting. Contact the Canadian Medical Association, 1867 Alta Vista Drive, Ottawa, Ontario K1G 5W8. Website www.cma.ca


**September 3-7, Bologna, Italy:** 23rd Congress of the European Sleep Research Society (ESRS). Contact ESRS 2016 c/o Congress Switzerland Ltd, Administrative Secretariat, Peter Merian-Strasse 80, Basel, Basel-Stadt, 4002, Switzerland. Telephone 41-61-686-7777, fax 41-61-686-7788, e-mail esrs@congress-switzerland.com, website www.esrs-congress.ch/esrs2016/general-information/general-information.html

**September 29-October 2, Montreal, Quebec:** Canadian Society of Allergy and Clinical Immunology Annual Scientific Meeting. Contact the Canadian Society of Allergy and Clinical Immunology, PO Box 51045, Orleans, Ontario K1E 3W4. Telephone 613-986-5869, e-mail info@csaci.ca, website http://csaci.ca

**October 15-18, San Antonio, Texas:** American Association for Respiratory Care Congress 2016. Contact the American Association for Respiratory Care, 9425 North MacArthur Boulevard, Suite 100, Irving, Texas 75063-4706, USA. Telephone 1-972-243-2272, e-mail info@aarc.org, website www.aarc.org

### 2017

**January 26-28, Toronto, Ontario:** Better Breathing. Toronto Marriott Downtown Eaton Centre Hotel, 525 Bay Street, Toronto Ontario M5G 2L2. Contact Clarys Tirel, telephone 416-864-9911 ext 226, e-mail ctirel@on.lung.ca, www.betterbreathing.ca

**April 29-May 2, Winnipeg, Manitoba:** Canadian Conference on Medical Education. Contact the Canadian Conference on Medical Education, Ms Chrissy Holloway, Conference Manager, telephone 613-730-0687 ext 240, e-mail cholloway@afmc.ca, website www.mededconference.ca
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- BREO® ELLIPTA® should not be used more often than recommended, at higher doses than recommended, or in conjunction with other medicines containing a LABA, as an overdose may result.
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- Hypersensitivity: rare reports of angioedema and urticaria have been reported. There have been reports of anaphylactic reactions in patients with severe milk protein allergy with other inhaled dry powder drug products containing lactose.
- Immune effects: greater susceptibility to infections. Administer with caution and only if necessary in patients with active or quiescent tuberculosis infections of the respiratory tract; chronic or untreated infections such as systemic fungal, bacterial, viral, or parasitic; or ocular herpes simplex. Chickenpox and measles can have a more serious or even fatal course in susceptible patients using corticosteroids. In such patients who have not had these diseases or been properly immunized, particular care should be taken to avoid exposure.
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- Drug interactions: caution should be exercised when considering coadministration with inhibitors of cytochrome P450 3A4; inhibitors of P-glycoprotein (P-gp); sympathomimetic agents; beta-adrenergic receptor blocking agents; non-potassium sparing diuretics (i.e., loop or thiazide diuretics); drugs that prolong the QTc interval (e.g., monoamine oxidase inhibitors and tricyclic antidepressants); xanthine derivatives; and acetalsalicylic acid.

Adverse Events:

Adverse reactions reported at a frequency of ≥1% and more common than placebo in one clinical study of BREO® ELLIPTA® 100/25 mcg included: nasopharyngitis, oral candidiasis, upper respiratory tract infection, headache, dysphonia, oropharyngeal pain, epistaxis. Adverse reactions reported at a frequency of ≥1% in another clinical study of BREO® ELLIPTA® 200/25 mcg and BREO® ELLIPTA® 100/25 mcg also included the following additional adverse reactions: influenza, bronchitis, sinusitis, respiratory tract infection, pharyngitis, cough, rhinitis allergic, abdominal pain upper, diarrhea, toothache, back pain, pyrexia, muscle strain.

Dosage and Method of Administration:

The recommended dose of BREO® ELLIPTA® 100/25 mcg or 200/25 mcg is one oral inhalation once daily, administered at the same time every day (morning or evening). Do not use more than once every 24 hours. The starting dose is based on patients’ asthma severity. For patients previously treated with low- to mid-dose corticosteroid-containing treatment, BREO® ELLIPTA® 100/25 mcg should be considered. For patients previously treated with mid- to high-dose corticosteroid-containing treatment, BREO® ELLIPTA® 200/25 mcg should be considered. After inhalation, patients should rinse their mouth with water (without swallowing). If a dose is missed, the patient should be instructed not to take an extra dose, and to take the next dose when it is due.

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