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Measuring impact and impacting practice / Les mesures d’impact et les impacts sur la pratique

EDITORIAL

Registered respiratory therapists as force multipliers in interprofessional complex continuing care

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Endotracheal suctioning practices of nurses and respiratory therapists: How well do they align with clinical practice guidelines?

REVIEW

Coaching patients during pulmonary function testing: A practical guide

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\(^*\) A randomized, double-blind, placebo-controlled, 24-week study in patients aged ≥40 years (N=819) with a clinical diagnosis of stable moderate-to-severe COPD (post-bronchodilator FEV1, of ≥30% to <80% of predicted normal value) and a history of smoking of at least 10 pack-years. Morning trough (pre-dose) FEV1 was defined as FEV1 measured 12 hours after the previous evening dose of TUDORZA GENUAIR.

REFERENCES:

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The growing burden of chronic disease attributed to aging populations and changing disease trends, among others, has presented new challenges to clinicians and contemporary health care. Given that seniors will represent a steadily increasing proportion of the Canadian population – projected to be 25% by 2036 – the prevalence of multimorbidity and demands for long-term care are also likely to increase. Currently, patients who are too ill to return home but for whom hospitalization in an acute care environment is unnecessary or inappropriate comprise a growing segment of the population for whom evidence-based practices and clinical guidelines are either unclear or absent. Accordingly, this quality improvement initiative provides an overview that may be used by other clinical centres to assess their complex continuing care environments.

Endotracheal suctioning practices of nurses and respiratory therapists: How well do they align with clinical practice guidelines?  60
Rosanne Leddy, Jenny M Wilkinson

Clinical practice guidelines are, in large part, developed from high-quality data obtained from evidence-based practice. Their aim is to optimize treatment efficiency and effectiveness, and to improve the clinical decision-making process. Although largely adhered to, studies have reported disparities between clinical guidelines and what is actually practised. This study investigated one such practice that is not supported by current evidence but, paradoxically, is believed to be common in the intensive care unit.

REVIEW
Coaching patients during pulmonary function testing  65
Heidi J Cheung, Lawrence Cheung

Pulmonary function testing is a cornerstone in the diagnosis and management of individuals with respiratory disease. However, correct interpretation of pulmonary function data relies heavily on acceptable test quality, which in turn is dependent on several factors including equipment, trained personnel, and patient cooperation and effort. This article briefly reviews key principles of patient instruction and several aspects of pulmonary function testing, and discusses factors that hamper performance. The authors also offer several coaching suggestions and examples readers may find useful in their practice.

BRIEF COMMUNICATION
Innovation in respiratory therapy and the use of three-dimensional printing for tracheostomy management  69
Andrew J West, Karen Taylor, Daniel W Rickey

Technological advances have influenced practice patterns and innovation in many health disciplines, including respiratory therapy. Collaborative approaches and knowledge-sharing environments are vital in addressing problems and adopting emerging technology. This article illustrates how the emergence of low-cost three-dimensional printing technology to physically reproduce the results of computed tomography imaging data can provide ways to assess airway abnormalities and symptomology not explained by traditional diagnostic methods.

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Measuring impact and impacting practice

The purpose of medical journals is to have an impact. Seemingly axiomatic, the idea that the work that we publish should impact patients, processes, drug and device development, and myriad other relevant factors is central to what journals do. However, defining and measuring this is, not surprisingly, far more complex.

The world of academic publishing trades in the currency of impact. The higher your impact, the more valuable your currency; the more valuable your currency, the more sought after your product. In journal parlance, the gold standard is the impact factor, a measure reflecting the average number of citations that articles published in a journal receive over the two preceding years. Other measures of impact exist, ranging from article-level impact measures to an index of the productivity of individual scholars or researchers. Regardless of the measure, the fundamental point is that impact relies on being seen, being read and being cited.

Over the past years, our team of editors, our newly formed Editorial Board and our managing editor have worked to improve the quality of the Journal, adhere to best editorial practices, and to solicit articles and reviewers that we believe will improve the practice of respiratory therapy in Canada and around the world. The products of this work have largely been visible and tangible: facilitating workshops on research in respiratory therapy; assisting authors in responding to peer-review feedback; mentoring first-time authors to ensure their work is reflected in high-quality publications; and many other tasks.

Behind the scenes, we have worked to improve the visibility of the Journal to respiratory therapists and the research community at large. In addition to maintaining our indexing in CINAHL, EMBASE and SCOPUS, the Journal is now searchable through Google Scholar, and we have been accepted into HINARI, a World Health Organization database of open-access journals to promote access to medical literature for users in low- and middle-income countries. We are continuing to work on additional opportunities for indexing, ensuring that our visibility grows.

Readers will also note that the Journal is now declaratively open access – a commitment to ensuring that the results of the research that we publish (and authors conduct) is highly visible, easily retrievable and accessible to all readers, regardless of ability to pay. This process is governed by a Creative Commons Non-Commercial Attribution (CC-BY-NC), which protects authors’ and the Journal’s rights, ensuring that proper credit is given and that the work is used only for non-commercial purposes, unless explicit permission is given to do so. This approach helps maintain the integrity of the work that we publish while ensuring it can be widely disseminated to those who use it.

The cumulative effect of these endeavours is a stronger, more visible journal with greater reach and impact. This work is being done to ensure that the articles that are submitted to us are accessible to those who can integrate them into patient care, and the development of new measures, the impact depend fundamentally of the fact of being seen, of being read and being cited.

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Les mesures d’impact et les impacts sur la pratique

Les revues médicales existent pour avoir un impact. Apparemment axiomatique, le concept selon lequel les travaux publiés ont un impact sur les patients, les processus, le développement des médicaments et des dispositifs et une myriade d’autres facteurs pertinents est au cœur des activités des revues scientifiques. Cependant, comme il fallait s’y attendre, il est complexe de définir et de mesurer cet impact.

Les publications universitaires négocient l’impact. Plus l’impact est élevé, plus la devise est précieuse. Plus la devise est précieuse, plus le produit est recherché. Dans le langage des revues scientifiques, le facteur d’impact est la norme de référence, qui reflète le nombre moyen de citations que l’article publié a suscité au cours des deux années précédentes. Il existe d’autres mesures d’impact, qu’il s’agisse de celles d’un article ou de l’indice de productivité d’un universitaire ou d’un chercheur. Quelle que soit la mesure, l’impact dépend fondamentalement du fait d’être vu, d’être lu et d’être cité.

Les dernières années, notre équipe de rédacteurs, notre nouveau comité de rédaction et notre directeur de rédaction se sont attachés à améliorer la qualité du Journal, à respecter des pratiques éditoriales exemplaires et à solliciter des articles et des réviseurs qui, à notre avis, amélioreront l’exercice de l’inhalothérapie au Canada et dans le monde. Le produit de ces travaux est à la fois visible et tangible : faciliter des ateliers sur la recherche en inhalothérapie, aider les auteurs à réagir aux commentaires issus de la révision par les pairs, faire du mentorat auprès des nouveaux auteurs pour que leurs travaux paraissent dans des publications de qualité, entre autres.

En coulisse, nous avons travaillé à accroître la visibilité du Journal auprès des inhalothérapeutes et de l’ensemble dans les domaines de la recherche. En plus de continuer à être indexé dans CINAHL, EMBASE et SCOPUS, le Journal peut maintenant être consulté à partir de Google Scholar et a été accepté dans HINARI, une base de données de revues en libre accès de l’Organisation mondiale de la Santé qui favorise l’accès aux publications scientifiques pour les usagers des pays à faible et à moyen revenu. Nous continuons de chercher d’autres possibilités d’indexation afin d’accroître notre visibilité.

Les lecteurs remarqueront également que le Journal est désormais officiellement en libre accès, afin que les résultats des recherches que nous publions (et que les auteurs réalisent) soient très visibles, faciles à consulter et accessibles à tous les lecteurs, quelle que soit leur capacité de payer. Ce processus est régi par une attribution non commerciale de Creative Commons (CC-BY-NC), qui protège les droits des auteurs et du Journal, afin que les sources soient bien citées et que les travaux ne soient utilisés que pour des fins non commerciales, à moins d’une autorisation explicite. Cette démarche contribue au maintien de l’intégrité des travaux publiés et en garantit la diffusion auprès de ceux qui les utilisent.

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technologies and approaches for improving the respiratory health of patients in Canada and elsewhere, and we continue to build the Journal to have a maximum impact on all aspects of respiratory therapy. While a goal is certainly to establish a measurable impact for the Journal by way of a quantification of citations and other metrics, we also view our responsibility more holistically, linking clinicians with researchers and with the field of respiratory therapy research, to support improvements in translating knowledge that we publish into clinical practice changes. Ultimately, this is the lasting impact that the Journal – and we as respiratory therapists – should seek to have.

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

Ces initiatives ont eu l’effet cumulatif de créer un journal plus consistant et plus visible, à la portée et à l’impact manifestes. Elles visent à garantir que les articles qui nous sont soumis soient accessibles à tous ceux qui peuvent les intégrer aux soins des patients et à favoriser l’élaboration de nouvelles technologies et de démarches pour améliorer la santé respiratoire des patients du Canada et d’ailleurs. Nous continuons d’ailleurs à édifier le Journal pour qu’il ait un impact maximal dans tous les volets de l’inhalothérapie. De toute évidence, nous cherchons à ce que le Journal ait un impact mesurable par la quantification des citations et d’autres mesures, mais nous avons également une perception plus globale de notre responsabilité, qui s’étend à l’établissement de liens entre les cliniciens, les chercheurs et le milieu de la recherche en inhalothérapie afin de mieux transformer le savoir que nous publions en changements pour la pratique clinique. En fin de compte, c’est l’impact durable que le Journal et les inhalothérapeutes devraient rechercher.

Jason W Nickerson RRT, FCSRT, Ph. D., rédacteur en chef
Registered respiratory therapists as force multipliers in interprofessional complex continuing care

Wrae Hill RRT BSc MSc FCSRT¹, Cory Bendall RRT BHSc MPH(c)²

Many acute care hospital access and flow challenges are attributable, in part, to inadequate resources for complex care clients outside of acute care hospitals. In the current issue of the Journal, Nickerson (1) (pages 55-59) describes multifactorial and mixed methods research to determine respiratory therapy care needs in complex continuing care (CCC). The author concludes “The burden of respiratory disease is significant, and includes a high prevalence of inhaled medication and oxygen use and a significant workload attributed to the respiratory needs of patients.”

Although there are no simple methods or answers, this is important foundational work. CCC registered respiratory therapist (RRT) staffing has not received much attention, and that should change (2,3). Guidelines for appropriate staffing ratios for RRTs working in critical care units have been described; however, no such guideline exists for CCC units. Even when such guidelines exist, Nickerson (1) points out that a staffing ratio does not necessarily reflect the suitability of patient care, and that “system level stressors are best identified at the bedside.”

FORCE MULTIPLIERS

In military parlance, a force multiplier refers to an attribute or a combination of attributes that make a given force more effective than that same force would be without it. A force multiplier can increase the effectiveness of a group.

A challenge for RRTs will be to learn more about the growing spectrum of other care providers in CCC, including physiotherapists, occupational therapists, social workers, licensed practical nurses, health care aides and rehabilitation assistants who have traditionally shared responsibility for chronic disease care plan interventions (2-9). RRTs will need to look beyond tasks, to codesign processes that enable respiratory services to work synergistically with these groups. A resilient, flexible approach may be more useful than rigid attempts to carve out definitive RRT roles. These RRTs will be integral system components for education, mentorship and knowledge translation within a truly integrated multidisciplinary community service team.

There are some examples to look to, including Red Eagle Ridge (Norwood) in Edmonton, Alberta (8), and the Freeport site of Grand River Hospital, in Kitchener, Ontario (9). The RRT skill set can be a force multiplier in chronic care. Perhaps the article by Nickerson (1) will be an impetus for RRTs to offer their services in CCC facilities for a skill mix that better addresses these complex care needs.

REFERENCES

A needs assessment to determine the need for respiratory therapy in complex continuing care: A methods paper


BACKGROUND: There is an emerging demand for complex continuing care for patients who are too ill to safely return home, but for whom hospitalization in an acute care environment is unnecessary or inappropriate. Despite the need and medical complexity of these patients, few respiratory therapists are practising in this environment, and little evidence exists to guide the implementation of respiratory therapy services in this setting.

OBJECTIVE: In response to a perceived need for greater respiratory services at Saint Vincent Hospital (Ottawa, Ontario), a needs assessment was undertaken to assess the prevalence of respiratory diseases and for increased respiratory therapist coverage at this complex continuing care hospital.

METHODS: An initial literature review was conducted to guide the assessment, and identified only one tool of relevance, which was obtained and formed the basis of the further development of tools for collecting data at the hospital level and on patient care units at the facility. This needs assessment tool was expanded to include priority areas of relevance that fall within the scope of practice of respiratory therapists, and was supplemented by the analysis of administrative databases and qualitative data gathered through unit walkthroughs and unstructured key informant interviews. A health systems framework was used to structure recommendations for the development of interventions and programs for this patient population.

RESULTS: The burden of respiratory disease was significant, and included a high prevalence of inhaled medication and oxygen use, and a significant workload that could be attributed to addressing the respiratory needs of patients.

CONCLUSION: A range of tools and methods are needed to conduct needs assessments for respiratory therapy in complex continuing care. Using multiple data sources, a significant burden of respiratory diseases was present at the Saint Vincent Hospital; further studies in other complex continuing care hospitals are needed to understand the significance of these findings among this patient population more generally.

Key Words: Complex continuing care; Long-term care; Needs assessment; Respiratory therapy

Changing population needs, disease trends, and increases in the complexity and the growing burden of chronic diseases present major challenges to clinicians, with evidence regarding the appropriate management of multimorbidity (defined generally as the concurrent presence of ≥2 chronic diseases in the same individual) lacking in both primary and hospital-based care (1,2) and growing questions of the appropriateness of applying clinical guidelines to their care (3). By 2036, Statistics Canada projects that seniors will represent 25% of the Canadian population, compared with 14% in 2009 (4) and, as the population ages, it is likely that demands for long-term care services will continue to grow, as will the prevalence of multimorbidity among the adult population in general (5,6).

A growing unmet need for long-term care and home care services is creating a backlog in acute care facilities, in which significant numbers of mostly elderly patients are waiting for placement in residential care (7). In the gap between acute care hospitals and community-based long-term care, there is an emerging demand for complex continuing care for patients who are too ill to safely return home, but for whom hospitalization in an acute care environment is unnecessary or inappropriate. These patients comprise a growing population who
often have multiple medical comorbidities and complex social situations that may operate synergistically to increase their health care needs (2,5). Comprehensively addressing the needs of this patient population necessitates the application of evidence-based practices in a manner that recognizes the individual needs and priorities of these patients (8).

Little research has been conducted to evaluate models of care that correspond with multimorbid patients’ unique constellation of multidimensional problems, priorities and decision making (9). This population is frequently excluded from clinical research owing to the complex nature of their multimorbidity, and a major gap in knowledge exists for the development of care pathways for these patients as they transition across the continuum of care (10). From the perspective of patients with respiratory diseases, there have been few studies that specifically examine the needs of multimorbid patients with chronic respiratory diseases; however, there is evidence that patients with chronic obstructive pulmonary disease (COPD) often present with several other comorbidities, suggesting a need to ensure the application of integrated disease management approaches to their care (11,12).

Bruyère Continuing Care operates two hospitals outside of the acute care system, including Saint Vincent Hospital (SVH), a 336-bed complex continuing care hospital located in Ottawa, Ontario. This hospital includes a 10-bed neuromuscular ventilation unit for patients requiring chronic assisted ventilator care, and a substantial patient population with tracheostomies and other complex social and medical needs.

Respiratory therapy services are provided by a group of respiratory therapists who rotate through the hospital and provide the equivalent of one full-time position. One therapist is on site per day, five days per week, with the stated purpose of providing care for mechanically ventilated patients. The role of the respiratory therapists has expanded to include care for an increasingly large population of patients with tracheostomies, responding to consultations for patients with other respiratory conditions and responding to emergencies.

The growing role of the respiratory therapists at SVH led the senior management to request a review of the role of the service within the hospital, as well as an assessment of the overall provision of respiratory care, including policies and procedures, care pathways, and physical and human resources availability. There was a perception among clinical staff of a significant burden of respiratory diseases among the patient population. It was generally believed that an expanded role for respiratory therapists could improve the care of patients with respiratory diseases in terms of clinical outcomes and quality of life through the implementation of evidence-based practices and programs for common acute and chronic respiratory conditions. In September 2013, the Bruyère Research Institute – an independent research organization affiliated with Bruyère Continuing Care – was commissioned to conduct a needs assessment to guide the development of any respiratory programs that could be needed but were not currently provided. The present article provides an overview of the methodologies used in conducting this review, which could be used as the basis for other clinical centres to perform similar reviews in a complex continuing care environment.

METHODS

The present project was a quality improvement initiative and, therefore, research ethics review was not sought. The project was reviewed using the Alberta Research Ethics Community Consensus Initiative (ARECCI) Ethics Screening Tool, which ranked the project as a quality improvement initiative that was determined to be "somewhat more than minimal risk" with a score of 14 (13). As such, the project was discussed with the institution’s research ethics board, and was determined to be a quality improvement initiative that did not require research ethics approval. Protection of privacy and patient confidentiality were addressed through institutional policies governing the handling of personal health information.

The specific objectives of the needs assessment are summarized in Table 1, and focus broadly on estimating the prevalence of respiratory conditions among the inpatient population at the hospital; assessing the availability and suitability of the resources to care for patients with respiratory diseases; and assessing and analyzing any gaps in the care of patients with respiratory diseases and to identify opportunities for enhancing this care. Achieving this required a systematic approach for conducting a situational analysis of the current model of respiratory care, focused not only on service provision but on all aspects of the essential elements of a well-functioning health system.

A methodological approach was developed to evaluate the availability of the resources necessary for delivering respiratory care, the role of different clinicians in providing this care, and any gaps that could be identified quantitatively or qualitatively. Recognizing that the integrated management of respiratory diseases includes a range of clinical, educational and social interventions provided by an interprofessional care team, the present assessment sought to explore these interventions and roles.

An initial literature review was conducted in August 2013 to locate existing methodologies, assessment tools or frameworks that could be used to guide the analysis and needs assessment in this setting. A search of the PubMed database using the MeSH terms “respiratory therapy” and “long term care” and of the CINAHL database using the terms “Respiratory Therapy Service” OR “Respiratory Therapy” AND “Nursing Home Patients” yielded no articles of relevance. A review of the abstracts from the Canadian Society of Respiratory Therapists’ Annual Educational Conference located one abstract of a poster presentation on the conduct of a needs assessment in complex continuing care by respiratory therapists in the University Health Network (UHN) at the Bickell Centre in Toronto (Ontario), and the authors of the study were contacted and a copy of the needs assessment was obtained (14).

Needs assessment tool development

Owing to the lack of standardized needs assessments, it was determined that the best approach was to develop and pilot a needs assessment tool for collecting data during unit walkthroughs, and to supplement the tool’s data with analyses from the hospital’s administrative databases and qualitative data gathered through unit walkthroughs and unstructured key informant interviews. The Bruyère assessment tool was developed using many of the indicators and criteria from the UHN assessment as a framework, and expanded on this to include priority areas of relevance to Bruyère that fall within the scope of practice of respiratory therapists, as established in the 2011 National Competency Profile (15). The UHN tool was developed for a similarly complex, multimorbid patient population as Bruyère, but did not include patients receiving mechanical ventilation, and did not specifically query smoking cessation or chronic disease management criteria that were important to Bruyère’s programs. Therefore, it was determined that some supplementation of the tool would be necessary to generate the most comprehensive analysis.

TABLE 1
Objectives of the assessment project

<table>
<thead>
<tr>
<th>Objective</th>
<th>Description</th>
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<tr>
<td>1. To review the current model of care, practices/standards in place for</td>
<td>The purpose of providing care for mechanically ventilated patients. The</td>
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<td>the care of patients with acute and chronic respiratory diseases at SVH;</td>
<td>role of the respiratory therapists has expanded to include care for an</td>
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<tr>
<td>2. To determine the prevalence of respiratory diseases among the</td>
<td>increasingly large population of patients with tracheostomies, responding</td>
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<td>inpatient population at SVH;</td>
<td>to consultations for patients with other respiratory conditions and</td>
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<tr>
<td>3. To identify best practices in the care of patients with complex</td>
<td>responding to emergencies. The growing role of the respiratory therapists</td>
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<td>acute and chronic respiratory diseases in CCCs in Ontario;</td>
<td>at SVH led the senior management to request a review of the role of the</td>
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<tr>
<td>4. To make recommendations on the continuation, renewal and/or</td>
<td>service within the hospital, as well as an assessment of the overall</td>
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<td>expansion of respiratory therapist services at SVH and the potential</td>
<td>provision of respiratory care, including policies and procedures, care</td>
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<tr>
<td>development of a respiratory therapy department within the hospital;</td>
<td>pathways, and physical and human resources availability. There was a</td>
</tr>
<tr>
<td>5. To identify and clarify improved service delivery and efficiency</td>
<td>perception among clinical staff of a significant burden of respiratory</td>
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<tr>
<td>opportunities for the care of patients with respiratory diseases at</td>
<td>diseases among the patient population. It was generally believed that an</td>
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<tr>
<td>SVH;</td>
<td>expanded role for respiratory therapists could improve the care of patients</td>
</tr>
<tr>
<td>6. To make recommendations on a direction forward for an enhanced model</td>
<td>with respiratory diseases in terms of clinical outcomes and quality of life</td>
</tr>
<tr>
<td>of care and service delivery for respiratory patients in the CCC program</td>
<td>through the implementation of evidence-based practices and programs for</td>
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<tr>
<td>at SVH.</td>
<td>common acute and chronic respiratory conditions. In September 2013, the</td>
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<td></td>
<td>Bruyère Research Institute – an independent research organization</td>
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<td></td>
<td>affiliated with Bruyère Continuing Care – was commissioned to conduct a</td>
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<td></td>
<td>needs assessment to guide the development of any respiratory programs</td>
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CCC Complex continuing care; SVH Saint Vincent Hospital, Ottawa, Ontario
Two separate – but related – tools were developed: one for the collection of data at the hospital level; and the second for the collection of data during individual unit walkthroughs. The hospital assessment assessed the availability of hospital-wide policies and procedures and other resources that would be available institutionally, but not on individual units (such as a laboratory or radiography services). The assessment for the individual patient care units collected details on the number of patients and staff present, the availability of relevant resources (eg, piped-in oxygen, suction equipment, pulse oximeters, etc) and assessments of processes (such as the administration of medications or performing suctioning).

To address the need for an assessment of the ventilated patient population, indicators regarding the number of ventilated patients, and the availability of equipment and human resources were included. The SaferHealthcareNow! indicators for the prevention of ventilator-associated pneumonia were also included as part of the present needs assessment. Although these indicators were developed for ventilated patients in an intensive care unit with acute respiratory conditions, rather than chronically ventilated patients, they were included in the present assessment to determine their feasibility and appropriateness in this setting. The SaferHealthcareNow! indicators for rapid response teams for acute medical events were also included.

Select indicators from The Ottawa Model for Smoking Cessation (OMSC) were also included in the needs assessment to identify systematic practices for identifying smokers, and providing smoking cessation therapies and counselling to inpatients. The indicators included were taken from the OMSC Pre-Implementation Needs Assessment Form and integrated into the analysis.

Preliminary versions of the needs assessment tools were created using EpiInfo 7 (Centers for Disease Control and Prevention, Georgia, USA) and circulated among the two respiratory therapists providing clinical services at SVH at the time for their feedback, as well as among the senior leadership of the hospital. Minor changes to the data collection of human resources information were made, and a final version of the assessment tools was created in EpiInfo.

From October 22 to 25, 2013, unit walkthroughs were conducted at SVH and relevant data were collected using the needs assessment forms using a mobile version of EpiInfo 7. Data for the hospital assessment form were collected through interviews with the senior nursing leadership. Data regarding individual units were collected through interviews with the nurse managers for each unit and direct observation of the patient population and the resources available and in use to provide respiratory therapy. All data were collected by one investigator (JWN).

Other data sources

Data from the hospital’s pharmacy order entry database were requested for the same time period as the unit walkthroughs, to identify the number of patients with an order for any medication by inhalation (excluding bland aerosols and nicotine replacement therapy). These were used to validate estimates of the prevalence of certain chronic respiratory conditions, as collected during the unit walkthroughs, and to identify any patients who may have been missed by this process.

Data were also requested from the hospital’s Resident Assessment Index Minimum Dataset (RAI-MDS), which is required to be completed by all long-term care facilities in Canada. Because these data are collected on admission, following a change in status (eg, an increase in medical need) and every 90 days following either of these events, only quarterly data were available for comparison. Numbers of patients coded in the RAI-MDS as having undergone a tracheostomy, requiring oxygen therapy, as having emphysema/COPD and coded as having shortness of breath were requested for analysis and comparison.

Workload data were requested for all respiratory therapy interventions recorded in the hospital’s workload measurement software. These interventions are self-reported by clinicians. All interventions from the respiratory therapy workload measurement tool were requested and analyzed for a period of one year, and all respiratory interventions performed by nursing staff were also requested for workload analysis.

To assess the frequency of acute events, ambulance call data were requested from the Ottawa Paramedic Service for a two-year period to determine the frequency of respiratory events in a historical cohort.

Other contextual factors were collected through a document review and through unstructured interviews with key informants during the unit walkthroughs, including issues related to service delivery, the health workforce, use and availability of information and evidence, medical products and devices, and financing and leadership/governance, each related to respiratory therapy specifically and the care of patients with respiratory diseases more generally (16).

Data analysis

All data collected through the needs assessment tools were initially analyzed using EpiInfo 7, and the raw data of interest were exported and analyzed using a spreadsheet (Excel, Microsoft Corporation, USA). Data from the other databases were also analyzed in Excel. Standard descriptive statistical analyses were performed on analyzable data. Qualitative data were used to inform the interpretation of quantitative data and to identify areas of concern, but were not systematically analyzed.

RESULTS

No single data source managed to comprehensively identify all patients with respiratory diseases. As such, the triangulation of findings through different data sources was essential for estimating prevalence and for validating the interpretation of the results.

Because of significant heterogeneity in the patient population and the organization of the care provided to them, the analysis was separated into three distinct patient populations: mechanically ventilated patients and patients with tracheostomies who are mostly cared for on one respiratory unit; patients with chronic respiratory diseases throughout the rest of the hospital; and patients with acute respiratory illnesses throughout the entire hospital. This disaggregation enabled an analysis unique to these patient populations, and the presentation of recommendations specific to these groups.

A significant burden of respiratory disease was identified among the hospital’s inpatients at the time of the assessment. Thirty-two percent (n=84) of all inpatients outside of the respiratory unit were prescribed at least one medication by inhalation, while RAI-MDS data for the same period identified only five (1.3%) patients coded with asthma and 17 (4.4%) patients with COPD for the yearly quarter of interest. The most recent historical quarterly data available at the time from 225 RAI-MDS assessments identified 48 (21.3%) patients who required oxygen either continuously or intermittently; a manual tally of oxygen use during the unit walkthroughs identified 41 (15%) patients of a total of 261 currently using oxygen on the units assessed. Twelve (4.5%) patients were prescribed either continuous positive pressure airway or bilevel positive airway pressure devices. The hospital provides care to 10 chronically ventilated patients and, at the time of the assessment, provided care to 36 patients with tracheostomies. The ambulance call data provided some insight into the numbers of ambulance calls related to acute respiratory events (66 between 2011 and 2013, comprising 22.3% of all ambulance calls to the hospital, excluding nonurgent calls); however, attempts to validate these findings among key informants suggested that these figures were likely incomplete or inaccurate.

Workload data revealed that approximately 92% of all respiratory therapy work occurred on the respiratory units where all of the ventilated patients and most of the tracheostomy patients are cared for. Despite the presence of respiratory therapists during weekdays, a significant amount of nursing time was involved in caring for these patients, with 23.88% of nursing workload on these units comprised of respiratory-related procedures such as suctioning; administering oxygen therapy or performing tracheostomy care. Respiratory therapy procedures outside of this unit comprised a small number of diagnostic tests and some consultations for medically complex patients.
Only one hospital policy related to the management of respiratory patients (for oxygen administration) was located because much of this care was physician directed.

**DISCUSSION**

Despite the growing need for long-term care, the role of the respiratory therapist in this setting remains underdeveloped, with only a small number of respiratory therapists practicing in this area (17). For this reason, there is currently little guidance regarding the essential competencies or groups of services that are necessary for successfully implementing a respiratory therapy role into these environments.

Several key themes emerged from the needs assessment. First, the prevalence of respiratory conditions (both acute and chronic) was generally high among residents of long-term care facilities, and the complex continuing care hospital examined in the present needs assessment, specifically. Second, despite the high prevalence of respiratory conditions in this patient population, little research has been conducted to identify and evaluate effective interventions for the management of respiratory diseases in this setting. Third, the availability and quality of data regarding the complex continuing care patient population is minimal across the health system, which is a significant limitation for understanding the population's health. Finally, the role of respiratory therapists in addressing each of these themes remains to be firmly established.

**Burden of respiratory disease**

The present needs assessment identified a substantial burden of respiratory disease among the inpatient population of one complex continuing care hospital. Although approximately one-third of the inpatients could reasonably be presumed to have been receiving treatment for a respiratory disease, virtually none were admitted for primary respiratory conditions. Rather, most were admitted for other conditions requiring continuing care, and respiratory diseases were a comorbidity. It should be noted, however, that although the burden of respiratory diseases appears to be high, the data for which this finding has been made were not robust, and showed sufficient variation among different data sources to warrant further investigation and questioning.

Existing databases may be of use in estimating this prevalence, including the use of the RAI-MDS, which collects information regarding COPD and other respiratory diseases, and whose comorbidity classifications have been validated in this context (18,19); however, a significant gap was noted between data in the RAI-MDS and pharmacy data at our facility. Administrative health databases in Ontario have also been used to identify cohorts of patients with COPD and to describe their rates of mortality and health services utilization (20,21); however, the RAI-MDS and the administrative databases have never been cross-validated for identifying COPD patients. There is a further need to correlate these prevalence data with important outcomes, such as mortality and health services utilization, and to identify predictors of these outcomes such as socioeconomic status, place of residence and access to health services, which are important determinants of respiratory health (22).

It is clear that additional clarification will be necessary to better understand the respiratory patient population in complex continuing care, including the development of more standardized measures and approaches. Of the 32% of patients prescribed some medication by a respiratory therapist in this setting, only a small number were admitted for primary respiratory conditions, with the majority of patients having more heterogeneous, comorbid needs. Applying evidence-based interventions to this patient population will likely necessitate the adaptation of existing evidence to a new context, for which there may be several barriers (24). Further research is required to understand the existence and quality of the evidence for respiratory therapy in complex continuing care, and to identify gaps in the research that ought to be addressed to ensure high-quality patient care. Presently, it appears that few studies have specifically been conducted in this care environment with this patient population. The absence of contextually appropriate evidence leads to a gap in clear guidance on the development of interventions and the composition of the care teams required to effectively manage respiratory diseases in this setting.

Several promising practices likely exist from acute, primary and home care settings for managing respiratory conditions in the complex continuing care setting, including evidence-based best practices for both acute and chronic respiratory diseases (25-27). However, the application of single-disease guidelines to multimorbid patients is controversial and requires further exploration (28). Addressing this evidence gap will require further research and evaluation of existing initiatives involving unique interventions and care teams, including the role of respiratory therapists in this setting.

**Needs assessment design**

Several questions in the Bruyère assessment tool referred to quantitative data that ultimately were not part of the final analysis, such as the number of staff present during various shifts. These data formed a component of the contextual analysis, enabling a more nuanced understanding of the potential systems-level stressors that exist on units and at the bedside, and the role that respiratory therapists can play in delivering patient care through the identification of gaps in coverage. The assessment included several metrics for standards of care from the acute care environment (eg, indicators for both ventilator-associated pneumonia and for rapid response teams) that, although relevant, did not specifically apply in the context of complex continuing care and likely require adaptation to this care environment despite their relevance. The development of key performance indicators to accompany the expansion of respiratory therapy in the long-term care and complex continuing care environment may be an area for future research that would drive innovation and improvements in clinical practice.

**Role of respiratory therapists**

There is growing concern in Canada for the future need for long-term care and complex continuing care beds as the population ages (29). Access to these services is currently poor, with many seniors waiting to be discharged from acute care to long-term care after their acute needs have been met (30).

Addressing the complex medical needs of subacute hospitalized patients necessitates ensuring that comprehensive respiratory services are available for the management of acute and chronic respiratory conditions, both of which appear to be prevalent and important predictors of health outcomes in this population (23,31). Respiratory therapists bring a unique skill set to the long-term care environment, with expertise in respiratory disease management, critical care, airway management and basic therapeutics, among others. Existing evidence demonstrates that in the acute care setting, respiratory therapist-driven care for asthma and COPD reduces health care costs and adverse events, while increasing adherence to appropriate therapies (32,33). Similar results have been shown with respiratory therapy consult services for non-intensive care unit patients and ventilator weaning (34,35). Research is needed to evaluate whether similar effects can be demonstrated in the complex continuing care patient population.

**CONCLUSION**

The results of the present assessment should be leveraged in two significant ways: first, to improve the availability of information and data.
on the prevalence of respiratory diseases and the availability of respiratory services in complex continuing care settings; and second, to serve as a starting point for improving the care of patients with respiratory diseases in complex continuing care.

In response to the results of the present needs assessment, the development of inpatient programs are underway to increase the coverage of respiratory therapy services, specifically with regard to the implementation of smoking cessation and COPD programs. Future work is planned to examine the role of respiratory therapists in the ventilator and tracheostomy care programs.

Given the high prevalence of respiratory diseases among patients in the complex continuing care hospital evaluated specifically, and long-term care facilities generally, there is a need to better understand the burden and impact of these diseases on patient outcomes and health services utilization, and to implement integrated disease management programs in response. Evidence exists to support the role of respiratory therapists as central to these initiatives; the logical next step is to extrapolate the evidence base derived from other settings to the long-term care environment and to carefully evaluate its impact.

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Endotracheal suctioning practices of nurses and respiratory therapists: How well do they align with clinical practice guidelines?

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BACKGROUND: A common procedure within intensive care units (ICUs) is the suctioning of respiratory secretions in patients who have been intubated or who have undergone tracheostomy. Previous studies have shown a wide variation in suctioning practices, and although current evidence does not support the routine practice of normal saline instillation (NSI), anecdotally, this is believed to be a common practice.

OBJECTIVE: To examine the suctioning practices of registered nurses (RNs) and registered respiratory therapists (RRTs) in six hospital ICUs in Ontario, with special attention devoted to the use of NSI.

METHODS: A 24-question, self-administered survey was distributed to 180 participants (90 RNs and 90 RRTs) working in the ICU of six hospitals in Ontario. The survey addressed individual suctioning practices within the ICU.

RESULTS: The survey response rate was 96%. There were many similarities between the RRT and RN groups, with both reporting high use of NSI. Both groups observed side effects following NSI with suctioning including decreased oxygen saturation, patient agitation and increased volume of secretions. A significant number of participants from both the RN and RRT groups were unaware of the existence of suctioning and/or NSI protocols in the ICU. Some respondents reported that they routinely suctioned mechanically ventilated patients rather than as required.

CONCLUSION: RNs and RRTs continue to practice NSI despite evidence-based practice guidelines suggesting that this therapy may be detrimental to patients. Increased awareness of best practices with respect to endotracheal tube suction generally, and NSI specifically, should be the focus of professional education in both groups of ICU staff.

Key Words: Artificial airway; Endotracheal suctioning; Normal saline instillation; Nursing; Practice guideline; Respiratory therapy

Many areas of health care practice have been viewed through the lens of evidence-based practice (EBP), with the intent of examining current practices to ensure that patients are provided with optimal and consistent care based on high-quality evidence for benefit. EBP has been widely adopted both at the policy and clinical levels, with a key element including the creation of evidence-based clinical guidelines. Clinical practice guidelines are a written guide for health care providers to follow for a specific practice element, and aim to optimize the effectiveness and efficiency of treatments. Well-designed protocols have been shown to improve clinical decision making and effectiveness of treatments (1-4). Despite the development of clinical guidelines, there continues to be discrepancies between best practice based on evidence and actual practice (5,6). Within intensive care units (ICUs), one such common procedure is the suctioning of respiratory secretions in patients who have been intubated or who have undergone tracheostomy (7). The traditional goal of suctioning is to aid in maintaining airway patency and prevent complications related to retention of secretions (8). Sole et al (7) conducted a large study involving 1665 registered nurses (RNs) and registered respiratory therapists (RRTs) at 27 sites throughout the United States and concluded that policies vary widely and do not always reflect current research. In their study investigating nurses, respiratory therapists and physiotherapists in Ontario, Brooks et al (9) similarly found wide variation in suctioning practices. These authors also found that one of the practices used by almost all of the respondents was instillation of normal saline (NSI) before suctioning. Although anecdotal evidence suggests that the practice (NSI before suctioning) remains common, this study was completed more than a decade ago and there has been little research to examine whether this remains the case or whether there is significant benefit from the practice.

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The effectiveness of NSI before suctioning was first investigated almost four decades ago (10), with various benefits attributed to NSI including loosening thick secretions and enhancing cough stimulation, which in turn mobilizes and increases secretion clearance and decreases the viscosity of pulmonary secretions (11,12). Concern has also been raised that NSI before suctioning may result in decreased oxygen saturation (7,13). For example, in a comparison of oxygen saturation following suctioning with or without NSI, Giakoumidakis et al (14) found that although NSI resulted in the removal of more secretions, it also produced a prolonged fall in patient oxygenation. Two reviews of the limited literature regarding this topic have both concluded that there was little evidence to support its continued use, with Paratz and Stockton (15), and Halm and Krisko-Hagel (16) also concluding that there was little evidence of safety risks. Paratz and Stockton (15) did, however, also note there was paucity of high-quality studies investigating this issue. The use of NSI to aid in the mobilization of secretions was supported by the 1993 American Association for Respiratory Care (AARC) clinical practice guidelines (17). However, in 2010, an update of these guidelines recommended that “endotracheal suctioning should be performed only when secretions are present, and not routinely”; and that “It is suggested that routine use of normal saline instillation before endotracheal suction should not be performed” (18). Most practice guidelines no longer recommend NSI into an artificial airway due to lack of evidence that it helps to maintain airway patency, and it is suggested that routine instillation be discontinued altogether due to adverse effects (19). The change in guidelines, and previously documented widespread use of this practice together with anecdotal evidence, suggests it is timely to re-examine this practice.

The objective of the present survey was to examine the suctioning practice of RNs and RRTs working in six hospital ICUs in Ontario, with special attention devoted to the use of NSI. The present study aimed to determine whether and why the surveyed RNs and RRTs continue to instill normal saline before suctioning patients with artificial airways.

METHOD
Survey design and development
A survey was used to gather information from RNs and RRTs working in ICUs at six hospitals in Ontario. The survey was entitled “Suctioning an Artificial Airway in the ICU,” and requested specific information about the practice and knowledge of participants with respect to the use of NSI before endotracheal suctioning, as well as other suctioning practices. A 24-question survey was developed by the authors and then reviewed by a small group of health professionals before finalization and being sent to participants. This small review group consisted of two RRTs who worked outside the geographical area being surveyed, one RN who was responsible for research in an ICU and one physician with research experience. The questions in the survey were developed based on a review of the peer-reviewed scientific literature and finalized from input from the small review group. The questionnaire comprised four sections that collected data regarding: demographics; normal (intubated) patient care practices within the ICU; practices relating to NSI before suctioning; and influences on individual practice.

Participants
The survey was mailed to managers in six ICUs at community hospitals within 50 km of the Trillium Health Centre (Mississauga, Ontario). Managers informed their staff about the survey via e-mail or in meetings and the questionnaires were left in staff rooms for any interested parties to complete. The goal was to have a total of 90 RNs and 90 RRTs complete the surveys. Surveys were returned to the principal investigator by a postage-paid envelope provided with the questionnaire. Participation was voluntary and no identifying information was collected, ensuring anonymity; responses were confidential and not disclosed to the unit managers.

Statistical analysis
Descriptive statistics were calculated for each question, both as a total and based on respondent professional group. Comparative statistics between RRT and RN responses was performed using a Pearson χ² test; P<0.05 was considered to be statistically significant. SPSS version 20 (IBM Corporation, USA) was used to perform data analysis.

Research ethics board approval
The present study, which was considered to be minimal risk, was approved by the School of Biomedical Sciences Ethics in Human Research Committee of Charles Sturt University (Burlington, Ontario) and the Trillium Health Centre’s Ethics Committee. A letter of introduction and explanation accompanied each survey. Participant informed consent was implied by the return of a completed survey.

RESULTS
Surveys were distributed to 90 RNs and 90 RRTs employed at six ICUs in Ontario. Of these, 83 completed surveys were received from RNs and 87 from RRTs, corresponding to a response rate of 94% and 97%, respectively.

Overall, approximately one-half (48%) of the respondents had a Baccalaureate degree as their highest level of education, with only 2% of respondents having a Master’s or doctoral degree; the remaining respondents possessed a diploma. Most individuals in each group held either a degree or diploma; however, there was no significant differences between the groups: diploma – RN 44%, RRT 56% (P=0.219); degree – RN 57%, RRT 43% (P=0.065). No RNs held a Master’s or doctoral degree compared with 5% of RRTs (P=0.122).

Most respondents had graduated between 2000 and 2010 (40%), followed by graduation in the periods 1990 to 1999 (33%), 1980 to 1989 (18%) and before 1980 (9%). One-half (50%) of the respondents had been working in the ICU ≥10 years. Of the remainder, approximately equal numbers had worked from two to five years and six to 10 years (26% and 21%, respectively); those who had worked in the ICU for <1 year accounted for 3% of respondents. Almost all (97%) respondents worked 12 h shifts with the remainder working 8 h shifts. There was no statistically significant difference between the RNs and RRTs in terms of year of graduation (P=0.263) or years working in the ICU (P=0.773).

The type of humidification used for ventilated patients in the ICUs employing respondents was split between those using heat and moisture exchanger (RN 31%, RRT 41%), and both heat and moisture exchanger and heated chamber (RN 68%, RRT 59%); only one respondent reported use of heated chamber only. There were few statistically significant differences between these two groups with regard to questions relating to artificial airways suctioning practice (Table 1). Differences were observed in awareness of ventilator-assisted pneumonia rates, routine preoxygenation of patients, awareness of protocols for mouth care and checking of endotracheal tube cuff pressures. During a shift, suctioning frequency was primarily as necessary (PRN); however, the data also showed that RRTs and, to a lesser extent, RNs were also suctioning on 2 h or 4 h schedules (P=0.003). For RNs, PRN frequency was 91.6% versus 71.3% for RRTs with remaining responses for RNs 6.0% 4 h and 2.4% 2 h compared with 17.2% 4 h and 11.5% 2 h for RRTs.

When asked about frequency of use of NSI before suctioning, there was a statistically significant difference between the responses from RNs and RRTs (P=0.014). Of the RRTs, 11.5% indicated that they never used NSI, 49.4% used it rarely, 36.8% frequently and 2.3% always. In contrast, RNs indicated that NSI was used in all patients at least some of the time, with 57.8% rarely using NSI, 41.0% frequently and 1.2% always (no RNs indicated they never used NSI).

Those who responded that they use NSI were asked further questions about instillation practices (how the normal saline was prepped, why instillation was used, what effects they noted following instillation and what influenced suctioning practices). The majority (97.5% of RRTs, 96.4% of RNs) of respondents used sterile nebul
TABLE 1

Responses to questions regarding suctioning practices in the intensive care unit (ICU)

<table>
<thead>
<tr>
<th>Question</th>
<th>RN (n=83)</th>
<th>RRT (n=87)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does your ICU have a suctioning protocol for intubated patients?</td>
<td>Yes 49</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No 30</td>
<td>19</td>
<td>0.241</td>
</tr>
<tr>
<td></td>
<td>Don’t know 21</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Do you routinely suction mechanically ventilated patients with an artificial airway?</td>
<td>Yes 86</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sometimes 1</td>
<td>0</td>
<td>0.590</td>
</tr>
<tr>
<td></td>
<td>No 13</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Do you routinely pre-oxygenate patients prior to suctioning?</td>
<td>Yes 60</td>
<td>77</td>
<td>0.021</td>
</tr>
<tr>
<td>Most commonly used suction type</td>
<td>Open 1</td>
<td>1</td>
<td>0.973</td>
</tr>
<tr>
<td></td>
<td>Closed (in-line suction catheters) 99</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>Does your ICU have a protocol for routine mouth care?</td>
<td>Yes 84</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No 1</td>
<td>0</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>Don’t know 15</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Does your ICU have a protocol for daily checking of ETT cuff pressures?</td>
<td>Yes 93</td>
<td>77</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>No 5</td>
<td>7</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>Don’t know 3</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Are you aware of your unit’s VAP rate?</td>
<td>Yes 29</td>
<td>60</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Does your ICU have a protocol relating to NSI prior to suctioning?</td>
<td>Yes 15</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No 39</td>
<td>53</td>
<td>0.098</td>
</tr>
<tr>
<td></td>
<td>Don’t know 47</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

Data presented as % unless otherwise indicated. Values may sum to >100% due to rounding. ETT Endotracheal tube; NSI Instillation of normal saline; RN Registered nurse; RRT Registered respiratory therapist; VAP Ventilator-associated pneumonia

to prepare the normal saline. The remaining (3.6%) RNs used a pre-drawn syringe although the RRTs drew the syringes themselves (2.5%). The volume of saline used was similar between groups, with most using 1 mL to 2 mL (RRT 50.0%; RN 41%), or 3 mL to 5 mL (RRT 46.2%; RN 51.8%); the remaining respondents used >5 mL. Most respondents suctioned the airways immediately following the NSI (RRT 79.2%; RN 67.1%). The remainder waited up to 1 min (RRT 16.9%; RN 30.5%) or 1 min to 2 min (RRT 3.9%; RN 2.4%). Respondents were also asked why they used NSI before suctioning (Figure 1) and whether they had observed any effects following NSI (Figure 2). Most respondents had multiple reasons for using NSI and all had observed ≥1 adverse effect(s) on patient(s) following NSI. The only statistically significant differences between the two groups were in relation to the use of NSI to thin secretions (RRT 10.3% versus RN 1.2%; P=0.018) and that NSI increased the volume of secretions (RRT 29.6% versus RN 8.9%; P=0.001).

The greatest influence on both RNs’ and RRTs’ practice was reported to be EBP guidelines followed by initial training and continuing education (Figure 3). There was no statistically significant difference between the two groups in this area (P=0.220). When asked whether they had attended any training or workshops that discussed suctioning of mechanically ventilated patients, most reported ‘no’ (45.3% overall; RRT 34.5% versus RN 56.6%; P=0.005) followed by ‘yes, but it was more than a year ago’ (RRT 32.25 versus RN 16.9%; P=0.022). Approximately 16% overall (RRT 19.5% versus RN 13.3%; P=0.306) reported they had attended training in the past 12 months, where suction was discussed and the remainder could not recall whether it was discussed (RN 13% versus RRT 14%).

DISCUSSION

In the present study investigating suctioning practices of ICU RNs and RRTs, there were few demographic or practice differences between the two professional groups. Most RNs and RRTs reported that they routinely suctioned mechanically ventilated patients and almost all respondents were aware of ICU protocols regarding checking of endotracheal tube cuff pressures and oral hygiene. This was not the case for suctioning protocols in general and specifically related to NSI before suction.

It was beyond the scope of the present study to investigate the documentation held in each ICU and, hence, it is unknown whether lack of knowledge of particular protocols reflects a lack of protocols or a lack of individual awareness of protocols. That the ‘don’t know’ responses for the question relating to knowledge of NSI protocols was double that for other protocols (47% for RNs and 40% for RRTs) may suggest that this is an area that is not discussed within the ICU. Despite the lack of evidence for benefits of NSI before suctioning (and concerns about possible
adverse effects), that this practice is not a recommendation in current clinical practice guidelines and a lack of knowledge about ICU protocols regarding NSI, all RNs and 89.5% of RRTs in the present study used NSI before suction at least some of the time. The most frequent reasons given for using NSI were to clear a mucous plug and/or to loosen secretions. Respondents also witnessed a range of adverse effects including decreased oxygenation, patient discomfort, increased heart rate and/or increased volume of secretions. The high level of NSI use reported in the present study is consistent with that reported previously (9,20,21); however, in contrast to the study by Schwenker et al (20), we report a lower level of combined ‘always’ and ‘frequent’ use of NSI. Schwenker et al (20) report ‘always + frequent’ use by 83% of RNs and 75% of RRTs, compared with 42.2% of RNs and 39.1% of RRTs in the present study. This may suggest a shift away from more routine use of NSI and toward the recommendations of the AARC that “routine use of normal saline instillation before endotracheal suction should not be performed” (18).

An interesting finding from our study was that 8.4% of RNs and 28.7% of RRTs appeared to suction patients on a regular basis (other than PRN). It is unclear whether this reflects a misunderstanding of the question (perhaps the option responses other than PRN were seen as an estimate of actual practice) or whether suctioning was performed at these times regardless of need. A lack of knowledge in ICU RNs regarding endotracheal tube suctioning has been reported by both Day et al (21) and Negro et al (22). Although the study by Day et al (21) was small (n=16), the study reported by Negro et al (22) was larger (n=247). ICU nurses from 11 Italian hospitals were surveyed on their knowledge of the 2010 AARC clinical practice guidelines and found only 58% of questions were answered correctly. These authors also reported higher knowledge by more experienced nurses; however, only 2.5% answered nine of the 10 questions correctly.

According to some authors, there continues to be a large discrepancy between EB and actual practice (23), and Beechey (24) suggested that many nursing and respiratory therapy practices are still based on experience and routine, rather than on evidence, and that a gap between knowledge (scientific evidence) and practice still exists. A large study involving 1665 RNs and RRTs at 27 sites in the United States found that 83% of respondents did not base their suctioning practice on evidence-based protocols, instead relying on their basic educational programs or the routine practice of their colleagues (7). The results of the current study are consistent with these findings and suggest that in the ICUs participating in the present study, best practice was followed in some suctioning practice areas (eg, oral care); however, there are gaps between best practice and actual practice in other areas.

Implementing changes to practices within health care can be complex and much has been written about implementing EB into a range of health areas. Although there is consensus that EB can improve the effectiveness and efficiency of health care, and improve patient outcomes, there can be significant challenges in adopting practices. Competing workload pressures, institutional and individual resistance to change, lack of EB champions, poor change management processes and lack of access to quality information can act as barriers to implementation, even among those most willing to adopt new practices (25-27). Critical to many implementation strategies is building knowledge in the topic of interest (28). Although there is limited literature specifically relating to improving adoption of EBPs in endotracheal suctioning practice, both McKillop (29) and Day et al (21) have demonstrated knowledge and practice improvements following interventions. Although the methods used by the two studies were different (McKillop [29]: best practice information checklists; Day et al [21]: structured teaching program) both programs aimed to increase participant awareness of current best practice.

It is a concern in the current study that while approximately one-half of the respondents in both groups stated that they were influenced by EB protocols or guidelines, there is a gap between best practice and self-reported practice. In addition, less than one-half recalled attending training or workshops covering endotracheal suction practice in the recent past. This is a training gap and an opportunity for the profession or employers to improve the quality of care and, hence, patient outcomes within the ICU.

There were several limitations to the present study; specifically, the geographical proximity of participants working within 50 km of the Mississauga Hospital. The participants may have received their formal education at the same institutions and clinical sites, which may have influenced their practice. The number of participants (n=180) does not constitute a large study and may be viewed as a limitation.

**CONCLUSION**

The present study identified a gap between what is considered best practice and what is used within groups of community hospital ICUs. This highlights the need for greater education for both RNs and RRTs with respect to endotracheal tube suctioning generally and, specifically, with regard to the use of NSI. The routine practice of NSI before suctioning an artificial airway is not recommended and may be detrimental to patients; however, current practice guidelines do not describe the conditions under which NSI may be used. The risk may outweigh the benefit and, as such, should be carefully considered before engaging in this practice. Lack of clarity regarding best practice will contribute to inappropriate and, possibly, unsafe procedures, which in turn reduces the quality of care and increases the potential of poor patient outcomes. Suctioning of an artificial airway is not a benign procedure and, as such, health care providers must be aware of the potential complications and side effects.

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

**REFERENCES**

Coaching patients during pulmonary function testing: A practical guide

HJ Cheung MHS RRT CRE RCPTP1, Lawrence Cheung MD FRCP FCCP2

Pulmonary function tests are an important tool to assist in the diagnosis and management of patients with respiratory disease. Ensuring that the tests are of acceptable quality is vital. Acceptable pulmonary function test quality requires, among others, optimal patient performance. Optimal patient performance, in turn, requires adequate coaching from registered respiratory therapists (RRTs) and other pulmonary function laboratory personnel. The present article provides techniques and tips to help RRTs coach patients during testing. The authors briefly review the components of pulmonary function testing, then describe factors that may hinder a patient’s performance, list common mistakes that patients make during testing, and provide tips that RRTs can use to help patients optimize their performance.

Key Words: Diffusion capacity; Flow volume loops; Nitrogen washout; Plethysmography; Quality control; Slow vital capacity

Les conseils aux patients pendant l’exploration fonctionnelle respiratoire : guide pratique

L’exploration fonctionnelle pulmonaire est un outil important pour contribuer au diagnostic et à la prise en charge des patients atteints d’une maladie respiratoire. Il est essentiel de s’assurer que les tests sont d’une qualité acceptable. Pour parvenir à une analyse des explorations fonctionnelles respiratoires de qualité acceptable, il faut, entre autres, obtenir le rendement optimal du patient. Pour ce faire, l’inhalothérapeute et le reste du personnel du laboratoire de fonction pulmonaire doivent donner des conseils pertinents. Le présent article présente des techniques et des trucs pour aider les inhalothérapeutes à conseiller les patients pendant les tests. Les auteurs analysent brièvement les éléments de l’exploration fonctionnelle pulmonaire, décrivent les facteurs qui nuisent au rendement du patient, énumèrent les erreurs courantes que font les patients pendant les tests et donnent des conseils à l’exploration fonctionnelle pulmonaire que les inhalothérapeutes peuvent utiliser pour aider les patients à optimiser leur rendement.

PRINCIPLES OF INSTRUCTION

Instructing patients about proper test performance in a short period of time can be challenging. Although models of instructional design exist (20,21), they rely on lengthy instruction over multiple phases and are difficult to apply to this context. Instead, encouraging optimal effort from patients during pulmonary function testing appears more akin to a trainer boosting athletic performance, in which verbal encouragement has been shown to help (22).

Giving patients a descriptive information pamphlet (23) or showing them a demonstrational video (24) before testing can prime them for what to expect. During testing, the RRT should exhibit enthusiasm, allay the patient’s anxiety, convey simple instructions, demonstrate each test, give vocal encouragement and provide feedback on performance. Others have found that observing the patient’s nonverbal cues, such as facial expressions and body language, and using one’s own body language effectively can enhance the patient’s test performance (25). Some of these coaching suggestions are listed in Table 1.

The sequence of events during testing includes instructing the patient on the proper technique, demonstrating the procedure, performing the test on the patient, assessing for acceptability and repeatability, and providing corrective feedback on the patient’s technique when needed.

OVERVIEW OF PULMONARY FUNCTION TESTING

While many different tests can evaluate lung function (26), the discussion is limited to the tests included in a typical PFT report. These tests include measurements of the slow vital capacity (SVC), forced vital capacity (FVC) and flow volume loops (FVL), diffusing capacity for carbon monoxide (CO) (DLCO) and lung volumes. The SVC is a measurement of the tidal volume, inspiratory reserve volume and expiratory reserve volume. These volumes are used together with other tests to measure and calculate all of the volumes and capacities of the lung, including inspiratory capacity and functional residual volume (FRC). The SVC should be performed before FVC because the latter may induce bronchospasm, fatigue the patient.
and hamper the test’s repeatability (27). The SVC should also be performed before the DLCO measurement. This is because an accurate DLCO measurement requires the patient to inhale at least 85% of the vital capacity (VC); thus, it is important to know the VC beforehand (16). The FVC and FVL are measurements of volume and flow. They are often performed on their own to assess airflow limitations. The DLCO is a measurement of how efficiently the lungs transfer gases across the alveolar-capillary membrane.

Lung volumes are measured using plethysmography. This involves briefly sealing the patient within a body box to derive the FRC, applying Boyle’s law relating volume and pressure under constant temperature (28). Lung volumes are also measured using the open-circuit nitrogen (N2) washout method that washes out N2 in the lungs using 100% oxygen (O2) (28).

Each of these components is discussed in more detail.

SVC
The SVC can either be measured during a slow, gentle, maximal expiration after a maximal inspiration or alternatively, during a maximal inspiration following a slow, gentle, maximal expiration (29). At least three acceptable VC trials are needed, and a difference $>$0.150 L between the first and next largest trial prompts the need for further trials (14). If performed correctly, the patients’ SVC should typically be $2\times$FVC due to the lack of dynamic compression on the airways (29-31).

After demonstrating the test, the patient is instructed as follows:

Please start with normal breathing. After a few breaths, I want you to fill your lungs completely, then blow out gently all the way until you are empty.

Alternatively, the patient can exhale first and then inhale fully, in which case, he or she is instructed to “fill your lungs as completely as you can” after a complete, gentle exhalation.

Patients may fail to achieve maximal inspiration and expiration, as indicated by the lack of a plateau on the graphical display of the volume versus time curve; this will underestimate their lung volumes. When this occurs, feedback is provided by showing them the graphical display as an incentive to improve their effort on subsequent tests. It has been found that that a tactile cue, such as placing a gentle hand on the shoulder of the patients and telling them to continue their inspiration or expiration until the hand is lifted, can help. Alternatively, a time cue, such as asking them to continue their effort for “another second” (or some other arbitrarily short and achievable duration) is used, once they have almost reached a plateau to coax that last small – but measurable – volume of gas from them. These coaching suggestions are listed in Table 2.

FVC and FVL – pre- and postbronchodilator
FVC is a measurement of the maximum volume of gas a patient can exhale – as forcefully and quickly as possible – after a maximal inspiration. The RRT must obtain three trials of acceptable quality, up to a maximum of eight. Acceptable trials are free from artefact and exhibit satisfactory start and end of test criteria, as defined by the ATS/ERS statement (14).

If the test is being performed to confirm or establish the presence of airflow limitation without treatment, withholding bronchodilators before the baseline test will aid this purpose (32). In this case, the physician may instruct the patient to refrain from using short-acting inhaled medications within 4 h of testing, long-acting beta2-agonists within 12 h of testing, and long-acting anticholinergics and leukotriene receptor antagonists within 24 h of testing (32). On the other hand, if the test is being performed to assess a patient’s response to treatment, the physician may instruct the patient to continue these medications.

After demonstrating the test, the patient is instructed as follows:

Please start with normal breathing. Then I want you to take a huge breath in until your lungs are completely full, and blast it out as hard and as fast as you can until you feel you are completely empty and cannot blow out further. Then I want you to take another big, fast, full breath in.

It is critical that the patient takes a maximal inspiration before expiration because a reduced inspiration will lead to a smaller exhaled total volume, likely resulting in data that lack repeatability (33). Patients are reminded to relax their neck and shoulder muscles to avoid syncope.

Patients may perform an exhalation that is hesitating or insufficiently fast at the beginning (leading to a back-extrapolated volume on the FVC, which fails to meet ATS/ERS standards), inadvertently vocalize and partially close their glottis during the test, terminate their effort too soon or incompletely inhale before the exhalation (27).

A hesitating start may be due to transient breath holding between inspiration and expiration: the patient is informed that exhalation should occur immediately after inspiration. If the problem persists because the patient fails to react quickly enough to the instruction to exhale, the command to “blast” is synchronized so that it occurs just before full inspiration. Of course, the danger then becomes that the patient exhales before maximal inspiration; therefore, this adjustment in timing requires some finesse. Others have observed that startling the patient into a fast exhalation also helps (23).

If patients vocalize during exhalation, this will lead to partial glottic closure, impediment to airflow and data that are not repeatable (27). The difference between exhaling with and without vocalization is demonstrated and patients are reminded to “keep the throat open” to prevent vocalization from occurring.

If patients terminate the exhalation too soon, tactile and time cues as described in the section on the SVC test are used. Also, patients may be instructed to “suck in” their abdominal wall muscles near maximal expiration to distract them from terminating the expiration. Patients often feel as though they have no further volume to exhale long before true maximal expiration; therefore, the RRT needs to provide encouragement and direction until completion of the test. Ultimately, developing a rapport with the patients and securing their trust is instrumental in optimizing their effort and convincing them to continue exhaling when they feel like they cannot. Some of these coaching suggestions are listed in Table 3.

Incomplete inhalation before the exhalation will likely result in data that are not repeatable. As with the SVC test, tactile or time cues are used to coax maximal inspiration from them.

To perform postbronchodilator testing, the RRT should administer four inhalations of 100 μg of salbutamol at approximately 30 s intervals – for a total of 400 μg – using a valved holding chamber. To administer the medication, the patient maximally exhales slowly and the RRT depresses the metered-dose inhaler (after shaking it for 5 s) into the valved holding chamber. Subsequently, the patient maximally inhales the medication from the chamber slowly and holds his or her breath for 10 s. After the RRT has administered all four doses of medication, the patient must then perform three further acceptable trials within 10 min to 15 min after receiving the bronchodilator (14). In clinical practice, the postbronchodilator testing is performed after the other PFT components have been completed.

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**TABLE 1**

General coaching suggestions

<table>
<thead>
<tr>
<th>Coaching suggestion</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide demonstration and/or video along with description</td>
<td>Enables the patient to see effort expected during the test and clarifies the instructions given</td>
</tr>
<tr>
<td>Provide vocal encouragement throughout the test</td>
<td>Encouragement motivates patient to provide maximal effort</td>
</tr>
<tr>
<td>Provide feedback on performance</td>
<td>When specific, feedback enables the patient to improve or maintain performance as required</td>
</tr>
</tbody>
</table>

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DLCO

During the single breath measurement of DLCO, the patient inhales a gas mixture containing 0.3% CO, 21% O₂, 0.3% methane or other tracer gas, and N₂ to make up the balance (34). The patient inhales this gas to total lung capacity after first exhaling to residual volume (16). Inhalation must occur quickly (35), and ≥85% of the total inhaled volume should be inspired in <4 s because lesser volumes cause significant reductions in the DLCO (36). The tracer gas is used to estimate this inhaled alveolar volume and also measures the initial dilution of the CO (37). After a 10±2 s breath-holding period starting at total lung capacity, the patient conducts a smooth, gentle exhalation (16) over a period of 4 s and a sample of exhaled breath is collected and analyzed to determine the amount of CO that has transferred across the alveolar-capillary membrane. Two acceptable trials within 3 mL/min/mmHg of one another should be obtained, up to a maximum of five trials, according to the 2005 ATS/ERS standards (16).

If clinically safe, the patient should be off any supplemental O₂ for at least 10 min before the test (16) because an elevated alveolar partial pressure of O₂ can decrease the affinity of hemoglobin for CO (thus, underestimating the DLCO (37)). At least 4 min must pass between DLCO tests to allow the lung to eliminate the test gas (16).

After demonstrating the test, the patient is instructed as follows:

- Please start with normal breathing. Then I want you to take a big breath in and blow out empty, and as you do this I will switch you to the test gas. After blowing out as much as possible, take the strongest, fullest breath that you can, hold it for ten seconds and then blow it out for me.

- Patients may inhale an inadequate volume (<85% of their VC) during the test, leading to a reduced CO uptake and an underestimate of their true DLCO (37). Patients also may inadvertently perform a Valsalva manoeuvre (attempted exhalation against a closed glottis) or Muller manoeuvre (attempted inspiration against a closed glottis) during the breath hold. The former could decrease pulmonary capillary blood volume and decrease DLCO, whereas the latter could have the opposite effect (38).

To encourage the patient to quickly and smoothly inhale an acceptable volume in the requisite time, “Up, up, up, up!” is exclaimed in an animated voice during inhalation, quickly raising our hand to the ceiling with palm flat and facing upward – similar to a conductor guiding a musician. If patients perform a Valsalva or Muller manoeuvre, they are informed and instructed to refrain from doing it.

Plethysmography

In this test, the patient gently pants – at a frequency of 0.5 Hz to 1 Hz and pressures between ±10 cmH₂O (39) – against a closed shutter at the end of a normal expiration to FRC, creating a pressure change that is measured using a transducer. When there is no airflow, mouth pressure equals alveolar pressure. Compared with the N₂ washout technique (described later), FRC measured using plethysmography (FRCPleth) may be higher in patients with airflow obstruction because it accounts for all thoracic gas, including the gas that is trapped and unable to communicate with the larger airways (15).

However, FRCPleth can also overestimate lung volumes in patients who pant at a frequency >1 Hz (39-41) or those with severe airflow obstruction (42). Three to five trials of panting at the appropriate frequency and pressure should be obtained, which will result in a series of straight lines that are almost superimposed on one another on the plot of plethysmograph pressure versus mouth pressure. (43).

At least three values of FRCPleth – calculated using the slope of the line in the plethysmograph versus mouth pressure plot – that are within 5% of each other should be obtained and the mean value should be reported (15).

After demonstrating the test, the patient is instructed as follows:

- I will be closing the door on the box for the next test. Please start with normal breathing with your hand pressing gently on your cheeks. I will then close a shutter and cut off your air for a few seconds. While the shutter is closed I want you to gently pant. (Note – we demonstrate the correct panting frequency during our instruction). When the shutter opens up again, you can go back to normal breathing. You do not need to try very hard with this test at all. Tiny, little pants back and forth is all I need.

- As the patient is performing the test, the RRT sitting outside the box coaches the patient on his or her technique. It is easiest to perform the tests serially without opening the box door and altering the temperature inside; however, the door may need to be opened for the patient’s comfort.

- Patients may pant too fast or too slow, or pant with too little or too much volume. They may pant ‘asymmetrically,’ with one part of the pant (either inhalation or exhalation) performed correctly but the other part of the pant performed incorrectly. Alternatively, patients may be too anxious or claustrophobic to sit in the box.

To coach panting at the appropriate frequency, some use a metronome (15). We move our hands back and forth to demonstrate the correct panting frequency and use the force of our hand motions to signal the use of more or less panting volume. For patients who are unable to sit in the box despite our reassurances and coaxing, we perform an N₂ washout (FRCN₂) to obtain FRC.

FRCN₂

The FRCN₂ uses an open-circuit system in which the patient breathes 100% O₂ for several minutes until the amount of exhaled N₂ is washed out of the lungs (28). At least one test must be obtained. If the patient is on supplemental O₂, they need to be off this for at least 15 min before the test (15).

After demonstrating the test, the patient is instructed as follows:

- Please just breathe normally throughout this test. You are breathing through a regulator so it will feel a bit like you are breathing through a straw. When I switch you over to the oxygen supply, you may hear a ‘click’ as the valve opens. The test will take a few minutes, so please do not take the mouthpiece out of your mouth. Your mouth may get dry and it may be difficult to swallow while using the mouthpiece. Please make sure that your lips are sealed tightly and your nose clip is on properly. If you need to take a bigger breath, that is OK. I will let you know when the test is over.
Patients may fail to seal their mouth completely around the mouthpiece, and any increase in $N_2 >1\%$ indicates a leak – that is, the patient has inadvertently inhaled atmospheric $N_2$ and subsequently exhaled it into the collected gas. In this case, the test should be discontinued and repeated after approximately 15 min (15). This test only measures gas that can communicate with the large airways; therefore, it is typically used if the patient cannot be sealed within the box for FRCpleth.

**CONCLUSION**

The present article provided tips on how to coach patients to achieve acceptable and repeatable trials during pulmonary function testing. One of the most challenging things about coaching patients is knowing how to adapt instructions because some patients will need more assistance than others. It is helpful if one can explain the same test in different ways. Exaggerated body language helps, especially when a language barrier is present.

Although it has been shown that RRTs and other pulmonary function laboratory personnel who participate in workshops can improve their attainment of the ATS/ERS standards for spirometry (44), further research is needed to determine the specific coaching strategies and adjuncts that help optimize patients’ performance.

**REFERENCES**

Innovation in respiratory therapy and the use of three-dimensional printing for tracheostomy management

Andrew J West MAppSc RRT FCSRT¹, Karen Taylor RRT², Daniel W Rickey PhD MCCPM³,⁴

Respiratory therapy (RT) is a profession with a long history of clinical applications of advanced and emerging technologies (1,2). A cursory review of the previous two iterations of the national competency profile for Canadian respiratory therapists provides insight into the rapid evolution of our professional practice (3,4). Many changes in practice patterns were influenced, at least in part, by technological advances. It is not, therefore, unexpected that the rapid evolution of technologies currently being witnessed, both clinical and nonclinical, will invariably have an impact on RT practice. It is by adopting emerging technologies that the profession of RT will advance in innovative ways.

Early literature in organizational change observed that variability in hospital adoption of innovation could be accounted for, at least in part, by a variability in the development of structural mechanisms that provide access to knowledge about change (5). Fortunately, organizational structures that support sharing of knowledge about change, including this Journal and professional conferences, exist in RT. It is by developing a rich culture of using these venues for knowledge sharing that the innovative capital existing in RT can be fostered.

We may typically believe that innovation occurs as a result of an ‘a-ha’ moment. However, the knowledge-building literature suggests that the majority of new ideas adopted into practice result from collaborative processes that develop organically over a period of time (6,7). Taking a page from educational design researchers, it has been theorized that professional innovation can be spurred by “creating environments where ideas can connect” (8). The following example illustrates how a collaborative approach, along with an environment supportive of knowledge sharing, became useful in addressing a problem in RT practice through adopting three-dimensional (3D) printing technology.

ADOPTING 3D PRINTING TECHNOLOGY

Additive manufacturing, more commonly known as ‘3D printing,’ has been used in the clinical sciences for planning complex surgeries and designing custom implants. The introduction of low-cost consumer-grade 3D printers enables this technology to be used for more routine procedures, although its application in RT has not been widely published. These 3D printers deposit 0.1 mm- to 0.3 mm-thick layers of hot acrylonitrile butadiene styrene or polylactic acid plastic. The resulting model (3D printout) is slowly built up layer by layer. An important feature of 3D printers is that they can produce complex objects. In addition, there are several software packages that import medical magnetic resonance or computed tomography (CT) images and enable the creation of models suitable for printing.

The use of medical imaging and 3D printing had previously been used for radiation therapy applications at CancerCare Manitoba. Additionally, the institution’s medical devices department regularly modifies tracheostomy tubes and, thus, has developed a strong collaborative relationship with the respiratory therapists of the Long Term Ventilator Service (LTVS), Winnipeg Regional Health Authority (Manitoba). It was natural then that this unique collaboration may lead to an innovative approach to client care by applying 3D printing technology to RT practice.

A COLLABORATIVE APPROACH TO INNOVATIVE TRACHEOSTOMY MANAGEMENT

The LTVS provides RT services to long-term clients in the community who require support for medically complex needs. These needs frequently include tracheostomy airway management in clients who may or may not also require mechanical ventilation. There are several well-known long-term effects of tracheostomy, including dysphagia, inability to phonate, tracheal granuloma and tracheomalacia (9,10). Respiratory therapists at the LTVS use various methods of customizing tracheostomy tubes to mitigate anatomical or other therapeutic challenges, or to manage complications resulting from long-term use of the airway itself. Routine diagnostic techniques, such as bronchoscopy, bronchoscopic lavage, radiography and CT, have been used to diagnose and monitor these long-term effects.

Although a cornerstone of management, these diagnostic techniques have occasionally proven insufficient for identifying the etiology of symptoms related to long-term tracheostomy use that have appeared clinically. This has limited the ability of the respiratory therapists to determine appropriate clinical interventions such as tracheostomy type, position and need for customization. For example, occasionally complicated tracheal anatomy may make airway visualization highly challenging and, thus, limit the ability to determine a differential diagnosis in the presence of multiple long-term complications.

One approach that has been used to give a detailed and informative understanding of the etiology of client symptoms has been the use of 3D printing technology to reproduce the results of high-resolution CT scanning. The genesis of the idea to use 3D printing technology in cases such as these came as a result of collaborative review and a shared desire to design a solution for these clinical concerns. The existing relationship between the respiratory therapists of the LTVS and personnel in the Medical Devices Department at CancerCare Manitoba served as an important environmental factor, which facilitated the connection of ideas. Encouraging professionals to connect ideas and expertise with those of colleagues and others in this manner brought individuals together and supported a sense of collective cognitive responsibility (11). Through sharing in the responsibility for knowledge creation, both the individual goals of the respiratory therapist and the patient, as well as the collective goals of the organization were achieved in an innovative way. As a result, 3D printing was used as a means of assessing airway abnormalities and symptomology not explained by traditional diagnostic and assessment techniques.

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InnOvATIoN DESIGn CHALLenGes

In this example, a client underwent a high-resolution CT scan. The resulting images were then imported into 3D modelling software (3D Doctor V5, Able Software Corp, USA) in which the trachea was outlined. Although parts of this task were automated, several hours of manual work by the medical devices personnel was necessary. A significant challenge is that because a trachea tube was in place during the CT scan, it was subsequently necessary to remove it from each image manually (Figure 1). The resulting outline of the trachea was then exported as a stereolithography (stl) file from which tracheal models were printed using a consumer-grade fused-deposition printer (Solidoodle 3, Solidoodle LLC, USA and MakerGear M2, MakerGear LLC, USA) (Figures 2 and 3). Printing the tracheal models was relatively straightforward as either a positive that was a copy of the patient anatomy, or as a negative that revealed the lumen of the trachea.

The 3D printed model of the tracheal lumen simplified observation of its complex shape. Furthermore, the ability to physically fit the tracheostomy tube into the positive model enabled the team to better determine the most appropriate airway specification relative to the anatomical limitations and other complications. Figures 4, 5 and 6 demonstrate three different models of the trachea that were printed using the 3D printer. These models provided a profound visual aid in understanding the unexpectedly extensive anatomical abnormality of this symptomatic client. An additional strength of 3D printing is that the models may be sliced in any plane before printing, and producing additional copies is simple.

Although 3D printing technology holds much potential for use in RT and in tracheostomy management, one notable limitation of this approach is the lengthy process of outlining the trachea on the CT images. Although this step is partially automated, the presence of the trachea tube in the images complicates the process considerably.

CoNCLUSIoN

The use of 3D printing technology to enhance clinical evaluation of clients with long-term tracheostomy provides an example of how innovative ideas lead to practical solutions using new technologies. The adoption of 3D printing in RT practice has not previously been reported in the literature. As is the case in many innovation-generating organizations, the roots of a new practice concept rest in sharing and synthesizing multiple perspectives, problem solving and collective
knowledge construction (12). Through dissemination of this idea, it is hoped that others will be prompted to share in further exploration and development of this particular idea, thus fostering new insights.

An interesting array of issues worthy of further inquiry have emerged from this innovation. To evaluate the possible scope of applicability of 3D printing in tracheostomy management, it would be valuable to quantify the prevalence and morphology of tracheal abnormalities in clients with long-term tracheostomy. Additionally, it would also be of great interest to determine whether routine assessment using 3D printing technology could impact client outcomes. Finally, we need to consider its application as a tool for professional and client education.

Beyond spurring interest and inquiry in this new assessment technique, it is also hoped that this discussion will promote wider awareness and use of the structural mechanisms available to respiratory therapists for sharing knowledge. Supporting an environment of information exchange and community knowledge generation will lead to enhancements in the support we provide to those with respiratory challenges.

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**REFERENCES**

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**CORRIGENDUM**

The x and y axes in Figures 2 to 5 of this article should have been labelled Reliability and Mean inspiratory pressure, cmH_2O, respectively.

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**ERRATUM**

Re: Melvin D, Markham A. Medical marijuana. Can J Respir Ther 2015;51(1):11-12.
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**August 22-26, Halifax, Nova Scotia:** 148th Annual Meeting of the Canadian Medical Association (CMA). Contact the CMA Head Office, 1867, Alta Vista Drive, Ottawa, Ontario K1G 5W8. Telephone 888-855-2555 / 613-236-8864, e-mail cmamsc@cma.ca, website www.cma.ca

**September 6-9, Denver, Colorado:** 16th World Conference on Lung Cancer. Contact the International Association for the Study of Lung Cancer, 13200 East Colfax Avenue, Unit 10, Aurora, Colorado 80011, USA. Telephone 855-464-2752, fax 855-593-5477, e-mail pia.hirsch@iaslc.org, website www.iaslc.org

**September 25-27, Toronto, Ontario:** 7th Conference of the Canadian Sleep Society. Telephone 866-239-2176 / 877-659-0760, e-mail info@css-scs.ca, website www.css-scs.ca

**September 26-30, Amsterdam, The Netherlands:** 25th International Congress of the European Respiratory Society (ERS). Contact ERS 2015, c/o K.I.T Group, Kurfürstendamm 71, Berlin 10709, Germany. Telephone 49-30-24603-220, fax 49-30-24603-399, e-mail ers2015registration@kit-group.org, website www.erscongress.org

**October 8-10, Phoenix, Arizona:** 29th Annual North American Cystic Fibrosis Conference. Contact the Cystic Fibrosis Foundation, 6931 Arlington Road, Suite 200, Bethesda, Maryland 20814, USA. Telephone 301-907-2513, fax 301-907-2563, e-mail nafc@cff.org, website www.nafccconference.org

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