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1 The Joint Commission Sentinel Event Alert Issue 49, August 8, 2012
2 Taenzer AH et al. Anesthesiology. 2010;112(2):282-287
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**Canadian Journal of Respiratory Therapy**

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

An examination of the role of the Canadian Journal of Respiratory Therapy / Un examen du rôle du Journal canadien de thérapie respiratoire

Jason Nickerson

COMMENTARY

Public health in Canada: Evolution, meaning and a new paradigm for respiratory therapy

Andrew J West

ORIGINAL ARTICLES

The Rematee Bumper Belt® positional therapy device for snoring and obstructive sleep apnea: Positional effectiveness in healthy subjects

Les Matthews, Normand Fortier

Obstructive sleep apnea (OSA) has been associated with hypertension, diabetes and cardiovascular disease. The most common cause of OSA is soft-tissue blockage of the upper airway and, although many physiological and pathophysiological processes are impacted by altered consciousness, OSA most often occurs or is exacerbated when an individual moves to a supine position during sleep. A positional solution to this problem was proposed more than 120 years ago, with several novel modifications since; however, the effectiveness of these potential solutions has been diminished by poor patient compliance rates. This article describes a study that investigated the utility of a commercially available device designed to significantly limit subjects from sleeping supine.

Research capacity of respiratory therapists: A survey of views, opinions and barriers

Concetta Martins, Chris Kenaszchuk

In step with rapid advances in technology, evidence-based practice has emerged as a major contributor to the contemporary clinical decision-making process. However, processing the tremendous amount of rapidly evolving available information has proven to be challenging for many health care professionals. Respiratory therapy is no exception to the innovation, evolution and rapid advances that have occurred over the past decade, and many in the field are in an ideal position to contribute to the scholarship of the profession. This study was prompted by the lack of studies investigating the perspectives and opinions of respiratory therapists with regard to their participation in research and implementation of findings.

EDITORIAL

Clinical trials registration

Norman H Tiffin, Jason Nickerson

REVIEWS

Respiratory complications in the postanesthesia care unit: A review of pathophysiological mechanisms

Marcin Karcz, Peter J Papdakos

Surgical, anesthetic and patient variables have been shown to impact pulmonary function in the postanesthesia period and contribute to complications in the postanesthesia care unit (PACU), with pulmonary atelectasis a common finding in more than 80% of anesthetized individuals. This comprehensive review discusses the major mechanisms causing deterioration of gas exchange in the immediate postoperative period; differential diagnosis of arterial hypoxemia in the PACU; preventive measures and treatment strategies for atelectasis; and the role of continuous positive airway pressure in the PACU.

Recruitment manoeuvres in acute respiratory distress syndrome: Little evidence for routine use

Oliver Poole

Acutely injured lungs consist of heterogeneous regions of aerated and collapsed alveoli. Implementation of alveolar recruitment manoeuvres (RMs) for the management hypoxemic respiratory failure, however, has been controversial. Randomized controlled trials have not demonstrated a significant benefit to support the routine use of RMs in patients experiencing acute respiratory distress syndrome. Nevertheless, the use of RMs continues to be a topic of clinical interest.
A new online submission system has been developed to streamline the publishing process. Authors are invited to visit http://system.pulsustrack.com/Frm_Login.aspx?jnlKy=14 to submit papers, case studies, commentaries, literature reviews, letters to the editor and directed readings. First-time authors are encouraged to submit. All manuscripts are peer-reviewed.

The CJRT is published four times a year and represents the interests of respiratory therapists nationally and internationally.

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An examination of the role of the 
Canadian Journal of Respiratory Therapy

Our profession has undergone tremendous changes since its Canadian inception some 50 years ago. Beginning with the establishment of a course for inhalation therapy technicians at the Queen Mary Veterans Hospital and the creation of the Technical Department of Inhalation Therapy at the Royal Victoria Hospital in Montreal (Quebec), the provision of competent respiratory care in Canadian hospitals and communities has continued to evolve to meet the changing needs of our patients (1). With this evolution, the profession has moved from being largely technical to increasingly independent in its clinical role, is almost totally self-regulated, and has established a growing number of schools within colleges and universities – a move away from having had these same schools embedded within hospitals.

A part of this transformation has always included a focus on knowledge sharing and research. In April 1965, the journal Canadian Inhalation Therapy was launched, which, over the past 48 years, became Respiratory Technology, then RRT: The Canadian Journal of Respiratory Therapy and, finally, today’s Canadian Journal of Respiratory Therapy (CJRT). As the Journal transitions to a new format, a new publisher and a new audience, and as the profession celebrates its 50th anniversary, it is timely for us to consider the role of research, generally, and of the CJRT, specifically, in the practice of respiratory therapy.

Today, the CJRT represents the culmination of years of work striving for the highest of publication standards in medical research. The Journal adheres to reporting guidelines for different study designs (2-4); has formed a team of competent and experienced associate editors; emphasizes the ethical conduct and reporting of research; and embodies a philosophy of being helpful to authors, recognizing that many are first-time authors. This work has been performed under the guiding assumptions that the Journal is of importance to Canadian respiratory therapists and to the practice of respiratory therapy, that the research and commentary that we publish drives the profession forward and ensures better care for our patients, and that the Journal plays a central role in strengthening the capacity of the profession to conduct research and report results.

Fundamentally, the CJRT exists to challenge the assumptions that underlie the care that we provide: Is an intervention effective? Is it a model of care safe? What are the impacts of a respiratory therapist in a new or expanded role? The guiding philosophy is that we, as clinicians, are constantly learning and challenging assumptions about the best ways of doing things, and the Journal exists to provide a venue for this discourse. In this context, the Journal is a vehicle, whose destination is determined by its passengers – we can provide the framework and the resources to facilitate high-quality publications, but it is ultimately up to researchers and clinicians to provide the content. Engaging clinicians and researchers to publish their results has been the single greatest challenge that we have faced and continue to face.

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This raises a fundamental question for Canadian respiratory therapists and for the Journal: if we are not constantly measuring, evaluating and sharing the impact of the interventions we provide, can the profession continue to evolve?

At the Journal, we continue to view ourselves as central to the advancement and growth of the profession. By fostering the conduct and publication of respiratory therapist-led research, our intention is to push Canadian respiratory therapists to take ownership of the science that guides the interventions we perform, the care we deliver and the philosophies that guide our practice. As a small Journal, we can play a significant role in leading changes within respiratory therapy that otherwise may not happen; simply because we are small does not mean that we do not have an impact (5).

With the current issue, we continue to push forward with novel research and reviews that highlight the changing roles, science and practice of respiratory therapy. We present the results of a survey of respiratory therapists’ views, opinions and barriers to engaging in research, and a review of the roles of respiratory therapists in public health in Canada. Additionally, we present two reviews of importance to practicing clinicians focused on recruitment manoeuvres and postoperative pulmonary complications.

Going forward, we plan on being a central part of the continued evolution of the science and practice of respiratory therapy in Canada. This, however, can only be achieved by strengthening the profession’s capacity and willingness to conduct and share the results of sound research and evaluation, and to adapt to the changing needs of our patients and the health care system. The articles presented in the current issue advance this discussion and provide a reminder that as good as we are, there is still room to grow.

Jason Nickerson RRT FCSRT PhD(c)
Editor-in-Chief

REFERENCES
Public health in Canada: Evolution, meaning and a new paradigm for respiratory therapy

Andrew J West MAppSc DipPH RRT

Chronic disease burden in Canada poses an imminent public health threat. The impact of respiratory disease in Canada alone is significant, affecting one in five and leading any other cause of repeat hospitalization in all age groups. Public health action is considered to be an important means of addressing these issues. Historical understanding of health has evolved to support the adoption of paradigms by professions that recognize the limitations of medical intervention in addressing the fundamental basis of disease when compared with the broader public health perspective. Several key historical events have shaped this understanding in the Canadian context including the Lalonde and Epp reports, and public health emergencies such as the severe acute respiratory syndrome outbreak in 2003.

The profession of respiratory therapy has historically existed within a medicalized paradigm of practice; however, forces both internal and external to the profession are pressuring it to consider adopting broader social and population-based approaches. As a rapidly evolving profession, there is a need to explore emerging areas of practice opportunities in the discipline. Investigating alternative knowledge and ideology can ensure that effective strategies for addressing the contemporary respiratory health needs of Canadians are undertaken. The present article explores the rationale for a public health- and population-based approach to health in general, and its applicability to the respiratory therapist’s role in addressing respiratory health-related issues in Canada.

Key Words: Determinants; Population health; Public health; Respiratory therapy

The primary causes of death in Canada include circulatory disease, cancer and respiratory disease, with an increasing burden of illness from other causes such as obesity and diabetes (1). The impact of respiratory disease alone is significant, affecting one in five Canadians and leading any other cause of repeat hospitalization in all age groups (2). Canadians who experience the worst health tend to belong to specific subgroups, and are often exposed to similar health risks that can broadly be described to include social, cultural and demographic features (1).

As health professionals primarily engaged with improving the respiratory health of Canadians, respiratory therapists (RTs) work in a wide variety of health-related settings, providing a broad range of service from acute to community and primary care, to all age groups. As a rapidly evolving profession, there is a need to explore the emerging areas of practice in the discipline. As part of this exploration, some reflection on whether respiratory therapy is effectively responding to the full spectrum of respiratory-related health needs of Canadians is warranted. Investigating alternative knowledge and ideology may help to assure that effective strategies for addressing the contemporary respiratory health needs of Canadians are undertaken by RTs.

The present article explores the rationale for a public health- and population-based approach to health in general, and its applicability to the role of the RT in addressing respiratory health-related issues specifically. To more fully understand the meaning of public health in Canada, an overview of key influences and developments will be outlined, and key paradigms that underlie both public health and respiratory therapy practice will be broadly discussed.

HISTORICAL INFLUENCES AND THE ORIGINS OF PUBLIC HEALTH

Scientific paradigms are a set of accepted beliefs that are used as a solution model by a community of practitioners (3). These logic models tend to be challenged when they fail to respond to contemporary problems. Several paradigms of thought have been recognized to be influential in the evolution of public health over the past few centuries. Throughout the 19th century, the major paradigm was that of ‘miasma’ – that is, that disease is transmitted through environmental vectors, namely foul emanations including atmosphere, vapour and odour. Miasmatist theory was later challenged by the ‘contagionists’ who believed that disease was spread by organisms passed from person to person. The contagionists purposed a single causative agent for any disease (3). As bacteria were discovered, and as infectious diseases and immunization advances predominated the period, it is not surprising that the contagionists’ germ theory was widely adopted as the

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TABLE 1
The determinants of health

<table>
<thead>
<tr>
<th>Income and social status</th>
<th>Personal health practices and coping skills</th>
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</thead>
<tbody>
<tr>
<td>Social support networks</td>
<td>Health child development</td>
</tr>
<tr>
<td>Education and literacy</td>
<td>Biology and genetic endowment</td>
</tr>
<tr>
<td>Employment/working conditions</td>
<td>Health services</td>
</tr>
<tr>
<td>Social environment</td>
<td>Sex</td>
</tr>
<tr>
<td>Physical environment</td>
<td>Culture</td>
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Adapted from reference 10

TABLE 1 is a table listing the determinants of health, including income and social status, social support networks, education and literacy, employment/working conditions, social environment, and physical environment. Each determinant is associated with specific health practices or factors, such as personal health practices, coping skills, health child development, biology and genetic endowment, health services, sex, and culture, respectively.

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granted at this time and there was resistance to official messages about vaccination, tobacco, water fluoridation and automobile safety (7).

After several decades of growth in Canada's health services, economic forces in the 1970s led to a period of greater scrutiny and reduced federal funding for the expansion of health care services. There was growing recognition of the fact that the substantial declines in mortality had not been prompted by medical advances, but by those influences earlier described by McKeown et al (5). This prompted a period of renewed thinking about how to address the health of the public in Canada (7).

Several influential government reports, including those commonly referred to as the 'Lalonde and Epp' reports (8,9), were released in the 1970s and 1980s proposing a broader view of health that focuses on the determinants of health of all Canadians. Table 1 provides a list of the key determinants of health. This macro perspective of health would instigate a renewed vision of the health promotion model to address the underlying determinants. Epp (9) described the "intrinsic mechanisms" necessary for the health promotion framework as:

- self-care: the decisions and actions individuals take in the interest of their own health;
- mutual aid: the actions people take to help each other cope; and
- health environments: the creation of conditions and surroundings conducive to health.

Through application of these mechanisms, it was believed that improved health conditions of Canadians could be achieved (9). The Lalonde and Epp reports each helped to effectively shift the concept of health into one that includes factors beyond curative medicine.

Several public health initiatives and policies were instituted in Canada over the subsequent decade addressing national health concerns. These included breastfeeding initiatives, motor vehicle safety initiatives and the federal Tobacco Act, to name a few (3). While there was recognition of the importance of these population-wide initiatives to improve Canadians' health, it was likely the occurrence of severe acute respiratory syndrome (SARS) in Canada in 2003 that truly awoke Canadians to the fact that the traditional, acute care-oriented health care system was insufficient in itself to protect them from all potential health risks (1,11). During this crisis, the risks came unexpectedly, facilitated by the ease of modern global airline travel. A heightened understanding of the influence that ecological and social factors, globalization and a rapidly changing world can have on the health of contemporary Canadians, clarified the need to effectively coordinate efforts to address these. This understanding was a powerful force, which in part led to the creation of the Public Health Agency of Canada (PHAC) (12).

PUBLIC HEALTH IN CANADA TODAY

The role of the PHAC is to "prevent and control chronic diseases and injuries; prevent and control infectious diseases; prepare for and respond to public health emergencies; serve as a central point for sharing Canada’s expertise with the rest of the world; apply international research and development to Canada’s public health programs; and to strengthen intergovernmental collaboration on public health and facilitate national approaches to public health policy and planning" (13). Through the PHAC’s research, programs and services, its goals are to bring about healthier Canadians, reduced health disparities, and a stronger capacity to deliver and support public health activities (13).

The PHAC defines public health broadly: "Public health focuses on the entire population at both the individual and the community level" (13). It further describes public health as "the organized efforts of society to keep people healthy and prevent injury, illness and premature death. It is a combination of programs, services and policies that protect and promote the health of all Canadians. Public health includes activities such as immunization, healthy eating and physical activity programs, infection control measures in hospitals, along with the detection, lab testing and regulation that support these activities” (13). These definitions of public health are certainly aligned with the predominant paradigm of the late 19th century and the first half of the 20th century.

Despite the movement away from support for the miasmist paradigm, the idea of environmental and social influence over disease remains an important concept in contemporary public health. Social epidemiological research investigating mortality rates in industrialized societies, such as that performed by McKinley and McKinley (4), has produced interesting results that support that premise. They demonstrated that technical advances and the availability of medical care appear to have had little impact on the decline in mortality apparent in the United States throughout the 20th century (4). In fact, they reported that many of the advanced medical interventions (e.g., immunization and infectious disease treatment) occurred only after substantial decline in mortality rates were apparent in many key diseases. They estimated that, at most, 3.5% of the total improvements in mortality rates apparent after 1900 could be ascribed to medical measures. In a different investigation of declining mortality rates in England and Wales (United Kingdom) through that same period, McKeown et al (5) concluded that the phenomenon was due entirely to a reduction in deaths from infectious diseases. They specifically suggested that the main influences over the decline included an improved standard of living and diet, improved hygiene standards, and favourable conditions with respect to human and microorganism interaction.

Notwithstanding its theoretical flaws, the miasmist strategy of environmental control, which led to improved sanitation and water, has been a primary contributing factor to the overall gains in health status witnessed in industrialized countries. It is also clear that, despite great advances in the understanding of microorganisms and disease, the contagionists’ germ theory of one causative agent and one disease does not address the evolving health problems of our contemporary society. As is the case in Canada, since the second half of the 20th century, the health of industrialized world has been heavily burdened by chronic diseases. Out of the need to address evolving challenges, a new paradigm of public health has since evolved. The paradigm of the era of chronic disease epidemiology has focused on identifying and addressing risk factors associated with disease (3). By considering each of the risk factors that underlie chronic disease patterns, as well as the environmental influences, microbial-specific treatments and immunization strategies that have been shown to impact mortality in the face of infectious disease, it stands to reason that an approach to disease management that addresses the range of these factors would be most effective.

THE EVOLUTION OF CONTEMPORARY PUBLIC HEALTH IN CANADA

The period after the Second World War was one of rapid social change and prosperity for Canadians. There was a rising degree of affluence, improvements to social programs and the introduction of guaranteed access to acute care services through the 1957 Hospital Insurance and Diagnostic Services Act (1). These would each have a positive influence on Canadians’ health; however, other factors that would have a significantly more sinister impact on health also emerged including widespread smoking, increased social drinking and recreational drug use, air pollution and injuries associated with motor vehicle use (6).

Generally speaking, however, public health appeared to be taken for...
actions that have led to the historic health gains realized by industrialized countries and the fails for broad population-based interventions that impact the social factors underlying inequality in health status. Public health, therefore, necessarily demands health actions that are directed at the root cause of health issues, and that are facilitated through the coordinated efforts of a wide variety of stakeholders. To deliver on this mandate, public health action in Canada requires the coordinated efforts of a wide variety of stakeholders including health care professionals such as RTs, government leaders, community leaders, educators and communities, among others.

To improve the health of Canadians, as health practitioners, we all must increasingly consider the broad range of factors that influence health. The determinants of health interact in complex ways with our rapidly evolving human ecology to influence health-related behaviours and health status. Public health offers a comprehensive approach to addressing these determinants and, thus, to improving health, which requires adoption of alternate paradigms of practice by practitioners for success.

**RESPIRATORY THERAPY AND PUBLIC HEALTH**

Increasingly complex respiratory technologies and procedures were being introduced into the Canadian health care system during the mid-20th century. Among these advances were bulk compressed gas systems, and new patient interfaces for therapeutic gas delivery and mechanical ventilation (14). Within the medical and anesthesia communities, the need for appropriately trained individuals to support these new technologies and therapeutic procedures became obvious (14). During that period, several Canadian hospitals sought to meet this need by introducing hospital-based training programs in inhalation therapy technology (14). It was also during this time that Canada witnessed the establishment of its first hospital inhalation therapy departments (14). Building on these initiatives, the Canadian Society of Inhalation Therapy Technicians (which would later become the Canadian Society of Respiratory Therapists (CSRT)) was formally established in 1964 to more universally address and standardize the discipline’s role in addressing changing national health care needs (15).

Since that period, the professional vernacular used to refer identity to the discipline has itself evolved in a manner that can be described as temporal with the changes that were occurring in health care and professional practice. The names ‘inhalation therapist’, ‘respiratory technologist’, ‘anesthetic technician’ and the contemporary RT all find common lineage in this history (14,16).

The discipline of respiratory therapy has undergone a remarkable evolution throughout this relatively short history. Once primarily technically trained health care workers, RTs quickly developed into highly educated and skilled professionals who function as part of an interdisciplinary team of health professionals delivering primarily acute care services. In part owing to the demands placed on them by industry and health care organizations, RTs have become actively engaged in health care delivery in nonacute settings such as rehabilitation centres, community care and primary care. However, what is the relevance of public health practice to the profession of respiratory therapy in Canada?

Historically, RTs have been on the frontline of public health emergencies as part of the coordinated effort to maintain the health of Canadians. This is highlighted by several recent examples, including the SARS outbreak in 2003 and the H1N1 pandemic of 2009. In each of these scenarios, RTs were called on to deliver acute and critical care services to Canadians such as diagnostic testing, respiratory therapeutic and, in severe cases, emergency airway management and mechanical ventilation. These types of services provided to Canadians by RTs, however, do not fully encompass the public health paradigm. Instead, these are examples of the biomedical model of care that focuses on the cause and treatment of health and disease only in terms of biological cause and effect (17). The biomedical model has long been accepted as a predominant paradigm in respiratory therapy, and is strikingly compatible with the germ theory of disease that emanated in the late 19th century, the limitations of which have already been discussed.

The rapid evolution in the professional role of the RT has, however, led to engagement in activities that are highly consistent with the notion of public health action. Many RTs are heavily engaged in health promotion activities. While these often occur primarily at the individual or vulnerable subpopulation level, there is also a move toward more community-level health promotion activity in respiratory therapy, one example being innovative smoking cessation programs. Also, in many health care organizations, RTs are also on the forefront of emergency preparedness planning for events such as impending influenza pandemics. Coordinated efforts such as these, often performed in association with provincial and/or federal public health officials and various community agencies, provide us with examples of the intersectoral and collaborative use of respiratory therapy expertise in real public health practice.

It should be noted that substantial opportunity remains for expanded engagement of RTs in prevention and promotion activities that aim to mitigate the occurrence and progression of respiratory conditions. As the Lalonde and Epp reports have suggested, this approach should include activities that support people’s ability to make healthy choices to cope with health-related issues, and should also create conditions and surroundings that promote health (9). For instance, considering the substantial impact that environmental issues, such as air quality and pollution, have on chronic respiratory disease, finding ways of addressing these should be priorities for RTs (18). The adoption of readily available tools, such as the Air Quality Health Index, into practice is an example of one such opportunity (19). Clarification of the role of the RT within existing public health units should also be explored. To more fully support individuals with chronic and infectious respiratory disease across the full continuum of care, RTs should use such a platform to support and participate in important public health initiatives such as vaccination campaigns.

The respiratory therapy community, through its professional associations, is more commonly participating in a variety of advocacy campaigns. The goal of many of these campaigns is to advocate for healthy public policy and to guide professional practice, often in association with partner associations in respiratory health. Perhaps one of the most comprehensive examples is the National Lung Health Framework project, a strategic action plan for Canada, developed by and for stakeholders, and supported by the Government of Canada. The plan was developed through a process that involved more than 500 stakeholders from many sectors working together to improve respiratory health for everyone in Canada (2). Stakeholders who contributed to the plan included consumer and patient groups, First Nations, Inuit and Métis communities, health professionals, including RTs, nongovernmental organizations, private sector/health industry, and federal/provincial/territorial government departments and agencies (2). Figure 1 illustrates the comprehensive nature of the plan, which encompasses a broad spectrum of public health actions and addresses the determinants of respiratory health for Canadians.

Several recent position statements by the national advocacy body for the profession of respiratory therapy, the CSRT, have called for increasing involvement of RTs in a variety of roles that are consistent with the public health mission. The CSRT has specifically called for increasing capacity among entry to practice respiratory therapy to understand and participate in health promotion and prevention initiatives (20). The CSRT has identified the “need for respiratory therapists to have a broader scope of knowledge, critical thinking and independent decision making skills to provide optimal care in the future” (20). As the 2014 celebration of the 50th anniversary of the profession of respiratory therapy in Canada approaches, careful consideration must be made as to how the profession will appear in the future. This professional evolution will require continued focus, not only on those substantial and essential health services currently provided by RTs, but, additionally, on the growing need for engagement in
opportunities that impact Canadians throughout the continuum of their care.

Achieving this goal will require great effort, creativity and leadership by RTs across Canada. One example of a strategy that has been undertaken to this regard is the development of entry to practice respiratory therapy curriculum at the University of Manitoba (Winnipeg, Manitoba) that addresses the theoretical and practical application of the public health paradigm as one means of addressing the health needs of Canadians at the individual and the population level. This innovative coursework is anticipated to be introduced in 2014.

Momentum currently exists with regard to respiratory therapy-driven public health initiatives, and an enhanced understanding of the concept and importance of public health action that addresses the root of respiratory health issues is evolving. With a professional responsibility to help achieve optimal respiratory health for all Canadians, it is time for RTs to engage more fully in the prevailing paradigms of public health in which the full spectrum of influence can be addressed.

CONCLUSION

Public health encompasses our coordinated efforts across Canadian society aimed at addressing inequalities in health and at improving the health of Canadians. Respiratory therapy practice in Canada today addresses some of those wide-ranging activities contained within the Canadian Public Health Association definition of public health. It is time for RTs to consider whether the current logic model they use in practice continues to effectively and universally respond to each contemporary respiratory health challenge.

Specifically, the burden of respiratory disease poses a substantial public health threat to Canadians and demands appropriate public health action. The National Lung Health Framework presents one means of addressing the respiratory health needs of Canadians founded in the wide-reaching and intersectoral principles of the public health model. Because the discipline of respiratory therapy has a mandate to effectively address respiratory health issues in Canada, its emerging practice areas are beginning to address these issues more often on a population health level. Further engagement in alternative paradigms of practice to those typically used in respiratory therapy may result in novel opportunities within the profession to address public health in a more comprehensive manner. Through a stronger understanding of the multidisciplinary principles of public health, RTs will be prepared to more effectively engage in addressing these issues.

ACKNOWLEDGEMENTS: The author gratefully acknowledges Dr Chris Green, Assistant Professor in the Department of Community Health Sciences, University of Manitoba, for his mentorship, and for sharing his ecological perspectives on public health.

DISCLOSURES: The author has no financial disclosures or conflicts of interest to declare.

REFERENCES

The Rematee Bumper Belt® positional therapy device for snoring and obstructive sleep apnea: Positional effectiveness in healthy subjects


The present study was designed to investigate body position changes resulting from wearing a Rematee Bumper Belt (Rematee, Canada) during sleep. The majority of obstructive sleep apnea (OSA) patients will experience up to two times as many apneas and hypopneas while supine relative to lateral or prone body positions during sleep. It has been suggested that a positional therapy device could reduce the number of apneas and hypopneas in such patients. The present study was conducted to determine whether the Rematee Bumper Belt positional therapy device could prevent healthy subjects from sleeping in the supine position. Test subjects wore the belt for one to two nights. Each belt was equipped with an accelerometer that was used to measure the orientation of the belt relative to the horizontal plane. The results suggest that the belt creates an exclusion zone approximately 80° wide centred near the supine orientation, where subjects are effectively prevented from sleeping in the supine position. The device appears to be most effective between 150° and 230°. A device with this capability may provide an inexpensive and potentially effective alternative treatment option for patients with OSA. This device has the capacity for reducing snoring and the apnea-hypopnea index in individuals with positional OSA.

Key Words: Body position; Positional obstructive sleep apnea; Positional sensor; Rematee Bumper Belt; Snoring

A n obstructive sleep apnea (OSA) event is defined as a >10 s cessation of breathing with continued breathing effort, during sleep (1). The most common cause of OSA is soft-tissue blockage of the upper airway (2). Gravity-dependent soft-tissue obstruction of the upper airway in the supine position is a common problem (2). This led Robert Bowles, in 1891 (3), to be the first to describe the recovery position solution. Muscle tone, gravity and a number of anatomical, physiological and pathophysiological processes can contribute to airway obstruction when consciousness is altered. Airway obstruction is usually preceded by snoring (4). This, in the absence of sleep arousal, can cause significant reduction of blood oxygen levels and elevation of blood carbon dioxide levels. The primary clinical manifestation of repetitive airway obstructions and sleep arousal is daytime sleepiness (5). OSA appears to be associated with hypertension, diabetes and cardiovascular disease (3). Although OSA can occur in any sleep position, the supine position can actually cause or, at least, exacerbate the condition (6).

Positional OSA has been described as having an apnea-hypopnea index (AHI) >5 that is reduced by >50% when in a nonsupine posture during sleep (6,7). The majority of OSA patients will experience up to two times as many apneas and hypopneas while supine compared with lateral or prone body positions during sleep (8,9). It has been determined that these ‘positional patients’ tend to be thinner and younger than ‘nonpositional patients’ (1). The upper airway of patients who experience positional exacerbation appears to be significantly different than their nonpositional counterparts (4). It is postulated that, in individuals with positional OSA, sleep quality could be improved by avoiding the supine position (6). The significance of positional OSA goes beyond the issue of daytime sleepiness. It has been determined that severe stroke patients tend to sleep supine, which is known to exacerbate their sleep apnea (10,11). It is interesting to note that in an least one study (5), the lateral AHI correlated better with daytime sleepiness than did the supine AHI. Sleep studies continue to emphasize the significance of body position during sleep. It is also important to note that head and trunk position may be of equal importance when studying sleep quality in individuals with positional exacerbations of sleep apnea (12).

Devices have been designed to modify or control body position during sleep. Sewing a tennis ball into a pajama top or T-shirt is a technique that has been used for many years and has shown some efficacy (13). Unfortunately, for a variety of reasons, studies have shown very poor compliance with the tennis ball technique (<10% after 30 months) (13). While numerous other devices have been developed in an attempt to control or modify body position during sleep, most continue to demonstrate poor compliance rates (2). Although the effectiveness of some devices has been demonstrated in at least one small study (14), the long-term compliance and effectiveness of these devices needs more study. In one study involving patients with positional sleep apnea (15), preventing the patients from sleeping in the supine position was as effective as using continuous positive airway pressure for treating OSA.

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In our sleep-disordered breathing outpatient clinic, we have encountered patients identified as having primarily positional OSA. Although we have many questions about devices and ideal body positions, we have studied one particular aspect and one device. This study was designed to investigate the effect of wearing a Rematee Bumper Belt (Figure 1) on body position during the night.

**METHOD**

**Population**

In total, 15 subjects comprising students and faculty members from the university volunteered for the study; seven were male and eight were female, with age ranging from 18 to 56 years (mean ± SD 30±11 years). The volunteers reported that they were good sleepers and in good health. The volunteers reported that they were good sleepers and in good health. They all attended an information session during which the purpose of the study was explained, the use of the accelerometer-equipped Rematee Bumper Belt was demonstrated and they provided their informed consent. The study was reviewed and approved by the Thompson Rivers University (Kamloops, British Columbia) Ethics Committee.

The collection of positional data occurred in the homes of the volunteers. The belt shown in Figure 1 is equipped with three inflatable bumpers. To assess its effectiveness at limiting subjects from sleeping in the supine position, volunteers slept with the bumpers inflated as well as not inflated. Of the 15 volunteers, six used the belt in both configurations. Of the remaining nine volunteers, three slept with an inflated belt and six slept with a noninflated belt. Each subject completed a diary that included age, sex, and the time in and out of bed while using the device. Subjects were also asked to complete a short postassessment of their experience with the belt. All participants indicated that it was comfortable to wear.

**Instrumentation**

A small accelerometer (Gulf Coast Data Concepts, model X6-2 mini, 63.5 mm × 25.4 mm × 12.7 mm, 18 g) was firmly inserted in a pouch located on the back of a Rematee Bumper Belt (Figure 1), placing the sensor midpoint between the shoulder blades of the subject.

The sensor recorded accelerations along three orthogonal directions shown in Figure 2A, with the negative y-axis pointing toward the head, the positive x-axis pointing toward the left shoulder and the plane formed by the x and y axes set parallel to the back of the subject. When stationary, the sensor measured the projections \( g_x, g_y \) and \( g_z \) of the gravitational acceleration vector \( g \), and could be used as an inclinometer to measure orientation relative to \( g \). For a subject lying horizontally (Figure 2B), the three outputs of the accelerometer were given by \( g_x = -g \sin(\phi), g_y = 0, g_z = g \cos(\phi) \), in which \( g = 9.8 \, \text{m/s}^2 \) and \( \phi \) is the angle between the positive \( z \)-axis of the sensor and the vector \( g \). With this definition of angles, the prone, left, supine and right positions are equal to \( 0^\circ, 90^\circ, 180^\circ \) and \( 270^\circ \), respectively, as illustrated in Figure 2C.

Just before bed time, the subject would activate the sensor and don the belt. Data-gathering sessions were between 2 h and 6 h in duration (mean 5.5 h). Once activated, the sensor would start recording at a rate of 10 Hz until turned off, or would automatically stop after 6 h. The acceleration values were stored in the internal memory of the sensor in individual files containing 1 h worth of data. Once the belt was returned, the data were immediately transferred to a personal computer for analysis.

The orientation of the torso was inferred from the sensor. For this method to be accurate, the position of the sensor relative to the subject must be constant (ie, the belt should not slip or fold during sleep). The accuracy of the approach was verified in a laboratory setting. Images of subjects continuously moving from prone to supine positions were recorded and later compared with the calculated orientations of the torso; in all cases, the agreement was excellent.

When a subject changes position during sleep (or while getting ready for sleep or getting up), accelerations are imparted to the sensor, and the values of \( g_x, g_y \) and \( g_z \) are no longer simply equal to the projection of the gravitational vector \( g \). When this occurs, the calculated angle no longer reflects the spatial orientation of the sensor. However, the duration of these transitions are typically short (ie, seconds) compared with the duration of a measuring session (ie, hours), and they do not affect the results presented here in the form of histograms.

**Analysis**

Once a subject returned the belt, each file was analyzed using Excel (Microsoft Corporation, USA). The measured components of \( g \) were smoothed using a moving average of five data points, and the angle \( \phi \) was calculated using the equation

\[
\phi = \tan^{-1} \left( \frac{-g_x}{g_z} \right)
\]

A plot of \( \phi \) versus time, an example of which is shown in Figure 3, was produced to assess to validity of the recorded data. Because the subjects were, for the most part, lying horizontally during their sleep, the value of

![Figure 2](image_url)

**Figure 2** A The sensor measured acceleration along three orthogonal directions. B A subject lying horizontally places the y-axis of the sensor in the same direction. In this case, \( g_y = -g \sin(\phi), g_x = 0 \) and \( g_z = g \cos(\phi) \). C Correspondence between and sleeping positions for a subject lying horizontally.
Similarly, the histogram shown in Figure 5 was obtained by combining the sleep orientation of 12 subjects for 67 h while wearing a noninflated belt. The area under the curve between 150° and 230° is equal to 24%, indicating that a noninflated belt is ineffective at preventing sleep in a supine position. On comparing the two histograms, an important reduction in the AUC is observed between 150° and 230° in Figure 4, consistent with the hypothesis that the inflated Rematee Bumper Belt reduces the probability of sleeping near a supine position. The results suggest that the Rematee Bumper Belt creates an exclusion zone approximately 80° wide centred near the supine orientation, where subjects are unlikely to sleep. The exclusion zone is illustrated in Figure 6. This range of angles is specific to the particular design of the Rematee Bumper Belt, and the range of effectiveness of other belts would need to be established.

More importantly, however, because of the location of the sensor, only the position of the torso was measured; the position of the head was not. The relationship between head and torso position has been found to be significant in airway occlusion (7). Future studies will include torso and head position. Despite our interesting findings, we are aware of several limitations to our study. Our subjects were self-reported healthy, good sleepers. Individual physical limitations and/or comorbidities could play a role in adaptation to this device during sleep. It is planned to continue collecting data to increase sample size and verify the effect of this device on a broader population base.

Although the sensor and body position relationship was validated in a

![Figure 3](image3.png) Evolution of the angle as a function of time for a subject wearing an inflated belt. For the first 12 min, the subject sleeps in a near prone position (~350°). For the next 44 min, the subject sleeps on the right side (~264°). At 44 min, the subject rolls to the right, briefly passing through the prone position. The subject remains on the right side (~84°) for the final 12 min of the 60 min recording.

![Figure 4](image4.png) Histogram showing the probability of observing a subject sleeping in a given orientation while wearing an inflated Rematee Bumper Belt (Rematee, Canada). The histogram was obtained by measuring the sleep orientation of nine subjects for 44 h while wearing an inflated belt. The area under the curve between 150° and 230° is equal to 2.0%, indicating that the inflated belt is effective at preventing sleep in a supine position.

![Figure 5](image5.png) Histogram showing the probability of observing a subject sleeping in a given orientation while wearing a noninflated Rematee Bumper Belt (Rematee, Canada). The histogram was obtained by measuring the sleep orientation of 12 subjects for 67 h while wearing a noninflated belt. The area under the curve between 150° and 230° is equal to 24%, indicating that a noninflated belt is ineffective at preventing sleep in a supine position.

TABLE 1

<table>
<thead>
<tr>
<th>Sleep orientation</th>
<th>Inflated belt</th>
<th>Noninflated belt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left (45°&lt; φ &lt;135°)</td>
<td>43</td>
<td>17</td>
</tr>
<tr>
<td>Supine (135°&lt; φ &lt;225°)</td>
<td>39</td>
<td>31</td>
</tr>
<tr>
<td>Right (225°&lt; φ &lt;315°)</td>
<td>14</td>
<td>28</td>
</tr>
<tr>
<td>Prone (315°&lt; φ &lt;45°)</td>
<td>25</td>
<td>14</td>
</tr>
</tbody>
</table>

Results from all volunteers were used. With a noninflated belt, the AUC in the supine orientation was 25%; with an inflated belt, it was reduced to 4.0%.

Dividing each histogram into four equal regions, each one centred on the supine, left, right and prone orientations, the AUC for each region was calculated (Table 1). The value of the AUC in the supine position is this time reduced from 25% to 4% when using the inflated belt. A t test for dependent samples was used to assess the statistical significance of the observed change in values of AUC, using the results obtained from six volunteers that used the belt in both modes (Table 2). It was determined that the use of the inflated belt significantly reduced the value of the AUC from an average value of 33% to 2.9% (t=−3.35, tc=2.57; P<0.05) and, therefore, reduced the probability of sleeping near a supine orientation. The inflated belt did not affect the AUC of the other sleep orientations in a statistically significantly manner (Table 2).

**DISCUSSION**

The objective of the present study was to assess the effectiveness of the Rematee Bumper Belt at significantly limiting volunteers from sleeping in a supine position. The results suggest that the Rematee Bumper Belt creates an exclusion zone approximately 80° wide centred near the supine orientation, where subjects are unlikely to sleep. The exclusion zone is illustrated in Figure 6. This range of angles is specific to the particular design of the Rematee Bumper Belt, and the range of effectiveness of other belts would need to be established.

More importantly, however, because of the location of the sensor, only the position of the torso was measured; the position of the head was not. The relationship between head and torso position has been determined to be a significant factor in airway occlusion (7). Future studies will include torso and head position. Despite our interesting findings, we are aware of several limitations to our study. Our subjects were self-reported healthy, good sleepers. Individual physical limitations and/or comorbidities could play a role in adaptation to this device during sleep. It is planned to continue collecting data to increase sample size and verify the effect of this device on a broader population base. Although the sensor and body position relationship was validated in a
laboratory setting, the application of this device was unattended. The absence of video recordings could call into question actual subject positions throughout the night. However, subjects did not identify issues with belt movement.

**CONCLUSION**

The present preliminary study suggests that the Rematee Bumper Belt positional therapy device is effective at limiting healthy subjects from sleeping in a supine position. The device appears to be most effective between 150° to 230°. A device with this capability may provide an additional, inexpensive and potentially effective treatment option for OSA patients. This device has the capacity for reducing snoring and the AHI in individuals with positional OSA.

**DISCLOSURE:** Unlimited funding for the sensor devices was provided by Rematee, Canada.

**REFERENCE:**


Research capacity of respiratory therapists: A survey of views, opinions and barriers

Concetta Martins BSc RRT1, Chris Kenaszchuk MSc2

BACKGROUND: Evidence-based practice (EBP) is increasing in health care services. This means that respiratory therapists (RTs) should be effective consumers, users and producers of scientific research pertaining to respiratory therapy technology and respiratory physiology. However, little is known about RT opinions and attitudes toward research. Survey instruments to measure them are also uncommon.

OBJECTIVE: The present article presents the results of a survey of RTs regarding research attitudes including interest, self-perceived skill and barriers.

METHODS: A survey was developed in consultation with practicing RTs and education researchers. It was fielded in six academic hospitals in Toronto, Ontario. Surveys were completed and returned anonymously. Descriptive statistics and associations were examined. Subgroup differences were tested using ANOVA methods.

RESULTS: Surveys were completed by 112 RTs (response rate 26.9%). The majority (approximately 80%) of respondents agreed that respiratory therapy research is important, that research can advance the profession and that RTs are suited to performing respiratory therapy research. More than 70% were interested in performing research as long as barriers were eliminated. Among eight potential barriers, lack of time was ranked as the least relevant barrier. RTs’ educational attainment was positively associated with willingness to perform research and belief in having the skills needed for research.

CONCLUSION: Many RTs want to conduct research. They would need substantial support, including increased research exposure during respiratory therapy training, more time and support from trained researchers. More research capacity of respiratory therapists: La capacité de recherche des inhalothérapeutes: un sondage des points de vue, des opinions et des obstacles

HISTORIQUE: La pratique fondée sur des données probantes (PDB) augmente dans les services de santé. Ainsi, les inhalothérapeutes (IT) devraient être des consommateurs, des utilisateurs et des producteurs efficaces de recherche scientifique portant sur la technologie en inhalothérapie et en physiologie respiratoire. Cependant, on ne sait pas grand-chose de l’avis et des attitudes des IT envers la recherche. De plus, il y a peu d’instruments de sondage pour les mesurer.

OBJECTIF: Le présent article contient les résultats d’un sondage auprès des IT au sujet des attitudes envers la recherche, y compris l’intérêt, les compétences autoperçues et les obstacles.


RÉSULTATS: Au total, 112 IT ont rempli le sondage (taux de réponse de 26,9 %). La majorité des répondants (environ 80 %) ont convenu que la recherche en inhalothérapie est importante, qu’elle peut faire progresser la profession et que les IT possèdent les compétences pour faire de la recherche en inhalothérapie. Plus de 70 % souhaitaient faire de la recherche, pourvu que les obstacles soient éliminés. Parmi huit obstacles potentiels, le manque de temps était classé comme le principal dans 59 % des cas. Le manque d’intérêt à effectuer de la recherche était le moins pertinent. Le niveau d’éducation des IT s’associait de manière positive à leur volonté de faire de la recherche et à leur conviction de posséder les compétences nécessaires pour en faire.

CONCLUSION: De nombreux IT désirent faire de la recherche. Ils auraient besoin d’un appui considérable, y compris une plus grande exposition à la recherche pendant leur formation en inhalothérapie et plus de temps et de soutien de la part de chercheurs formés.

Evidence-based practice (EBP) in health care settings has significantly increased. EBP is important because, in combination with experience and expertise, it is a tool that guides clinical decisions to provide the best care possible (1-3). With specialized fields advancing rapidly, scientific inquiry has become more relevant to ensuring that current and new treatment modalities are used appropriately. As the roles of the respiratory therapist (RT) and other allied health care professionals evolve, and the scope of practice increases, responsibility for establishing EBP increasingly lies with disciplinary clinicians. In fact, many experts assert that the future success of allied health professions, including respiratory therapy, depends on EBP (4-7).

Despite knowing the benefits, using EBP and research findings is challenging for many, if not all, health professionals (2,8-15). These challenges involve the ability to process the tremendous amount of available information and use it in practice (8,10,12-14). At the same time, it appears imperative that clinicians not only become efficient at using research to support clinical decisions, but that they also develop the skills to contribute their knowledge to the medical realm by conducting their own research (3,4,5,7,16,17). Clinicians are in an ideal position to do this because they work intimately within their disciplines. For example, RTs assess the patient condition, make appropriate adjustments to mechanical ventilation, and monitor and reassess the patient’s response. Thus, through experiential knowledge, RTs are uniquely qualified to think critically and identify gaps within their own area of practice. Although many RTs and other allied health members become successful clinicians in academic teaching hospitals, it does not automatically mean that they are willing and able to engage in the scholarship of their own profession (17). In the years since EBP emerged, many scholars have presented findings on the opinions, experiences and barriers to research initiation, participation and implementation among allied health professionals (2,3,9-12,14, 18-24). To date, there are no studies that have examined the perspectives of RTs.

The present article reports the attitudes about research held by RTs practicing at academic teaching hospitals in Toronto, Ontario. The study had two main objectives: first, to identify RTs’ views and opinions about general research, and respiratory therapy research in particular; and second, to identify RT-perceived barriers to conducting research.

METHODS

The St Michael’s Hospital (Toronto, Ontario) Research Ethics Board approved the study. An extensive literature search for RT-appropriate measurement surveys and opinion questionnaires was conducted. The

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PubMed, Medline, CINAHL and ProQuest Nursing and Allied Health databases were searched using the terms “respiratory therapist”, “views”, “attitudes”, “opinions”, “interest”, “experience”, “research” and “survey”. The search did not find an instrument suitable for RTs; therefore, a paper-based survey was developed. The survey was pilot-tested for clarity and content with a small RT subgroup from one of the participating sites. The survey underwent minor revisions based on the feedback received and results from the pilot group were excluded from the final results.

The survey had eight sections. Three sections had five-point Likert responses that ranged from ‘strongly agree’ to ‘strongly disagree’ or ‘false’ to ‘very true’. One section included a forced-rank-order question in which respondents ranked a set of eight barriers. Another section asked respondents to select the best response from a list of five statements characterizing their belief about research when training to become an RT and the type of involvement they expected to have postlicensure. Finally, there were sections for demographic characteristics and open-ended comments. The demographic section did not request specification of practice areas and, thus, the results represent RTs in various roles within the academic centres.

The survey was distributed to all 416 RTs practicing in six University of Toronto-affiliated teaching hospitals (Toronto, Ontario). Distribution occurred via departmental mailboxes, handouts by departmental leaders or managers, or by leaving the survey in a common area used frequently by RTs. An initial contact e-mail message accompanied the survey distribution as a formal invitation and explanation of the project. A reminder e-mail was sent after one week. The responses were anonymous and collected using deposit boxes in the hospitals. The deposit boxes were retrieved two weeks after the reminder e-mail.

The survey broadly operationalized facets of RT research capacity and motivation using several question and response formats. The analysis was exploratory-descriptive, did not have classical test theory measurement objectives, and did not analyze validity and reliability of constructs. Responses were analyzed using SPSS (IBM Corporation, USA) in consultation with a statistician. Descriptive statistics and frequency tables were produced and associations were examined using cross-tabulations and the $\chi^2$ statistic. The Kruskal-Wallis ANOVA was used to test equality of group locations. Subgroup analyses were performed on educational attainment and years of work experience as an RT using the least significant difference post hoc test. The four education categories were: diploma; diploma plus advanced training (diploma+); diploma plus Bachelor’s degree; and Master’s degree. The five work experience categories were 0 to 5, 6 to 10, 11 to 15, 16 to 20 and >20 years. Alpha was set at 0.05 to declare associations and differences statistically significant.

RESULTS

Of 416 surveys, 112 were returned (response rate 26.9%). All (100%) respondents either strongly agreed (84.8%) or somewhat agreed (15.2%) with the statement ‘Research is important’ (Figure 1). The majority of the respondents either strongly agreed (78.6%) or somewhat agreed (20.5%) that ‘Respiratory therapy research is important’. ‘Research plays an important role in advancing respiratory therapy as a profession’ was answered ‘strongly agree’ by 56.8%, ‘somewhat agree’ by 39.6%, and

![Figure 1](image)

Figure 1) Respiratory therapist (RT) views about research

![Figure 2](image)

Figure 2) Respiratory therapist (RT) opinions regarding suitability of professions to investigate respiratory therapy topics. MD Medical doctor; RN Registered nurse

‘neither agree nor disagree’ by 3.6%. For the statement, ‘Research plays an important role in my day-to-day practice as an RT’, the responses were 33.9% strongly agree, 45.5% somewhat agree, 17.0% neither agree nor disagree, and 3.6% somewhat disagree.

Three statements were used to identify RTs’ opinions as to who they believe is best suited to conduct respiratory therapy research (Figure 2). The statement ‘RTs are best suited to research respiratory therapy-related topics’ was answered as strongly agree by 50.9% and somewhat agree by 39.3%. For ‘RNs are best suited to investigate respiratory therapy-related topics’, 52.7% strongly disagreed, 31.3% somewhat disagreed, and 12.5% neither agreed nor disagreed. The third statement was, ‘MD and other scientists are best suited to investigate respiratory therapy-related topics’. These responses had some variability: 4.5% strongly agreed, 20.5% somewhat agreed, 25.0% neither agreed nor disagreed, 44.6% somewhat disagreed and 5.4% strongly disagreed.

To differentiate between who should perform respiratory therapy research and how RTs feel about their day-to-day practice, the statement, ‘I trust the Staff MDs to keep respiratory care practices in the ICU up-to-date and current’ was used. Strongly agree was selected by 9.8%, somewhat agree by 42.2%, neither agree nor disagree by 17.9%, somewhat disagree by 21.4% and strongly disagree by 8.9% (Table 1).

The survey asked how RTs view their colleagues’ relationship to research (Table 1). The five-point response scale ranged from false to very true. The statement, ‘There is a general lack of interest by the department’s RTs to do research’, was believed to be false by 1.8%, somewhat false by 18.8%, somewhat true by 46.4% and very true by 7.1%; approximately 25.9% were unsure. For the item, ‘Respiratory therapy research would not be valued by anyone else other than RTs themselves’, 18.9% of respondents believed this statement was false and 36.0% somewhat false. Only 15.3% believed it was somewhat true and 0.9% very true; approximately 28.8% did not know.

Respondents ranked eight barriers to research participation in order of significance for them personally. Rank 1 indicated the most significant barrier and rank 8 the least significant. Rank proportions are provided in Table 2. Lack of time was ranked as the most significant barrier by the largest proportion (59.0%). Each barrier’s mean rank was calculated and barriers were sorted in ascending numerical order according to mean (ie, decreasing order of barrier relevance). The top three most significant barriers were lack of time (mean M=1.9), lack of incentive (M=4.0) and lack of skill (M=4.1). Lack of interest was the least significant barrier (ie, it had the largest mean M=5.8). A large majority (71.8%) said that if barriers were eliminated they would be interested in pursuing a respiratory therapy research project and 17.3% said maybe (Table 2).

Cross-tabulations and the $\chi^2$ statistic were used to identify demographic characteristics associated with RT willingness and self-perceived ability to conduct research. Willingness was assessed by the statement ‘If I had dedicated time away from clinical responsibilities, I would be willing to work on a research project’. The five-point response scale ranged from strongly disagree = 1 to strongly agree = 5. Educational attainment and willingness to work on a research project were

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TABLE 1
Frequency distribution of responses to respiratory therapists’ (RTs) opinion and attitude items

<table>
<thead>
<tr>
<th>Item</th>
<th>Strongly agree</th>
<th>Somewhat agree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I trust in the staff MDs to keep respiratory care practices in the ICU up-to-date and current</td>
<td>9.8</td>
<td>42.0</td>
<td>17.9</td>
<td>21.4</td>
<td>8.9</td>
</tr>
<tr>
<td>There is a general lack of interest by the department’s RTs to do research</td>
<td>False</td>
<td>Somewhat false</td>
<td>Unsure/don’t know</td>
<td>Somewhat true</td>
<td>Very true</td>
</tr>
<tr>
<td>Respiratory therapy research would not be valued by anyone else other than RTs themselves</td>
<td>18.9</td>
<td>36.0</td>
<td>28.8</td>
<td>15.3</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Data presented as %. MD Medical doctor

TABLE 2
Frequency table of barrier ranks and frequency of responses for research interest

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Per cent ranking the barrier number</th>
<th>Sum</th>
<th>Mean rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of time and dedicated work hours</td>
<td>59.0</td>
<td>18.1</td>
<td>6.6</td>
</tr>
<tr>
<td>Lack of incentive (monetary, other)</td>
<td>7.8</td>
<td>22.6</td>
<td>17.6</td>
</tr>
<tr>
<td>Lack of skill and knowledge</td>
<td>5.8</td>
<td>21.4</td>
<td>18.4</td>
</tr>
<tr>
<td>Lack of access to resources (guidance, networks)</td>
<td>6.9</td>
<td>14.9</td>
<td>22.7</td>
</tr>
<tr>
<td>Other personal commitments</td>
<td>12.7</td>
<td>14.7</td>
<td>11.8</td>
</tr>
<tr>
<td>Lack of peer and colleague support</td>
<td>1.1</td>
<td>8.8</td>
<td>8.8</td>
</tr>
<tr>
<td>Lack of recognition</td>
<td>5.1</td>
<td>5.1</td>
<td>11.1</td>
</tr>
<tr>
<td>Lack of interest</td>
<td>9.9</td>
<td>2.0</td>
<td>5.9</td>
</tr>
<tr>
<td>Other</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

If barriers were eliminated, would you be interested in pursuing a respiratory therapy research project? Yes: 71.8, Maybe: 17.3, No: 10.9

Data presented as % unless otherwise indicated

Figure 3) Willingness to work on a research project according to educational attainment. Diploma+ Diploma plus advanced training

Figure 4) Have the required skills to perform research according to educational attainment. Diploma+ Diploma plus advanced training

associated (P=0.029). RTs with more education were more willing to work on a research project (P=0.023) (Figure 3). RTs with a Bachelor’s degree had a higher mean (M=4.3) than diploma respondents (M=3.5) and the difference was statistically significant (P=0.001). RTs with a Master’s degree were more willing to conduct research (M=5.0) than those with a diploma (M=3.5; P=0.001).

The belief in having research skills (‘I have skills required to do research’) was also associated with educational attainment (P=0.006). RTs with Master’s and Bachelor’s degrees were more likely to believe they had research skills than those with a diploma (P=0.006) (Figure 4).

Willingness to learn skills required to do research (‘I want to learn the skills required to do research’) was associated with years of experience as an RT (Pearson χ²; P=0.048; Kruskal-Wallis χ²; P=0.001). Respondents with 11 to 15 years were more willing to learn than others (M=4.4; 0 to five M=4.0; six to 10 M=3.9; 16 to 20 M=4.2; >20 M=3.3). Furthermore, in response to the statement ‘I want to be left to do my job, fulfill my clinical responsibilities and nothing else’, those with six to 10 (M=1.8) and 11 to 15 (M=1.8) years of experience expressed more disagreement (Pearson χ²; P<0.001; Kruskal-Wallis χ²; P=0.03) than those with 0 to five (M=2.0), 16 to 20 (M=2.4) and >20 (M=2.9) years of experience.

RTs were asked to share their expectations pertaining to research when they were training to become an RT by selecting one of five qualitative response options (Figure 5). ‘Research could be a part of the job if you were interested’ was selected by 47.6% of respondents. ‘Research was not part of the job and not discussed’ was selected by 27.6%. ‘Research was discussed as something people in other professions did’ was selected by 18.1%. ‘Research would be encouraged’ was selected by 3.8%, and ‘Research would be an expected part of our job and duty’ was selected by 2.9%. The associations between these expectations and educational attainment (P=0.93) and years of experience (P=0.13) were not statistically significant.
DISCUSSION

Respiratory therapy practice has thrived on change and innovation. What was once a job that involved hauling tanks and titrating oxygen is now a skilled career in which professionals manage life support devices for critically ill patients. RTs now create recommendations for respiratory care plans and are valued members of the multidisciplinary team (4-6). They are bedside specialists who combine a technological understanding of machinery with an advanced knowledge of respiratory physiology and particular training to assess this interaction (4-6). It appears consistent that the group best suited to critically question and analyze respiratory therapy practice is the very group of people responsible for respiratory interventions. Without continuous critical assessment through research, any health profession could render itself obsolete (4). However, few RTs have time to perform the research that establishes EBP (17). Although many RTs are competent clinicians in academic hospitals, research barriers are numerous.

By participating in the present study, RTs in several academic hospital roles have established their opinions about research. The most relevant result is that RTs believe that research is generally important and that respiratory therapy research is particularly important. RTs also believe that research is necessary in their day-to-day practice and for advancing the profession. However, the level of agreement decreased the more specific the survey statements became about research in relation to respiratory therapy. For example, 84.8% of RTs strongly agreed that ‘Research is important’; while 78.6% strongly agreed that ‘Respiratory therapy research is important’. It is unclear why the strength of agreement decreased when respiratory therapy research was specified, or why RTs believe that respiratory therapy-related research is slightly less important. The level of agreement continues to decrease with each successive statement and suggests that there is a sense of uncertainty within the profession regarding the association between respiratory therapy and research. The reason for the progressive change in response is speculative without further investigation. Despite this observation, RTs believe that research is important. Had the opposite been true, a starting approach to respiratory therapy research would require a shift in motivation. This is not the case; RTs are motivated. Consequently, academic hospital leaders should be aware that RTs’ values with respect to research are similar to the organization’s values. Academic hospitals should support RTs who want to pursue research that is in accord with the institution’s mission.

RTs often facilitate other investigators’ research. However, to develop independent research capacity, RTs must display professional responsibility toward research within their area of practice (2, 5, 12, 14, 16, 19, 23). RTs expressed a sense of ownership over respiratory therapy research; they believed that RTs are best suited to conduct respiratory therapy research. RTs do not believe that registered nurses (RNs) are best equipped to investigate respiratory therapy topics. They disagreed with the statement about RNs with the same frequency that they agreed with RTs’ suitability. In addition to the small percentage of respondents that disagreed with the statement that RTs are best suited to investigate respiratory therapy topics, there was a small percentage that believed that RNs are best suited to perform respiratory therapy research. It is unclear why they had this opinion. Perhaps they believe that RTs lack the time or skill. Few RTs have Master’s degrees and some respondents may perceive RTs to be academically unprepared for research. This also may reflect a belief that respiratory therapy research should be multidisciplinary. The role RTs believe RNs should or should not have in respiratory therapy research requires further investigation to fully comprehend the ensuing dynamic. It may relate to complex interprofessional relationships. It may also relate to how comparatively new respiratory therapy is as a discipline that has not secured as many academic avenues and research supports as nursing.

Although many RTs believed that physicians are best suited for respiratory therapy research, a near majority disagreed. This result further exemplifies RTs’ sense of professional responsibility and it provides a small glimpse of how health care is changing. With the evolution of specialties, such as respiratory therapy, these respondents believe that medical doctors (MDs) or scientists, despite having the skill to conduct research, are not necessarily best suited to research respiratory therapy topics. RTs are the end user of the technology or therapeutic modality. They work with the intricacies of the processes and procedures of patient care within their daily practice. They have clearly identified themselves as respiratory specialists and the candidates best suited to generate questions and add to the information base in this area of expertise.

Although RTs believe that they themselves should be asking questions and contributing to research, their views do not suggest a strong desire to perform it all themselves. Moreover, it does not imply that MDs and other scientists should not research respiratory therapy topics. When asked whether they ‘trust the staff MDs to keep respiratory care practices in the intensive care unit [ICU] up to date and current’ the majority of RTs agreed with the statement. Clearly, these respondents believe that MDs still play an important role in the process of establishing and implementing practice guidelines. At first glance, the responses to the statements about MDs conducting research on respiratory therapy topics (MDs are not best suited for it) and MDs updating intensive respiratory care practices (they are trusted to do so) appeared to be contradictory. However, this indecisiveness as to what role RTs believe the MDs should have in respiratory practice is more likely a reflection of the professional responsibility that RTs carry. As illustrated by the responses, there is a demarcation on what RTs believe the role of the RT should be as it pertains to research. They have distinguished themselves as having a role in generating knowledge more so than implementing practices.

We found that RTs do have a sense of self-worth in relation to research. The majority believed that respiratory therapy research would be valued by others. However, they also expressed apathy. One-half of the respondents perceived a general lack of interest among their department colleagues to conduct research. Although this is a rather negative opinion about their colleagues’ motivation for research, the perception may not match reality because, for example, lack of interest in research was self-ranked as the least significant barrier to research. Furthermore, nearly three-quarters said that they would be interested in conducting a research project related to respiratory therapy if barriers were eliminated.

Approximately one-quarter of RTs did not know whether their colleagues lacked interest in research and did not know whether respiratory therapy research would be valued by non-RTs. These figures are reasons for concern because they suggest that some RTs are substantially unaware of local norms in relation to research.

We are concerned by the results regarding RTs’ beliefs about research while training to become RTs. Very few respondents reported impressions that research was encouraged or that it was an expected part of the job. These impressions were consistent regardless of educational attainment and experience. For example, new RTs and those with 20 years of experience shared the same belief about research when training to become an RT. Similarly, regardless of educational attainment, research exposure, encouragement and support during training were uncommon. The belief about research when training to become an RT was the same.
Three main barriers to conducting research that RTs encounter in standard practice were identified: lack of time, lack of incentives and lack of skill. RTs are busy clinicians and the foundation of the profession remains at the bedside (17). For this reason, RTs need to have time available for research – whether it be dedicated hours away from bedside, higher RT-patient ratios or a supported research program. Other incentives, such as flexibility in hours and scheduling, could be alternatives to monetary offerings. Research requires advanced skills that exist in abundance in most academic hospitals. Lack of skill is a factor that employers, professional organizations and academic hospitals could jointly remEDIATE by making research available to RTs who do not have formal training necessary to conduct their own research.

The study identified two associations with educational attainment: first, willingness to work on a research project; and, second, a belief in having the skills necessary for research. Respondents with more education were more willing to conduct research and assert that they have the necessary skills. Willingness to learn the skills required to conduct research was greatest in the 11 to 15 years’ experience range. Groups with moderate experience (eg, six to 15 years) were more willing to pursue activities in addition to clinical practice. It appears that these RTs have become proficient in their bedside responsibilities and wish to have a greater impact on the profession in which they have become so adept. Less experienced RTs were not as willing to conduct disciplinary research and are perhaps focused on developing their clinical bedside skills. The most experienced RTs (>16 years) were the least willing to learn research skills. Most clinicians in this group also do not want to take on additional duties outside of their clinical responsibilities. It is possible that this group lacks confidence to work in novel areas. For departments that want an active respiratory therapy research program, it may be helpful to recruit RTs with higher educational attainment and moderate levels of work experience.

The present study had some limitations. The obtained sample size was low and there may have been a response bias favourable research. RTs who completed the survey may have had stronger research interests than nonrespondents. Most respondents held a Bachelor’s degree, and the survey should be fielded at community hospitals to assess the generalizability of our results. The items in some scale sections should be analyzed with statistical methods to judge the data’s validity and reliability with a larger sample size and when formal measurement constructs are developed.

CONCLUSION

The broadest challenges to respiratory therapy research are the lack of systematic exposure to research during respiratory therapy training, as well as within colleague networks and the work environments. If RTs intend to conduct research, respiratory therapy curricula should be modified to convey research as a valuable activity. This will help foster a culture of inquiry through which new graduates, regardless of whether from an academic centre, can enter the profession with a view on research as an expectation rather than simply an afterthought.

Administrative leaders of academic centres should acknowledge that their bedside clinicians share similar organizational values. With this knowledge, resources can be allocated to eliminate barriers and support the willingness and urgency of RTs to conduct research. RTs could then perform at a level that is expected of them and which they desire.

AUTHORSHIP: CM conceived the research idea and its design, acquired and analyzed the data, wrote the first draft of the manuscript and contributed to revisions. CK contributed to research design, data analysis and results interpretation, and revised the first draft of the manuscript for important intellectual content.

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

Norman H Tiffin BSc MSA1, Jason Nickerson RRT FCRT PhD(c), Editor-in-Chief2

Over the past eight years, the registration of clinical trials has been strongly advocated by journals and editors, and is now considered to be mandatory for publication by most medical journals. In the United States, it became legally mandated by the Food and Drug Administration in 2007 (1), although Canada has no law requiring registration.

Registration of a clinical trial ensures that the public has access to information regarding trials involving human subjects and health outcomes. Published clinical trials strongly affect decision making in health care, including decisions made at the bedside, in the boardroom and in the legislature. Therefore, the public needs to have access to the same evidence as the decision makers. Moreover, registering clinical trials and their protocols before data collection begins helps correct the distortion created by selective reporting in the literature (ie, ‘positive publication bias’), in which only trials with positive outcomes are published. Many also believe that the research community, by using human subjects, has a moral obligation to the public to publish their findings and a registry can reveal a disconnect in communication. In addition, registries can help standardize and improve clinical trial protocols, reduce overlapping or redundant publication and scientific misconduct, and improve accuracy in reporting.

Several registries exist today, with the largest at <www.clinicaltrials.gov> administered by the US National Institutes of Health. Individual countries often have their own registry, many of which use the WHO’s International Clinical Trial Registry Platform guidelines. The International Committee of Medical Journal Editors has established six guidelines for the establishment of registries (2); although not all registries adhere to these guidelines, they provide insight to registry characteristics and expectations:

1. Accessible to the public at no charge.
2. Open to all prospective registrants.
3. Managed by a not-for-profit organization.
4. A mechanism to ensure the validity of the registration data must be available.
5. Electronically searchable.
6. Trial registration with missing fields or fields that contain uninformative terminology is inadequate.

The International Committee of Medical Journal Editors defines a clinical trial as “any research project that prospectively assigns human subjects to intervention or concurrent comparison or control groups to study the cause-and-effect relationship between a medical intervention and a health outcome” (2). Health outcomes are further defined as “any biomedical or health-related measures obtained in patients or participants, including pharmacokinetic measures and adverse events” (3).

In the current issue of the Canadian Journal of Respiratory Therapy, the study by Matthews and Fortier (4) (pages 11-14) – ‘The Rematee Bumper Belt positional therapy device for snoring and obstructive sleep apnea: Positional effectiveness in healthy subjects’ – has not been registered as a clinical trial despite the use of human subjects. Why? First, although the editorial board of the Journal strongly support registration of clinical trials, we do not believe that the study’s dependent variable – sleeping position – reached the definition of a health outcome. In addition, we believed that because the main reason for registration is to ensure the publication of important findings and the authors had submitted the manuscript for publication, this became a moot criterion. Although the Journal strongly believes in the value of clinical trials registration, we believed that, on balance, the rejection of an article reporting on a completed study solely on the basis of the absence of clinical trial registration was not in the best interests of patients nor health care providers. In making this decision, we consulted with experts in medical publishing and in clinical trials registration, and believe this to have been the most appropriate decision.

As the Journal progresses in reputation and quality, we anticipate more submissions of clinical trial manuscripts and have been prompted by this particular article to codify a policy for clinical trial publication criteria that will be communicated in 2014. Going forward, we strongly encourage all authors and investigators to prospectively register their clinical trials in advance of conducting data collection. It is our intention to include these details in the publication of clinical trials manuscripts to enhance the transparency and quality of respiratory therapy research.

REFERENCES


General anesthesia and mechanical ventilation impair pulmonary function, even in normal individuals, and result in decreased oxygenation in the postanesthesia period. They also cause a reduction in functional residual capacity of up to 50% of the preanesthesia value. It has been shown that pulmonary atelectasis is a common finding in anesthetized individuals because it occurs in 85% to 90% of healthy adults. Furthermore, there is substantial evidence that atelectasis, in combination with alveolar hypoventilation and ventilation-perfusion mismatch, is the core mechanism responsible for postoperative hypoxemic events in the majority of patients in the postanesthesia care unit (PACU). Many concomitant factors also must be considered, such as respiratory depression from the type and anatomical site of surgery altering lung mechanics, the consequences of hemodynamic impairment and the residual effects of anesthetic drugs, most notably residual neuromuscular blockade. The appropriate use of anesthetic and analgesic techniques, when combined with meticulous postoperative care, clearly influences pulmonary outcomes in the PACU. The present review emphasizes the major pathophysiological mechanisms and treatment strategies of critical respiratory events in the PACU to provide health care workers with the knowledge needed to prevent such potentially adverse outcomes from occurring.

Key Words: Alveolar hypoventilation; Atelectasis; Postanesthesia care unit; Pulmonary shunt; Respiratory complications; Ventilation-perfusion mismatch

R espiratory complications in the postanesthesia period are an important area of concern because they are a major cause of morbidity and mortality. A critical respiratory event in the postanesthesia care unit (PACU) is the complex of major unanticipated ventilation problems, including hypoxemia (hemoglobin oxygen saturation <90%), hypoventilation (respiratory rate <8 breaths/min or arterial carbon dioxide tension >50 mmHg) or upper-airway obstruction (laryngospasm or stridor), that require a physical or pharmacologic intervention (eg, insertion of an oral/nasal airway, ventilation, tracheal intubation, opioid antagonism, muscle relaxant reversal) (1). There is large variation in the incidence of critical respiratory events in the PACU, with several prospective observational studies reporting an incidence of between 0.8% and 6.9% (1-5). Multiple factors, including surgical, anesthetic and patient variables, contribute to the etiology of postoperative respiratory complications (2,4). Surgical risk factors include chronic obstructive pulmonary disease (COPD), diabetes, obesity and nonmodifiable risk factors such as advanced age and male sex (2,4). The present article reviews the major mechanisms causing deterioration in gas exchange during the immediate postoperative period, the effects of anesthetic pharmacology and measures to improve oxygenation relevant to clinical practice.

RISK FACTOR OVERVIEW AND CLINICAL GUIDELINE

Respiratory complications are as common as cardiac complications following noncardiac surgery in the PACU and beyond. Fleischmann et al (6) found that the incidence of respiratory events was highly comparable with that of cardiac complications (2.7% versus 2.5%). However, they differ from cardiac complications in that surgical- and anesthesia-related factors are more predictive of respiratory complications than are patient-related factors (6).

The 2006 American College of Physicians (ACP) clinical guideline on risk assessment for and strategies to reduce perioperative respiratory complications in patients undergoing noncardiothoracic surgery (7-9) assigned letter grades to the risk factors based on the strength of evidence (Table 1). According to this guideline, surgical site was found to be the most important of any of the procedure- or patient-related risk factors, and the closer the incision is to the diaphragm, the greater the risk for postoperative respiratory complications (8). When considering the different types of procedures, thoracic, abdominal and aortic surgeries carry the highest risk (8). Furthermore, upper abdominal surgery carries a greater risk than lower abdominal surgery among abdominal procedures (8). Good evidence also supports the procedure-related risk factors of prolonged surgery and emergency surgery (8).

The most important of the patient-related risk factors identified in the ACP guideline are increasing age and increasing American Society of Anesthesiologists classification of comorbidity (8). The effect of advanced age becomes particularly notable at approximately 60 years of age and worsens from there (8). Of note, smoking and COPD were only minor risk factors in the ACP analysis (8).

A serum albumin level <35 g/L is the most powerful predictor among potential laboratory tests to stratify risk, and predicts risk to a similar degree as the most important patient-related risk factors (8).
TABLE 1
Strength of evidence for association of risk factors with postoperative respiratory complications

<table>
<thead>
<tr>
<th>Level of evidence</th>
<th>Patient related</th>
<th>Procedure related</th>
<th>Laboratory tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Good)</td>
<td>ASA class II</td>
<td>Thoracic surgery</td>
<td>Albumin level &lt;35 g/L</td>
</tr>
<tr>
<td></td>
<td>Cardiac failure</td>
<td>Abdominal surgery</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Advanced age</td>
<td>Upper abdominal surgery</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Functional dependence</td>
<td>Aortic aneurysm repair</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chronic obstructive pulmonary disease</td>
<td>Neurosurgery</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B (Fair)</td>
<td>Impaired sensorium</td>
<td>Perioperative transfusion</td>
<td>Chest radiography</td>
</tr>
<tr>
<td></td>
<td>Cigarette use</td>
<td></td>
<td>BUN level &gt;7.5 mmol/L (&gt;21 mg/dL)</td>
</tr>
<tr>
<td></td>
<td>Alcohol use</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weight loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Abnormal findings on chest examination</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table adapted from reference 8. ASA American Society of Anesthesiologists; BUN Blood urea nitrogen

DIFFERENTIAL DIAGNOSIS OF ARTERIAL HYPOXEMIA IN THE PACU

There are several factors that can contribute to arterial hypoxemia in the immediate postoperative period (10). The most important mechanisms will be discussed at length.

Atelectasis
Atelectasis causes pulmonary shunt and, therefore, undoubtedly contributes to the impairment of gas exchange during general anesthesia. According to Lundquist et al (11), 20% to 25% of the lung tissue in basal regions or approximately 15% of the entire lung may be atelectatic in adults with healthy lungs, resulting in true pulmonary shunt.

A pulmonary shunt of 5% to 10% of cardiac output is found in adults during general anesthesia with mechanical ventilation (12,13). Although shunt does not increase with age, regions with poor ventilation in relation to their perfusion show a dependency on age (12). Furthermore, larger atelectatic areas are present in obese patients whereas patients with COPD may show less or even no atelectasis (14). Atelectasis appears immediately with induction of anesthesia and is present after muscle paralysis and during spontaneous breathing regardless of whether inhalational or intravenous anesthetics are used (11,15). The use of ketamine is the only exception to this rule (16).

Three possible mechanisms may cause atelectasis including gas resorption, impaired function of surfactant and compression atelectasis (17-19).

It has been shown that a lung unit will ultimately collapse if it is not ventilated (20). Hence, lung collapse may occur if induction of anesthesia results in an increased number of lung units with poor or no ventilation, and if such lung units are filled with an easily resorbed gas (21). Even short periods of breathing 100% oxygen near the residual volume may cause atelectasis (22). Therefore, if there is a concomitant increase in low ventilation/perfusion (V/Q), an increased inspired fraction of oxygen (FiO₂) may promote the formation of atelectasis (23,24).

It is known, however, that there may be a decreased content of active forms of alveolar surfactant due to a lack of intermittent deep breaths, as is usual during mechanical ventilation (25). Furthermore, anesthesia and atelectasis per se may impede the function of surfactant (26). Such decreased function results in reduced alveolar stability and causes alveolar collapse. This may also contribute to liquid bridging in the airway lumen and cause airway closure (27).

The end-expiratory intrathoracic pressure is normally lower than the abdominal pressure because the diaphragm separates two spaces with different pressures as well as vertical pressure gradients. In an awake patient, the vertical pressure gradient in the pleural space is 0.2 cmH₂O/cm to 0.4 cmH₂O/cm, whereas this gradient approximates 1 cmH₂O/cm in the abdomen (28). This abdominal pressure will be transferred into the thoracic cavity if the diaphragm no longer acts as a rigid wall between these two spaces, thus increasing the pleural pressure in dependent lung regions. This process could result in compression atelectasis. This was indirectly reflected in a study by Tokics et al (16), who showed that no atelectasis developed during anesthesia with ketamine, a drug known to maintain respiratory muscle tone and rib cage function. Furthermore, several studies (29,30) showed a cephalad shift of the diaphragm with anesthesia and muscle paralysis.

The attenuation of hypoxic pulmonary vasoconstriction (31,32) may further contribute to impairment in gaseous exchange by increasing pulmonary shunt (because atelectasis is present throughout anesthesia). This effect may be apparent with the inhalational anesthetics (33) but is less prominent or even absent with intravenous anesthetics (33). Such an effect does not cause any disturbances in an otherwise normally functioning lung and is only relevant in the setting of V/Q mismatch or pulmonary shunt.

In summary, atelectasis is found in 85% to 90% of anesthetized adults, appears immediately after induction of general anesthesia and primarily causes pulmonary shunt (11). Two mechanisms most commonly involved in the perioperative formation of atelectasis are compression and resorption. The early formation of atelectasis and the increase in pulmonary shunt are unavoidable adverse effects of anesthesia leading to respiratory complications in the postanesthesia period (34).

Alveolar hypventilation
CO₂ retention is the hallmark of hypventilation and is always present. Review of the alveolar gas equation according to West (34) indicates that partial pressure of oxygen (PaO₂) is both directly and inversely proportional to alveolar ventilation; therefore, when patients breathe room air while hypventilating, hypoxia results secondary to an increase in alveolar CO₂. Furthermore, hypoxemia of pure hypventilation can be readily improved by increasing the FiO₂ (34). This is especially important when monitoring patients for airway or ventilation adequacy in the PACU. According to Stemp and Ramsay (35), a fall in arterial oxygen saturation on pulse oximetry in patients breathing room air is indicative of alveolar hypventilation or possible airway obstruction. Rapid detection of this phenomenon in the PACU thus enables early intervention.
In the immediate postoperative period, causes of hypoventilation are myriad and include the following (34,36): depressed central respiratory drive secondary to drug overdose or the residual effects of opioids, sedative hypnotics and inhaled anesthetics and, possibly, due to metabolic derangements such as metabolic alkalosis and severe hypothyroidism; ventilatory muscle dysfunction and generalized weakness secondary to residual neuromuscular blockade or underlying neuromuscular disease such as Guillain-Barré syndrome or myasthenia gravis; ventilation failure attributable to chest wall abnormalities, such as severe kyphoscoliosis, injuries, such as rib fractures or flail chest, or postoperative thoracotomy pain; injudicious use of oxygen; and increased minute ventilation due to metabolic acidosis (common in patients receiving crystalloid resuscitation), sepsis, anxiety and agitation.

Obstruction of the upper airway secondary to muscle paralysis caused, at least, in part, by gravity-independent inhomogeneity of regional ventilation (51,52).

In patients with COPD, V/Q inequalities contribute to hypercapnia (37). The associated hypoxemia is more severe in relation to hypercapnia than in other forms of hypoventilation. Furthermore, injudicious use of oxygen therapy in such patients can worsen hypercapnia and ventilatory failure. This effect is often attributed to a decrease in hypoxic ventilatory drive associated with this group of patients (38).

In most patients with hypoventilation, hypoxemia is reversed with supplemental oxygen therapy and the main focus of management is treating the cause of hypoventilation (34). It is important to note, however, that the use of supplemental oxygen in these settings can mask the progression of bradynea to apnea, preventing the onset of hypoxemia as evidenced by pulse oximetry and, thus, can lead to unrecognized severe hypoventilation with potentially catastrophic consequences (35). In this situation, the pulse oximeter becomes an important tool for monitoring not only oxygenation but also the adequacy of ventilation when supplemental oxygen is not used (39).

**V/Q mismatch**

The mechanisms for V/Q mismatch during general anesthesia and mechanical ventilation involve changes in both the functional residual capacity (FRC) and the distribution of ventilation. According to several studies (40,41), FRC is reduced by approximately 20% during general anesthesia compared with the awake state. Such a reduction is caused by a change in rib cage configuration (42) and cranial shift of the diaphragm (mostly of its dependent parts) (43,44).

The magnitude of such changes depends on several factors including the type of anesthetic used and whether muscle relaxation is added. Rib cage contribution to normal tidal breathing is reduced (45) or unchanged with inhalation anesthetics (46), whereas ketamine, on the other hand, increases rib cage contribution (47) or may at least keep the contribution unchanged (48). A change in intrathoracic blood volume is an additional factor relevant to the decrease in FRC (49). These changes may also result in a change in regional ventilation. During spontaneous breathing, there is some gravity-dependent distribution of ventilation, with an increase in regional ventilation from nondependent to dependent lung regions (50), as well as marked gravity-independent inhomogeneity of regional ventilation (51,52).

There is a marked change in ventilation distribution with induction of anesthesia and muscle paralysis caused, at least, in part, by a change in the position and movement of the diaphragm (39). Inspiratory gas predominantly shifts to nondependent lung regions during normal tidal breathing, whereas dependent regions are less ventilated (53).

There is also a change in the distribution of pulmonary blood flow in addition to the change in ventilation distribution (54). Increased intrathoracic pressure, present during positive pressure ventilation, may reduce cardiac output and affect pulmonary vascular resistance (55). This may result in decrease of blood flow to West's zone I lung region (37). There is also some change in distribution of pulmonary perfusion with induction of general anesthesia and mechanical ventilation, with the net result being a well-documented impairment in V/Q distribution (56). These changes contribute significantly to respiratory complications in the postanesthesia period.

Regional anesthesia, compared with general anesthesia, usually results in markedly less impairment of V/Q distribution (30,57).

**Pulmonary shunt**

Hypoxemia attributable to shunt is characterized by a decrease in arterial oxygen content in the setting of constant alveolar ventilation. Consequently, venous blood passes to the arterial system through areas of unventilated lung. An important diagnostic element of shunt is apparent in the shape of the oxygen-hemoglobin dissociation curve (36); the addition of supplemental oxygen cannot ameliorate the hypoxemia.

This is because the saturation of nonsaturated blood is on the flat portion of the oxygen-hemoglobin dissociation curve and, thus, additional oxygen has little impact in raising the PaO₂. The PaO₂ drops precipitously when this blood mixes with poorly oxygenated shunted blood. This is in contrast to arterial hypoxemia secondary to V/Q mismatch, hypoventilation or diffusion abnormality, which is easily resolved with oxygen therapy (34).

Furthermore, treatment with 100% oxygen in the postanesthesia period, which causes nitrogen washout, can result in alveolar collapse creating an area of low V/Q ratio and, therefore, worsening the hypoxemia characteristic of patients with V/Q abnormalities.

Pulmonary disorders, such as pulmonary edema (both cardiogenic and negative pressure), transfusion-related lung injury and pneumonia, represent potential causes of shunt commonly encountered in the PACU. The less common extrapulmonary causes of shunt may include congenital cardiac defects such as atrial septal defect, patent ductus arteriosus and ventricular septal defect, which are associated with increased right heart pressures.

**Diffusion impairment**

Diffusion impairment reflects the lack of equilibrium between PaO₂ in the alveolar gas and pulmonary capillary blood. Such a situation can occur when the alveolar capillary membrane is thickened, thus limiting the rate of diffusion of oxygen between the capillary and alveoli (34). Underlying lung disease, such as emphysema, interstitial lung disease, primary pulmonary hypertension or pulmonary fibrosis, are classic examples. Damage or loss of whole lung units reduces alveolar capillary surface area and capillary volumes, resulting in a lack of equilibrium and decreased red cell transit time through alveolar capillaries. Such a decreased transit time through alveolar capillaries may be due to increases in cardiac output, as observed in sepsis for example, thus worsening arterial hypoxemia in the context of an already injured lung.

**Increased oxygen extraction**

Increased oxygen extraction typically refers to low cardiac output states and is due to the mixing of desaturated venous blood with oxygenated arterial blood. Typically only 2% to 5% of cardiac output is shunted through the lungs, and this shunted blood with a normal mixed venous saturation has a negligible effect on PaO₂ (34,37). However, blood returns to the heart severely desaturated in low cardiac output states. Furthermore, the shunt fraction increases significantly in conditions that impede alveolar oxygenation such as pulmonary shunt or V/Q mismatch and mixing of desaturated shunted blood with saturated arterialized blood under these conditions decreases PaO₂ (34,37).

**THE EFFECTS OF PHARMADEOLOGY**

General anesthesia and mechanical ventilation are facilitated by many drugs, mainly opioids, sedatives and neuromuscular blocking agents, that can impede the physiological control of breathing after the
weaning process. At the conclusion of surgery, it is therefore especially important that residual effects of anesthetic agents be adequately reversed or dissipated.

As long as the airway is maintained, adequate spontaneous ventilation is readily possible during surgical levels of anesthesia, but a picture resembling sleep apnea may be induced at lighter planes of anesthesia that requires control of the airway (58). Thus, many of the problems noted in the PACU are related to the loss of mechanical support of the upper airway.

Pharmacological effects are of little importance in the control of breathing throughout general anesthesia and mechanical ventilation; however, during and after the weaning process, any depression of ventilator control may require the reinstatement of mechanical ventilation.

Furthermore, the effects of these drugs on the control of breathing are complex and can affect breathing by alterations in: the chemoreflexes (both hypercapnic and hypoxic); the nonchemoreflex or the so-called ‘wakefulness drive’; and upper airway tone. Because the control of ventilation is under both feedback and feedforward control, the effects of specific drugs can vary greatly, depending on the patient’s physiological state (59,60). Thus, during periods of patient sedation in the PACU, adequate ventilation may depend solely on the chemoreflexes as opposed to when the patient is fully awake, when feedforward influences from the higher centres typically predominate (59,60). Ventilation may, therefore, be adequate when the patient is awake and aroused but may become inadequate during oversedation (61).

**Opioids and sedatives**

Opioids are commonly used for analgesia in the PACU and are mainstays in the treatment of acute severe pain. It is well known, however, that they are the classic respiratory depressants and produce a dose-related depression of total ventilation through a decrease in both respiratory frequency and tidal volume. The respiratory depressant effect of the opioid is a central µ receptor action (62), and there is little benefit in recommending one opioid over another as far as this side effect profile is concerned. The pharmacokinetic characteristics of the different opioids may, however, have a profound impact and those that are short acting after a single dose may produce extended respiratory depression manifesting in the PACU after prolonged infusion in the operating room (63). Thus, the increase in CO₂ secondary to the reduction in spontaneous minute ventilation when an opioid is given will tend to counter the depression of ventilation if the onset of the opioid is slow. On the other hand, a bolus of a rapid-onset opioid may induce apnea before the CO₂ can increase sufficiently to stimulate ventilation (64).

Neuraxially administered opioids, either epidurally or intrathecally, depress both the hypoxic and hypercapnic responses even though the plasma levels are not significant and, thus, the route by which the opioid reaches the brainstem does not appear to be as important (65). Delayed respiratory depression must, however, be considered with neuraxial administration, particularly if lipophilic opioids are used. Thus, postoperatively, such opioid administration is potentially associated with upper airway obstruction and desaturation (66).

The effects of midazolam on the upper airway may be more important than its effects on decreasing respiratory drive (67). It reduces both the hypoxic and hypercapnic chemoreflexes, and it is the loss of the wakefulness drive that may account for the mild reduction in hypercapnic sensitivity (67). Both the sedative and respiratory depressant effects of midazolam can be reversed by flumazenil, although the sedation reversal may outlast reversal of the respiratory depression (68).

The combination of opioids and sedatives can be synergistic in the extent of respiratory depression produced (66). This synergism may result from the effect of the sedative on the wakefulness drive (a hypothesis originally proposed by Fink [69], that cerebral activity associated with wakefulness is a component of the normal respiratory drive) and the effect of the opioid on the chemoreflex and, thus, should be closely monitored in the PACU.

**Neuromuscular blocking drugs**

Neuromuscular blocking drugs are frequently used intraoperatively and residual neuromuscular blockade is commonly observed in the PACU. Approximately 33% to 64% of patients have evidence of inadequate neuromuscular recovery on arrival to the PACU (70,71), despite the application of techniques proven to limit the degree of residual paralysis such as pharmacological reversal and the use of intermediate-acting agents. Residual neuromuscular blockade may produce postoperative hypoxemia by several mechanisms. These include the deleterious effects on both chemoreception and upper airway patency in addition to their predictable effects on the phrenic nerve-diaphragm neuromuscular junction (72).

In an study by Eikermann et al (73), significant upper airway obstruction was detected in eight of 12 volunteers at a train-of-four (TOF) ratio of 0.50 and four of 12 volunteers at a TOF ratio of 0.83 (73). Similarly, other investigators have demonstrated significant pharyngeal muscle dysfunction in healthy volunteers at TOF ratios <0.90 (73,74) suggesting that residual neuromuscular blockade is a primary contributing factor to airway obstruction in the PACU.

At the receptor level, it is generally accepted that the neuromuscular blocking drugs act to block the neuromuscular junction nicotinic receptors, with little effect on neuronal nicotinic receptors. As a result, low doses of vecuronium appear to depress hypoxic ventilatory drive through depression of carotid body chemosensitivity in both rats (75) and humans (76).

**Cardiovascular medications**

Medications used to support the cardiovascular system can also have significant respiratory effects, but auspiciously, most of them do not cause major clinical problems in the PACU. Of these agents, dopamine has the most pronounced ventilator effects because even low doses significantly blunt the hypoxic ventilatory response (77). Several studies have demonstrated that a low-dose dopamine infusion has depressant effects on minute ventilation when given during hypoxia or during states with compromised oxygen delivery to tissues such as during exacerbation of congestive heart failure (78). Other cardiovascular drugs, such as digoxin and adenosine, have ventilatory effects that can be readily measured; however, there is no evidence that any of these effects are clinically significant (77).

**PREVENTION AND TREATMENT OF ATELECTASIS**

Atelectasis is clearly an important cause of postoperative hypoxic events in the PACU. Identifying various procedures in the operating room that can prevent atelectasis or reopen collapsed alveoli are, therefore, worth mentioning. At the outset, using an anesthetic, such as ketamine, that enables maintenance of respiratory muscle tone will likely preclude the formation of atelectasis (17,18). Nonetheless, if combined with muscle paralysis, atelectasis will most likely develop (16).

In anesthetized adults with healthy lungs, alveolar recruitment reduces the amount of atelectasis and pulmonary shunt and, despite a concomitant increase in perfusion to poorly ventilated lung units, it also improves ventilatory efficiency as measured by CO₂ elimination (79). A single recruitment breath may result in the release of surfactant (80), thus contributing to improved alveolar stability and preventing lung collapse. It has also been shown that recruitment attenuates bacterial growth and translocation in an animal model of pneumonia (81). However, in patients with COPD, anesthesia causes only a small amount of atelectasis, and impaired oxygenation is primarily caused by a V/Q mismatch (14). Therefore, any further expansion of lung tissue in these patients may be of limited value or may even be harmful because of possible regional overinflation. For that reason, one should carefully weigh the assumed benefits and possible risks before performing a recruitment manoeuvre (82).

The use of positive end-expiratory pressure (PEEP) is another approach to reopen the collapsed lung. PEEP reduces the amount of
atelectasis if used in patients with healthy lungs, but it has a variable effect on pulmonary shunt and often results in increased dead space (83). However, atelectasis redevelops within a few minutes after cessation of PEEP (84) and, therefore, if sustained reopening of atelectasis and reduction of pulmonary shunt are the main goals of a therapeutic measure, a vital capacity alveolar recruitment manoeuvre may be more appropriate than PEEP used alone (85). Alternatively, when used after a recruitment manoeuvre, PEEP significantly reduces the rate of renewed lung collapse even if a high FiO\textsubscript{2} is used (86-88). PEEP may also be used to prevent formation of atelectasis and to prolong the time of nonhypoxic apnea during induction of anesthesia (89,90).

**TREATING THE CAUSES OF ARTERIAL HYPOXEMIA IN THE PACU**

According to the oxygen dissociation curve (which defines the relationship between \(\text{Pao}_2\) and oxygen saturation \(\text{SaO}_2\)), a \(\text{Pao}_2\) of 60 mmHg results in an \(\text{SaO}_2\) of approximately 90%. The main aim of supplemental oxygen therapy in the PACU is, therefore, to maintain a \(\text{Pao}_2\) ≥60 mmHg (91) because any further decrease in \(\text{Pao}_2\) would result in a marked drop in \(\text{SaO}_2\). Herein, we discuss the goals of oxygen therapy based on the causes of arterial hypoxemia in the PACU.

Alveolar hypoventilation

The level of hypoxemia in alveolar hypoventilation is usually not severe and is easily reversed by the use of oxygen. The main goals of the management of hypoventilation in the PACU are the recognition and treatment of its underlying cause. A major cause is COPD and V/Q mismatch plays a key role in the pathophysiology of the increased pressure of CO\textsubscript{2} (PCO\textsubscript{2}) in these patients (37,92).

Oxygen should, therefore, be carefully titrated because too high an FiO\textsubscript{2} can reduce hypoxic vasoconstriction or abolish hypoxic ventilatory drive, thereby leading to an increase in dead space (92) and, consequently, can contribute to dangerously high levels of PCO\textsubscript{2} and ventilatory failure. Regardless of this concern, adequacy of tissue perfusion is the primary goal in these patients in the PACU.

It is not recommended, however, to sacrifice adequate arterial oxygen levels and tissue oxygen delivery to improve hypercarbia. Thus, if the PCO\textsubscript{2} remains dangerously high after careful titration of oxygen in the PACU, as indicated by a patient’s clinical status and arterial pH, and the oxygen saturation remains too low, then bilevel noninvasive positive pressure ventilation or even intubation and mechanical ventilation may be required.

V/Q mismatch

The use of supplemental oxygen increases \(\text{Pao}_2\) in the setting of V/Q mismatch, but the extent of increase depends on the predominant pattern of inequality. The response may, however, be unpredictable and could take many minutes (93). Treatment with 100% oxygen can potentially increase \(\text{Pao}_2\) to very high levels and subsequent nitrogen washout can cause alveolar collapse that can turn areas of low V/Q mismatch to true shunt.

Aside from the use of oxygen therapy in the PACU, treatment should be targeted at improving the V/Q abnormality. This includes the use of bronchodilators for patients with COPD and asthma, and PEEP for patients with acute lung injury and pulmonary edema.

Pulmonary shunt

Hypoxia caused by pulmonary shunt is less responsive to supplemental oxygen in and beyond the PACU. However, meaningful increases in \(\text{Pao}_2\) can occur with use of high concentrations of oxygen in these patients. At high \(\text{Pao}_2\), there is significant additional dissolved oxygen (34,37) and, consequently, important increases in the arterial oxygen content and saturations can occur because the FiO\textsubscript{2} is increased. However, with shunt fractions ≥50%, little benefit to high concentrations of supplemental oxygen is apparent.

**Diffusion impairment**

The use of supplemental oxygen in the PACU easily overcomes hypoxemia-associated diffusion impairment. The main reason for this is that the pressure difference between the capillary and the alveolus determines the rate of movement of oxygen across the alveolar-capillary membrane. Therefore, increasing the FiO\textsubscript{2} will raise the driving pressure and, thus, improves the \(\text{Pao}_2\) (34,37).

Increased oxygen extraction

The benefit of supplemental oxygen during low cardiac output states (increased oxygen extraction) is that the use of high FiO\textsubscript{2} increases the dissolved oxygen in the blood, thereby improving tissue oxygen delivery. This is fundamentally crucial because decreases in tissue oxygen delivery due to poor cardiac output or low arterial oxygen content can cause a reduction in mixed venous oxygen saturation. Such a situation can contribute to arterial hypoxemia because many of the disease processes causing inadequate tissue perfusion are often associated with V/Q abnormalities of the lung. Therefore, assessing and treating the underlying cause of decreased tissue perfusion with fluids, blood, vasopressors, inotropes and antibiotics are critical interventions that begin in the PACU.

**THE ROLE OF CONTINUOUS POSITIVE AIRWAY PRESSURE VENTILATION AND NONINVASIVE VENTILATION IN THE PACU**

The use of continuous positive airway pressure ventilation (CPAP) in the PACU can potentially decrease hypoxemia due to atelectasis by alveolar recruitment. The subsequent increase in FRC decreases the work of breathing and improves pulmonary compliance. In 2005, Squadrone et al (94) conducted a randomized controlled trial involving 209 patients to determine the effectiveness of CPAP compared with standard treatment in preventing the need for intubation and mechanical ventilation in patients who develop acute hypoxemia after elective major abdominal surgery. The authors showed that the application of CPAP (at 7.5 cmH\textsubscript{2}O pressure) in the PACU in conjunction with oxygen versus oxygen alone significantly reduced the incidence of endotracheal intubation and other severe complications including pneumonia, infection and sepsis.

There will still be a number of patients who will require additional ventilatory support even with the application of CPAP in the PACU. There is a limited experience in the application of noninvasive ventilation (NIV) in the PACU despite being an effective alternative to endotracheal intubation in the treatment of both chronic and acute respiratory failure in the critical care setting (95-97).

The use of NIV was avoided in the immediate postoperative period in the past because of the potential for wound dehiscence, gastric distraction and aspiration, which can occur in patients who have undergone gastric or esophageal surgery (98). In 2000, Tobias (99) reported the successful application of NIV in two patients, one after gastroscope tube placement and another after cholecystectomy. Similarly, in a larger case series, Albala and Ferrigno (100) reported the successful use of NIV in a variety of rapidly reversible causes of postoperative respiratory failure in the PACU. Careful consideration of both surgical and patient factors is necessary, however, before making a decision to use NIV in the PACU.

Furthermore, relative contraindications to the use of NIV include altered mental status, high risk of aspiration, refractory hypoxemia, hemodynamic instability or life-threatening arrhythmias, and an inability to use nasal or facial mask such as after head and neck surgery (101).

**SPECIFIC SITUATIONS**

Laparoscopic versus open surgery

Laparoscopic surgery has multiple benefits, such as a shorter recovery, and shorter hospital stay (102). It would, therefore, seem intuitive that laparoscopic procedures would reduce the risk for postoperative...
pulmonary complications compared with open surgical procedures, especially because they are associated with less postoperative pain, thus potentially improving postoperative lung volumes and facilitating deep breathing.

Only a few studies, however, have reported the postoperative respiratory complication rates associated with laparoscopic versus open surgical procedures. Weller and Rosati (103) showed that the rate of postoperative pulmonary complications was nearly double if patients underwent open surgery as opposed to laparoscopic surgery in an analysis of 19,156 patients who underwent bariatric surgery. Two other studies have also shown a reduction in atelectasis and other postoperative pulmonary complications following laparoscopic surgery compared with open cholecystectomy and open sigmoid resection, respectively (104,105).

Despite these obvious advantages, marked intraoperative and postoperative cardiorespiratory dysfunction may also occur in certain patients secondary to the effects of pneumoperitoneum (106,107). Changes regarding the respiratory system that are most prominent during laparoscopic surgery include a cephalad displacement of the diaphragm, reduction of FRC with derangement of gas exchange (108) and a decrease in the compliance of the respiratory system by up to 50% (109). Obesity (110) and patient positioning (111) during the procedure further modify these effects.

Furthermore, there may be an increased alveolar-arterial CO₂ tension difference in patients with underlying cardiopulmonary disease (112,113) as a result of CO₂ absorption (113,114), V/Q mismatch and an increase in pulmonary shunt (115,116). Clinically relevant respiratory complications that can occur during laparoscopic surgery using CO₂ insufflation include gas embolism, CO₂ emphysema, pneumothorax, pneumomediastinum and pneumopericardium (114-116).

**Obstructive sleep apnea**

Patients with obstructive sleep apnea (OSA) should be carefully monitored in the PACU because they can present during the postoperative period with more frequent, more severe or more prolonged episodes of oxyhemoglobin desaturation often accompanied by new or worse hypcapnia (117).

In a series of 438 patients with known or suspected OSA, Bolden et al (117) demonstrated that the frequency of oxyhemoglobin desaturations to <90% during sleep occurred in 16% of cases, while oxyhemoglobin desaturation to <80% during sleep occurred in 7% of patients within the first 24 h to 48 h after the surgical procedure.

In a study by Hwang et al (118), 172 patients undergoing elective surgery underwent nocturnal oximetry before surgery and were divided into two groups based on number of desaturation episodes per hour. Markedly higher rates of postoperative respiratory complications (eight complications among 98 patients) were observed in patients with five or more desaturations as opposed to those with fewer than five desaturations (one complication among 74 patients). Furthermore, the presence of five or more desaturations was also associated with higher rates of bleeding as well as cardiac and gastrointestinal complications.

It is the early postoperative period (first 24 h) that can be especially tenuous for patients with OSA because they are particularly prone to airway obstruction and numerous factors that can exacerbate OSA are active during this time (119).

These patients are especially sensitive to opioids that inhibit the upper respiratory muscles and, therefore, have the potential to induce or worsen upper airway collapse (120,121). Sedatives, such as benzodiazepines, can have an even greater effect on pharyngeal muscle tone than opioids, and act synergistically with opioids to decrease central respiratory drive. Thus, their use in the perioperative setting can also contribute significantly to airway obstruction in the PACU (122).

Alternative strategies to reduce or eliminate the need for systemic opioids postoperatively include the use of regional analgesia and nonopioid analgesics (123). Neuropathic analgesia (both spinal and epidural analgesia) may also reduce the need for postoperative systemic opioids. Caution should, however, be used because it can be complicated by sedation and respiratory depression if the medication extends too far cephalad (124). Using local anesthetics without the addition of opioids for neuraxial analgesia may reduce this risk (123).

Finally, patients with OSA should receive their oral appliance therapy or positive airway pressure therapy in the immediate postoperative period (123). Positive airway pressure therapy should be initiated at the level prescribed preoperatively and, if this is not known, it is reasonable to begin at an empirical level of 8 cmH₂O to 10 cmH₂O and then titrate the level until apneas, episodes of oxyhemoglobin desaturation and snoring are eliminated (123).

**CONCLUSION**

Pulmonary function is markedly altered both by general anesthesia with mechanical ventilation and by surgery. Significant atelectasis is found in most anesthetized adults and there is a marked increase in alveolar hypoventilation, V/Q inequalities and pulmonary shunt as early as with induction of anesthesia. These mechanisms are responsible for the majority of cases of arterial hypoxemia in the PACU. Many concomitant factors that contribute to postoperative hypoxic events must be considered such as the type and anatomical site of surgery causing a change in lung mechanics, hemodynamic impairment and respiratory depression from residual effects of anesthetic drugs (125). Even patients treated with intermediate- and short-acting neuromuscular blocking drugs may manifest residual paralysis in the PACU despite what was deemed clinically adequate pharmacological reversal in the operating room (126).

A thorough understanding of the changes that occur during specific procedures, such as laparoscopic surgery, are prerequisites for adequate care and appropriate monitoring of these patients in the PACU.

Pulmonary outcomes may be significantly influenced by the appropriate choice and use of analgesic techniques. More beneficial effects have been demonstrated in terms of pulmonary morbidity when comparing the use of epidural opioids, epidural local anesthetics or patient-controlled analgesia with systemic opioids (127-129).

Clinical correlation should guide the workup of a postoperative patient who remains persistently hypoxic in the PACU. The signs and symptoms may include tachypnea with increased minute ventilation, dyspnea, tachycardia and altered mental status. New-onset delirium or agitation secondary to acute hypoxemia can be confused with psychosis or ‘sun-downering’ (increased agitation, and confusion in late afternoon, evening or night) in elderly patients. As hypoxemia worsens or its duration increases, respiratory distress, respiratory muscle paradox and arrhythmias ensue, with elevations in myocardial oxygen consumption. Ultimately, respiratory muscle fatigue, coma, and respiratory and cardiac arrest may occur (130). The provision of oxygen therapy in such postoperative acutely hypoxic patients in the PACU is, therefore, critical and keeping the oxygen dissociation curve in mind can provide a conceptual reference regarding delivery of oxygen to the tissues. Ultimately, careful consideration of the cause of hypoxemia enables the appropriate titration of oxygen at the patient’s bedside.

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

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Can J Respir Ther Vol 49 No 4 Winter 2013-2014
Karcz and Papadakos

Respiratory complications in the PACU

Recruitment manoeuvres in acute respiratory distress syndrome: Little evidence for routine use


The use of alveolar recruitment manoeuvres for the treatment of acute respiratory distress syndrome is a topic of uncertainty in current critical care practice. Acute respiratory distress syndrome leads to inflammatory atelectasis, which challenges the gas exchange properties of the lung. Recruitment of atelectatic lung tissue requires elevation of transpulmonary pressure. Transpulmonary pressure can be suppressed at a given airway pressure when pleural pressures are elevated. The present review discusses recruitment of lung tissue in detail, highlighting the key research in the field. Differing techniques for recruiting lung tissue, as well as various outcome measures to determine efficacy, are analyzed and critiqued. The commonly used sustained inflation manoeuvre is perhaps regarded as the only strategy to recruit the lung, explaining its prevalence. Staircase recruitment with positive end-expiratory pressure titration is shown to be an equally – if not more – effective therapy that devotes attention to the maintenance of lung recruitment.

Key Words: Acute respiratory distress syndrome; Lung mechanics; Lung recruitment; Recruitment manoeuvre; Transpulmonary pressure

The use of alveolar recruitment manoeuvres (RMs) is a topic of uncertainty in the management of the hypoxemic respiratory failure found in acute respiratory distress syndrome (ARDS). An RM is a deliberate application of elevated transpulmonary pressure (airway pressure – pleural pressure) intended to reopen previously collapsed lung units, thus increasing the surface area available for gas exchange. It is also suggested that recruiting collapsed lung tissue enables a more homogeneous distribution of ventilation throughout the lung, reducing ventilator-induced lung injury (1,2). Acutely injured lungs have been shown to consist of heterogeneous regions of aerated and collapsed alveoli. Morphologically, ARDS is characterized by inflammatory atelectasis, causing considerable reduction in functional residual capacity (3) and air-to-tissue ratio. A computed tomography study published in 2000 (3) reported a 17% reduction in end-expired lung volume in ARDS patients versus healthy volunteers. This alveolar collapse (ie, atelectasis) has been attributed to increased interstitial pressure and the compressive forces of the weight of the lung. This atelectasis can be worsened by factors such as obesity, high abdominal pressure, disconnections from the ventilator and tracheal suctioning (4).

Furthermore, ventilation of acutely injured lungs with positive pressure leads to the generation of shearing forces at the junctions of aerated (compliant) and nonaerated (noncompliant) lung units, inducing lung injury (1).

Recruitment of lung tissue is believed to minimize ventilator-induced lung injury by two mechanisms. First, alveolar recruitment increases the aerated lung mass, thus promoting a homogeneous distribution of ventilation. This minimizes shearing forces at the junctions of inflated and underinflated lung units. Lachmann (5) introduced this notion in a 1992 editorial titled ‘Open the lung and keep the lung open’, explaining that at a transpulmonary pressure of 30 cmH₂O, the shearing forces at the junction of an atelectatic region surrounded by a fully recruited lung region can exceed 140 cmH₂O, a pressure very likely to induce barotrauma. Second, obtaining appropriate alveolar recruitment minimizes the cyclic opening and closing of terminal lung units (4).
outcome predictor. Patients with focal lung morphology were found to have a smaller potential for alveolar recruitment, with lung hyperinflation predominant over lung recruitment. A hyperinflated lung can reach up to 24% of total end-expired lung volume in patients with focal lung morphology (this would likely be much greater at end inspiration). Furthermore, the hyperinflated lung can remain elevated at up to 10% of total lung volume after a post-RM steady-state, implying that RM-induced hyperinflation can cause some degree of airspace enlargement secondary to alveolar wall damage (12). This heterogeneity in distribution of recruitment volume has been shown to impact the incidence of complications. In the largest clinical study on RMs to date, Fan et al (13) found that primary focal consolidation was associated with marginal lung recruitability and a higher complication rate when compared with more diffuse morphologies apparent in extrapulmonary processes. This is consistent with animal data showing that RMs are more effective at recruiting collapsed lung tissue in extrapulmonary lung injury than direct pulmonary lung injury (14). The number of RMs applied was also significantly associated with incidence of complications (13). These findings suggest considerable caution be exercised when performing RMs routinely on ARDS patients without knowledge of the baseline morphology. This also seriously questions the application of a ‘one-size-fits-all’ therapeutic intervention to a demonstrably diverse disease population.

Alveolar recruitment can be achieved using a variety of techniques, and lack of standardization in this regard acts as a barrier to widespread use in critical care. The ideal technique would provide sustainable alveolar recruitment to correct and prevent hypoxemia, and improve lung mechanics (improving ventilation) while having a low incidence of complications/adverse effects. Additionally, to increase the potential for widespread implementation, an ideal RM would not be complicated and time consuming to perform. The most prevalent technique is the sustained inflation (SI) RM, which uses a sustained elevation of plateau pressure in a continuous positive airway pressure with pressure support mode. The pressure support is set to zero and the continuous positive airway pressure is elevated to the desired recruitment pressure (often 30 cmH\textsubscript{2}O to 45 cmH\textsubscript{2}O) for a given period of time (often 20 s to 45 s) (9,11,12,14-16). SI RMs have shown a transient improvement in oxygenation and respiratory mechanics (8,11,14); however, these improvements appear to be short-lived and associated with various adverse effects such as desaturation, hemodynamic instability and hyperinflation (9,11-13,15,16). There is evidence to suggest that the vast majority of recruitment (up to 98%) occurs within the first 10 s of an SI RM, with any additional inflation time providing insignificant benefit while triggering/worsening cardiovascular depression (15,16). It is certainly possible that the prevalence of this technique is based on lack of knowledge of alternative strategies and, thus, regarded as the only option. This method has the potential to overlook the complicated lung mechanics found in ARDS. As mentioned, recruitment is achieved by elevation of transpulmonary pressure, not merely airway pressure. Esophageal balloon measurement has estimated that the average pleural pressure in an ARDS patient is 17 cmw (17). The resulting transpulmonary (recruiting) pressure applied during a ‘40-for-40’ trial would then be reduced to only 23 cmw, a pressure unlikely to exceed the critical opening pressure of unstable lung units. Piraino (18) elegantly demonstrated this concept at a recent respiratory therapy conference by showing images of balloons inflated within pressurized 18.5 L water jugs. Increasing the pressure in the jug mimics increased pleural pressure, thus reducing balloon inflation at a given pressure as the balloon ‘feels’ a lower distending (transpulmonary) pressure. The mounting data regarding esophageal balloon pressure as a surrogate for pleural pressure may justify investigation into the causes of high pleural pressure, and strategies to identify patients at a higher risk, improving our ability to individualize protective ventilation.

A more recent RM technique involves ventilation with pressure control ventilation with progressively increasing positive end-expiratory pressure (PEEP). Staircase recruitment manoeuvres (SRM) with PEEP titration provides 15 cmH\textsubscript{2}O of pressure control above PEEP, while increasing PEEP from 20 cmH\textsubscript{2}O to 30 cmH\textsubscript{2}O to 40 cmH\textsubscript{2}O every 2 min, reaching a maximum peak pressure of 55 cmH\textsubscript{2}O. PEEP is then titrated at 3 min intervals to 25 cmH\textsubscript{2}O, 22.5 cmH\textsubscript{2}O, 20 cmH\textsubscript{2}O, 17.5 cmH\textsubscript{2}O, to a minimum of 15 cmH\textsubscript{2}O until an oxygen saturation decrease of 1% to 2% is observed. This is defined as the derecruitment point. The lung is then re-recruited before the ‘optimal PEEP’ is set at 2.5 cmH\textsubscript{2}O above the derecruitment point (19). This approach has been found to be safe and effective in up to 80% of early ARDS patients (19). Of interest, this success rate is higher than found in the literature for SI manoeuvres. Concerns regarding SRM tend to focus on the potential adverse effects of higher ventilating pressures. However, returning to the physiology of transpulmonary pressure versus airway pressure may suggest they are a necessity. LaPlace’s law also provides explanation as to why atelectatic lung regions require higher distending pressures, as Lachmann (5) stresses in a previously mentioned editorial. Hodgson et al (20) found that although 40% of patients experienced transient desaturation, this did not preclude a positive response to the RM. This is noteworthy because desaturation is typically an indication for termination of the RM, and interpreted as a RM failure in the literature to date, which may explain the lower percentage success rate observed. The data presented in the study by Hodgson et al (20) demonstrate that transient desaturation is well tolerated, with many patients still showing significant improvement from the RM. Open lung ventilation with SRM and permissive hypercapnia has demonstrated improvement in inflammatory markers, PaO\textsubscript{2}/FiO\textsubscript{2} and static lung compliance, as well as decreased time on the ventilator compared with the ventilatory strategy defined by the ARDS Network protocol (19,21). There are also trends toward shorter intensive care unit and hospital stay with the aforementioned strategy, although trials to date have not been powered to demonstrate statistical significance (19). It is, however, worth highlighting some methodological differences in the literature around recruitment and PEEP titration. Oxygenation alone may not be the best predictor of optimal PEEP/recruitment. Studies to date have used a variety of outcome measures to determine optimal recruitment with little consistency. Lung compliance and deadspace fraction have been discussed as equally valuable outcome predictors. Striving for the highest PaO\textsubscript{2}/FiO\textsubscript{2} ratio may come at the expense of more optimal lung mechanics, and may provide explanation for the lack of robust data for clinically relevant outcomes. Borges et al (22) compared SI RM (40 cmH\textsubscript{2}O for 40 s) with an SRM similar to the previously described technique. Oxygenation was significantly improved in the SRM group compared with the SI group. The use of high airway pressures (>35 cmH\textsubscript{2}O to 40 cmH\textsubscript{2}O) was necessary to achieve this improved recruitment. This came at a cost because transient hemodynamic depression occurred in some patients, although no significant clinical consequences were observed. They concluded that the widely used SI method was ‘suboptimal’ when compared with the SRM method.

Recruitment of collapsed lung units is a key strategy in the management of hypoxemia in ARDS. What is needed is large-scale investigation into standardizing RM technique and indications, as well as outcome predictors that encompass lung mechanics, not merely oxygenation. It is clear from the present review that RMs are not a one-size-fits-all therapy. Lung morphology greatly influences the response to RMs, and predicts the degree of hyperinflation and airspace damage caused by high transpulmonary pressures (12). SRM with PEEP titration may be a more effective strategy than SI manoeuvres; recent evidence supports this inference (22). The potential implementation of SRM to supplement or replace the favoured SI manoeuvres will require education of clinicians because the technique is more complicated and time consuming than the SI manoeuvre, and often requires more worrying peak airway pressures (19,20,22). It is certainly arguable that the evidence to support SRM is not sufficiently robust to change practice. The use of SRMs is a growing area of investigation, with only a few well-conducted studies published. It should be considered, however, that the current therapy (SI manoeuvres) are by no means a gold standard to...
SUMMARY

The key messages of the present review are that recruitment of the atelectatic lung tissue of ARDS is based on the degree of transpulmonary pressure applied. High pleural pressure reduces transpulmonary pressure at a given airway pressure, reducing recruitment. Tools, such as esophageal balloon measurement, can be used to accurately predict pleural pressure, allowing for more individualized PEEP application. Maintenance of recruitment after effective lung inflation is paramount to protective ventilation and recruitment without attempt to obtain optimal PEEP has only shown short-lived improvements. At this time, the routine use of RMs in the management of ARDS remains unsupported by evidence.

DISCLOSURES: The author has no financial disclosures or conflicts of interest to declare.
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The Anchor Fast Oral Endotracheal Tube Fastener combines a number of unique features that make it the right choice. Together, these features help to prevent the formation of lip ulcers and ease access to the oral cavity to optimize patient oral care.