Respiratory Care Informatics and the Practice of Respiratory Care

Constance C Mussa MSc RRT

Introduction
Respiratory Care: A Distinct Profession
Information Needs of Respiratory Therapists
Information Uses of Respiratory Therapists: Decisions, Judgments, and Skills
Use of Data, Information, and Knowledge in Delivering and Managing Respiratory Care
Management and Processing of Respiratory Care Information
Framework for a Unified Respiratory Care Language
Identifying and Describing Respiratory Care Diagnoses
Developing a Respiratory Care Taxonomy and Ontology
Summary

Recently I reported the results of a study that was conducted to determine how respiratory care information is managed and processed in respiratory care departments. Data obtained from the respiratory care departments surveyed indicated that their information systems (paper-based or automated) do not manage and process respiratory care information effectively or efficiently. Since the goal of an information system is to improve delivery of services, any useful information system must mirror business processes (or professional activities) to achieve that goal. Consequently, I suggested that, in addition to inadequate database management systems, the shortcomings of the information systems surveyed may have stemmed from a failure to accurately define and describe the data, information, and knowledge unique to the respiratory care profession. Accurate description and definition of respiratory care data, information, and knowledge, however, require a formal language and taxonomy for the respiratory care profession. This article explores the concept of respiratory care informatics and its relevance to the practice of respiratory care. *Key words: information systems, data, information, knowledge, informatics, taxonomy*. [Respir Care 2008;53(4):488–499.

Introduction

Advances in information technology have accelerated the growth of informatics to the extent that informatics has now become an important field of study in our society. Though there are many variations on the definition of informatics, the key component of all such definitions is that informatics involves "the cognitive, information processing, and communication tasks of [the named discipline], education, and research including the information science and the technology that supports these tasks."[1] To date, the only health care groups that have integrated informatics as a legitimate discipline within their respective professions are physicians, nurses, pharmacists, and dentists. The allied health professions, such as physical therapy, respiratory care, occupational therapy, nutrition and dietetic sciences, and speech and hearing sciences, to name a few, do not seem to be actively involved in the *science* of medical informatics.

Constance C Mussa MSc RRT is affiliated with the Respiratory Care Department, New York University Medical Center, New York, New York.

The author reports no conflicts of interest related to the content of this paper.

Correspondence: Constance C Mussa MSc RRT, Respiratory Care Department, New York University Medical Center, 560 First Avenue, New York NY 10016. E-mail: constance.mussa@nyumc.org.

The 1999 debate of the American College of Medical Informatics was an event of great importance to the field of medical informatics, because the debate focused on the proposition that medical informatics and nursing informatics are distinct disciplines that require their own core curricula, training programs, and professional identities. According to Masys et al, opponents of the proposition asserted

SEE THE RELATED EDITORIAL ON PAGE 431

that informatics is built on a reusable and widely applicable set of methods that are common to all health disciplines, and that "medical informatics" continues to be a useful name for a composite core discipline that should be studied by all students, regardless of their professional orientation.[2] Masys et al further assert that the purpose of the debate was to bring attention to contemporary views of the similarities and differences of the health-related disciplines involved in informatics training, research, and development. This historic debate raised a very important issue that is pertinent to the focus of this paper. During the debate, proponents of the idea that nursing informatics is a distinct discipline reminded their opponents that natural language processing requires decoding both syntax and semantics to convert text into computerized representations. This prompted one of the debate participants to make the following observation:

> It is both essential to understand the base clinical disciplines that make up the various subfields of health informatics and it is impossible to construct a single, overarching field of health informatics that is anything but a concatenation of these subfields. Furthermore, since the definition of nursing and the definition of medicine are different from each other, this fundamental difference between these 2 fields jointly engaged in health care, demands fundamentally different informatics tools.[2]

This observation reinforces the cautionary statement made by another debate participant that one must be careful to note that "proximity, while it does not preclude parallelism, does not presuppose parity."[2] It was resolved in this debate that medical informatics and nursing informatics are distinct disciplines that require their own core curricula, training programs, and professional identities. The focus here will be on the respiratory care profession and its relationship (if any) to informatics.

Respiratory Care: A Distinct Profession

Many professions are authorized to practice in the same, related, or similar fields and as a result have overlapping practice areas. Courts, attorneys general, and, on occasion, even organized medicine have acknowledged that practice areas overlap and are not exclusive.[3] In particular, respiratory care has overlapping practice areas with other professions. Pierson stated that:

> The term respiratory care, in addition to being the designated name of a distinct health care discipline, also refers to a collection of principles, skills, and patient needs that have arisen because of the nature of respiratory disorders and their effects on individuals. Respiratory care, however, is not synonymous with critical care medicine, or with pulmonary medicine or anesthesiology, although each of these medical specialties includes areas that coincide with aspects of the respiratory care profession.[4]

Although there is no standard definition of a profession, there are certain agreed-upon essential characteristics of a profession, namely, a period of extensive training, a specialized body of knowledge, a professional association, a code of ethics, and a process of certification or licensing.[5,6] Respiratory care has all the above specified essential characteristics of a profession and is described within this context in more detail below.

Although respiratory care was established as a discrete health discipline in the late 1940s, it was not until 1974 that scientific inquiry into the efficacy of respiratory care treatment modalities was conducted. According to Weilacher's history of the American Association for Respiratory Care (AARC), prior to 1974, "respiratory care treatment modalities were based primarily on clinical impressions, not rigorous clinical studies."[7] The Conference on the Scientific Basis of Respiratory Therapy,[8] supported jointly by the (then) National Heart and Lung Institute and the American Thoracic Society, was convened in May 1974 at the Temple University Conference Center at Sugarloaf in Philadelphia. Prominent scientists nationwide reviewed the efficacy of several modes of respiratory therapy, including oxygen therapy, aerosol therapy, and intermittent positive-pressure breathing therapy. A surprising and disappointing outcome of that scientific review was that the efficacy of intermittent positive-pressure breathing therapy, the major clinical task of respiratory therapists (RTs), could not be established. Dismayed by this unexpected outcome, RTs decided that rigorous scientific investigation was necessary to determine the efficacy of respiratory care treatment modalities. Thus, the Sugarloaf Conference set the stage for scientific examination of every form of clinical respiratory therapy. In fact, the clinical practice guidelines developed by the AARC are based on the results of scientific inquiry and are currently used by RTs in their day-to-day practice of respiratory care.

Specialized training is necessary before an individual is permitted to practice respiratory care. The United States

Bureau of Labor Statistics *Occupational Outlook Handbook*[9] contains the following statement regarding training and other qualifications necessary for practicing respiratory care:

> Formal training is necessary for entry into the field of respiratory care. Training is offered at the postsecondary level by colleges and universities, medical schools, vocational-technical institutes, and the armed forces. An associate's degree is required for entry into the field. Most programs award associate's or bachelor's degrees and prepare graduates for jobs as advanced RTs . . . Among the areas of study in respiratory therapy are human anatomy and physiology, pathophysiology, chemistry, physics, microbiology, pharmacology, and mathematics. Other courses deal with therapeutic and diagnostic procedures and tests, equipment, patient assessment, cardiopulmonary resuscitation, the application of clinical practice guidelines, patient care outside of hospitals, cardiac and pulmonary rehabilitation, respiratory health promotion and disease prevention, and medical recordkeeping and reimbursement.
>
> The National Board for Respiratory Care offers certification and registration to graduates of programs accredited by the Commission on Accreditation of Allied Health Education or the Committee on Accreditation for Respiratory Care. Two credentials are awarded to respiratory therapists who satisfy the requirements: Registered Respiratory Therapist (RRT) and Certified Respiratory Therapist (CRT). Graduates from accredited entry-level or advanced-level programs in respiratory therapy may take the CRT examination. CRTs who were graduated from advanced-level programs and who meet additional experience requirements can take 2 separate examinations leading to the award of the RRT credential. All states (except Alaska and Hawaii), the District of Columbia, and Puerto Rico require respiratory therapists to obtain a license.[9]

The AARC recognizes that RTs have a moral obligation to deliver the highest quality respiratory care to patients and to respect the inherent dignity of every individual. Consequently, the AARC, which represents RTs across the United States, promulgated the *AARC Statement of Ethics and Professional Conduct*,[10] to guide ethical decision making and everyday professional conduct of RTs.

The preceding description of the characteristics of respiratory care suggests that it is indeed a profession, distinct from nursing, medicine, and other health care professions. Consequently, the information needs of RTs are not necessarily equivalent to those of other health care professionals. Moreover, the information systems designed and implemented under the auspices of medical informatics may not adequately meet the needs of the respiratory care profession, and may even have deleterious consequences for the profession.

Information Needs of Respiratory Therapists

Smith proposed 6 categories of information needed by physicians: (1) information on particular patients, (2) data on health and sickness within local populations, (3) medical knowledge, (4) local information on doctors available for referral, et cetera, (5) information on local social influences and expectations, and (6) information on scientific, political, legal, social, management, and ethical changes that affect both how medicine is practiced in a society and how doctors will interact with individual patients.[11]

Like other health care professions, the health information and data needs of respiratory care is not a single concept. More specifically, the health information and data needs of the respiratory care profession refer to the information needs of an RT, whose individual needs differ according to specialty (eg, perinatal/pediatric, adult, diagnostic, home care), level of responsibility, and work setting. Moreover, the practice of respiratory care requires the RT to assess problems, make decisions, exercise judgment, and perform services and procedures for patients who require respiratory care services. Thus, respiratory care information needs in this instance are defined by activities that support knowledge acquisition germane to the practice of respiratory care. The information needs of the respiratory care profession also include information that is directly related to the care of individual patients. In this instance, information needs are patient-specific and are defined by all patient care activities.

RTs' health information and data needs are determined not only by tasks but by other factors as well. More specifically, many organizational and social factors, as well as RTs' pre-existing knowledge, also influence information needs. For example, the restructuring of many health care organizations as a response to factors such as managed care has resulted in expansion of the role of RTs, which created a greater need for information regarding the management of patients with respiratory disorders. On the other hand, a well trained respiratory care staff with highly developed critical thinking skills may have less need for explanations and instructions to facilitate information gathering, decision making, and troubleshooting with respect to diagnosis and treatment.

Current health care literature has extensive coverage highlighting the move from traditional, intuition-driven clinical decisions to evidence-based practice, and the necessity for collaboration between researchers and practitioners to enhance the diffusion of knowledge and clinical reasoning that are supported by evidence-based practice innovations.[12] Furthermore, because of new trends in health

care, such as managed care, health care personnel who know only discrete pockets of knowledge or who have specific clinical skills are no longer considered sufficient. The need for health care practitioners who have professional competence that exceeds technical training or clinical skills is increasing.[13] More specifically, RTs are now being challenged to assume the role of decision makers and consultants, in addition to their specialized knowledge and skills. Furthermore, according to the American Medical Informatics Association, "the vast amount of knowledge that is necessary to make real-time decisions based on evidence-based medicine requires a union of knowledge bases and patient data through decision support and clinical guidelines." This means that research specific to respiratory care needs and applications is needed to create, integrate, and evaluate information technologies.

The respiratory care profession needs to become actively involved in defining and describing respiratory care data and information for patient care. This involves, at the very least, developing and testing the validity and reliability of clinical language for respiratory-care-related assessments, diagnoses, interventions, and outcomes. A step in the right direction is the development and refinement of the AARC's clinical practice guidelines, which can help to effectively determine "best practice" methodologies through the use of clinical decision-support systems for respiratory care. The clinical practice guidelines can serve as a template from which the decision-support system can prescribe diagnoses, actions, and processes. Ultimately, the goal of respiratory care informatics is to bridge the gap between information availability and use, to enhance patient care. This means that RTs must become actively involved in designing information systems in order to increase the likelihood that such systems adequately meet the information needs of the respiratory care profession.

Information Uses of Respiratory Therapists: Decisions, Judgments, and Skills

Decision making is the ability to reach a judgment or conclusion based on relevant supporting information. RTs routinely use information obtained from primary data, such as numerical blood gas values and fraction of inspired oxygen (F_{IO_2}), to inform an assessment or action such as the diagnosis of hypoxemia or determining appropriate ventilator settings for a particular patient based on disease process, clinical assessment, and pulmonary mechanics. According to Mishoe, "judgment, decision making, scientific reasoning, and lifelong learning are highly related and often used synonymously to mean critical thinking."[13] Without appropriate, useful information, RTs will not be able to engage meaningfully in critical thinking skills to positively impact patient care. A review of the literature on medical informatics reveals that health care workers underutilize the vast amount of information available to assist in medical decision making because this information is spread out across multiple sources, such as textbooks, policy and procedure manuals, instruction manuals, audio and video tapes, and human experts, to name a few. Accessing information from several different sources is labor-intensive and time-consuming, and synthesizing this information manually often leads to errors and redundancy. On the other hand, electronic storage of data involves organization of data in a logical manner, which enhances data retrieval and synthesis. Electronic databases also facilitate data integration so that clinicians can obtain patient care information from various sources, thus enabling them to see the "big picture" when making decisions.

In her qualitative study of critical thinking skills in respiratory care practice, Mishoe observed that the expert RTs she studied often obtained information for patient care decisions from bedside experimentation. More specifically, Mishoe describes the following scenario:

> The RTs experimented to make individual decisions for oxygen and aerosol therapy, ventilator management (including flow rate, respiratory rate, tidal volume, and mode), intubation, re-intubation, and extubation . . . The therapists used phrases such as "trial and error," "experimentation," and "working in the gray zones" to describe their methods for making individual clinical decisions.[14]

Though medicine is not an exact science and has involved trial and error in many instances, the above scenario suggests that it may be beneficial to have a computerized database of evidence-based guidelines that can be accessed via a decision-support module to augment RTs' decision making ability.

Use of Data, Information, and Knowledge in Delivering and Managing Respiratory Care

The term "information" has several definitions. However, in terms of information systems concept, information may be defined as the increase in knowledge that may be deduced from a set of data, from the raw material that facts represent.[15] In other words, information is data that has been interpreted or data that has meaning. The value that a piece of information contains, however, depends upon context. According to Clarke, "Until it is placed in an appropriate context, data is not information, and once it ceases to be in that context, it ceases to be information."[16] This is consistent with the previous observation that the interpretation of respiratory care data often depends on the context. For example, if an RT is asked to evaluate a

patient who presents with exacerbation of asthma and is given a report that contains the patient's peak expiratory flow rate measurement, but has no information about the patient's baseline peak flow value or about when the measurement was taken (ie, before or after bronchodilator administration), it is difficult for the therapist to determine the appropriate dosage and frequency of bronchodilator therapy for the patient.

According to Graves and Corcoran, "Information has the attributes of accuracy, timeliness, and utility. Utility has the additional attributes of relevance and quality. Taken together with accessibility, these attributes determine the value of the information."[17] Respiratory care is a techno-clinical field that involves, to a large extent, cardiopulmonary support of critically ill patients. This means that RTs often need accurate information in a timely manner. Not only must the information be accurate and timely, it must also be relevant to the situation at hand and be of good quality. More specifically, the information obtained from the data should have enough integration and meaning to facilitate decision making or problem solving. For example, at the beginning of their tour of duty, RTs need to have enough information about their patients and work assignments to plan and prioritize their care of patients.

Moreover, in many cases, it is possible for RTs to quickly obtain important information about a patient, such as the patient's age group (eg, neonatal, pediatric, adult), severity of illness, and disease entity, from data attributes such as the type of respiratory care device being used (eg, oxygen delivery device) and the device settings (eg, F_{IO_2} or mechanical ventilation parameters). For example, the data, F_{IO_2} = 28%, oxygen delivery device = mist tent, immediately conveys the information that the patient is a pediatric patient, since mist tents are used exclusively with pediatric patients. Thus, these data have been interpreted within the context of prior knowledge to convey information. Additionally, since RTs know that mist tents are usually used to relieve the symptoms of upper-airway swelling in pediatric patients, and that an F_{IO_2} of 28% is considered a relatively low concentration of supplemental oxygen, they may be able to deduce that this is a pediatric patient with croup or bronchiolitis and mild hypoxemia, who needs certain medical and respiratory care interventions. This reflects information synthesis (knowledge) based on experience and knowledge of respiratory care.

Standardization of medical language facilitates indexing, sorting, retrieving, and classifying varied medical data in clinical records, in information systems (for care and documentation and/or management), and in literature and research reports. The practice of respiratory care, like medicine and nursing, involves assessment, diagnosis, intervention, and outcomes. Consequently, any attempt to standardize language specific to the respiratory care profession should include the development of classification systems that address concepts within the domains of assessment, diagnosis, intervention, and outcomes.

Management and Processing of Respiratory Care Information

Although respiratory care technology has kept pace with technological advancements in health care in general, automated management and processing of respiratory care information has lagged behind that of other health care professions such as nursing, pharmacy, and medicine. This may be attributable to the fact that the respiratory care profession is not actively involved in studying the science of respiratory care information management. A study of the management and processing of respiratory care information by Mussa and Langsam revealed limited use of computer technology in the respiratory care departments studied. Moreover, it was reported that none of the information systems in those departments manage and process respiratory care information effectively or efficiently.[18] Ford reported that there are only 3 commercial information systems developed specifically for the respiratory care profession. Moreover, current hospital information systems support only certain information needs of respiratory care departments.[19] Most hospital information systems focus on administrative and financial data, physician order entry, laboratory and radiology data, and pharmaceutical data. Documented respiratory care data are seldom captured and aggregated in these systems to facilitate information synthesis, linkage of respiratory care interventions and outcomes and evaluation of cost-effectiveness of care.

Recognizing the need for automated information systems to support the activities of RTs, some respiratory care managers have utilized the talents of RTs and the expertise of hospital information technology personnel to build ad hoc, stand-alone automated departmental information systems.[20,21] However, most often these systems address only basic information needs of RTs, such as billing, charting, and providing a more organized list of patients receiving respiratory care services. One major shortcoming of current automated respiratory care information systems is that their design is based on current tasks performed by RTs, because there is no respiratory care ontology to facilitate data modeling. A domain ontology helps to refine terms and check for consistency, accuracy, and completeness during the design phase. Additionally, the use of a domain ontology during systems development "provides a mechanism to interpret and understand the problem descriptions" (ie, information that needs to be addressed), helps to reconcile system objectives presented from multiple perspectives, and enhances reusability of the system. Moreover, a robust and accurate ontology facilitates the development of a system that supports knowledge sharing,

which is an important attribute of clinical information systems.[22]

Framework for a Unified Respiratory Care Language

Like the language used in medicine, nursing, and other health care professions, the language used by RTs is complex. Moreover, the terms used are often vague and imprecise. For example, the term "increased work of breathing" is often used, but this term is not rigorously defined. Although this does not prevent RTs from communicating well, it complicates the use of computers in respiratory care practice and research. Since today's computer systems require some form of structured terminology to process data according to pre-programmed rules, ambiguities must be resolved and vocabulary standardized in order to collect information for documentation, clinical research, or medical decision making. This is usually achieved by creating classifications and coding systems.

According to van Bemmel and Musen, in a classification, concepts are ordered according to generic relations. Generic relations are relations of the type "A is a kind of B," for example, pneumonia is a kind of lung disease.[23] Furthermore, classifications contain concepts within a certain domain. Examples of domains are assessment, diagnosis, intervention, and outcome. Most classifications used in current medical information systems are based on diagnoses (eg, the International Classifications of Diseases, 9th edition, and the Systematized Nomenclature of Medicine—Clinical Terms). In fact, the nursing profession's concern for the lack of standardization of nursing language resulted in successful implementation of a diagnosis-based classification system to standardize nursing language: the North American Nursing Diagnosis Association Classification of Nursing Diagnoses.[24] One nursing scholar asserted, "If we cannot name it, we cannot control it, finance it, teach it, research it, or put it in public policy. It is clear that the future of nursing depends on systematic efforts to label and define nursing contributions to health care."[25] The same holds true for the respiratory care profession. This has motivated me to explore the idea of identifying and describing diagnoses that reflect the activities of RTs. Standardized respiratory care diagnoses could help RTs develop respiratory care plans for their patients.

Identifying and Describing Respiratory Care Diagnoses

Though there are medical diagnoses based on disorders of the respiratory system, a thorough search of the relevant literature did not yield any research on the general topic of diagnoses specific to the respiratory care profession. However, experience suggests that there are diagnoses specific to the practice of respiratory care. It must be emphasized that respiratory care diagnoses are not medical diagnoses, because RTs are not trained to make medical diagnoses. Rather, what are referred to as respiratory care diagnoses are patient reactions to an impaired respiratory system that are identified by RTs and can be addressed by respiratory care interventions. Such diagnoses might include patient-ventilator asynchrony; mechanical ventilation, ineffective; respiratory self-care deficit: suctioning, tracheostomy care; respiratory health promotion practices, impaired; self-treatment of acute inflammation-induced airway obstruction, ineffective; self-treatment of asthma, ineffective; peak flow monitoring, noncompliance with; work of breathing, altered: high risk for imposed work of breathing above physiologic load (resistive loads, lung and chest wall elastic loads); air hunger; and pulmonary hygiene, impaired. An expansion of the proposed respiratory care diagnoses is presented in Tables 1 through 6, which employ the North American Nursing Diagnosis Association[24,26] format for nursing diagnoses. The diagnoses are grouped according to shared characteristics, under the following proposed diagnostic categories:

Respiratory mechanics
Gas exchange
Ventilatory assistance
Respiratory disease self-management
Lung/airway defense
Patient teaching/learning

The proposed respiratory care diagnoses by no means exhaust the conceivable diagnoses specific to the respiratory care profession, but serve as a starting point for respiratory care data definition. Some of these respiratory care concepts and their relationships are presented in Figure 1.

Developing a Respiratory Care Taxonomy and Ontology

A taxonomy identifies membership in classes or subclasses within a domain. "An ontology on the other hand, defines a set of constructs used to represent real-world phenomena."[27] In other words, it completely describes a domain. Ontology building is a structured process that consists of specific activities, namely, specification (defining the purpose and scope of the ontology), conceptualization (description of domain concepts and their relationships), formalization (translation of conceptual model to a formal model), implementation (use of a formal knowledge representation language to write the formal model [eg, first-order logic]), maintenance (updating and correcting the ontology), knowledge acquisition (obtaining knowledge about the domain from domain experts), evaluation (assess the completeness, accuracy, usefulness and

Table 1. Respiratory Care Diagnoses Related to an Individual's Reactions to Problems With Ventilatory Assistance

Problem	Patient-ventilator dyssynchrony
	Definition: A state in which there is a conflict between the timing of mechanically delivered breaths and spontaneous breaths, putting the individual at risk for ineffective mechanical ventilation
Etiology	Related factors
	Pain or anxiety-induced breathing irregularity
	Inappropriately set ventilator parameters
	Severely compromised respiratory system
	Equipment malfunction (eg, obstructed exhalation valve, air leak)
	Compromised artificial airway (eg, kink in endotracheal tube, loss of cuff integrity, mucus plug)
Signs and symptoms	Defining characteristics
	Subjective
	Dyspnea
	Expressed fear/anxiety
	Objective
	Activation of ventilator alarms (eg, volume and pressure limit alarms)
	Stacking of breaths, as evidenced by a significant increase in expiratory tidal volume over inspiratory tidal volume
	Tachypnea
	Inverted inspiratory-expiratory ratio
	Observed abnormalities in the display of flow, volume, and airway pressure signals
Problem	Mechanical ventilation, ineffective
	Definition: A state in which the goals of mechanical ventilation have not been met (ie, achieve and maintain adequate pulmonary gas exchange with minimal lung injury, and decrease the individual's work of breathing).
Etiology	Related factors
	Decreased lung compliance
	Increased airway resistance
	Inappropriately set ventilation parameters
	Patient-ventilator dyssynchrony
Signs and symptoms	Defining characteristics
	Subjective
	Dyspnea
	Objective
	Deviation of blood gas values from acceptable range
	Paradoxical breathing
	Tachypnea
	Diminished breath sounds
	Inadequate chest excursion
	Tachycardia

usability of the ontology), and documentation (detailed report about the process). The 3 most frequently used ontology-building methodologies are TOVE (Toronto Virtual Enterprise ontology project), ENTERPRISE, and METHONTOLOGY.[28] Of the 3, the most recent methodology is METHONTOLOGY, which is heavily influenced by software engineering methodologies. METHONTOLOGY can be used by domain experts (eg, RTs) with little or no formal knowledge-representation skills to construct intermediate conceptual representations of domain knowledge, which can later be formalized with the help of knowledge engineers.

Like any other domain ontology, a respiratory care ontology would consist of terms, relationships, and axioms (statements assumed to be true). Unambiguous and coherent definition of all concepts, such as respiratory care diagnoses and interventions, would be required. Developing a respiratory care taxonomy and ontology for the respiratory care profession can be accomplished by forming a working group within the AARC that consists of expert RTs. Members of this working group would need to identify and apply an appropriate research methodology such as the Grounded Theory qualitative research approach to identify and describe concepts unique to the respiratory care profession that add value to the patient care process. "Grounded theory is used to develop a theory inductively and contextually from a corpus of data and involves data analysis to discover or label variables, which are referred to as categories, concepts, or properties, and their interrelationships."[29] Sources of data include brainstorming, interviews, questionnaires, observations, work sampling, and literature review. Members of the working group may also use their own work experience as an additional data source. A qualitative analysis tool can be used to code and analyze the data to facilitate identifying, labeling and defining key respiratory care concepts that describe patient findings, patient responses to respiratory system dysfunction, events, and interventions. The relationships between concepts can also be identified and described during this process.

An independent respiratory care taxonomy is necessary to define aspects of the patient care process that are distinctive to the respiratory care profession. This has the potential to increase the visibility of respiratory care contributions to patient care in health care databases, because a respiratory care taxonomy would facilitate standardized respiratory care documentation in patient records. Although a broad taxonomy and classification system for health care is a desirable goal, domain-specific taxonomies (eg, nursing, radiology, respiratory care) are necessary to present a more complete picture of the patient care process. Moreover, domain-specific terminologies can serve as "interlocking extensions of larger terminologies, patient findings, and outcomes."[30] For example, the term "work of breathing" has a different meaning for the RT than it does for the nurse or the physical therapist. More specifically, work of breathing may be increased by inappro-

Table 2. Respiratory Care Diagnoses Related to an Individual's Reactions to Patient Teaching/Learning Problems

Problem	Respiratory self-care deficit: suctioning, tracheostomy care
	Definition: The state in which the individual experiences an impaired ability to perform or complete suctioning, tracheostomy care, or respiratory care equipment cleaning/changing for her/himself
Etiology	Related factors
	Hypoxia-induced intolerance to activity
	Inadequate knowledge of self-care skills
	Unresolved fears and anxieties regarding failure of life-support devices
	Knowledge deficit
	Lack of knowledge of lung health promotion behaviors
Signs and symptoms	Defining characteristics
	Subjective
	Reported dyspnea on exertion
	Objective
	Oxygen saturation $<$ 90% on room air
	Display of fear during brief separation from life-support device
	Observed lack of knowledge in lung health promotion behaviors
Problem	Respiratory health-promotion practices, impaired
	Definition: The state in which an individual's behavior and/or the environment threatens the optimal functioning of the respiratory system
Etiology	Related factors
	Personal health beliefs
	Apathy
	Susceptibility to peer pressure
	Lack of knowledge regarding behaviors that optimize respiratory system function
	Environmental deficiencies
Signs and symptoms	Defining characteristics
	Subjective
	Expressed belief that risk for impairment of the respiratory system does not exist
	Expressed lack of interest in changing behavior
	Perceived or observed inability to control environment
	Objective
	Demonstrated knowledge deficit regarding respiratory health promotion practices
	Reported or observed inability to abandon practices such as smoking that threaten respiratory system health
	Reported exposure to allergens and respiratory irritants on a regular basis
Problem	Peak Flow Monitoring, non-compliance with
	Definition: The state in which the individual encounters barriers to measuring and establishing a "personal best" peak expiratory flow rate and monitoring this parameter on a consistent basis
Etiology	Related factors
	Lack of knowledge
	Unavailability of equipment
	Disinterest
Signs and symptoms	Defining characteristics
	Subjective
	Expressed skepticism regarding necessity of taking peak flow measurements
	Expressed lack of interest
	Verbalization of uncertainty regarding the correct peak flow measurement technique
	Objective
	Demonstrated knowledge deficit with regard to importance of peak flow measurement
	Demonstrated knowledge deficit regarding procedure for establishing "personal best" and performing peak flow maneuver
	Reported or observed unavailability of equipment

Table 3. Respiratory Care Diagnoses Related to an Individual's Reactions to Respiratory Disease Self-Management Problems

Problem	Self-treatment of acute inflammation-induced airway obstruction, ineffective
	Definition: Inability to independently administer inhaled respiratory medications to prevent or treat acute airway obstruction triggered by an inflammatory response
Etiology	Related factors
	Inability to assemble equipment due to physical limitations or lack of knowledge
	Incorrect technique
	Incorrect dosing
	Use of wrong medication
	Equipment malfunction
	Fear/anxiety
Signs and symptoms	Defining characteristics
	Subjective
	Verbalized uncertainty in assembling equipment
	Expressed fear/anxiety
	Complaints such as, "My inhaler never helps me"
	Objective
	Demonstrated inability to assemble equipment
	Demonstrated incorrect technique
	Lack of knowledge regarding correct dosing and medication
	Frequent emergency room visits that do not require hospitalization; good response to bronchodilator when administered by health care personnel
Problem	Self-management of asthma, ineffective
	Definition: The state in which the individual encounters barriers in adhering to her/his specified asthma action plan leading to frequent exacerbations of asthma symptoms requiring health provider intervention
Etiology	Related factors
	Impaired cognitive skills
	Insufficient finances
	Knowledge deficit
	Inadequate support system
	Perceived or observed inability to control environment
	Desire to "fit in" with one's social group
Signs and symptoms	Defining characteristics
	Subjective
	Expressed difficulty in understanding relevant instructions
	Expressed fear/anxiety of being ridiculed by peers when engaging in behaviors that conform to asthma action plan
	Reported or observed lack of personal support, finances
	Reported or observed lack of financial and/or other resources
	Objective
	Demonstrated impairment of cognitive skills
	Demonstrated knowledge deficit with regard to controlling symptoms
	Reported or observed isolation from peers

priately set parameters on a ventilatory assistive device or malfunction of the device. On the other hand, it may be increased by cardiac dysfunction or abdominal distention due to gastrointestinal dysfunction. Thus, increased work of breathing requires different interventions from a nurse and an RT and would therefore be defined one way in a respiratory care taxonomy and another way in a nursing taxonomy, to recognize both nursing and respiratory contributions to patient care. A unified ontology for health care, which does not yet exist, would greatly facilitate interaction between the different clinical taxonomies. A complete and robust respiratory care ontology would enable the building of automated respiratory care information systems that are interoperable with other clinical information systems.

Summary

The centerpiece of the discipline of informatics is the conceptual modeling of and computational representation of domain knowledge and data. Therefore, even though sub-disciplines within informatics rely on the same kinds of fundamental building

Table 4. Respiratory Care Diagnoses Related to an Individual's Reactions to Problems With Respiratory Mechanics

Problem	Work of breathing, altered: high risk for imposed work of breathing above physiologic load (resistive loads, lung and chest wall elastic loads)
	Definition: The state in which a mechanically ventilated individual experiences respiratory muscle overload
Etiology	Related factors
	Resistance added by the artificial airway, the breathing circuit, and the humidification device
	Work required to trigger the ventilator demand flow system
	Prolonged spontaneous breathing through the ventilator system without addition of the minimal amount of support required to overcome resistance of the artificial airway and breathing circuit
Signs and symptoms	Defining characteristics
	Subjective
	Dyspnea
	Expressed discomfort
	Objective
	Tachypnea
	Marked use of accessory ventilatory muscles
	Diaphoresis
	Tachycardia
	Paradoxical abdominal motion

Table 5. Respiratory Care Diagnoses Related to an Individual's Reactions to Problems with Gas Exchange

Problem	Air hunger
	Definition: The state in which an individual experiences an uncomfortable urge to breathe or the sensation of not being able to breathe, similar to the sensation of drowning
Etiology	Related factors
	Pulmonary congestion
	Massive hemoptysis
	Severe acidosis
	Anaphylaxis
	Insufficient tidal volume
	Insufficient inspiratory flow rate
	Dying process
Signs and symptoms	Defining characteristics
	Subjective
	Expressed discomfort
	Expressed feeling of impending death
	Objective
	Tachypnea
	Marked use of accessory ventilatory muscles
	Gasping/panting

Table 6. Respiratory Care Diagnoses Related to an Individual's Reactions to Problems With Lung/Airway Defense

Problem	Pulmonary hygiene, impaired
	Definition: The state in which an individual experiences difficulty in clearing debris from the lungs and airways
Etiology	Related factors
	Failure of the mucociliary transport system
	Mucus hypersecretion
	Impaired cough reflex
	Bypassing of upper airway due to need for artificial airway
	Insufficient humidity during mechanical ventilation
Signs and symptoms	Defining characteristics
	Subjective
	Expressed discomfort
	Verbalization of choking sensation
	Dyspnea
	Objective
	Adventitious breath sounds (rhonchi, rales)
	Gurgling noise during breathing
	Use of accessory muscles to breathe
	Wet cough with no sputum production

> blocks, each sub-discipline is unique because it needs to model its own set of professional activities and define its own set of ontologies.[31]

This holds true for the respiratory care profession given that it is a distinct health discipline with its own set of professional activities. A standardized respiratory care language and taxonomy would greatly facilitate data modeling. Creating a respiratory care taxonomy and classification system that is patient-centric (ie, based on assessment, diagnosis, intervention, treatment, and outcome), as opposed to one that is task-oriented (ie, based on current respiratory care clinical tasks), contributes to more complete and accurate information. This may help to achieve the goal of the respiratory care profession, namely, the delivery of high quality, cost-effective respiratory care.

It is crucial that RTs conduct research specific to respiratory care needs and applications to create, integrate, and evaluate information technologies. Furthermore, the respiratory care profession needs to become actively involved in defining and describing respiratory care data and information for patient care. This involves, at the very least, developing and testing the validity and reliability of clinical language for respiratory-care-related assessments, diagnoses, interventions, and outcomes. The creation of a respiratory care taxonomy and classification system has

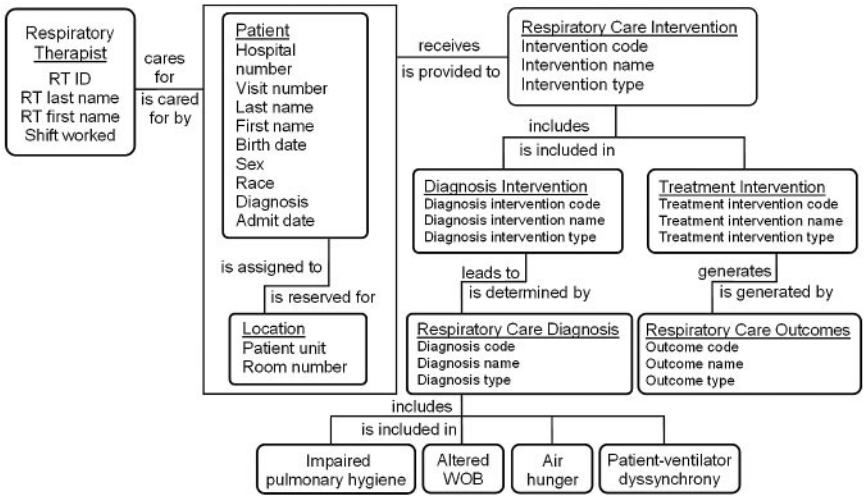

Fig. 1. Entity relationship diagram for respiratory care. In the figure, each concept/entity is represented as a rectangle with rounded corners. A relationship may represent an event that links the entities or merely a logical affinity that exists between the entities. Consider, for example, the entities Patient and Respiratory Therapist (RT). We can make the following assertions that link patients and RTs: (1) an RT cares for one or more patients, and (2) during a particular shift a patient is assigned to only one RT but may be cared for by more than one RT. The entity RT has the attributes of RT identification (ID), RT last name, RT first name, and Shift worked. The relationship between the RT and Patient entities is portrayed by the connecting line linking the 2 entities, and verb phrases describe the relationship. In caring for a patient, an RT may describe the patient's problems by assigning a respiratory diagnosis such as patient-ventilator dyssynchrony or air hunger, based on assessment. Each respiratory diagnosis belongs to a diagnostic category, such as lung exchange or ventilatory assistance. Respiratory care interventions may be diagnostic or therapeutic in nature and a patient may receive more than one respiratory care intervention simultaneously. For example, a patient may require interventions to correct patient-ventilator dyssynchrony and altered work of breathing simultaneously. Moreover, each respiratory care intervention can be offered to more than one patient. The smaller rectangles (eg, impaired pulmonary hygiene) denote subtypes of the Respiratory Care Diagnosis rectangle. An identified patient problem (diagnosis) requires a particular intervention from the RT, and RT interventions can be linked to outcomes.

the potential to enhance the patient care process because they can subsequently be mapped/linked to other terminologies such as the Systematized Nomenclature of Medicine Clinical Terms. Mapping enhances the patient care process by enabling information sharing (ie, data collected for one purpose can be used for another purpose), the meaning of the data are not lost when migrated to databases with different formats and schemas, and cost and errors are minimized because entry of the same data does not have to be done multiple times.

A taxonomy and classification system specific to the practice of respiratory care facilitates accountability for processes and outcomes of care through standardized documentation of care. A standardized respiratory care vocabulary makes it easier to identify diagnoses, interventions, and outcomes that are specific to the practice of respiratory care. A possible benefit of this is improved reimbursement for respiratory care services, which may ease the financial burden some respiratory care departments identified as "cost centers" impose on their organizations. Another major benefit of a standardized vocabulary is that it helps to bridge the gap between research and practice by providing researchers with data needed to identify "best" practices, design decision-support systems, and determine efficient and effective utilization of respiratory care services. It is obvious that a respiratory care taxonomy and, ultimately, an ontology could help secure the future of the respiratory care profession.

REFERENCES

1. Greenes RA, Shortliffe EH. Medical informatics: an emerging academic discipline and institutional priority. JAMA 1990;263:1114–1120.
2. Masys DR, Brennan PF, Ozbolt JG, Corn M, Shortliffe EH. ACMI debate: are medical informatics and nursing informatics distinct disciplines? J Am Inform Assoc 2000;7(3):304–312.
3. Blumenreich GA. The overlap between the practice of medicine and the practice of nursing. AANA J 1998;66(1):11–15.
4. Pierson DJ. What is respiratory care? Respir Care 1998;43(1):17–19.
5. Cottrell RR, Girvan JT, McKenzie JF. Principles and Foundations of Health Promotion and Education, 2nd ed. California Pearson;2002:3.
6. Leddy S, Pepper JM. Conceptual Bases of Professional Nursing, 6th ed. Pennsylvania: JB Lippincott; 2005.
7. Weilacher RR. AARC. 50 Years of Service. http://www.aarc.org/member_services/history.html. *Accessed January 16, 2008.*
8. Conference on the scientific basis of respiratory therapy. Final reports-summaries and recommendations. Am Rev Respir Dis 1974; 110(6 Pt 2):4–15.
9. Bureau of Labor Statistics, US Department of Labor. Occupational Outlook Handbook, 2006-07 edition, Respiratory Therapists. http://www.bls.gov/oco/ocos084.htm. *Accessed January 16, 2008.*
10. American Association for Respiratory Care. AARC Statement of Ethics and Professional Conduct. Irving, Texas; 2000. http://www.aarc.org/media_center/position_statements/ethics.html. *Accessed January 24, 2008.*

11. Smith R. What clinical information do doctors need? BMJ 1996; 313(7064):1062–1068.
12. Rosswurm M, Larrabee JA. Model for change to evidence-based practice. Image 1999;31(4):317–322.
13. Hess DR, MacIntyre NR, Mishoe SC, Galvin WF, Adams AB, Saposnick AB. Respiratory care—principles and practice. Philadelphia: W.B. Saunders; 2002.
14. Mishoe SC. Critical thinking in respiratory care practice: a qualitative research study. Respir Care 2003;48(5):500–516.
15. Degoulet P, Fieschi M. Introduction to clinical informatics. 2nd ed. New York: Springer-Verlag; 1999.
16. Clarke, R. Fundamentals of information systems. http://www.anu.edu/people/roger.clarke/sos/isfundas.html. *Accessed January 16, 2008*.
17. Graves JR, Corcoran S. The study of nursing informatics. Image J Nurs Sch 1989;21(4):227–231.
18. Mussa C, Langsam Y. Management and processing of respir care information in respir care departments. Respir Care 2007;52(6):730–739.
19. Ford RM. Respiratory care management information systems. Respir Care 2004;49(4):367–375.
20. Howard WR. Development of an affordable data collection, reporting, and analysis system. Respir Care 2003;48(2):131–137.
21. Howard WR. Respiratory care billing using a personal digital assistant. Respir Care 2004;49(11):1339–1348.
22. Benjamin P, Patki M, Mayer R. Using ontologies for simulation modeling. Proceedings of the 38th Conference on Winter Simulation. ACM Press; 2007, 1151–1159.
23. Van Bemmel JH, Musen MA. Handbook of medical informatics. Houten, The Netherlands: Springer-Verlag; 1997.
24. North American Nursing Diagnosis Association. Nursing diagnoses: definitions and classification, 2007–2008. Philadelphia: Nursecom; 2007.
25. Clark J, Lang N. Nursing's next advance: an internal classification for nursing practice. Int Nurs Rev 1992;39(4):109–111.
26. Wilkinson JM. Nursing diagnosis handbook: with NIC interventions and NOC outcomes, 8th ed. New Jersey: Prentice Hall; 2004.
27. Allen G, March S. The effects of state-based and event-based data representations on user performance in query formulation tasks. MIS Quarterly 2006;30(2):269–290.
28. Pinto HS, Martins JP. Ontologies: how can they be built? Knowl Inf Syst 2004;6:441–464.
29. Onabajo A, Jahnke JH. Properties of confidentiality requirements. 19th IEEE Symposium on Computer-Based Medical Systems, 2006: 841–846.
30. Chute CG. Clinical classification and terminology: some history and current observations. J Am Med Inform Assoc 2000;7(3): 298–303.
31. Musen MA. Medical informatics: searching for underlying components. Yearbook of Medical Informatics. New York: International Medical Informatics Association; 2003:215–222.