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Journal of Biomedical Informatics 36 (2003) 232–239
Journal of Biomedical Informatics
www.elsevier.com/locate/yjbin

Methods in informatics: using data derived from a systematic review of health care texts to develop a concept map for use in the neonatal intensive care setting

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Received 12 March 2003

Abstract

A qualitative systematic review of textbooks and clinical guidelines identified assessment criteria for initiation of nipple feeds in premature infants cared for in the neonatal intensive care unit (NICU) setting. Using a structured method for text source selection and data extraction, 43 health care texts were systematically reviewed yielding 153 separate statements related to assessing premature infants' feeding readiness. Following this procedure, a pile sort method was conducted wherein an expert neonatal nurse practitioner (NNP) grouped the statements according to similarity in meaning. Ten piles of terms emerged from this process. Each pile was "named," depicting discrete components used when assessing premature infants' readiness for nipple feeding. Using these public data and the private knowledge of the NNP informant, a concept map was constructed to illustrate a framework for decision support development and to examine the map's usefulness for structuring knowledge that will provide input to an intelligent decision support system.

Keywords: Informatics; Research methods; Systematic review; Terminology; Concept map; Cognition; Infant nutrition; Premature infant

1. Introduction

To develop an intelligent decision support system (DSS), the knowledge base must be built in a manner such that is it accurate, reflects best practice, and is acceptable to practitioners who will use it to assist in making decisions for complex, costly problems when caring for patients. A challenge in the field of DSS development is to assist knowledge engineers in designing and deploying a repertoire of specific elicitation methods that comprise an overall knowledge acquisition strategy [1]. This study depicts one portion of an ongoing research project aimed at developing and documenting methods for eliciting knowledge that will assist knowledge engineers in developing DSS for clinical practice setting. In the present study, the knowledge acquisition methods are applied to the development of a knowledge base for an intelligent DSS for neonatal nurse practitioners (NNPs) who care for high-risk neonates in a neonatal intensive care unit (NICU) setting.

Previously, studies were conducted to identify clinical problems deemed appropriate for development of an intelligent DSS in the NICU that would support decision-making by NNPs [2,3]. These studies demonstrated that the clinical problem of assessing readiness for oral feeding was crucial to a premature infant's clinical progress and that NNPs' practice could be augmented in a meaningful way by an intelligent DSS. Once the clinical problem of interest was defined, ethnographic research was conducted and showed that oral feeding was a broad term encompassing other more specific feeding terms.

In an effort to develop an expert system (ES) for use by NNPs practicing in the NICU [2,3] two studies were conducted to identify clinical problems deemed appro-

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doi:10.1016/j.jbi.2003.09.010

priate for development of ES in the NICU. In the first study [2], NNPs identified the five most important clinical problems for which they believed access to ES would greatly enhance care giving. The five clinical problems were fluid management for the very low birth weight (VLBW) infant, codes in the delivery room, micropremie resuscitation in the delivery room, management of babies with reactive airway, and shock. These clinical problems identified by the NNPs were complex and had discernable interventions, but the majority would have required rapid decision-making.

A follow-up study [3] focused not only on identifying important clinical problems for ES development in the NICU, but also on modeling problems that allowed for deliberative decision-making. This increased the chance that the system would address an important clinical problem and, at the same time, would have been designed to give the NNP sufficient time to interact with the system when planning care for a premature infant. The results of the study revealed 15 important clinical problems, 10 of which were deemed amenable to modeling for ES development. Of the ten problems identified, four relating to feeding and/or fluid management were identified: (1) determination of readiness for oral feeding, (2) feeding intolerance, (3) when to begin enteral feedings post-NPO status, and (4) fluid management of the low birth weight infant. At this point, the clinical problem of greatest interest for ES development was that of "determination of readiness for oral feeding."

Since understanding terminology at the outset of expert system development forms the crucial foundation needed to build a system that is accurate, relevant, and useful for assisting clinicians, a third study [4] using ethnographic research was undertaken to elucidate terms surrounding the clinical problem of initiating oral feeding in premature infants cared for in the NICU. Results showed that oral feeding was a complex term that encompassed several feeding options; specifically, nipple, breast, gavage and transpyloric feeding, and that each of the terms had a specific meaning within the context of the NICU.

As a result of these studies addressing issues of defining a clinical problem discretely [4], determining the clinical problem's relevance for intelligent DSS development [2], and addressing feasibility issues [3], the more discrete clinical problem of assessing premature infants for readiness to nipple feed was chosen as the central topic for development of the intelligent DSS. Nipple feeding is defined as taking nourishment through a manufactured nipple [4].

In this present study, a method for structuring the complex qualitative data required for assessing the premature infant for readiness to nipple feed is presented along with the concept map that has been derived from this process.

2. The method

Trochim [5] describes concept mapping as a type of structured conceptualization that can be used to guide evaluation or planning. This process is usually carried out in a group setting, with several steps defined including a technique of brainstorming to generate statements describing a conceptual domain that will be used as input for the concept map, structuring the statements to provide information on how the statements are related to each other, and finally, constructing the concept map, interpreting it, and implementing the map for planning and evaluation purposes. The method used in this study differs somewhat from Trochim's model [5] in that it comprises a systematic review of health care textbooks and practice guidelines as a means of eliciting public knowledge to develop the statement list and uses a qualitative "pile sort" technique to elicit the private knowledge used by an expert NNP to structure the statements related to assessing an infant's readiness to feed. Public knowledge is described as knowledge that has been made available in the literature and usually comes from textbooks, reports, and journals, whereas private knowledge is comprised of heuristics and experientially based information that has not been made available in the literature [6]. Private knowledge usually comes from expert clinicians [6]. In this study, the additional difference of eliciting knowledge from one expert to construct the concept map is viewed as highly appropriate since true experts are difficult to find. In fact, in 'significant domains' such as medical diagnosis, it can take a long time to become an expert, i.e., on the order of a decade or more years of practice in the field [7]. The expert NNP, a master's prepared NNP with 21 years experience as a NNP, was deemed "expert" initially from information received from faculty members from a master's program preparing NNPs at a leading nursing school in the Baltimore area. This designation was supported with direct observation of the expert NNP's decision-making abilities by the principal investigator and the medical anthropologist in the actual clinical setting. The NNP also demonstrated the characteristics of an expert that encompassed the qualities of pattern recognition, the ability to manage rapidly changing situations, self-recognition of comfort level with decision-making, a sense of urgency that differed from non-expert practitioners and, finally, a realistic sense of agency and responsibility for the infants' well-being [8]. An example of the NNP's demonstration of characteristics associated with domain experts can be seen in the following ethnographic interview excerpt:

> "When I think of nipple feeding I think of nipple feeding at its easiest. [It's] the full term kids who know how to do it without blinking. They just come programmed, come out of the womb programmed to do it without any difficulty whatsoever. And even those kids still have an adjustment to make in terms of

volume, what they take. The volume they take, how often they take it, so each baby is an individual. But preterm kids are on the other end of the spectrum. So those kids don't have a clue. They're hard wired. Their wiring is there and as it matures they reach the developmental milestones that they are going to need [..] to coordinate that, but that is an incredible amount of work for a baby who has been very, very ill and has made it through to the point where post-conceptionally or gestationally [the baby is] able to nipple feed. So you're looking at two ends of the spectrum and then in between are all those other kids that may be a little early. [The] 32 to 34 week kids are the kids that truly [may] sometimes take forever to get it together. Sometimes the big 34 to 35 week boys are just the pokiest things [···] in terms of how to nipple feed. So you see the two ends of the spectrum and anything in between. [A]nd then all the kids who have trouble with feeds for whatever variety of reasons: reflux, feeding intolerance from a [gastrointestinal] point of view, protein intolerance, milk allergies. [I think] about all of that when I think about nipple feeding because when you start nipple feeding, you start down the road to discover if a baby is going to have any trouble with taking in nourishment and any trouble with the nourishment that you offer the baby." [Interview excerpt, Spring 2000]

Finally, it was noted that this expert NNP served as consultant in the clinical field, taught in a formal master's level NNP program, and held leadership positions in national organizations serving neonatal nurses. As a result, it was felt that this individual would be best able to provide a quality standard when structuring the concept map. Regarding methodological considerations related to using one participant to develop a concept map, Dumont [9] used multidimensional scaling to generate computer maps from a group of participants and, when comparing these concept maps with hand-constructed concept maps and, in particular, the hand-constructed map of one individual, demonstrated a striking pattern of configural similarity. Dumont's [9] study illustrates the merit of using the one-case method of concept map construction based on a theoretical system of beliefs.

2.1. The systematic review

To provide a list of statements for use in developing the concept map, textbooks and practice guidelines were systematically reviewed. A method, published in detail elsewhere [10] has been developed for systematically selecting, reviewing, and extracting data from the textbooks and clinical guidelines to ascertain evidence-based data related to oral feeding in premature infants. For readers' information, a synopsis of this method is provided here.

2.1.1. Selection of textbooks

Initially, the following health care information sources were used to select the health care textbooks: (1) Brandon/Hill's Selected List of Print Nursing Books and Journals; (2) Brandon/Hill's Selected List of Books and Journals for the Small Medical Library; and (3) the Interagency Council's List of Information Resources for Nursing [11–13]. (4) MEDLINE ⟨1966 to December Week 4 2000⟩; (5) CINAHL ⟨1982 to January 2001⟩; (6) HealthSTAR ⟨1975 to December 2000⟩; and (7) EMBASE ⟨all years⟩. In addition, board certification agencies of pediatric nurse practitioners, NNPs, and neonatologists provided two unpublished recommended reading lists [14,15].

Using the book lists and databases, 166 textbooks and practice guidelines were determined to provide pertinent information on the concept of oral feeding in premature infants. Subject headings that were searched included the following: dictionaries, maternal-child nursing, obstetric and gynecologic nursing, pediatric nursing, gynecology and obstetrics, nutrition, and pediatrics ($N = 105$). When searching for relevant textbook titles, the keywords *premature infant*, *infant nutrition*, and *feeding methods* were used as inclusion criteria in the selection process [10]. Examples of textbooks meeting the inclusion criteria were *Mosby's Medical*, *Nursing*, & *Allied Health Dictionary and* W*haley* & *Wong's Essentials of Pediatric Nursing*. Examples of titles excluded since these books did not meet the inclusion criteria were the *Dictionary of Medical Acronyms* & *Abbreviations and Maternity* & *Women's Health Care* [11–13]. A similar process was used to examine the textbook offerings from two unpublished book lists and resulted in retrieval of 58 pertinent titles for analysis [10]. Examples of pertinent titles included the *Pediatric Nutrition Handbook and the*, *Manual of Neonatal Care.* Examples of textbooks excluded because they were not related to the selected keywords were *Sports Medicine: Health Care for Young Athletes and Pediatric Primary Care* [11,12]. Practice guidelines ($N = 3$) [16–18] were retrieved from the electronic databases using a structured strategy that included pertinent keywords combined with the use of Boolean operators [10]. Finally, a health sciences librarian conducted an independent search and deemed the search process and output to be reliable. The outcome of the procedure for the selection of textbooks and practice guidelines was an initial list of 47 pertinent selections. After redundancy among lists was corrected, a corrected list of 40 selections was compiled [10].

Finally, a panel of experts reviewed the list of textbooks and clinical guidelines to ensure relevancy and comprehensive coverage of the topic. The expert panel comprised a neonatologist who is Director of Nurseries at a large, private, metropolitan medical center and oversees a 20-bed Level III NICU and who holds an academic affiliation with a large university-based medical center. Two NNPs also acted as expert consultants. One NNP worked full-time as a clinician in a NICU, while the other NNP and the neonatologist held clinical faculty positions at academic institutions, with dual clinical and teaching responsibilities, respectively.

The expert panel members suggested three additional texts for a total yield of 43 selections that would be reviewed to identify the statements that would be used for developing the concept map [10].

2.1.2. Rating textbooks and clinical guidelines for usefulness

Textbooks were categorized by clinical focus and yielded 17 medical texts, 14 nursing texts, 5 nutrition texts, 4 reference books, and 3 clinical practice guidelines. Textbooks and practice guidelines were then scored using the following questions: (a) Is there a reference to at least one of the feeding terms in this source? (b) Do at least one of the feeding terms in this source refer to *infants* or *premature infants* or *both*? Scores ranged from a low of one (non-informative on the topic of oral feeding in premature infants) to a high of four (highly informative on the topic of oral feeding in premature infants). Once the definitive selection of textbooks and clinical guidelines was determined, coding each textbook and clinical guideline commenced [10].

2.1.3. Coding the textbooks and clinical guidelines

Using a structured method [10], the textbooks were initially rated for applicability to the task and then, using a set of scoring criteria, were scored for their usefulness. Finally, utilizing Weber's [19] approach to creating and testing a coding scheme, four categories were defined to structure the data collection surrounding the term *oral feeding*. The categories were as follows: (1) basic definition; (2) nursing activities/behaviors related to the implementation of the intervention; (3) signs/indications for nursing interventions; and (4) caregiver/premature infant dyad activities/behaviors related to the implementation of the intervention. A member of the research team who is a nurse practitioner and a doctoral candidate in a nursing program at a leading university acted as coder for coding the textbooks and clinical guidelines. The coder's training took place over several months with frequent consultation with the principal investigator and with the research methodologist. In cases where content validation was required, the research team consulted with the previously mentioned expert panel members. While data from all four of the above-mentioned categories were extracted by the coder, data related to assessment criteria specific to readiness to nipple feed comprised the focus of the present study. An example of the coding process specific to assessing nipple feeding readiness is presented in Table 1. The textbook cited in Table 1, listed as Source #15 from a population of 43 Sources, was rated as a level 4, indicating a high level of usefulness in providing information about oral feeding in premature infants. As can be seen in the table, the coder extracted text pertinent to assessing an infant's readiness to nipple feed verbatim and then selected pertinent phrases that represented discrete assessment criteria. This data extraction method produced 153 discrete statements related to assessing a premature infant for readiness to nipple feed. The sources that provided the bulk of the statements were as follows: *Core Curriculum for Neonatal Intensive Care* ($N = 20$) [20]; *Handbook of Neonatal Intensive Care* ($N = 22$) [21]; and the *Handbook of Pediatric Nutrition* ($N = 10$) [22].

2.2. The pile sort

For the unstructured sorting of the 153 statements, a pile sort method was used [23]. Each statement was transcribed onto a separate card by the researcher. The NNP expert informant reviewed the statements and then grouped the cards into piles *in a way that made sense when considering assessing a premature infant for readiness to nipple feed*. Once the cards containing the statements were sorted, the NNP "named" each pile. These piles constituted the concepts for building the concept map. Following the naming of concepts, each pile of cards was reviewed by the expert NNP and the terms were reduced in number wherever the expert NNP noted a similarity in semantic meaning of the terms. For example, the group of statements clustered under the concept *Weight*, *Growth*, *Nutrition* revealed two terms that stood alone: *feeding pattern* and *energy expenditure* and two terms that resulted from reducing terms that were either identical or similar in meaning: Weight (listed seven times), and *Overall Growth* (resulting from combining two statements: Growth curve—gaining weight consistently over time while on gavage feeds; and Growth pattern). This procedure yielded 56 distinct terms from the original list of 153 statements reflecting assessment criteria for determining a premature infant's readiness to nipple feed (Table 2). Next, the concepts

Table 1
Example of coding procedure for assessment criteria related to determining readiness to nipple feed in the premature infant

Source #15	Excerpted text passage	Text selected by coder as assessment criteria
Kleinman RE, & AAP Committee on Nutrition Pediatric nutrition handbook. American Academy of Pediatrics; 1998	The route for enteral feeding is determined by the infant's ability to coordinate sucking, swallowing, and breathing which appear at *approximately* 32–34 weeks gestation. Preterm infants at this gestational age who are alert and vigorous may be fed by nipple	Ability to coordinate sucking, swallowing, and breathing Age (about 32–34 weeks' gestation) [level of alertness] Preterm infants of this gestational age who are alert and vigorous may be fed by nipple

Table 2
Concepts with associated statements and semantic terms

Concepts identified for determining assessment of readiness to nipple feed	Ranked by order of importance	Original statements ($N = 153$)	Semantic terms ($N = 56$)
Clinical stability	1	31	13
Neurodevelopmental maturity	2	38	6
Physical exam/assessment	3	12	7
Gestational/post-conceptional age	4	16	6
State/organizational behavior	5	22	7
Physiological function	6	6	3
Vital signs	7	12	5
Weight/growth/nutrition	8	11	4
Environmental/staffing issues	9	3	3
Lab values	10	2	2

were ordered according to their level of importance when assessing a premature infant for readiness to nipple feed. In Table 2, the number of original statements clustered under each concept varied from a high of 38 statements to a low of two statements. When the statements were reduced by semantic meaning, the highest ranked concept, *Clinical Stability*, comprised the greatest number of semantic terms depicting assessment criteria for assessing feeding readiness. Table 3 shows the actual concepts and their associated semantic terms. These concepts and semantic terms were clustered in a way that they made clinical sense to the expert NNP.

3. The concept map

In a concept map, knowledge is displayed as a network of *concepts* (as represented by boxes) and the relationship between them, *propositions* (represented by words and phrases). *Cross-links* show the connections between, and among, concepts and create an interdisciplinary space, in this case, for understanding the decision-making process for determining readiness to nipple feed in the premature infant. Concepts may be related either hierarchically, from general to specific, or by cross-links, which can vary on the basis of individual style [24]. Concepts maps have been generated to identify core semantic concepts, relationships, and qualifiers of nursing interventions/activities [25], to develop a type definition for nursing activity terms in patient charts and using nursing terminology systems [26], to assess perceived usefulness of telehealth technology for child protection services [27], to describe the current practice of nurse case management in a health network [28], to explore the meaning of hope in older adults with chronic illness [29], and to develop an on-line educational tool for a woman-centered women's health curriculum to assist medical students' learning [24].

Here, the concept map was developed in a two-session interview process wherein the investigator instructed the expert NNP to develop the map in a way that "made sense." Fig. 1 depicts the concept map as visualized by the expert NNP. The structure of the map has as its focal point the concept of clinical stability. The informant described this as follows: "*the goal is to have the baby [be] clinically stable. In order to achieve that goal, [a practitioner] has to ask all the questions that pertain to clinical stability.*" Therefore, the *concept* of *clinical stability* is centered at the top of the map. As the map construction proceeded, the NNP visualized the layering of decision-making as hierarchical, in three layers with Layer 1 including the assessment of vital signs, the physical exam and assessment, and a determination of the infant's physiological functioning. In fact, the first question that the informant stated should be asked is: "*Are the vital signs stable?*" This would logically initiate a series of questions related to the infant's physiological status. Layer 2 of the concept map relates to neurodevelopmental maturity. State/organizational behavior and gestational/post-conceptional age would feed into the concept of neurodevelopmental maturity. The NNP viewed these two layers as related by a two-way *cross-link* wherein both clinical stability and neurodevelopmental maturity would be evaluated in turn before deciding to nipple feed. However, the expert NNP stated that: "*The baby has to be clinically stable, regardless of neurodevelopmental status. [The baby] can be 32 weeks, but I'm not going to offer a nipple [if he is not clinically stable].*" The final layer was comprised of contributory factors to assessing an infant's clinical stability: weight/growth/nutrition and lab values. Throughout the map, the concepts are linked by *propositions* that explain the relationships among the concepts. For example, lab values are viewed as an objective expression of physiologic function. Finally, environmental and staffing issues were viewed as separate but related in that these issues could influence a decision to nipple feed regardless of other factors.

A unique perception that emerged from the concept map development process was the recognition by the expert NNP that there existed a binary decision point in this map. In essence, the expert NNP saw that if clinical

Table 3
Concepts and associated semantic clinical terms

Clinical stability
Clinical stability
Normal esophageal motility
Amount of time since extubation
Temperature stability
No bradycardic episode with trial of nipple feeding
Individual responses to feeding method
Ability to tolerate feeding
Oxygenation status
Cardiopulmonary status
"Laundry-list" of risk factors
Age, interest, and apnea
Respiratory rate and other qualifiers
Gastrointenstinal function
Neurodevelopmental maturity
Ability to coordinate sucking, swallowing, and breathing
Presence of gag reflex
Sucking mechanics
Ease with which rooting reflex is elicited
Small gastric size and slow emptying [of stomach]
[Handling of] non-nutritive sucking
Physical exam/assessment
Bowel sounds
Soft, non-distended abdomen
Generalized muscle tone
Breathing patterns
Color
[Presence of] gag reflex
Patency of anus and nares
Gestational/post-conceptional age
32–34 weeks
Greater than 34 weeks
Maturation and gestational age
Gestational age
34 weeks gestational age
Usually gestational age of 34–35 weeks
State/organizational behavior
Level of alertness
Physical demands/energy reserves
Activity level
Infant state
Receptivity to non-nutritive sucking opportunities
Behavioral organizational skills
Behavioral cues
Physiologic function
Intact neuro status
Cardiorespiratory function
Gastrointestinal function
Vital signs
Heart rate
Respiratory rate of less than 70 breaths/min
Oxygenation saturation
Vital signs
Temperature
Weight/growth/nutrition
Energy expenditure
Feeding pattern
Overall growth
Weight

Table 3 (*continued*)

Environmental/staffing patterns
Equipment or procedure barriers
Experience of staff
Environmental factors may contribute to infant's disorganization
Lab values
Hypercapnea
Blood gas values

stability was not ensured, then the infant would not be deemed ready for nipple feeding. While this decision node appears straightforward, it can be seen from the pictorial depiction of the assessment process that determining clinical stability is complex and is made only after careful consideration of several important concepts related to a premature infant's physiology, maturation, and to the environment within which care takes place.

4. Discussion and conclusion

It can be seen from the systematic review that the terms used to describe how one assesses a premature infant are complex. By working with an expert to develop a concept map that illustrates these complex assessment criteria, information about how an expert views these data can begin to be made available for use in the context of actual practice. In addition, the concept map illustrates how public data can be melded with the private knowledge of an expert practitioner. The concept map developed for this study represents a high-order map with only the most abstract concepts depicted. Lower-order concepts maps can now be structured using the data sets that are subsumed under each higher-order concept gleaned from the systematic review and by using the method for structuring the concepts described in this study. In addition, it would be useful to build a concept map using the knowledge of other NNPs, possibly using the group technique [5] to determine whether a new structure may emerge when the knowledge from several individuals is explicated. Also, techniques such as multidimensional scaling and cluster analysis, that are applicable to the group model, may assist in deriving accurate and trustworthy conceptual representations of the concepts related to assessing feeding readiness [9].

In the broader context of structuring and representing nursing knowledge for use in intelligent DSS, the concept map illustrates a method of using clinical assessment data that are freely available to readers in print and, yet, are enriched by an expert's synthesis of these data into clinically relevant terms used in actual practice. As has been noted [30], if clinicians are free to record a representation of what they perceive as clinically

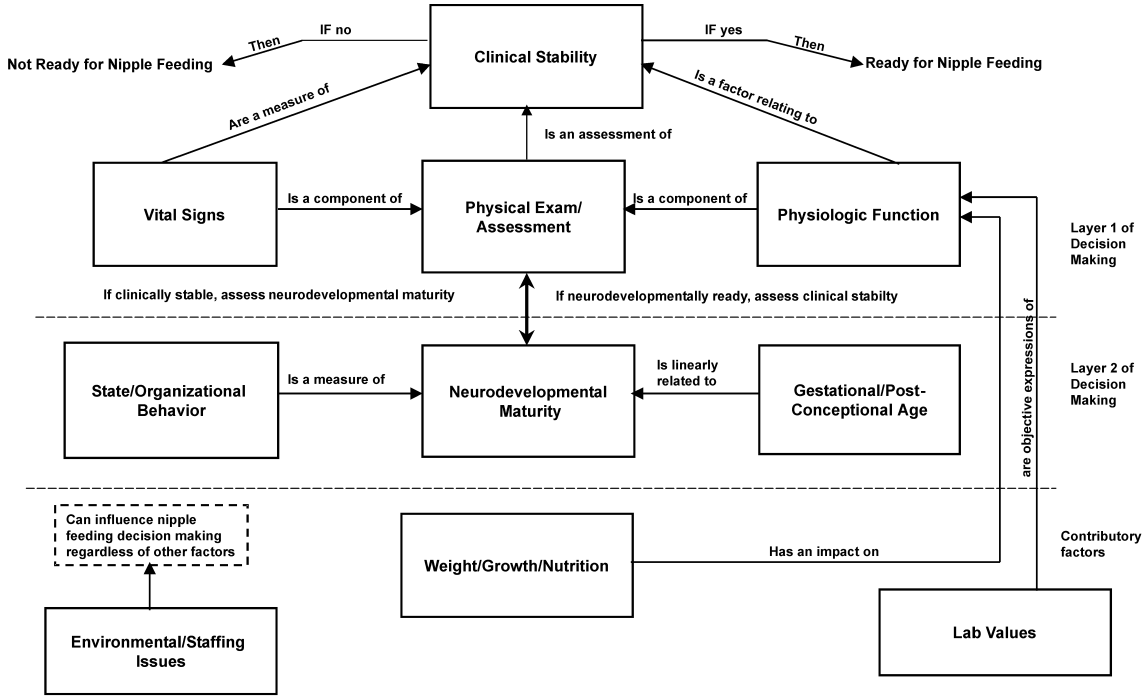

Fig. 1. Concept map depicting assessment criteria for determining a preterm infant's readiness for nipple feeding.

relevant data that seem important within the context of care, development of cogent individual domain models can be made evident. Here, the domain model relates specifically to the complex issue of assessing a premature infant for readiness to nipple feed with a goal of incorporating this knowledge into intelligent DSS. A recent international study describing the development of an expert system for mechanically ventilated neonates recounts many challenges in the development of an expert system and exemplifies the complexities involved in building such a system. What may be of particular interest to developers of intelligent DSS is the researcher's description of the challenge of assisting nurses gain knowledge of how to "work up" a neonate with the assistance of the expert system [31]. The researcher recommends training nurses on the complicated clinical assessment skills before having the nurses consult the system. The present study responds to Jirapaet's [31] recommendation by structuring assessment criteria for determining how to assess a premature infant for feeding readiness. This knowledge base can assist nurse practitioners in their clinical decision-making and, while the domain is specific, the methods described here may be transferable to other complex domain problems and can assist developers of intelligent DSS in nursing.

In summary, while in many cases elicitation techniques used are routine, unstructured methods, it has been suggested that the field of intelligent DSS development should address not a single unitary approach to knowledge acquisition but rather should develop a broad set of methods for knowledge acquisition [1]. The specific method described here generates knowledge from relevant print sources and then, through concept mapping, organizes these data into coherent categories with illustrative depictions of attributes associated with each of the identified concepts. Concept mapping combines the data derived from the print sources with an expert's experiential and intuitive knowledge and, ultimately, provides input for the development of formal propositional statements necessary for building intelligent DSS [32]. This study provides a concrete example of a specific method for using public knowledge from text sources combined with private knowledge from an expert to develop an organized schema that forms the foundation for intelligent DSS development. A comprehensive understanding of how practitioners identify terms for use in making clinical decisions and how they structure these data conceptually has the potential for providing knowledge-based systems engendered with a high level of veracity and acceptability to users of these systems.

Acknowledgments

This study has been funded by the National Library of Medicine, National Institutes of Health (RO1-LM06967). The authors thank the neonatology nurse practitioners, neonatologists, and NICU nursing staff at Mercy Medical Center, Baltimore, MD, for their support during this study.

References

[1] Cullen J, Bryman A. The knowledge acquisition bottleneck: time for reassessment? Expert Syst 1988;5(3):216–24.

[2] Panniers TL. Determining an appropriate clinical problem for expert system development in the neonatal intensive care unit. Stud Health Technol Inform (1997);46:241–46.

[3] Panniers TL. Levels of urgency as a criterion for selecting an appropriate problem for decision support system development in the neonatal intensive care unit. In: Saba V, Carr R, Sermeus W, Rocha P, editors. Proceedings of the Seventh International Conference on Nursing Use of Computers and Information Science. Auckland, NZ: Adis International Limited; 2000.

[4] Panniers TL. Refining clinical terminology for expert system development: an application in the neonatal intensive care unit. Pediatr Nurs 2002;28(5):519–23, 529.

[5] Trochim WMK. An introduction to concept mapping for planning and evaluation. Eval Program Plann 1989;12:1–16.

[6] Benfer A, Brend EE, Furbee L. Expert systems. Newbury Park, CA: Sage; 1991.

[7] Hoffman RR, Shadbolt NR, Burton AM, Klein G. Eliciting knowledge from experts: a methodological analysis. Organ Behav Hum Decis Process 1995;62(2):129–58.

[8] Benner P, Tanner C, Chesla C. From beginner to expert: gaining a differentiated clinical world in critical care nursing. Adv Nurs Sci 1992;14(3):13–28.

[9] Dumont J. Validity of multidimensional scaling in the context of structured conceptualization. Eval Program Plann 1989;12:81–6.

[10] Feuerbach RD, Panniers TL. Building decision support systems: development of an instrument for data extraction from the literature. J Nurs Care Qual 2003;18(2):129–38.

[11] Hill DR, Stickell HN. Brandon/Hill selected list of print nursing books and journals. Nurs Outlook 2000;48(1):10–22.

[12] Hill DR, Stickell HN. Brandon/Hill selected list of books and journals for the small medical library. Bull Med Libr Assoc 1999;87(2):145–69.

[13] Allen M, Barry R, DuBois K, et al. Interagency council on information resources for nursing. Nurs Health Care Perspect 2000;21(5):247–54.

[14] The National Certification Board of Pediatric Nurse Practitioners and Nurses, PNP Certification Resource List. Gaithersburg, MD: The National Certification Board of Pediatric Nurse Practitioners and Nurses, Inc.; 2001.

[15] National Certification Corporation for the Obstetric, Gynecologic and Neonatal Nursing Specialties (NCC), 2001 Guide to NCC Certification: Neonatal Nurse Practitioner Bibliography. Chicago, IL: National Certification Corporation for the Obstetric, Gynecologic and Neonatal Nursing Specialties (NCC); 2001.

[16] Nutrient needs and feeding of premature infants. Can Med Assoc J 1995;152(11):1765–85.

[17] Professional: hypoglycaemia of the breast fed newborn. Modern Midwife 1997;7(10):31–3.

[18] Hypoglycaemia of the newborn. Midwives 1997;110(1317):248–49.

[19] Weber RP. Basic content analysis. 2nd ed. Newbury Park, CA: Sage; 1990.

[20] Deacon J, O'Neil P. AWHONN, AACN, NANN. Core curriculum for neonatal intensive care. 2nd ed. Philadelphia: W.B. Saunders; 1999.

[21] Merenstein GB, Gardner SL. Handbook of neonatal intensive care. 4th ed. St. Louis: Mosby; 1998.

[22] Samour PQ, Helm KK, Lang CE. Handbook of pediatric nutrition. 2nd ed. Gaithersburg, MD: Aspen; 1999.

[23] Bernard HR. Research methods in anthropology: qualitative and quantitative approaches. 2nd ed. Thousand Oaks, CA: Sage; 1994.

[24] Hoffman E, Trott J, Neely KP. Concept mapping: a tool to bridge the disciplinary divide. Am J Obstet Gynecol 2002;187(3):S41–3.

[25] Button P, Warren JJ, Bakken, S., Androvich, I, Mead, CN. Development of the loose canon model for nursing interventions. In: Saba V, Carr R, Sermeus W, Rocha P, editors. Proceedings of the Seventh International Conference on Nursing Use of Computers and Information Science. Auckland, NZ: Adis International Limited; 2000.

[26] Bakken S, Cashen MS, Mendonca EA, O'Brien A, Zieniewicz J. Representing nursing activities within a concept-oriented system: evaluation of a type definition. J Am Med Inform Assoc 2000;7(1):81–90.

[27] Pammer W, Haney M, Wood BM, et al. Use of telehealth technology to extend child protection team services. Pediatrics 2001;108(3):584–90.

[28] Forbes MA. The practice of professional nurse case management. Nurs Case Manag 1999;4(1):28–33.

[29] Forbes MA. Hope in the older adult with chronic illness: a comparison of two research methods in theory building. Adv Nurs Sci 1999;22(2):74–87.

[30] Harris MR, Graves JR, Solberg HR, Elkin PL, Chute CG. Embedded structures and representation of nursing knowledge. J Am Med Inform Assoc 2000;7(6):539–49.

[31] Jirapaet V. A computer expert system prototype for mechanically ventilated patients: development and impact on clinical judgment and information access capability of nurses. Comput Nurs 2001;19(5):194–203.

[32] Hoffman RR. The problem of extracting the knowledge of experts from the perspective of experimental psychology. AI Mag 1987;8(2):53–67.