Computer-assisted Pregnancy Management

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Abstract

A computer system under development for the management of pregnancy is described. This system exploits expert systems tools in the HELP Hospital Information System to direct the collection of clinical data and to generate medical decisions aimed at enhancing and standardizing prenatal care.

Introduction

The last three decades have seen a dramatic decrease in the mortality and morbidity associated with maternity and child birth. Maternal mortality has dropped from 83.3 deaths per 100,000 in 1950 to less than 8 deaths per 100,000 by 1982[1]. Fetal mortality has seen a similar decrease from 19.2 per 1000 to 8.9 per 1000. These changes reflect a substantial increase in both the availability of maternal care and in the medical knowledge concerning the delivery of prenatal and intrapartum care.

The existence of medical knowledge is not, however, necessarily synonymous with its application. McDonald has described significant disagreement between the intentions of physicians to perform medically appropriate actions and the realization of these intentions[2]. Similarly, while conducting a study to define the usefulness of a computerized decision system in an obstetric setting, Anderson noted a 20% discrepancy between decisions to order maternal glucose tolerance tests and the expected frequency of these tests based on accepted obstetrical criteria[3].

This paper describes a computerized health-care delivery system, currently under development, designed to capture obstetrical knowledge and to assist in the application of this knowledge to the delivery of prenatal care. A central feature of this system is the use of the coded medical knowledge to help assure the collection of essential clinical information for obstetrical decision making.

The setting for the system described is the HELP hospital information system in Salt Lake City[4]. The processes described represent a departure from the inpatient-oriented research that has traditionally been associated with this system. The OB management system functions entirely in an outpatient setting.

Design Features

The HELP OB system was designed to support the three primary functions of medical information systems, data collection, data analysis, and data and decision reporting. These elements, as they apply in this setting, are described below.

Data Collection

The data collected in the outpatient OB setting consists primarily of observations entered into the computer by the patient, the physician, and the nursing staff. A modest amount of clinical laboratory data and the results of specialized studies (fetal ultrasound, amniocentesis, etc.) are added to this, as needed. However, the primary producers of clinical data in the outpatient setting are human. The data collection system must match their needs.

To be useful, such interactive data collection must be simple and clearly directed toward well understood goals. The collection of superfluous data in the outpatient setting is a waste of the relatively brief amount of time that can be devoted to each patient. For these reasons, we have chosen a data collection model that limits data entry requirements to that information needed for the processing of appropriate decisions. Data collection is driven largely by a frame-based expert system. The ultimate goal is to ask for no information that does not appear in computerized medical logic.

At each visit the patient is interviewed by the computer using an interactive process called Decision-Driven Data Acquisition (DDA)[5]. The interview begins with a fixed set of questions appropriate to screen for maternal or fetal abnormalities. Affirmative answers to any of these questions trigger logic which analyzes the information known about the patient and determines if a decision concerning the patient should be made. Typically, additional data is required to make a decision and the decision frame directs a series of questions back to the patient asking for elaboration of the symptoms that triggered the medical logic. Questions directed to the physician and the obstetric nurse are also generated and saved, until these personnel sign on to the system. This process may be cyclic with each series of responses triggering new frame logic which in turn requests more data.

The result is a series of questions which specifically explore the medical problems currently affecting the patient. A patient with no problems enters a brief screening history while a patient with active complaints is interviewed using a series of questions specifically chosen to explore those conditions suggested by her initial complaints.

A similar process is active during data input by the physician and nurse. They enter a standard set of screening data using computerized forms designed to organize and simplify the terminal interaction. Subsequently, the decision logic is activated and any requests for additional data are sent to the

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terminal. The responses are used by the system to make decisions concerning further treatment and testing of the patient.

Data Analysis/Decision Support

Data analysis in the HELP system is supported through a frame-based system for representing medical knowledge. The syntax is designed to allow specification of the data requirements and the logic for any medical decision. Boolean, algebraic, and statistical models can be represented. In addition certain types of data acquisition, such as the DDA mode described above, are under the control of the decision author.

Fifty decision frames were initially authored for this project. Table 1 is a partial list of the decisions developed. Figure 1 is an example of one of these frames. The frames are designed to represent medical logic in a modular form. Each frame begins with identifying information indicating the type of frame and the frame author. This is followed by the text that represents the frame's message to the physician. This message will appear on a report if the frame is evaluated true (concluded).

The data to be used in the frame are then described and given labels (variables) for use in the frame logic. The variable descriptions represent links to the HELP data dictionary in which all clinical data stored in the system is described. Previously processed frames may themselves be used as data in a frame.

The frame logic indicates the conditions that must be satisfied in order to make the decision described in the frame. Boolean logic and algebraic forms were used in the frames for the OB system. If this logic is satisfied, the frame is concluded as true and the results are stored in the clinical data base for later reporting. The medical logic may be followed by a description of the data necessary to trigger processing of the frame or by a directive to ask for certain data by posing a question of a specified person when they sign on at a terminal. These data will be requested only if they are absent from the patient's record.

The OB frames used in this project were created by a team consisting of three practicing obstetricians, a medical informaticist and a graduate student in medical informatics. This group met weekly for 15 months to generate the logic for these decision frames.

A three phase approach to the development of this medical knowledge base was used. First the obstetricians would identify a decision applicable in prenatal care and discuss the logic. The medical informaticist and the graduate student would further interrogate the obstetricians to be sure the logic was understood and following the meeting would create a frame describing the decision. During a subsequent meeting, the obstetricians would review a printed version of the frame and critique the logic. This guaranteed that the frame would accurately reflect the medical knowledge originally described. Finally, the frame would be tested on the data of a series of OB patients and the results would be reviewed by the development team. Alterations suggested by this process would be introduced into the frames and they would be retested against new patients.

DURATION OF PREGNANCY
ESTIMATED DATE OF DELIVERY
SCREEN FOR DIABETES AFTER 26 WEEKS OF PREGNANCY
SUSPECT IMPAIRED MATERNAL LIVER FUNCTION
SUGGEST PHENOBARBITAL AND DILANTIN RX FOR EPILEPSY
EXISTENCE OF PREGNANCY INDUCED HYPERTENSION, PREECLAMPSIA
EXISTENCE OF PREGNANCY INDUCED HYPERTENSION, ECLAMPSIA
INDUCE LABOR AND GIVE MgSO4 AND/OR APRESOLINE TO CONTROL BLOOD PRESSURE
CONSIDER GESTATIONAL TROPHOBLASTIC DISEASE
SUGGEST L/S RATIO AND P.G. TEST (pregnancy induced hypertension noted and pregnancy beyond 34 weeks)
*** PREPARE FOR POSSIBLE MECONIUM ASPIRATION *** Alert pediatrician & NBICU; Suction oral and nasopharynx before delivery of chest, then check trachea--possibly intubate; Send to NBICU if any of the following are present: 1) Increased respiratory effort, 2) Tachypnea, 3) Increased CO2, 4) Low pH, 5) Rales, 6) Abnormal CXR.
SUGGEST TRIAL OF LABOR FOR PREVIOUS C-SECTION ONLY IF PERSONNEL ARE AVAILABLE TO HANDLE AN EMERGENCY C-SECTION IN 30 MINUTES OR LESS
PATIENT HAS BISHOP'S SCORE OF ==
DIAGNOSE PREMATURE RUPTURE OF MEMBRANES - **ADMIT TO HOSPITAL FOR OBSERVATION**
CONSIDER TERMINATION OF PREGNANCY
CONSIDER HOSPITALIZATION FOR DIABETIC PATIENT
DURATION OF PREGNANCY BEYOND 12 WEEKS. FETAL HEART TONES NOT YET HEARD USING DOPPLER. CHECK ON THIS.
* SUGGEST ULTRASOUND TO DETERMINE ACTUAL DURATION OF PREGNANCY * (doppler, fetoscope and physician estimates differ by ==.= weeks)
SCREEN FOR GESTATIONAL DIABETES

(etc.)

Table 1: A partial list of the frames developed to assist in decision making in the outpatient obstetrics setting. These are the messages returned to the physician when the respective frames come true.

Title: Pregnancy Management - Trophoblastic Disease (7.42.13).

Type: Diagnostic

Author: Peter Haug

Message: "Consider Gestational Trophoblastic Disease".

Variables: duration_of_pregnancy **as** (DURATION OF PREGNANCY FRAME),

systolic_BP **as** (SYSTOLIC BLOOD PRESSURE),

diastolic_BP **as** (DIASTOLIC BLOOD PRESSURE).

Logic: **If** (systolic_BP **GE** 140 **or** diastolic_BP **GE** 90) **and** duration_of_pregnancy **LT** 20 weeks **then conclude.**

Evoke: **If** systolic_BP **GE** 140 **or** diastolic_BP **GE** 90

Ask: (systolic_BP,diastolic_BP) physician/nurse

Figure 1: Frame to screen for Trophoblastic Disease. This example is written in the general purpose version of the HELP decision language. The frame variables are represented in small_text while the UNDERLINED CAPITALIZED TEXT represents data structures in the HELP clinical data base. The frame is processed if the criteria in the **Evoke** slot is met. The **Ask** slot indicates which information the frame may interactively collect.

For many of the frames this approach was adequate, but some of the frames represented decisions made infrequently in the OB clinic. When it appeared that patients appropriate for testing a given frame would be rare, the obstetricians synthesized patients from memory to test the frames. This allowed the authors to determine at least that the frames ran properly with the "typical" patient for which they were designed.

Data Reporting

Flexible reporting of both the information collected and the decisions made is essential to make a computerized OB system acceptable to the physicians who use it. The reports used in this project are generated through a query language specifically created to access patient data in the HELP system. This language is designed to facilitate generating reports from data which is defined in the HELP data dictionary and stored in the HELP clinical data base.

The initial reports created include 1) a patient history summary, 2) a summary of physician/nurse input data, and 3) a list of the patient-specific decisions generated by the system. This list is the beginning of a collection of reports that will ultimately allow review of the facts and decisions concerning each patient in a variety of useful ways.

Experience

In order to evaluate the potential impact of decision support in an OB setting a pilot study was done during the development of this system. The goal of this study was to assess the frequency with which the decision system might be expected to contribute to patient care.

To collect data for this evaluation a terminal connected to the HELP system was placed in the physicians' office. The DDA mode was not yet operational and therefore three paper questionnaires were created. The first was a prenatal history filled out by the patient during her first visit. The second was a follow-up history to be filled out during return visits by the patient. And the third was a physician/nurse's questionnaire for gathering pertinent physical exam, laboratory, and special testing information. The data gathered through these forms was input using a branching questionnaire by a nurse in the OB clinic.

After the clinical data for each patient had been collected, the available frames were run against it as a group and the results were reported. These results were used to ascertain the need for modification of the frames as well as to assess the potential impact of the system.

One hundred eighty five maternity patients, in various stages of pregnancy, were entered into the system and evaluated by the frame logic[6]. Because frame development continued during this process, each patient was evaluated by a subset of the fifty frames. For all 185 patients the system was able to calculate the duration of pregnancy, estimate the date of confinement, and assess Rh compatibility.

The remainder of the decisions were valid only for patients with potential abnormalities suggested by data in their records. In 102 patients (55%) the computer suggested one or more appropriate management actions which would have assisted in providing care during her pregnancy.

Typical in its behavior was the frame that suggested fetal ultrasound to confirm dates. This frame was run against the data of 142 patients. Seventeen patients were eliminated from further consideration based on the observation (made by the frame) that they were outside of the time window (21 to 36 weeks gestation) where this decision was appropriate. Of the remaining 125, the frame identified 36 of 45 (80%) of the patients who ultimately received ultrasound and 70 of 80 (88%) of those who did not. Since the frames were tested at only one point in each patient's pregnancy, the missed patients partially reflect the appearance of new information collected after the frames were run which led to an ultrasound examination.

Conclusion

Two aspects of this prenatal medical information system deserve comment. First, the system is able to provide decision support based on logic authored by medical experts. The logic can be simple or complex, using data from multiple time periods and in a variety of combinations. While the decision to follow the suggestions of the system rests with the physician, the prompts generated are timely reminders of a standard of care based in expert medical knowledge. Experience with decision systems of this sort in the inpatient setting demonstrates the willingness of physicians to alter care based on the suggestions of a medical expert system and their appreciation for the prompts provided[7].

The second theoretical advantage to this type of system is the potential improvement in medical documentation available. The system assures that whenever information exists that should prompt consideration of available decision logic, data will be collected until the decision can be either made or effectively eliminated from consideration. All of this data is added to the patients computerized medical record. Thus any decision made (or considered and not made) is documented to the extent required by the frame logic.

We believe that medical information systems of the sort described are highly applicable in the maternal care setting. Much of the decision logic in this field lends itself to a coded representation. And, as in other outpatient settings, the combination of complex decisions and the relatively brief interactions possible with each patient favors the computer as a tool to maximize the effectiveness of each prenatal visit.

The system described here is in an early stage of development and will require detailed evaluation when it becomes completely operational. However, our initial experience suggests that we can develop medical logic that will contribute to care in the outpatient obstetrics setting.

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