DISTRIBUTED DATA BASE AND NETWORK FOR ICU MONITORING

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ABSTRACT

Care of the critically ill requires the prompt storage, retrieval, and processing of large amounts of clinical data. Over the past 10 years we have developed a computer based intensive care monitoring and record keeping system which is in routine clinical use. Based on our clinical experience, we found that once the computer system became highly reliable our clinical users bacame dependent on the system. This dependancy presented us with problems of giving the users faster response time and simpler and more responsive data review and entry mechanisms. To solve these problems we studied the system architecture to see how we could make improvements. The amount of data stored on each patient varies by severity of illness and intensity of monitoring. We store from 2 to 16 KBytes of data per patient per day (average 8 KB). Communications between the ICU minicomputer and the central data base system (HELP) operates at a rate of about 16 KB per patient per day for data input and control and about 430 KB per patient per day for data output -- primarily in the form of data review screens and reports. Based on the nearly 50 to 1 ratio of "read" to "write" seen in the ICU, we decided to distribute the data base onto a disc based microcomputer in the ICU. A network of microprocessors was established with a star topology. A database at the central node (HELP) contains a complete set of data for all hospital patients. A subset of the data, based upon which patients are being served by the microprocessor, is kept in a local data base. In addition, terminals have been placed at each patient's bedside so data entry and review can be made "patient specific". Both of these steps have speeded and simplified data entry and review in the ICU. We are optimistic that implementation of these system changes will enhance our systems to the point that nurses and physicians will record virtually all patient data and thus minimize the need for data entry technicians.

INTRODUCTION

Physicians and nurses caring for the critically ill patient are required to retain and process large amounts of clinical data. As a result of their illness or injury these patients have more laboratory tests and monitoring data than the normal hospital patient. Computers have been likely candidates to assist with this data processing and decision-making task for several years. Unfortunately there have been very few successful "clinical" applications of computers in intensive care. At the LDS Hospital in Salt Lake City, Utah we have been developing computer based intensive care programs for over 10 years. A central hospital information system using TANDEM computers called HELP was installed giving us the reliability we needed to support crucial clinical functions such as intensive care (1). Although this system gave us high system availability, at times there were not enough computer terminals available, and the response time was "slow". To alleviate these problems we undertook to distribute the data base and processing capabilities using networking concepts.

METHODS

To help us design a more optimum critical care computer system we conducted two studies. The first study evaluated the data acquisition, data storage, and data reporting mechanisms of our exisiting system. The second study assessed which types of data were used by physicians and nurses in clinical decision-making.

To evaluate how we were utilizing our system resources we measured several system parameters. For a one month period we reviewed the data stored on each ICU patient in the following intensive care units: Shock-trauma, Coronary care, Thoracic (post open-heart), Respiratory, and Intermediate care. Each patient's data base was evaluated to determine the amount of data stored each day. Since the data base is divided by type of data (e.g., laboratory, monitoring, drugs etc) we were also able to determine which types of data we were storing. In addition we monitored the transactions on the communications lines going to and from the central (HELP) system and the Shock-trauma ICU.

To assess the data usage in the ICU we monitored the utilization of data in teaching rounds and estimated the type and quantity of data used by nurses and physicians at the bedside (2). Data used for decision-making was categorized into six areas: 1. Bedside monitoring data, 2. Laboratory data, 3. Blood Gas data, 4. Drugs Intake/Output (I/O) and drug data, 5. Observations, and 6. Other types of data. Two studies during two different months were conducted covering a total of 63 patient days on 30 different patients.

RESULTS OF DESIGN STUDIES

Results of the first study (data acquisition, storage and use) provided some very interesting insights. We found:
1. The amount of data stored in the data base for a typical patient averaged about 8 KBytes per patient per day. The range of data storage varied with the "intensity" of monitoring and data collection. A patient in the Respiratory Unit actually had 20 KB of data stored on one day. Patients in the Coronary Care Unit and the Intermediate ICU required only about 2 KB of data storage per day.
2. Data Entry and Control information sent from the ICU's to the central system for a typical patient averaged about 16 KB per patient per day.

3. Data output from the central system to the ICU for each patient averaged 430 KB per day. Thus there is a ratio of about 50 to 1 (430/8) of data review to data written in the record each day.

The second study of data used in the decision-making from teaching rounds showed the following:
1. Bedside monitor: 13%
2. Clinical Laboratory: 32%
3. Blood Gas Laboratory: 10%
4. Drugs, I/O and IV: 23%
5. Observations: 21%
6. Other: 3%

We were surprised at the small fraction of data used in decision-making in rounds which came from the bedside monitoring. Even when we looked at the data used by physicians and nurses at the bedside the monitoring data only contributed to about 30% of the total data used. On the other hand we were impressed by the large amount of other data, expecially laboratory data which contributed to decision-making.

Based on these two studies we drew several conclusions:
1. That an integrated data base was needed to serve the ICU environment -- data from many sources is used in medical decision-making.
2. Networking of the data from several sources was essential for operation of the ICU.
3. Since data in the ICU is reviewed many times (about 50) for each time it is store, it makes sense to distribute the data for faster and more efficient data review.

Based on these findings we undertook a project to develop a computer system network and distribute the data base (3).

DESIGN SOLUTION

Figure 1 shows a block diagram of the system we developed to help optimize data review and data entry. The HELP system forms the central "star" of the network. Data from all hospital sources is stored in the central data base for secure (highly reliability) archival and decision -making needs which require data integration. The HELP system then transmits the data to the Charles River Data System (CRDS) microcomputers located in each of the ICU's. The distributed data base in the CRDS microcomputer systems is then updated. If data is sent to the HELP system from the ICU microcomputer then the data is first stored in the local data base and then transmited to the HELP system. Programs on the CRDS microcomputer access the local data base for patient information thus speeding data review and entry. By accesing the local data base we also free the HELP system from its large input/output load and will simultaneously speed its operation. By reducing the communications load by about 50 to 1 we have enhanced the entire systems efficiency.

A second step we have taken to make the system easier to use and faster to respond is to place a "smart" computer terminal in each ICU patient room. These smart terminals have 128 KB of memory and we are able to store several pages of "patient specific" data. By having the computer terminal in each room we have eliminated the problem we had frequently encountered of unavailability of terminals. In fact, having the terminals at the bedside allows us to make the data entry and review "patient specific". For example, since the computer knows what drugs are prescribed for each patient, by pressing a single soft key on the terminal those drugs are displayed. The nurse can select the drug just given and with a minimum of key strokes "electronically chart" the medication.

CONCLUSION

We have developed a distributed data base system with extensive computer networking. Major parts of this network are now in clinical use and are meeting our design expectations. Analysis of the impact of the system on response time and user acceptance is underway. Initial response to the system by our clincal users has been enthusiastic.

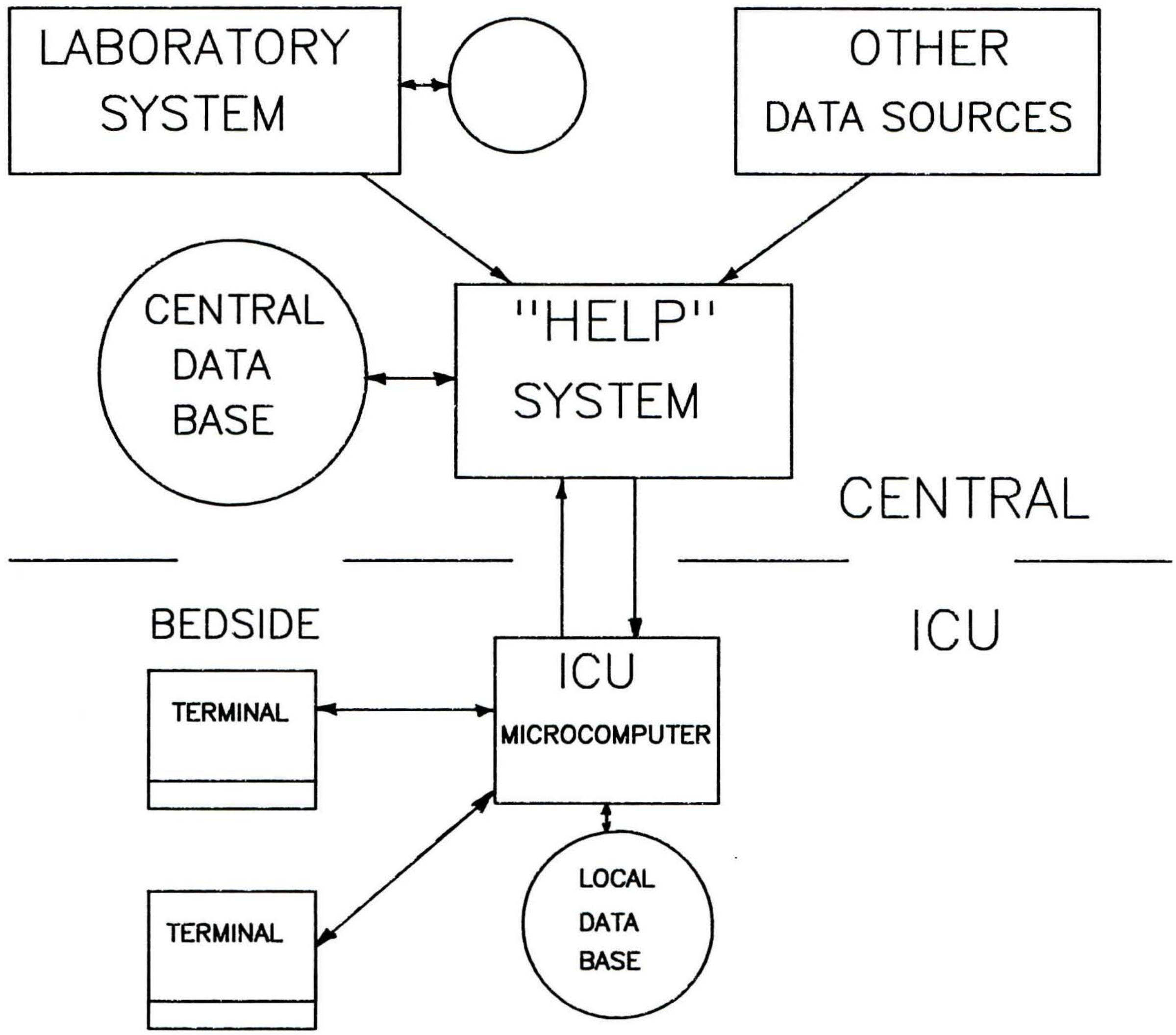

Figure 1 Block Diagram of the Network and Distributed Data Base Used in 4 ICU's with 16 Beds Each.

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#)97

IEEE COMPUTER SOCIETY REPRINT

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Reprinted from IEEE COMPUTERS IN CARDIOLOGY
SALT LAKE CITY, UTAH, September 18-24, 1984

IEEE COMPUTER SOCIETY
1109 Spring Street, Suite 300
Silver Spring, MD 20910

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