THE COMPUTER IN CARDIAC SURGICAL INTENSIVE CARE*

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When the computer was introduced into the intensive care unit in the early 1960's, many believed that monitoring of critically ill patients would be revolutionized. Expectations were running high as this new era of intensive care monitoring emerged. The Federal Government proclaimed in 1970 that the ICU computer had come of age, and through a mysterious selection mechanism each of several medical centers was awarded a million dollar computer system, along with the associated monitoring equipment and computer programs. Their charge was to employ these systems in the ICU to reduce costs, improve the quality and distribution of care, enhance teaching, reduce staff requirements, and lower mortality. Many millions of tax dollars later, much to the disappointment of everyone involved, clearly all of these projects had been able to achieve only marginal clinical success.

Many problems contributing to technology's failure to fulfill expectations were pinpointed. Few, if any, could be considered indictments against the computer per se. In retrospect it appears that insufficient effort was allocated to identifying needs and defining requirements resulting in premature implementation of poorly designed systems unsuited for the clinical care of critically ill patients. Elsewhere productive application of computer technology was being achieved.

In 1964 because of anticipated increases in case loads and a growing shortage of nursing staff, Dr. John Kirklin, than at the Mayo Clinic, spearheaded a joint project with the IBM Corporation to explore the feasibility of employing a computer based system to automate the measurement and charting duties and perhaps certain therapeutic interventions performed by the nurses in the care of patients following open intracardiac operations. During the phase in

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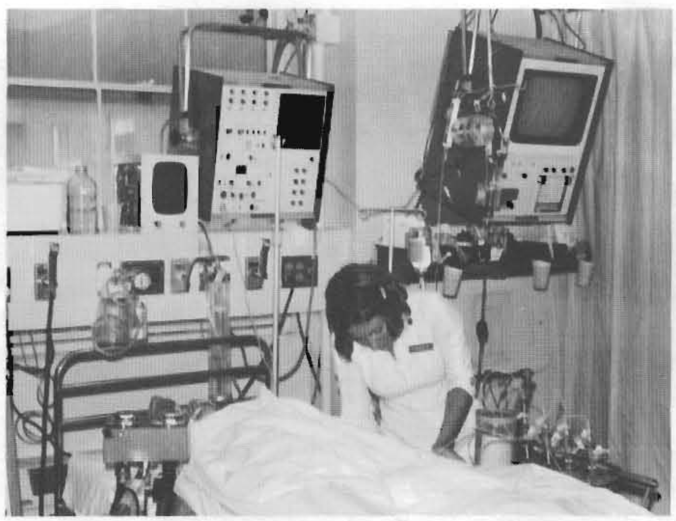
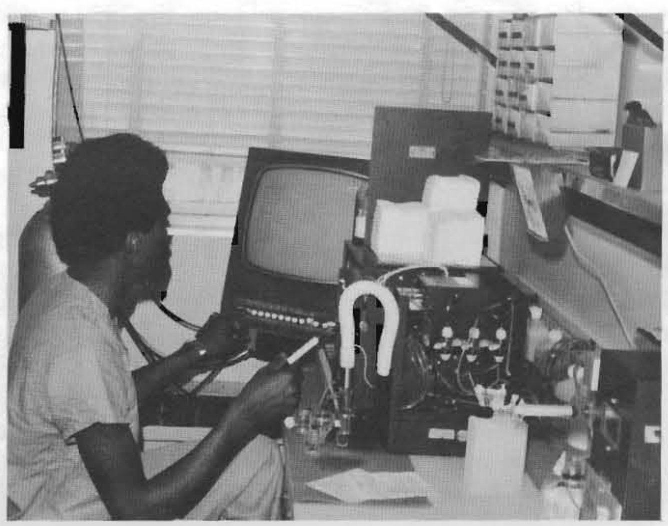
Mr. Louis C. Sheppard, Associate Professor of Surgery, Assistant Professor of Information Science, and Associate Professor, School of Engineering scans the system message log.

Mrs. Janice Shotts, Programmer Analyst, reviews tabular listing of clinical measurements automatically prepared by the system for inclusion in the hospital record.



Ms. Pat Carraway, R.N., at the patient's side in the ICU, inspects chest drainage tubing. The computer terminal, measurement services and electronics modules which are connected to the computer can be seen in the background and at the side of the bed.



Mr. Arthur Johnson, CICU technician, analyzes arterial blood samples and enters the blood gas results via the computer terminal in the lab adjacent to the ICU.

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practically impossible to influence according to Mr. Lawton. Although Senator Kennedy's subcommittee last year reported to the floor legislation which would have required all medical school graduates to serve two years in a medically underserved area, Congressman Rogers thinks this unnecessary, for it would cull out a class of citizens for the first time since the Civil War to perform mandatory non-military service.

Mr. Lawton said, "our legislation as opposed to Senator Kennedy's legislation is trying to influence these problems without getting into the problem of mandatory service of physicians in the United States." Mandatory service is repugnant to Congressman Rogers and to the majority of the subcommittee. Mr. Lawton thinks the House will not agree to this type legislation this year.

Earlier, Mr. Lawton stressed the quid pro quo that Congress enacted to require medical schools to increase enrollment in order to receive money. The quid pro quos have now been modified by the Congress in the House bill that should reach the floor of the House in June (HR-5546, Congressman Rogers' bill). There are options, for Congress recognizes that increasing the number of physicians is not enough. The schools may either increase enrollment or conduct remote site training programs not near tertiary care centers nor large urban hospitals but in either ghetto areas or rural areas, using faculty members to conduct this ambulatory care type of education.

The only requirement for a medical school is that at least 50% of the graduates receive at least six weeks training at these sites. The University of Washington has trained students in Alaskan villages. There is evidence there that a vast number of their students are going into the primary care specialties and into areas of 10,000 people or less.

The second piece of the health manpower bill which current students have escaped is "the pay-back provision." Mr. Lawton told the students that the only kind of education in the United States that received a direct subsidy from the federal government was health education.

Mr. Lawton stated, "your education cost the American taxpayer $12,000 per student per year, of which you are paying $1,600 in tuition – a miniscule part of what it cost the taxpayer to train you." Much of that part comes from the federal government as $2,000 is paid to the medical school for each student enrolled.

The position of the administration that the medical profession is the highest paid profession in the United States gives rise to the question of why should the federal government give capitation support to medical schools whose people are going to be earning so much money later on?

Mr. Lawton said that in order to answer the administration's argument, the legislation would require the student to repay to the federal government the $2,000 per student per year that the school has received for the students education. An option provides that the student may serve on a year for year basis in a critical health manpower shortage area designated by the Secretary of HEW. The Congress sees no reason to increase to any great extent the present subsidy by the federal government to most schools for training medical students who do not meet the acute national needs.

The third attempt of the Congress to satisfy the gross health manpower problem is a funding of what is called Area Health Education Centers. There are eleven area Health Education Centers in the United States today which involve the training of both undergraduates and graduate students in smaller community hospitals. Mr. Lawton said that the best center is located in North Carolina where they are training both undergraduates and graduate students in smaller community hospitals. The Congress has authorized special money for this type of training in the bills that Congressman Rogers subcommittee has reported out.

Two other special project grants that the legislation contains are first, a new program to finance family medicine departments that stand on their own and that have comparable faculty, clinical time, and number of hours with other major clinical departments in the medical school.

The second funding mechanism continued this year is the residency training program that is funded under the program in family medicine. There is money in this bill for training in family medicine and Congress does not intend to get into debate as to what is primary medical care. It sees family medicine as a way of enhancing general practitioners, more good faculty and well-trained students who have demonstrated a willingness to render primary care in underserved areas.

The final most important provision Mr. Lawton discussed was the program designed to control and plan the medic. residency programs in the United States. There is a surplus of residency training programs and a surplus of positions which are not properly balanced according to the needs of the country. Most are located in urban areas which demonstrate little if any need for more positions. The total number of postgraduate physician traineeship positions far exceeds the number of graduates of United States medical schools. Mr. Lawton pointed out that the balance among the positions is badly skewed away from primary care and it is badly skewed toward the subspecialties, the surgical residency programs and the non-patient care specialties.

In 1974 there were 1.7 first year residency training positions for every graduate in United States medical schools. The total excess amounted to more than 21,000 first year positions. The percentage of trainees in the primary care specialties is substantially lower than the percentage of practicing physicians in the primary care specialties.

Mr. Lawton said that the legislation will limit foreign medical graduates' ability to convert their visas after coming to the United States for training and getting into medical residency training programs whether they are properly trained or whether they can speak the English language. At last, for the first time, legislation controls and limits the number of residency training programs and will control the production of specialists with appropriate emphasis on geographical location. It will also keep some foreign medical graduates from entering the United States.

The controls are: The present number of first year residency training programs in the United States is 170% of the number of U.S. medical graduates. This number under the legislation would be reduced to 155% in 1978, 140% in 1979 and 125% in 1980. There are guidelines established to influence which residency programs that should be retained or established.

These guidelines are as follows: First, medical residency training programs would have to be accredited like medical

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which the ICU procedures and operations were intensively analyzed, it was con-ned that certain therapeutic measures and their indications were formally structured so that decisions could be made and interventions controlled logically based upon numerical measurements applied within the framework of rules and limits. Because Dr. Kirklin always organized his care procedures in this way, the feasibility of directly involving the system in delivery of care was a certainty.

Near the end of 1966 when Dr. Kirklin assumed his duties in the UA School of Medicine, he assembled a small team of specialists within the Department of Surgery to carry on with the project to automate tasks in the care of the cardiac surgical patients in University Hospital. The principal thrust of this work was to relieve the nurses of time-consuming routine not directly related to patient care. From the outset the focus has been on mechanizing clinical tasks which were repetitive and well defined so that computer system could be used to reduce the work load.

After modest beginnings eight years go the system has grown such that today monitoring modules and other specialized equipment for eight beds in the Cardiac Surgical ICU of the University of Alabama Hospital are connected to computer systems. During the first 24 to 48 hours following open heart surgery, the computer automatically takes the measurements on all eight patients every two minutes, displays and stores the current values, retrieves past data for review at bedside on command, and tabulates the data in printed form to be included in the patients' hospital records, relieving the nurses of many measurement and charting duties.

Commercially available medical electronics and sensors are employed frequent measurement of heart rate, intra-arterial pressure, right and left atrial pressure, and rectal temperature. Chest tube drainage and urine output are measured by weighing devices constructed in the hospital laboratory.

The infusion of blood is automatically controlled by the computer system in a closed loop feedback mode. The procedure utilizes left atrial pressure and chest drainage with rules derived from the relationship between stroke volume and left atrial or left ventricular filling pressure. The infusion pump delivers a 20 ml dose of blood when actuated by the computer. The infusion is automatically repeated if needed at two minute intervals. This unique clinical involvement of the computer in direct delivery of care has been successfully utilized in the day-to-day postoperative care of patients since October of 1967.

Recently we began using a computer controlled pump for the automated infusion of vasoactive agents to reduce and regulate mean arterial pressure in selected patients exhibiting elevated pressure associated with hypertension or increased afterload.

Cardiac output is measured intermittently in patients by the indicator dilution method. The computer is directed to acquire the dilution curve and calculate the cardiac output.

The bedside computer terminal permits communication with the remote computer for the display and retrieval of clinical data, entry of blood gas measurements and pressure limits for blood infusion, the revision of measurement status, and the control of the computer in measuring cardiac output.

Patient status analysis, decision-making regarding treatment, and selection of interventions are aided by programming which incorporates standardized patient management procedures in the computerized analysis of the data. Current patient measurements are matched with rules which suggest the appropriate therapeutic interventions such as pacing, isoproterenol, trimethaphan, epinephrine, blood infusion, reoperation, sodium bicarbonate, lasix, digoxin, etc.

Since routine, repetitive tasks which are well defined have been relegated to the system, the nurses are able to devote a higher percentage of their time to direct patient care. Consequently, more patients can be served with the existing nursing staff than would be possible without the system and the CVICU technicians. Compared to the usual manual methods of measurements, the automated measurements are more accurate, more reliable, and more consistent. Furthermore, loss of data due to oversight, distraction, or work load has been eliminated as a problem. Trends in the patient's condition can be assessed more accurately from the automated measurements. The past data can be retrieved more quickly by way of the bedside terminal than by search through the patient's chart. Physicians trust the computer generated data more than the data transmitted by people. The explicit nature of the system reduces the tendency to apply judgment unnecessarily in those situations which have well defined decision-making rules. The care of the individual patient is not compromised by the need for the nurse to temporarily assist with a crisis elsewhere in the unit.

The patient's postoperative course in the crucial early hours following surgery is more stable because the computer controlled blood infusion is more objective, less eratic, and more intense than with manual methods. Because of the consistency of the automated technique, continuation of blood infusion beyond 7 am is usually unnecessary. As a result seventy-five to eighty-five percent of the patients remain connected to the automated system twenty-four hours or less. The average duration is twenty-five hours per patient. Normally after the patient has been extubated, the intracardiac and intra-arterial catheters have been withdrawn, and the chest drainage tubes have been removed, he is returned to his hospital room. This usually occurs by noon of the day following surgery. However, if respiratory care must be continued or if anti-arrhythmic, vasoactive, or inotropic drugs are still being administered, the patient is usually moved to a non-automated bed and may remain in the unit for an additional twenty-four hours.

Measurement of cardiac index has been contributed to earlier initiation of therapeutic intervention. Experience indicates that estimation by the usual clinical criteria is considerably less reliable than indicator dilution measurement in some cases clinical judgment may be totally misleading. Without knowing by measurement the cardiac output, the physician may unwisely defer the decision to intervene with aggressive therapeutic measures until clinical evidence of low cardiac index becomes apparent.

The extra cost of the bedside electronics and computer system (less than $100 per patient day) is small compared to the total hospital bill for open heart surgery. The short mean length of stay

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Pathology department chairman named

Dr. Jack Charles Geer of Columbus, Ohio, who has been professor and chairman of the Department of Pathology of The Ohio State University College of Medicine and associate pathologist of Davidson Laboratories in Columbus, will assume his new responsibilities as professor and chairman of the Department of Pathology in the Schools of Medicine and Dentistry of The University of Alabama in Birmingham (UAB) in August. He will have responsibility for the combined Departments of Anatomical and Clinical Pathology.

Dr. Geer, who has won numerous awards for medical student teaching in general pathology at Louisiana State University and Ohio State, will contribute significantly to the education and training programs for physicians and dentists, according to Dr. James A. Pittman Jr., dean of the School of Medicine, and Dr. Charles A. McCallum, dean of the School of Dentistry.

A native of Galesburg, Illinois, Dr. Geer earned his B.S. degree in chemistry and his M.D. degree from Louisiana State University, where he was selected as the outstanding senior medical student. He received the J.A. Majors Award for Scholastic Achievement in Pathology and the George W. McCoy Award for interest and aptitude in the field of parasitology.

Dr. Geer received the Distinguished Faculty Citation from Louisiana State in 1964 and a Citation for Teaching in Basic Medical Sciences from Ohio State in 1972. He has held numerous academic and administrative appointments at Louisiana State, The University of Texas South Texas Medical School, and Ohio State.

Dr. Geer, who has a distinguished record in cardiovascular pathology, earned board certification from the American Board of Pathology in 1960 and is a member of the American Heart Association, the American Society of Experimental Pathologists, and the American Association of Pathologists and Bacteriologists.

Drs. Pittman and McCallum said the Medical Center is fortunate to have a man of Dr. Geer's caliber assuming the administration leadership of the Department of Pathology.

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(between one and two days) in the Intensive Care Unit suggests that care is enhanced and a dollar savings ($80 or more per patient for each day saved) is realized through early discharge from the Intensive Care Unit.

The application of technology and system engineering techniques to the delivery of health services has made possible the successful implementation of a computer based system which has been used in the care of 6000 patients during the critical early hours following heart surgery. The University Hospital has been able to manage the continually increasing number of cardiac operations without proportionate growth in the nursing staff.

Hopefully the experience at UAB will serve to place in perspective what can be achieved through enlisting the aid of the computer in caring for critically ill patients. Widespread acceptance must be preceded by careful analysis of the ICU requirements followed by judicious application of the appropriate technology.