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Editor
Subrata Saha

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EDITOR
Subrata Saha

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BIOMEDICAL ENGINEERING
AND
DELIVERY OF HEALTH SERVICES

J.H.U. Brown, Ph.D.
Coordinator
Southwest Research Consortium

Modern medicine is slowly changing under the onslaught of cost and quality assessment pressures. More people are demanding medical services and the demands are coupled with complaints of loss of personal contact and high costs. Still the ghettos and the rural areas of the country receive little additional services. In fact, it has been stated that the rural population received more care during the horse and buggy days when every small hamlet had its family doctor, than it doew nowadays with modern communications.

Most people put their reliance upon technology to change the situation. There is a firm belief in our society that technology has exemplified by the airplane and the television set can solve all mysteries. Although there is some disquiet at the thought of a technological monolith which could run all society, this fear is in general subjugated to the idea that machines are the servant of man.

In matter of fact, it has been the machines which to date have increased rather than decreased medical costs, have complicated the delivery system, and have tended to depersonalize medical services. Our attention has been focused upon the patient in the hospital bed and the myriad services which he receives--albeit at high costs--rather than the effects of system development, ambulatory care, and the advantages of size.

It is axiomatic that changes in technology in either concrete or theoretical form will effect the system into which it is placed. So far, however, with

The exception of innovative instrumentation, technology has made little impact on the health care system. The development of the artificial kidney, pacemakers, automated clinical laboratories, and intensive care patient monitoring have made very real advances in patient care. They have not markedly affected the health of the general population, although practice has improved as a direct result.

Those R & D efforts which will markedly effect the policies of health care are just now beginning to surface. The studies on cost of medical care, bed utilization, quality of care, use of physicians' assistants, the informed user, etc., are all designed to effect the whole system and policies of the government, the community, and the practitioner.

We need to apply the knowledge now present in engineering to the often mundane problems of everyday medicine. Many of these problems are not glamorous, but they are worthy of solution. And, before the health care delivery system can progress, they must be solved. A few general examples of solvable systems are in order here.

The Records System: The present health care system is based on patient records. In the large majority of cases, these documents relate only in a time sequence and with no detectable relationship between the problems of the patient and his record, as a result the patient who transfers from one part of the system to another is at a great disadvantage. His records are difficult to transfer, the numbering systems do not coincide, and the new unit to which he transfers may use a different form of computer input or an entirely different record format. The theoretical solution is simple. We desperately need a standardized admissions form and discharge abstract, and we need some form of problem-oriented patient record. These records must be computer-based and should be tied to the billing and bookkeeping systems in the hospital. This is an engineering problem pure and simple. But like so many facets of health care, it has a strong sociological base. The system must be used by doctors and nurses, so it must be acceptable to them.

Clinical Care: There are many problems relating more directly to the patient and his needs. The present laboratory in the average hospital may perform hundreds of different tests. These tests are often archaic--performed in the same manner as the same test of 50 years ago. They have been mechanized, not automated. Tests are inaccurate and often must be repeated many times. There is no real process control and no real operations research on the procedures and the arrangements in the laboratory.

In another vein, trauma emergency is the nations third largest disease. (Fig. 1) Each year hundreds of thousands of people die and millions are hospitalized from injury, heart attacks, and other major sudden illnesses. It has been estimated that 25 percent of all these deaths could be prevented with an adequate emergency system. Transportation, communication, and information distribution in such a system must be grounded in technology.

We have mentioned the hospital and its problems, but the hospital is only a small part of the system. (Fig. 2) For every 1,000,000 people in the hospital beds of the nation, there are 20 times as many in outpatient clinics and in doctors' officers or receiving no care at all. Attention must turn from the sick care of the hospital to preventive medicine and health care of the citizen as a whole. Here again, technology plays a critical part.

TECHNOLOGY IN HEALTH CARE

There is no real question but that technology has made a great impact on the life style of America. It has also made a lesser impact on health care. Nevertheless, the impact has been a mixed blessing. We have no way os knowing the actual cost benefit of health care improvements in increased life span, decreased health care costs, or better life style for survivors.

Spencer has examined the problem of health care technology in detail and concluded that the situation is not as fruitful as it might be. His tables are reproduced here (Fig. 3). They illustrate that much of the technology is not yet available for widespread distribution although a great deal is in the process of feasibility testing. It is significant that more basic science applications (mass spectrometry, clinical analysis) and other basic ideas are much nearer exploitation than those test ideas which will lead to system development. In other words, we have not yet been able to develop the system to examine the entire body or to manage the health care system or a series of sub-systems.

This more or less general discussion of technology in health care has set the stage for a series of examples of how technology can become involved in every part of the health care system. There is no question of the need for some sort of model which will more closely define the system and enable the crucial decisions to be made. The providers have no real mechanism for decision making. Each physician or hospital makes decisions on the basis of individual choice. The classic example is the construction of high energy cancer therapy units. Many cities have enough of these units to treat the entire nation because the decisions are not made on the basis of population need and the costs of medical care. The same situation is now beginning to apply to whole body scanners and EMI's. Last year about 800,000,000physician visits occurred outside the hospital by either personal contact or by phone (50%). About one-half of these visits were performed by the private practitioner and about 20% by outpatient departments including emergency departments. It is particularly interesting that group practice health centers and free clinics constituted a small portion of the total health care delivery. The health science centers delivered less than 1% of the total health care.

The handling of this enormous load is complicated by the disappearance of the primary physician. In 1931, 85% of all physicians were in private practice. By 1971 that figure had decreased to 26%. There was an absolute decrease from 112,000 to 50,000 general practitioners. Yet these few physicians were providing 61% or more of the total primary health care.

In 1972, twelve percent of the physicians in this country were serving that one-third of the population. This same population of one-third of the total who live on ninety percent of the land area are served by eighteen percent of the total nurses in this country. Only fourteen percent of the pharmacists serve this population, eight percent of the pediatricians, and four percent of the psychiatrists.

Yet there are some solutions to these problems which have succeeded in specific locations but which have not received wide notice.

The Health Information System:

The HIS is a computer based information system containing a large volume of diversified health information for approximately 13,000 Papago Indians in Southern Arizona, specifically oriented towards prevention.

Two key elements of the HIS program are its problem orientation and the surveillance data base (programmed preventive intervention). The health status program utilizes a set of minimum health surveillance requirements, including immunizations, skin tests, laboratory tests, X-rays, and special examinations and histories, that are scheduled for all members of the service population as a function of age and sex. Surveillance data requirements have been defined in a manner to permit early detection of health problems and to identify patients who are at a high-risk with reference to specific disease categories.

The HIS provides to the physician, a current listing of all surveillance procedures that are past due or that are scheduled within the next twelve months. This permits the use of the routine spisodic encounter as an occasion for the collection and review of basic health surveillance procedures.

The automated problem list program provides the capability for computer generation and maintenance of a consolidated problem list for each patient. Problems included in these lists may be medical, emotional, social, environlmental, education, etc., in nature. The problem list forces health team members to view each patient in the context of the total spectrum of his health related problems rather than in the context of a single complaint or a current problem.

<u>Health Care in Remote Areas</u>: One of the major problems of bringing good health care at a reasonable cost to everyone is the problem of access. Millions of people are unable to obtain care when it is needed. This group does not always live in remote areas. In the ghettos and the suburbs of

large cities, health care is often remote if "remote" is defined as being unable to obtain care within a reasonable period of time. Any attempt to provide health care in remote areas must take into consideration the remoteness of time as well as distance. However, it is clearly apparent that the health care problems in rural areas are quite significant and, in many respects, more difficult to approach and deal with than those in urban areas. Mortality from accidents in rural areas is considerably higher, and chronic diseases are more persistent and less cared for in rural areas. Even the urilization rate of health services in rural areas is lower than that in other more urban parts of the country.

Using the Intelsat Satellite, HOPE has transmitted X-rays, patient pictures and records to the United States for consultation and specialty advice. The system has also been used for the closed circuit consultation between specialists in the United States and physicians on board.

Alaskan villages are isolated by geography, weather conditions, unreliable radio communications, and a lack of telephone service. Village medical aides and their patients depend on infrequent contacts with doctors in larger towns and cities for consultation, diagnosis and treatment. The inadequate communications services in Alaska have forced the State to examine alternate technoligies which can provide communications facilities to all areas of the State.

Twenty-eight villages and towns in Alaska have been outfitted with inexpensive (about $2000) VHF, voice-bandwidth, transceiever ground stations. (Fig. 3). Access to the VHF transponder on the ATS-1 satellite (and not ATS-6) has been more available to the experimenters. Communications can now take place among the villages and with the larger stations in Fairbanks and Anchorage.

The satellite receiving terminal equipment is located in the village medical aide work area. In the 20 villages in the Tanana region, the equipment is time-shared with the school teacher who has a remote line from the terminal. One of the joint educational-medical experiments includes the evaluation of specially designed listening equipment for the native Alaskan children, who generally have a severe hearing disability. Satellite channels are used to transfer medical records, diagnosis date and research materials.

	"Satellite Village"	"HF Village"
Average number of days Tanana doctor contacted.		
10/1/70 to 7/31/72 (via HF)	49.6	39.5
10/1/71 to 7/31/72	230.7	20.0 (via HF)
Average number of cases treated:		
10/1/70 to 7/31/71 (via HF)	43.6	22.0
10/1/71 to 7/31/72	152.9	14.8 (via HF)

These efforts represent the first attempt to use paramedical personnel and a sophisticated communications system in areas where medical facilities are lacking and where physicians are not available to provide medical care for an indigenous population. The lessons learned here including the ability to transfer medical records to and from the HIS system in Tucson will provide information for further design of large scale communications systems.

The STARPAHC (Space Technology Applied to Rural Papago Advanced Health Care)(Fig.4) system is installed on the Papago Indian Reservation in Tucson, Arizona. It is closely integrated with the HIS system. The system, makes maximum use of advanced medical instrumentation, computers and modern communications to transmit medical information on a patient at a remote site to physicians many miles away. The data received at a control center will enable physicians to diagnose conditions and prescribe treatment to train medical assistants at the remote site.

The local health service centers are equipped with biomedical instrumentation, first aid equipment, routine medical supplies and television, and voice communication systems likned to the control center. Trained medical assistants will be on duty at the local center to provide outpatient care for people in the area covered by that site.

Information transmitted to physicians will include measurements on the cardiovascular and respiratory systems, X-ray and biochemical and microscopic data.

The mobile facilities are scaled down versions of local health service centers and perform basically the same medical functions. Ambulances and portable equipment will support the local centers and mobile facilities.

The hospital participating in the test program has a full range of diagnostic facilities, an emergency room staffed on 24-hour basis, and a full range of practicing medical specialists on the staff.

The Mount Sinai Telecommunications Project: More than 20,000 Americans are over the age of sixty-five. Most of them have T.V. becuase 99% of American homes have at least one television set; 60% have colour television. The average elderly person spends more hours watching television than does any other age group. Although they comprise about 10% of the population, the elderly account for 27.4% of all expenditures on health.

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As many tenants as possible are involved in the production of software. Software will be developed that not only informs resident, but also elicits the desired behavioral responses, e.g., paying more attention to their own health problems, treatment, and actively dealing with preventive medicine for their own wellbeing.

At a later date, interactive terminals will be introduced to enable each tenant to respond to questions posed over the channel, solicit information, make clinic appointments participate in club acitivities, etc. Plans are also underway to explore various NASA sensory devices for medical feedback to the Emergency Room at Mount Sinai Medical Center.

The Automated Physicians' Assistant: The APA is a computer oriented system designed to increase efficiency of the solo practitioner in remote areas by providing him with otherwise unobtainable information and services and full communications with a university medical center. In the APA system, the patient operates a terminal in the physician's office and enters data concerning his medical history. In addition tc the automated patient history, a number of other functional computer program packages tailored to the needs of the rural practicing physician have been developed. These programs permit patient data from the physician's office to be entered into a remotely located large central computer. Patient data consists of vital signs, hearing test results (audiometer), vision test results (acuity, phoria, color perception, etc.), X-ray reports blood chemistry analysis report, urine analysis report, hematology report, pulmonary function, physical examination findings, diagnosis, and treatment or therapy. Programs have been developed which display upon the office terminal various reports pertaining to a particular patient which can be called up quickly for review by the physician. Another program has the capability of inserting, deleting or modifying an entry into the file to update or correct files.

Blood samples from the physician's office are transported to automatic analyzers. The results of these tests are entered into the patient's file via terminals located in the pathology laboratory. The physician has access to this information as soon as entry has been made from the pathology laboratory.

A summary of all of the information available about a particular patient can be obtained from a printer located in the physician's office. The summary report includes all items of medical data such as the patient history, the specialized reports of pathology, radiology, EKG, etc., the diagnosis, and the vital signs, the eye test, the hearing test, the EKG interpretation, the urinalysis report, the X-ray report, and the pulmonary function test results can be made available to the physician before the physical exmination is given. The physical examination results and the impression and treatment prescribed are also entered.

Patients have had no difficulty using the automated terminal and the personnel in Dr. Bass' office are enthusiastic. The technological aids are accepted by the physician, his allied health personnel, as well as his patients.

THE PATIENT AS PROVIDER

We have hundreds of thousands of persons who need kidney dialysis. The procedure costs perhaps $10,000 per year in the hospital but is a means of training were available to train the individual in the home to do dialysis on a relative or himself, the cost might be reduced to $3,000. Some 23,000,000 Americans have high blood pressure. We may come eventually to a means of monitoring the more critically ill of these and providing treatment in the home. The same situation obtains with other chronic illnesses and with the diabetic who can be trained to regulate his blood sugar and diet. The Bolt, Baranek, and Newman CAPO operation currently furnishes patient education programs in diabetes, family planning, obesity, lung disease, dieting, and hypertension as a start in this direction. The several programs now available to allow a patient to take his own history in a computer format offer a similar opportunity. In each case we need a simple, foolproof technological advance for home use with capability of monitoring from a remote station. Since many of these must be produced by the millions, they must also be inexpensive.

SUMMARY

The American people have a right to expect good health care. A country as affluent as ours should be able to provide the three essentials of a good health care system: easy access of everyone to high quality care at a reasonable cost. Our efforts must be bent toward these ends and a major input will be technology.

The health care system today is under many strains. The complexity of modern medicine places a premium on the exchange of information and the handling of data. The physician is faced by the increasing pressures toward group practice, by the advent of a variety of paramedical personnel who may pose as much a threat as a help to him, and by the many problems of a system which is not designed to handle the number of cases which it receives.

Each of these problems demands immediate solution and most of the solutions are in the area of technology. Most of the needed technology is state-of-the-art--we do not need vast new instrumentation or theoretical studies. We need to apply the knowledge now present in engineering to the often mundane problems of everyday medicine. Many of these problems are not glamorous but they are worthy of solution and before the health care delivery system can progress, they must be solved.

Cause	Number of Deaths			Death Rates*		
	Total	Male	Female	Total	Male	Female
All Causes	**1,930,082**	**1,087,220**	**842,862**	**966**	**1,115**	**824**
Heart disease	744,658	425,796	318,862	373	437	312
Cancer	318,547	173,694	144,853	159	178	142
Stroke (cerebrovascular disease)	211,390	96,701	114,689	106	99	112
Accidents	**114,864**	**79,424**	**35,440**	**57**	**81**	**35**
Motor-vehicle	*54,862*	*39,788*	*15,074*	*27*	*41*	*15*
Pneumonia	66,430	37,285	29,145	33	38	28
Diabetes mellitus	38,352	15,781	22,571	19	16	22
Arteriosclerosis	33,568	14,645	18,923	17	15	18

Children aged 1 to 14

For children aged 1 to 14 years, accidents claim more lives than the six leading diseases combined. (Among infants less than one year old, such causes as congenital anomalies, asphyxia of newborn and immaturity have the largest death totals.)

Cause	Number of Deaths			Death Rates*		
	Total	Male	Female	Total	Male	Female
All Causes	**30,580**	**18,129**	**12,451**	**54.4**	**63.3**	**45.1**
Accidents	**13,112**	**8,574**	**4,538**	**23.3**	**30.0**	**16.4**
Motor-vehicle	*5,773*	*3,641*	*2,132*	*10.3*	*12.7*	*7.7*
Cancer	3,760	2,095	1,665	6.7	7.3	6.0
Congenital anomalies	2,442	1,301	1,141	4.3	4.5	4.1
Pneumonia	2,062	1,081	981	3.7	3.8	3.6
Heart disease	651	341	310	1.2	1.2	1.1
Homicide	514	287	227	0.9	1.0	0.8
Stroke (cerebrovascular disease)	403	210	193	0.7	0.7	0.7

Youths aged 15 to 24

For youths aged 15 to 24 years, accidents claim more lives than all other causes combined, and nearly 7 times more than the next leading cause. Four out of five accident victims in this group are males.

Cause	Number of Deaths			Death Rates*		
	Total	Male	Female	Total	Male	Female
All Causes	**41,140**	**29,953**	**11,187**	**124.4**	**183.5**	**66.8**
Accidents	**23,012**	**18,480**	**4,532**	**69.6**	**113.2**	**27.1**
Motor-vehicle	*16,543*	*12,911*	*3,632*	*50.0*	*79.1*	*21.7*
Homicide	3,357	2,688	669	10.1	16.5	4.0
Cancer	2,731	1,637	1,094	8.3	10.0	6.5
Suicide	2,357	1,789	568	7.1	11.0	3.4
Heart disease	946	545	401	2.9	3.3	2.4
Pneumonia	851	492	359	2.6	3.0	2.1

Source: National Center for Health Statistics.

*Deaths per 100,000 population.

Fig. 1 Accidents as a Major Cause of Death