Computers Can Change Cardiology

DR. ROBERT P. GRANT, the late Director of the National Heart Institute, initiated a major clinical research program in 1966 to improve the treatment of patients with acute myocardial infarction and our understanding of the disease. In addition to the support of specific research, a network of myocardial infarction research units was envisioned with a shared purpose in the accurate description of the disease, its natural history, and response to therapy. It was largely these latter considerations which led Dr. Grant and his successors to allocate sufficient monies so that each Myocardial Infarction Research Unit could develop a sophisticated computer-based information management system. Certain of the MIRUs focused on the development of systems for acquiring physiologic data from patients while others worked on systems for the collection, storage, and handling of both discrete and categoric data. The MIRU directors and leaders at the National Heart and Lung Institute felt an important responsibility to explore the potential offered by computer systems to develop something which would have an impact on the study of cardiovascular disease—an impact greater than that which might be anticipated as the result of any single research project or collection of projects.

During the past 5 years, I have had the opportunity to examine a number of computer systems which are being used for cardiovascular studies, and I have had the privilege of associating with many investigators who are dedicated to developing the full potential of this new technology. Much of the interest has been focused on methods for improving the speed and reliability of what we already know how to do. I have no doubt that these are worthwhile projects that will contribute to medical practice, research, and education. I am convinced, however, that the computer offers a greater potential—not unlike the impact of methods of tissue culture to research, of the electron microscope to diagnosis, and of cardiopulmonary bypass to treatment of patients with heart disease. The potential I speak of is that computer-based information systems will allow us to achieve important goals in research and practice which cannot be achieved without the computer.

To appreciate my view of the potential role of computers to the future of cardiology one must first examine how cardiology is practiced now, and we must honestly identify the weaknesses of our present approach to patient care. The successful practice of medicine is based on the science of problem solving. Patients present to doctors with manifestations of their problem and these are sometimes overt and sometimes latent. The solution is to remove the problem or to lessen its effects on the patient. A doctor’s first job is to establish a mechanism for communication with his patient and to collect data. In this role he functions as a transducer, and to succeed requires both art and science. The data which the doctor collects are of various types: historical, physical findings, laboratory results, X-rays, ECGs and, in some cases, hemodynamic measurements. Each piece of data is a descriptor, some discrete and some categoric, some hard and some soft. Together, these data serve to characterize the problem and the patient in whom the problem exists. The doctor’s next job is to try and recall patients, like his, who had a similar problem. In this role the doctor performs the function of pattern recognition. When a patient has chest pain, exhibits certain changes on the ECG, and elevated serum enzymes, we recognize a pattern we have seen before and label it “acute myocardial infarction.” By itself, though, this label or diagnosis is seldom sufficient to make accurate predictions of outcome or to select a treatment. It is a common misconception that the diagnosis is the solution of a clinical “unknown.” As noted above, the only solution that really counts is whether or not we make the patient better. To accurately predict the outcome and to select a form of treatment, we need to know more than the diagnosis. In the case of acute myocardial infarction, the age, blood pressure, P-R interval, frequency of VPCs, and estimates of infarct size all contribute to the prognosis for immediate survival. The doctor tries to predict what will happen to his patient because the patient wants to know what to expect and because the doctor must know what the natural history is in order to decide whether treatment is indicated. I should like to emphasize that the

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prognosis, and even a first approximation of the plan, depend upon many descriptors, and almost always upon more information than that which is required to make the traditional diagnosis. If the natural history of patients like his can be identified, and if it is such that the problem will not go away by itself, then the plan is to treat the patient. Treatment often involves selection from two or more alternatives, and the selection of one of these options assumes that the doctor has knowledge that the treatment prescribed is better for the patient than no treatment and furthermore that it is better than other potential alternatives.

My experience is that good doctors are good at establishing mechanisms of communication with their patients and in collecting reliable data. Even good doctors, however, are no exception to the well-known fact that man's ability to recall is limited. In an effort to overcome the limitations of his memory, the doctor writes in the chart, but time is short so he lumps descriptors into syndromes such as "angina pectoris," he pools descriptors such as values of the blood sugar into "diabetes," and he deletes descriptors which are "negative." Problem-oriented or not, more often than not the record is of little research value. Even in the most compulsively written problem-oriented record, the descriptors are not coded in a way which permits easy retrieval. As a consequence, pattern recognition cannot take place except at the most superficial level.

At the stage of data gathering, a computer forces upon data gatherers a degree of discipline which is seldom present without the computer. This discipline operates primarily at three levels. First, the computer user finds that his records are more complete. The capacity for data storage and the ease of retrieval encourage the user to keep a larger data base because practical obstacles to a large data base are essentially removed. Furthermore, each time he gets a listing of his data the computer user is embarrassed by missing data, so he places a higher priority on his day-to-day operations, assuring that all pertinent observations are recorded. Secondly, the computer user finds that his data are more accurate. When data are stored in the computer, they are used, and when they are used errors in data recording become significant. If a patient's blood pressure is recorded erroneously in the traditional chart, no one seems to care too much because the doctor knows his patient had hypotension and the information recorded in the chart makes little difference. Suddenly, however, when the blood pressure goes into the computer and is used to calculate averages and trends in a group of patients, the accuracy of each recorded observation becomes essential. Finally, the computer forces upon its users the discipline of more precise definitions. Terms such as shock, heart failure, and anginal syndrome become relatively useless unless they are accompanied by more precise descriptors which document the problem and characterize its severity. Doctors are not immune from a common human trait—that they demand more of others than they demand of themselves. Thus, one doctor won't use the experience of another unless it is well documented. When terms are defined and used and when the record is documented, then and only then can it be used by others for clinical decisions or for clinical research.

The computer is a mechanism for improving the record, but the payoff comes when good records are stored in the computer and are accessible. At the stages of pattern recognition and prediction of outcomes, the computer-based information system is a powerful extension of the doctor's memory and his ability to handle large numbers of patients and descriptors in a valid analysis. Let me cite an example: can any of you (the readers) remember a patient like this one?

A **white male** in his middle 50s has crushing substernal **chest pain** which radiates to the left arm. The pain is brought on by **exertion**, and is relieved in 2–3 minutes by **rest** or **nitroglycerin**. These pains began 1 year ago and occur with a frequency of 3–5 **times/week**. The resting ECG shows 5–6 PVCs/min and is **otherwise normal**. Two minutes after entering **Stage II** of the Bruce test, 3 mm of S-T segment depression developed in leads V4, V5, and V6. Chest **X-ray normal**. Blood pressure 160/95. Cholesterol 220. Triglycerides 50. Lipoprotein electrophoresis **normal**. Cardiac index 3.3 liters/min/m². Ejection fraction 60%. Coronary arteriogram shows a 90% occlusion of the left anterior descending, an 80% occlusion of the right coronary artery, and a "clean" left circumflex.

The patient smokes 20–30 cigarettes per day and has for 25 years. Can you remember such a patient? If you can, how long did it take to identify him? How was he treated and what was the result? What is the probability that patients like this will be alive 5 years from now? What would the operative mortality be if such a patient underwent a saphenous vein bypass graft? Are this patient's
chances for survival and relief of angina better with no treatment, propranolol, an exercise program, or surgery? I submit that each of the italicized descriptors is very probably pertinent to the prognosis of this patient with either traditional medical therapy or with surgery. Neither our current record system nor our memories will allow us to identify patients like this one. If major medical centers kept computer-based records, including follow-up, on their patients with angina pectoris, any doctor could find out what happened to patients like this one, with or without surgery, in a matter of minutes.

The information system I have described would allow us, for the first time, to design clinical experiments and therapeutic trials in a manner which would greatly enhance the probability that trials would yield meaningful results. Many, if not most, of the important unresolved problems in adult cardiology involve chronic disease, for which the only forms of treatment are preventive or palliative. The difficulty is that these diseases, for example coronary disease, are probably multifactorial in cause, take years to pass from a presymptomatic stage to a symptomatic stage and, even when manifest by specific signs or symptoms, have a tremendously variable prognosis. It is not surprising, therefore, when we take a very nonhomogeneous sample of patients with such a disease and randomly allocate a treatment which may help some, not affect some, and hurt others that the results seldom constitute acceptable clinical proof. The question is not whether randomized trials are a valid test; they are. The real questions relate to the completeness and accuracy of the descriptors of the population under study and when to carry out the randomization. The number of patients required to complete the trial will be influenced enormously by the degree to which the sample population has a homogenous and predictable outcome. For example, a number of studies suggest that patients with myocardial infarction complicated by intraventricular conduction disturbances have a high risk of sudden death within a year after discharge from the hospital. A randomized trial of prophylactic pacemakers in this subgroup could surely answer the question of efficacy of this form of treatment with respect to prevention of sudden death, and a small number of patients studied for a short time would be sufficient. On the other hand, if all patients with myocardial infarction were randomly assigned to pacemaker or no-pacemaker groups, without prior prognostic stratification, the trial would very likely fail. The positive results anticipated in a small subgroup (those with conduction disturbances) would be so diluted by patients who were not helped that the numbers of patients and the time required might well exceed practical limits, and thus the trial would end inconclusively.

Much the same argument can be brought to bear on the question of the saphenous vein bypass graft for the treatment of symptomatic coronary disease. We already know that, considered as a whole, the 3-5 year mortality of medically treated patients with angina pectoris is 10-15%, and this does not differ dramatically from the combined operative and early postoperative mortality of patients who have undergone the bypass graft. We also know that 10-15% of patients who survive the operation develop perioperative myocardial infarction; and this is not dramatically different from the incidence of infarction during a 3-5 year follow-up of medically treated patients. A randomized trial of surgery versus no surgery in patients with angina, without prior prognostic stratification, would very likely fail to show any net benefit from the operation in terms of mortality or the incidence of infarction. However, if a subgroup of patients with angina could be identified in whom the prognosis without surgery was poor, i.e., 30-50% in 3-5 years and in whom the operative mortality was low, i.e., 5% or less, then such a subgroup might represent an optimal sample in which to conduct a randomized trial to evaluate efficacy. When a complete and accurate description including follow-up is available on patients, some of whom were operated on and others of whom were not, then prognostic stratification could be used to identify the group to be studied and to aid in designing the optimal study. It is the data base and its accessibility to analysis which would make this type of clinical research possible and practical.

During the past 5 years we have developed a data base on approximately 800 patients admitted to our Myocardial Infarction Research Unit with documented acute myocardial infarction. The descriptors are less complete and less accurate than we would wish, but they include historical, physical findings, selected ECG and other lab reports, a hemodynamic profile, and follow-up data at 6-month intervals. We have a similar data base on approximately 800 patients who have undergone coronary arteriography for evaluation of the anginal syndrome and its variants, some of whom were operated on and some of whom were not. These data are in computer-based files which are available.
for recall and analysis in less than 1 minute. We can
tell our students many of the descriptors which are
important in determining hospital mortality after an
MI or sudden death after hospital discharge. We
can tell our students which findings influence the
mortality of patients with angina pectoris without
surgery and which descriptors identify patients with
a high operative mortality. The members of our
cardiology staff can recall their individual patients
or their collective experience with other patients
similar to their current patient. In a few instances
we are at a stage, or will be in the foreseeable
future, where we can identify the descriptors which
define subgroups with sufficiently predictable out-
comes, so that prospective randomized trials are
likely to be meaningful and practical. Many of our
colleagues share my view that this is the most
important contribution of our MIRU, and we also
share the expectation that continued development
and extension of this system to other categories of
cardiology practice will have an important impact
on patient care, learning, and research.

The information system I have described, and its
use, have and will continue to improve medical
record keeping. To the extent that a more carefully
kept record reflects more accurate observations of
patients, patient care should improve. Doctors who
use such a system should have a distinct advantage
over doctors who do not use the system. This
conclusion is based on the premise that informed
action is more likely to be efficacious and safe than
uninformed actions. The improvements which
would result from the application of computerized
records would help to bring into actual practice
certain elements of practice which we all agree are
essential but are seldom realized. I do not doubt
that physicians can treat ventricular fibrillation or a
strep throat with current skills and information
systems. These are acute problems for which there
are standardized and highly effective treatments. I
seriously doubt, however, whether any physician is
able to acquire and recall the experience which
would enable him to provide optimal care for
patients with chronic heart disease without the aid
of the type of information system I have described.
With chronic multifactorial diseases, there are just
more questions than answers to what is the best
treatment and when it should be applied.

The principles of the scientific method apply to
any experimental design, but the tools for studying
chronic multifactorial disease differ from those
which have and will continue to aid the investigator
with one enzyme in a test tube, or the clinical
investigator with patients who suffer an acute
reversible disease. The computer will force the
clinical investigator to keep records as assiduously as
he would if he did a laboratory experiment. The
computer can provide the memory extension which
is necessary for the doctor to recall the pertinent
variables which describe patients who constitute his
own experience and that of his colleagues. Compu-
ter-based records can be interfaced to powerful
statistical technics which will aid the investigator in
defining subgroups of patients who are sufficiently
homogenous in their outcome so that therapeutic
trials will be meaningful. Only if records and the
results of treatment are computerized can the
information be available to a doctor within a time
frame which will help him care for his next
patient.

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