# COMPUTERS IN MEDICINE

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This article will attempt no technical analysis of specific computer techniques but will put forward some basic principles of computer operation, its capabilities, its limitations, its use in a number of fields of medicine, and finally, a hint of its possible future role.

Initially, it might be valuable to make two simple comparisons in order that there be no mistake about who is superior, man or machine. First the computer can be compared to a hammer and then to a cow. Like the hammer, the computer is a useful tool, which must be carefully guided lest it destroy the very thing it is helping to build. A cow cannot give milk unless she has been well cared for and has been fed in fertile pastures. So, too, the computer cannot on its own, yield results apart from a man's direction and cannot yield reliable and accurate results unless it has been well maintained and has been fed by imaginative and fertile minds. Here, however, the analogy must end, for as dull as the cow might appear to be, she has infinitely more innate intelligence that the most majestic of computers. This is a safe statement because computers simply **have** no innate intelligence.

A computer is an extension of some of man's own abilities - specifically:

**1. Computers are able to read and write -** The language it uses is a well-defined code, very much like the Morse Code, in which combinations of electrical pulses, of magnetic fields, or of holes punched in cards convey information.

**2. Computers are able to memorize information in coded form.**

**3. Computers are able to follow instructions -** a computer, will, for example, when ordered perform arithmetical and logical operations upon information stored in its memory. This "teaching" in order to yield a solution to a problem is called programming.

**4. Finally computers** are able to operate rapidly, accurately, and usually more economically than men assigned to the identical tasks.

We should now examine the anatomy and physiology of this machine. There are two basic types of computer - The digital and the analogue. Briefly, digital data are presented in terms of a finite number of characters or symbols - examples are the decimal number system and the alphabet. Any count such as blood count or pulse yields digital data, as would the observation of the presence or absence of a symptom. Analogue data on the other hand involve no explicit use of language - they are represented by magnitudes of length, voltage and pointer deflection which are continuously varying with time. Pictures or curves such as the E.C.G. and E.E.G. are analogue presentations. Here the potential difference at each instant of time is represented by the ordinate of the curve.

The relative merits of these two types are not important in this discussion, suffice it to say that conversion from one system to the other is possible, as is the combination of the two.

How does one communicate with a computer? The ideal method and the one which most physicians would prefer would be to speak into a dictaphone and have the computer understand and obey. This obviously cannot be so. One has to formulate his problem or request into the "machine language" - This is the specialized duty of the computer programme and although it is relatively easy few physicians have attempted it. To the physician, coding can simply mean devising card forms for storage of data on cards or tape. For example, a "zero" in card-column ten can be made to signify "no angina", a "one" to signify angina. 28

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may be necessary to provide for other contingencies, such as angina unassociated with positive exercise cardiogram.

With these brief and basic concepts in mind the more appropriate and perhaps more interesting aspects of the topic may be covered by looking at a number of medical applications of computers.

One of the most outstanding problems in any field of science today (Medicine included) is that of keeping abreast of the changes and advancements in the field. The difficulties of such a volume of scientific literature are becoming extremely acute and the computer is being looked upon to solve them. The volume of medical literature is now so great that it is exceedingly difficult for the medical researcher and practically impossible for the practising physician to maintain contact without medical knowledge. For example, it would take a physiologist 3 years, 161 days to read the 350,000 pages of physiological literature published in 1960. In 1964, there were approximately 220,000 medical articles published throughout the world of which 15-20% were not even indexed in the U.S. National Library of Medicine. Dr. David D. Rutstein recently pointed out that "it is not farfetched to plan on having an electric console in the medical school or hospital that will print on high speed tape the requested summary of a medical article stored in the memory of a computer in a distant central library". A computer based system is already in operation by the National Library of Medicine which is designed to (1) reduce the time, required to produce the **Index Medicus** (2) Improve the quality and enlarge the **Index Medicus** (3) Make possible requests for special bibliographies on demand and on a recurring basis and (4) reduce duplication of literature screening elsewhere.

The Hospital Medical Record is another huge and growing facet of medical literature which will eventually, out of necessity, come under the expanding wing of the computer. These records have become such a bulk of names, symptoms, initial diagnosis, medications, laboratory results, etc. that it is no wonder the record library of the modern hospital engenders such emotional reaction among the people who tend it and those who use it. If we appreciate the mass of information contained in such an assembly of records, if we appreciate the tremendous statistical and correlative analyses which could come from such a library we can agree with those who consider it of prime importance to the hospital. Unfortunately, however, if we examine and appreciate the monstrous task of retrieving any but the simplest information from such a massive store of data, we can sympathize with those who value the records primarily for the thermal content of the cellulose on which it is written. Add to this morass a certain lack of uniformity in describing even the simplest of symptoms and diseases, and a collection of patients in a large general hospital, numbering perhaps in the tens of thousands over a relatively short period of time. It can be seen that reliable computer handling of this problem would bring about a certain revolution among the administrative, research, and patient-care components of the hospital, and also in our statistical understanding of disease.

A consideration of how a computer might give such aid is given in a report by Dr. J. J. Baruch, Cambridge, Massachusetts. Basically, it consists of the following:
The strictly narrative portions of the record are deleted and the rest filed, not in some obstruse coded form but directly by commonly accepted medical terms. The machine can substitute very abbreviated codes (for its internal storage only) for commonly used but complex multisyllable or multiword descriptions. As a result, such a record system can provide, for each patient, an average of thirty pages of typical forms. The amount of information just described for the full 10,000 patients would require only about one reel of high-density magnetic tape for its total storage.

It should be realized that by storing information in such a list structure, it is possible to base a retrieval essentially on any item in that list. For example if a nurse were to type out a prescription, she might type out the patient's name or number in addition to the drug and the dosage. The machine would search through the drug and dosage list, search for the patient's name along another dimension and for the listed drug along still another dimension in that patient's record. Having found the drug unlike past drugs administered, it would then check against it to see if there had been any notation of sensitivity or other contraindicative information. If so, the prescribed therapy could be changed immediately; if not, the medication, upon its administration, would become a new part of the hospital record for that patient.

However, even at the present time, there is generally no difficulty in acquiring any specific hospital record, given the name or number of the patient. But a far different situation exists if, for example, the records of all patients demonstrating symptom A are desired, or if one wishes to know, out of a sample of 10,000 patients, how many patients exhibited symptom A, how many patients were heavy smokers, and how many patients exhibited symptom A and were heavy smokers. Dr. Branch makes the interesting notation that for the 10,000 patient records one could program the machine to perform the above type of analysis in approximately one minute.

The above mentioned abilities of computers - storage, statistical analyses, and retrieval of data are widely known and easily understood - but essentially consist only of those duties man himself could perform given enough time and energy. A lesser known but extremely valuable ability is that of a computer analogue to dynamic physiological systems of the body. By this is meant that it is possible to build a system of electrical circuitry which exactly simulates the behaviour of and corresponds in all parameters to a dynamical system of the body.

There are two basic scientific methods of simulating one system with another. One is to express mathematically all the complex functions and variables of the system under study and then build an electrical system, the components of which exactly conform to the mathematical model. An easier method, especially when dealing with the multivariable systems of physiology, is to represent each function by an electrical component and then with a sort of "educated trial and error technique", adjust or balance the parameters and constants of the electrical circuitry until all aspects of the physiological system are exactly simulated. The method eliminates the complex mathematical analyses.

An example of this aspect of computer use is seen in the analogue of the circulatory system reported by Manfred Clynes of the Rockland State Hospital, New York. The basic analogy of the system was blood volume = charge; blood pressure = voltage; vessel elasticity = integrative capacitance; vascular resistance = resistance; inertia = differentiating capacitance and cardiac valve = diode. By various combinations of electrical circuitry it is possible to simulate: The muscular force of contraction of the atria and ventricles; the four cardiac valves; The two arterial and venous systems, (including venous values) separated by the vascular capillary resistance, and modified by simulation of reflex changes in vasoconstriction. Nonlinear relations between pressure and volume are also taken into account. It is readily feasible to break up any of these vessels into as many branches as desired and introduce the appropriate parameters for each.

Such an analogue may be readily used to study the dynamic effects of various forms of pathology, such as valvular stenosis and insufficiency, aortic coarctation, arterio-venous shunts, tachycardia and bradycardia, heart block, and blood loss, as well as the dynamics of adrenergic action on the heart muscle, the effects of blood pressure and heart rate regulatory reflexes, and the relative dynamic effects of the pulmonary and systemic circulations. Also, the effects of repair of cardiac defects could be observed on the analogue before the patients physiology is altered. This would be particularly important in the evaluation of certain congenital heart cases.

The dynamics of such a relatively simple positive feedback loop as this analogue of the circulation are yet far too complicated to be solved in practice without the use of computers.

Finally, the most controversial and perhaps the most interesting application of computers enters the realm of diagnosis and treatment regarded by many physicians as the core of medical practice. A consideration of the ways such applications might effect the practice of medicine in the future and thus the type of medical education needed by the physician of tomorrow would be in order.

The practice of medicine might be divided into specific jobs, the first of these being the collection of information about the patient. In taking a history and doing a physical examination, a physician seeks to determine

the presence or absence of certain symptoms and signs. In doing this, particularly with the history, he takes certain short cuts; that is the answers to certain questions lead him to ask more questions and not to bother with certain others. In other words, he is making decisions about the probable diagnosis as he takes the history. This may be time-saving, but it may also bias him prematurely toward a diagnosis which may be unlikely when all the information is in. Thorough system review may be too often eliminated because of impatience on the doctor's part or because evaluation of the diagnostic implication of many seemingly unrelated symptoms is a difficult exercise in logic. Perhaps if a computer were used to evaluate the information collected by a careful system review by a physician whose only concern is the accurate determination of the presence or absence of a discrete list of symptoms and signs, diagnosis might be improved.

The second job is that of deducing from the signs and symptoms, the differential diagnosis. This may be looked upon as a problem in conditional probability and may be solved with a computer with an accuracy which depends only upon the accuracy of the statistical data regarding the incidence of symptoms in diseases and the accuracy of the data collected from the patient in question.

The third step commonly involves deciding which laboratory tests should be performed in order to best distinguish among the diseases listed in the initial differential diagnosis. This again may be reduced to a straightforward mathematical problem, capable of computer solution, once the statistics have ben collected concerning the frequency with which each test is positive in each disease. It is simply a matter of calculating the differential diagnosis in the presence of a positive and negative result for each of the tests and then choosing that test which would indicate the minimum number of diseases in the differential diagnosis.

Finally, the choice of treatment, once the diagnosis has been established as accurately as possible, is again a problem in probability. That is the probability of survival or improvement with or without the treatment. This calculation depends upon the collection of accurate statistical information for a valid decision to be made.

In performing the various tasks just mentioned, the computer has the advantage of recalling accurately each time the correct statistics upon which to base its conclusion and that this conclusion will not be biased by irrevelant factors. For instance the computer will not weigh most heavily on its most recent experience, as a physician is prone to do. The computer performs just as well at 2 a.m. as at noon.

Another advantage in using a computer lies in the fact that once a programme and a statistical matrix of symptoms and diseases has been worked out, this information may easily be applied to most other computers. As new information is published, this may be inserted into the data matrix, allowing the computer to use this information with every subsequent decision it makes. This latter task has become an impossibility for the physician, with the rapid increase in the volume of medical research and publication.

The possible effects of these developments on the type of physician needed to practise medicine in the future are startling. It is possible that the training of large numbers of expert diagnosticians may be unnecessary and that the general practitioner, trained to collect information accurately and to administer certain forms of treatment expertly, may, with the help of a computer (as accessible as his telephone), handle the bulk of medical practice once again. The medical student of the future may not be burdened with learning the great mass of statistical information concerning the likelihood of finding a particular symptom in a particular disease. Instead, more emphasis may be placed on accurate data collection, effective management of the patient's psychological and emotional needs, and administration of particular forms of treatment.

In conclusion, the role of the computer in Medicine has been summarized to include the statistical analysis of research data, simulation of physiological systems, storage and retrieval of clinical records and diagnosis and treatment of disease. Numerous applications have been omitted, e.g., the filing of information on drug action, but the basic principles which have been mentioned apply regardless of the tasks to which the computer is put. It is conceivable and may be expected that computers will enter into almost all the intellectual activities of Medicine except those which require imagination or those which by their nature require the personal relationship of doctor to patient.