REVIEW ARTICLE

THE USE OF COMPUTERS IN MEDICINE WITH PARTICULAR REFERENCE TO GENERAL PRACTICE

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IN THE context of this essay I use the word computer to mean an electronic digital computer. There is a second type of electronic computer, an analogue computer, which is also used in medicine, particularly when attached to sensing devices or instruments with a variable output such as electrocardiographs.

A computer is a machine without moving parts which can store digits indefinitely and manipulate them at speeds approaching that of light. All its information is stored and worked by simple procedures at a two-state level, perhaps best represented by the presence or absence of a hole in paper, or by the figures 0 and 1. Typically, it consists of banks of tiny ferrite cores, each of which is of such a size that several would be required to cover a match head. These ferrite cores can be magnetized in a stable but easily changed manner in either a clockwise, or an anticlockwise direction, hence the name two-state. As "any data procedure that can be rationally articulated can be analysed into at most a dozen or so very elementary operations" (L. C. Payne), this equipment can perform the remarkable feats one reads about when a large number of these units are suitably wired.

No commonly used information occurs in this two-state form, so information and instructions (i.e., the programme) have to be translated into this form (or made computer compatible) before presentation to the computer. Ancillary machinery largely performs this task, and while it is easier to translate numerical data (e.g., by conversion to the binary code) into a computer compatible form, such machinery is now sophisticated enough to accept restricted language forms and directly translate them. These stylized languages (and numerical data), can thus be fed directly into a computer through an electric typewriter or indirectly by using an intermediate stage of punched paper tape or punched card. These paper tapes and

punched cards are read by a photo-electric cell and converted into the two-state form. Similarly, computer output is normally directly translated into the printed word by a high-speed electric typewriter. However, if the information is not for immediate use it is better stored in its two-state form on reels of magnetic tape. This allows compact storage and easy handling, both physically and computer-wise. Punched tape or punched cards can also be used for storing smaller amounts of information.

The rate at which information can be given to and taken from a computer is very much slower than the rate at which a computer can internally process such information, and this has given rise to the development of multiple access, first performed in project M.A.C. In this, several users are apparently simultaneously using the same computer. Information is given and returned through an electric typewriter directly (on line) to a geographically distant computer which, operating in milli-seconds, switches from one user to another, each of whom is operating in large fractions of a second, and each of whom is dealt with without waiting. It is likely that most general practitioners will use computers in this way. That is some 20 will be connected by telephone line over varying distances to a smallish central computer. Each will have a peripheral console in his consulting suite consisting of an electric typewriter and a television screen. Whenever required a dialogue will ensue. The doctor or his secretary will type out questions in a stylized language directly to the computer and back will come the answers, chattering out at high speed on the typewriter or displayed on the small screen.

The computer, together with its backing stores can accurately hold enormous amounts of information, and can analyse or compute any factors contained in this information as instructed, then display any selected parts of this information accurately at a distant site, all at a few seconds notice. Complex mathematics are rarely of immediate use to a doctor but quick access to an immense memory of unimpeachable accuracy, and the ability to match current situations rapidly against this memory do open immense vistas. This memory will be the sum of many individual contributions, eventually over many years, and will obviously be of a different order of magnitude and accuracy than that of the most erudite individual. Moreover it will be easily accessible.

There are few disadvantages in the use of computers in medicine. Logically they will improve the service any doctor can give his patient, but some difficulties will arise during their widespread adoption. It has been calculated (Collins 1967) that a peripheral console as described above will cost about £500. Both its installation and running cost are of the same order as that of buying and running

a motor car. The central computer envisaged would cost £200,000. With modern equipment difficulties of reliability have been solved. A recent order for an air traffic control system had a specification to guarantee that it will not be out of order for more than 30 sec. in a year (Richardson 1967).

The method of collecting data is probably the biggest immediate problem especially if one considers the application of computers to medical record keeping. As all information is eventually reduced to a two-state form, the more nearly initial information approaches this, the more readily and the more efficiently it will be used. Thus such things as age, sex and definite diagnoses (referred to as type 1 or hard data) are easy to deal with, while letters, or descriptions of symptoms are difficult. It will thus be necessary to achieve a shift in outlook in the collection of data (Galloway 1966).

Computer record-keeping poses two other problems, that of confidentiality and that of accurate patient identification. Users of any system would have to identify themselves before access was granted to it, by a password procedure. This would ensure that only authorized people could use the records and confidentiality higher than that of present record-keeping procedures may be assumed. A theoretical temptation to the State to interfere if comprehensive and accurate records were held centrally exists, once a national network had been built up. In this respect it is likely that the State's temptation would be actuated by reason of finance or security. This temptation could be minimized if direct Treasury (or other government department) control of the National Health Service was avoided. This could be achieved by the creation of a medical corporation, an apparently prudent future step.

Secondly, accurate patient identification at present can be difficult where patients share the same christian and surnames and perhaps also other identifying characteristics such as addresses. Failure to notify a change of surname on marriage provides a further source of error. In the local systems envisaged where the information supplied by the computer is assessed by the doctor in immediate relation to his patient there should be no increase in this present problem. If the eventual establishment of an United Kingdom linked system is envisaged accurate patient identification would pose a problem of first importance (E. D. Acheson).

In this country during the last five years, and for a rather longer period in the United States, a good deal of operational research into the use of computers in medicine has been carried out. I should like to consider this briefly under three headings.

First, there is their use primarily in research problems.

In this field mathematical models can be constructed and used to

test postulates. Examples of work done in this field include a mathematical model of the spread of infection (Kendall 1964), a mathematical model for the study of nerve conduction (Noble 1964), a study of geometrical relation between the retina and visual cortex (Whitteridge 1964), and simulations of other functions of the human brain (Zeeman 1964). Also relatively sophisticated epidemiological analysis is greatly facilitated by a computer, as is analysis of therapeutic trials (new developments in the assessment of therapy (Armitage 1964).

In the second or primarily clinical field is the exciting prospect of computer-aided diagnosis. This major development is still in its earliest stages. In it the doctor will take a history and note the symptoms. He will then elicit the signs by an appropriate examination. Following this, should there be reasonable doubt about the diagnosis and should a definitive one appear desirable, he will submit his findings to his computer. By a process of discrimination or probability the computer will then give the most likely diagnosis together with the degree of likelihood involved, and suggestions for further tests which would increase the accuracy of the diagnosis. There are immense difficulties in building up an authoritative and comprehensive computer memory for this project, not least of which is agreeing definitions of symptoms. I believe months have been spent defining the term heartburn. Limited excursions in this field, such as Glasgow University's programme for the assessement of thyroid nodules have all been highly promising.

Furthermore computers can be used to access the diagnostic procedures themselves. At present interpretation of EEG's, and to a lesser extent ECG's is an empirical and fairly subjective exercise. Accurate interpretation of ECG's by analogue-digital conversion and computer analysis is already available, and automatic analysis of both these procedures may be expected within a few years in centres where the demand would justify the cost. Computers are also used to count and analyse human chromosomes (by a process known as FIDAC) and those of a single cell in a good preparation can be dealt with in 20 secs. (Hedley 1964). In the measurement and interpretation of data they remove tedium, increase accuracy and should allow the much wider application of these and similar techniques such as scintiscans to the point where widespread screening is feasible. Computers also have value in patient monitoring in theatres and intensive care units. The Royal Infirmary of Edinburgh's coronary care unit for surveillance of patients suffering from coronary thrombosis allows continuous monitoring of pulse rate and ECG's with the corollary of immediate action should correctable arrhythmias threaten or develop. In laboratories equipped with automatic analysers connection of these devices to a computer allows

an accurate immediate print-out of results in any desired form, regardless of the number of specimens involved.

This leads to the third use of computers—in medical administration. There is much overlapping in this artificial division of computer applications to medicine into these three separate trends, and this is particularly evident in the field of record keeping where clinical and administrative applications are inextricably intertwined. Their use in local health administration has been beautifully demonstrated in West Sussex (Galloway 1966). Here a computer has been used for the vaccination and immunization scheme for the whole area (excluding Worthing) since 1962. Substantially better protection indices, reduced numbers of refusals, readily accessible, accurate, up-to-date records contained in a smaller storage space and the relief of family doctors from a complicated managerial, clerical chore have been the unequivocally demonstrated results. At the correct times the machine prints out all the necessary correspondence and lists, and all the records are kept entirely on magnetic tape. Bradford and three other local authorities also use computer-aided vaccination and immunization schemes, while they, and other authorities, use them to help administer other services, such as ambulances.

In the hospital service University College Hospital set up a magnetic file of 28 items on every discharged inpatient on 1 January 1962 using a teleprinter with punch attachment. St. Thomas' Hospital who also use limited magnetic filing employ a lector, a device which accepts prepared forms of various sizes and senses marks made on them in pen and pencil, translating them into punched paper tape for computer input. Maternity records in Bristol and a survey of psychiatric patients in north Scotland have also been made in a suitable form and submitted to a computer.

In general practice a working party of the Royal College of General Practitioners has experimented with magnetic tape filing while an ambitious scheme to maintain all his practice records (with the exception of hospital letters) in this form is in an advanced state of preparation by Dr J. H. Barber, Livingston, Midlothian, in conjunction with the Scottish Home and Health Department and Elliott Automation.

A more purely administrative function is instanced by the allocation of nurses' duties within a hospital by computer, as is done in Oxford and as will be done shortly in Edinburgh Royal Infirmary.

General practitioner applications

With the two exceptions noted above, little has been done by general practitioners in the study of applying computers to our

specific problems, due no doubt to our geographical and financial peculiarities.

Keeping records in general practice demands a cheap flexible system, which is not time consuming and is easy to operate. After all any system of record keeping is only of value in so far as it assists in the art of diagnosis and treatment, or aids in other ways our primary function of keeping our patients healthy. Statistics are at best an interesting by-product even if they do have clinical and administrative value when considered in a larger context.

Yet the development of the smallish multi-access computer and programmes for its use should be ideal for our situation. The growing use of computers in medicine will affect us as profoundly as any other section of the profession, perhaps more so, and it is valuable to consider where the impact will first be felt. The future of computer-aided diagnosis and computer-aided analysis of biochemical specimens and diagnostic procedures seems secure as well as tremendously exciting. To participate actively in this we will require to know how to get access to and how to use these machines. This is reason enough to familiarize ourselves with the techniques. Of these the most difficult is undoubtedly that of keeping our patients' records in a manner that allows easy translation into computer form, and, eventually, of keeping them on magnetic tape instead of on paper. Adoption of these procedures has been shown to have many other important advantages. First, a very considerable improvement in record keeping occurs. This increased accuracy imposes a salutory discipline on the doctor to the benefit of his patients. Better use can be made of these records, the only ones which are individually comprehensive and which cover virtually all illnesses presented to the profession. When on tape not only is each patient's record readily accessible, but so are any groups or categories of patients within a practice or group of practices. Thus a printed list of all patients on a practice list diagnosed as having pernicious anaemia could be obtained with their last haemoglobin reading and the date it was made, simply by typing a short sentence. Reminders for postnatal examinations and cervical smears, or any other follow-up procedures, would be typed out by the computer when due, in a form ready for posting. Subsequently lists of non-attenders would be available. Analysis of any type of morbidity (this would be based on virtually all illness for which medical attention was sought) and the identification and surveillance of high risk groups, such as prediabetics and postgastrectomies, would be child's play. These surveillance procedures would enable the doctor to make more direct offers of help to patients than at present. As now, many patients would refuse such offers but it seems unquestionable that those who accepted would enjoy a higher standard of health. Not only would

our present requirements for record storage be greatly reduced, but so would all book and ledger keeping undertaken either for disease recording or attempts at patient recall.

These are the advantages of undertaking this substantial alteration in our present methods of record keeping. It should be no greater trouble to keep computer-compatible records than it is our present ones, and they will be infinitely more valuable.

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