AN INTERACTIVE GRAPHIC DATABASE MICROCOMPUTER FOR CLINICAL CONTROL IN DATA INTENSIVE THERAPIES

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Summary

Experiments showed a small computer could improve access to large concentrations of clinical data in renal dialysis and transplantation and enhance the clinical feedback loop which controls substitute renal function. Interactive access adds a sub-loop which allows close adaptation to clinical use.

Prototype software was transferred to an LSI-11 microcomputer with 20 Mbyte cartridge discs, multiple remote VDUs and video graphic displays and printer-plotter. Data capture is both manual and by automatic transfer from laboratory computers. Push-button interaction displays clusters of data, including computed functions, as graphs and tables on variable time scales. Programmed scans generate data-base analyses. The system reconfigures for individual sites.

The microcomputer version has run routinely for a year and proved a practical tool at acceptable cost. Down-time has been small but strongly resented by medical and nursing staff. The system can accommodate 750 patients, but has also been 'stretched' for an oncology laboratory and configured for other specialties.

Introduction

This paper describes a computer system developed over several years and now in use at a number of renal units in the United Kingdom. The reason for developing it was the difficulty of dealing with the large volumes of data essential to good dialysis and transplantation. In renal failure a major controller of bodily function is disabled. Medical and nursing staff have to maintain an equivalent 'clinical control loop' for artificial renal function [1].

Control depends on large volumes of 'hard data'. Paradoxically, these must be interpreted in the light of experience, and of conceptual models which presently we do not know how to translate into mathematical or computer language [2].

Presently therefore at best the computer can only be used to help the doctor
make his own interpretation of the data. We have optimised the auxiliary control loop by which the nurse or doctor controls the computer so it delivers data which is most relevant to the line of thought at a given moment. We have used computer graphics extensively to ensure data is readily absorbed and interpreted.

Methods

**Hardware and software**

Early experiments were carried out with a variety of mini- and mainframe computers at the University of London and elsewhere. The main experimental phase was in the Department of Medicine between 1974 and 1979, using a minicomputer (Digital Equipment Company PDP 11/40) and a refreshed graphic display (DEC GT 40). Subsequently a sophisticated video display (Grinnell Corporation) was used. Software and operational techniques were evolved which allowed the computer to be effective in the clinical environment [3].

The software was written again subsequently on a commercial basis to obtain a properly engineered system which could be distributed and maintained at other sites. The engineered software runs on a DEC LSI 11/02 or LSI 11/23 microcomputer or on any PDP 11 computer.

The standard backing store is twin 10 Mbyte cartridge discs which appear sufficient for storing data on perhaps 750 patients for up to 10 years.

The system has up to six keyboard VDUs to display and accept character data, and one or more video generator systems (Matrox Corporation, 515 X 512 resolution, 8 level grey scale), to feed graphic displays to standard video monitors.

The central unit of the computer occupies a cabinet the size of a small desk. It can run 24 hours a day without special operations staff and without any special environment. It is normally equipped with a printer which can print lists of information, or graphs of variables stored on the discs.

Instantaneous graphical and tabular display of stored information can be requested by nurses and physicians at the VDUs and graphic monitors, which may be situated hundreds of metres from the computer. The same, or different, data may be viewed at several places simultaneously.

The software is written in DEC MACRO language, and runs under a specialised operating system. The DEC RT-11 executive can operate concurrently with the clinical software, allowing FORTRAN access to the clinical data and concurrent operation of standard word-processing and statistical packages.

Access to data is protected by a system of passwords which must be given before a terminal can be used.

**Data capture**

Data can be entered manually from any of the VDUs after a suitably privileged password has been entered. The basic identification data for the patient is entered in this way, as are other categories of data the renal unit may have chosen to keep, such as diagnosis, details of family doctor, and synoptic histories. Variables — such as blood pressure, weight, temperature, dialysis flows, or laboratory results —
which it has been decided to store, may also be entered manually.

Biochemical and haematological and microbiological data may be transferred directly from other computers serving these laboratories. Entirely manual input is however normally manageable by the ward clerk, and is not worse than the process of transcription on paper which it can replace.

**Data retrieval**

The techniques used for data retrieval are common to the update, reporting and utility subsystems. However, they are described in more detail to explain the method of operation.

When a suitable password is typed into a VDU keyboard, the VDU is connected to the 'retrieval subsystem'. The keyboard has a group of twelve separate keys (the 'key pad') set off to the right of the standard keyboard. The top three keys are used to select the patient, which can be done by a single touch on the centre top key, followed by entry of the patient's local serial number, hospital number, surname or part of the surname, followed by a touch on the 'Return Key'. In the case of a partial name, the computer finds the nearest matching name. The patient's identity is displayed at the top of the VDU screen for confirmation, and the two outer top keys allow the index to be searched for a nearby identification if necessary.

The remaining nine keys control all remaining retrieval functions. At the bottom right of the VDU screen there is displayed a group of nine small text 'labels' which give the functions of the nine keys and correspond with their layout. Thus one sees at a glance, from the top left and top centre labels, that the top left key of the nine will fetch identity data on the VDU screen and the top centre key the details of family doctor. Similarly, certain other keys fetch synoptic histories.

The bottom right key marked 'Next Page' fetches nine more labels and thus nine more functions, which will fetch biochemistry, haematology, blood pressure or any other variable it has been decided to store.

This 'spatial correspondence' between the layout of labels and layout of keys is similar to but simpler than the techniques evolved by Negroponte at MIT for graphical information retrieval [4].

On the video monitor one can rapidly show the information graphically, again by typing single keys. For example, one may display blood pressure, weight and potassium over a period of six months.

The time scale can be changed at will by the same push-button technique to see the data over longer periods. Pathological abnormality may sometimes be signalled by slow rises over long periods, for example in alkaline phosphatase, even though individual values are in the normal range. Such rises can be discerned graphically where they would not be obvious in character displays. Even over short periods important patterns may be observed, such as the development of nephrotic syndrome in the weeks after start of dialysis.

The variables presented and the organisation and layout of the graphs are again defined by each renal unit for its own needs. The calibration and labelling of the graphs, and the arrangement of typical range markers which allow quick
assessment by eye, are at the unit’s discretion. Computed means, products, quotients, logarithms, reciprocals and other functions may be displayed from a standard repertoire of graphic presentations.

Report generation

The computer can prepare printout from any information on either the VDU or the graphic screen. It can scan all stored information held in its ‘data base’, and can search for specific conditions. For example, it will list all patients with a laboratory variable over or below a stated level, or list all patients having a particular treatment. It can generate local statistics, reminders and letters, and generate scheduling lists for the work of the renal unit.

It can also print the annual EDTA return form, with negligible effort on the part of clinical staff and can generate a tape cassette containing the return, which can be sent to EDTA for direct input to its computerised registry.

Copies of a particular species of graph for all patients may be generated automatically and this has been used in routine reviews of the patient population, for example of calcium metabolism, or liver function.

Utility functions

The utility subsystem allows the integrity of the stored data to be tested and corrected if need be and provides a full range of housekeeping functions, including index building and sorting, disc copying and record archiving.

Configuration

The commercially engineered software package has been designed to be reshaped to suit the working methods of different units, including not only renal units but, for example, hypertension clinics, cancer chemotherapy departments and liver support units which have similar problems with large volumes of data concerned with specialised problems. Because of the way the programmes are designed, this reshaping does not need a skilled programmer.

Results

At Charing Cross data on more than 300 patients is stored, in some cases extending back seven years. The system is used routinely by nurses and doctors to review data before ward rounds and clinics, at weekly group meetings and whenever data on individual patients is required. The computer has become ‘built in’ to clinical operation of the unit, and this is evidenced by the sharp reaction of clinicians should the computer service for any reason not be available.

Daily lists are printed and circulated of new pathology results which are outside specified ranges. Up-to-date patient directories are printed as required, and comprehensive printout, text and graphical, is produced on request for case studies of individual patients.
With the present technique of keyboard operation, no member of the nursing, medical, or para-medical staff has ever failed to learn how to use the computer to the extent he or she needs in the space of an hour.

The system has adapted to three other UK renal units, with working methods different from Charing Cross, and also to an oncology laboratory assay system, and an oncology clinical data system. Additionally, it is being used to collect statistical survey data in a gastro-enterology department, and will probably be used as a clinical data system in gastro-enterology.

Discussion

At the Charing Cross Renal Unit the computer is becoming the method of choice for accessing information about patients but still more important, clinicians are beginning to read data in a quite new way, looking at the shapes and meaning of graphical presentations, instead of working laboriously through columns of figures.

Once nurses and doctors begin to trust the computer as a tool, rather than fear it as a threat or a mystery, further techniques will certainly develop, and extend the usefulness of the established base of good-quality data already within the computer.

The work of Knapp [see 5] at Nottingham is attempting a further step in making the computer useful. Abnormalities and abnormal trends should be reliably detectable by his techniques on an individual basis, not merely on a generalised definition of abnormal levels. In time, ‘expert’ systems may be programmed into the computer, which retain the knowledge base of authorities in the field and could be interrogated for advice on treatment.

Benefits will accrue from the proliferation of systems which can exchange data so that a patient who transfers between units can become quickly known and understood by the clinical staff of the new unit. The possibility of exchanging data direct with the EDTA central computer suggests that, equally, newly introduced local computers could be ‘primed’ with retrospective data from the central registry system. The exchange of data will certainly be stimulated by the new information network technologies.

References

1 Gordon M. Bio-Medical Engineering 1970; 5: 539
2 Gordon M. Bio-Medical Computing 1973; 4: 259
5 Smith AFM, Cook DG. J Roy Statistical Society 1980; Series C, 29: 180

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Open Discussion

DAVIDS (Copenhagen) What security do you have to prevent these patient data going into the wrong hands if you know the password?

GORDON From experience I do not think that in a computer of this kind, which serves a localised requirement in a localised area of a hospital, there is any more likelihood of confidential data going into the wrong hands than there is without such a computer. I have no knowledge with over five years of operation of a computer, of any breach of security which was in any way worse than any person could acquire by walking into the hospital or department and locating notes which are, after all, frequently circulating or to be found on desks or on trolleys. I believe that the worst threats to security come with large global computer systems which are designed to be readily accessed by many people, perhaps from a distance. This computer we see as a tool for a local area. With regard to the security of the data itself and lack of damage to it in any way, this also has not been a problem in five years or more of operation. It is necessary to be careful and methodical about backing up the data and to keep adequate paper copies, should it fail for a limited period of time.

BERGSTRÖM (Stockholm) Could you tell us about the cost of this? Is it very expensive or is it feasible for any unit to have it?

GORDON The cost is approximately £25,000 sterling and I am told that that is about the cost of the first year’s treatment for two patients.

HIREL (France) Could you tell us what manpower was needed for developing such a system? I am speaking in terms of doctors and programmers.

GORDON Because of many difficulties which occurred in the course of development, including the great difficulty of obtaining funds, it is difficult to quantify that. I would have said up to ten man-years.

HIREL How much time was spent by the doctor to develop this system — do you have any idea of that?

GORDON That’s even harder to quantify because after the initial phase in which Prof de Wardener and some other colleagues injected many ideas, the main contribution from the doctors was to make life extremely difficult if the computer did not work well for them. Consequently, they exerted over a long time a very considerable pressure to shape the system so that they found it easy and convenient to use.

DRÜEKE (Paris) Would you suggest that the utilisation of computer be extended to diagnosis and treatment in clinical medicine?

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GORDON  In the short-term, only very slowly because our philosophy has been to reject the idea entirely that the computer could replace the clinician. I think that what will emerge from successful developments, as I believe this to be, is first a confidence on the part of the doctor that the computer can be an extremely useful tool which in the first place can take a weight off his back in working for him. I have no doubt that in the long-term we shall see the extension of that to the introduction of so-called expert systems in which the doctors' own expertise is in some way embodies in the computer, but the final judgement I am sure will always be with the clinician, because the computer in the end will not accept responsibility for the patient.