Computers in the service of medicine

Essays on current research and applications

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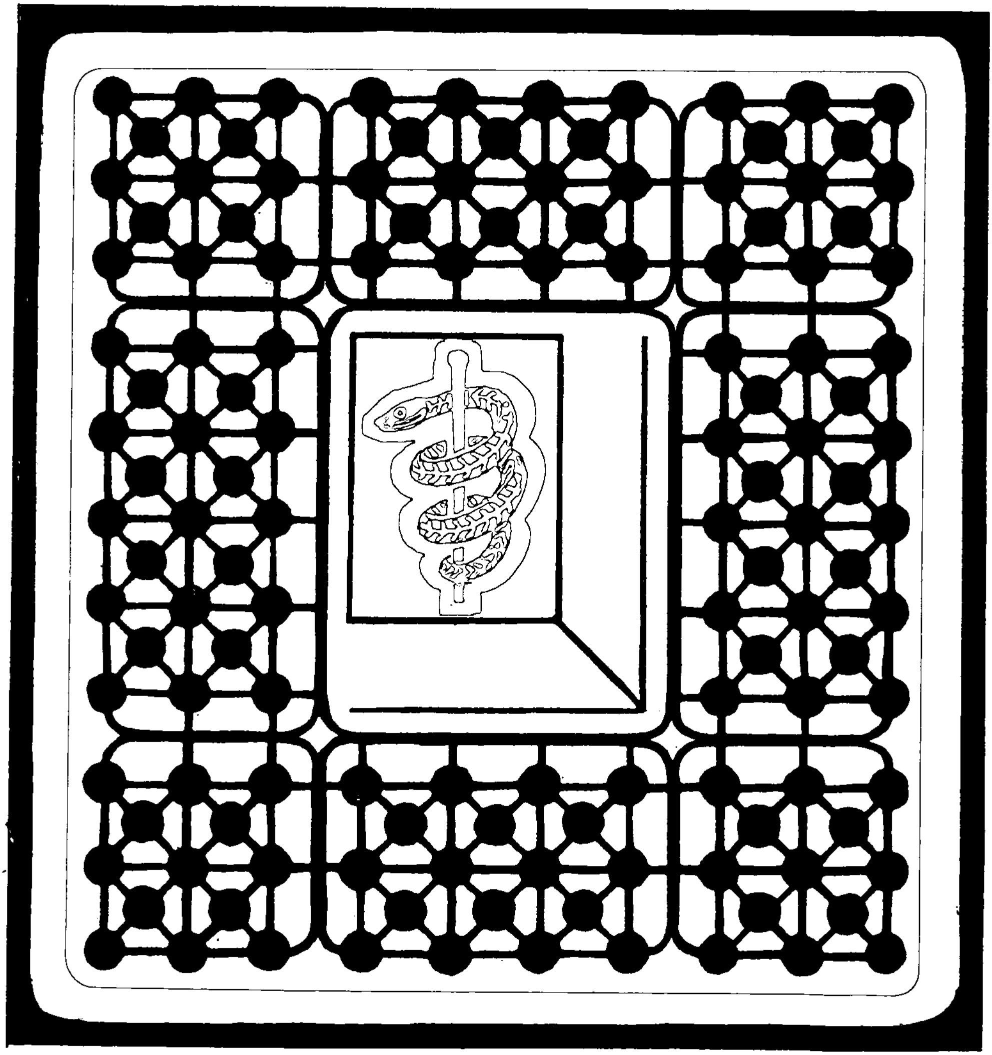

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OXFORD

Contents

13

The systems analysis of a large out-patient department

G. A. DEBENHAM

Feasibility studied and illustrated with a flow chart

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English Electric Computers Ltd

The systems analysis of a large out-patient department

The purpose of this article is to describe the initial stages of introducing a computer system into a hospital setting, in this case an out-patient department. It can only go as far as describing the initial stages because the project has not yet gone any further, and was aimed at answering the question: what can be done to improve the efficiency of the out-patient department by computer techniques?

The project was commissioned by a regional board, the terms of reference being to advise on the feasibility of using a computer to aid the running of the OPD, and to estimate the resources in personnel and machinery necessary to implement and run any possible system.

The term 'feasible' needed some interpretation, for it can be said straight away that given time and resources a system can be implemented for almost any organization which, though it may not be economical, will make the organization run more smoothly. An airline type of reservation system, for instance, could no doubt be introduced into the OPD but, as is explained later, would require more than a small inexpensive computer and was therefore considered not to be feasible.

Methods used

Since the end product of the study was to be a statement as to whether or not a computer could be used and an estimate of the resources required to implement and run such system, the current procedures had to be investigated and numerous possibilities explored. By going through these stages of systems analysis and systems design it was in the end possible to arrive at a definition of what could be done. This definition, or outline system specification, was then used to form estimates of the resources required.

The project entailed about four man-months of effort, three of which consisted of on-site work. The on-site period was divided roughly into two halves. During the first half an analysis was done of the procedures from the moment an appointment is requested to the time when the patient is discharged; and data concerning record movements, patient waiting times, patient movements between clinics and service departments, utilization of resources in the service departments, delays in being given appointments and receiving investigations, etc., were gathered. The analysis was done by talking to medical, nursing, administrative, and clerical staff, and by observing actual procedures. The collection of quantitative data was achieved with the assistance of two of the Regional Board's organization and methods staff who noted the movements of patients in service departments and in a surgical and a medical clinic. The sisters in these two clinics lent their help when the movements of patients from clinics to service departments were being traced; and likewise the clerical staff in records offices when gathering data about record movements.

After the first half of the on-site work had been completed a first report was written in which the existing procedures were depicted in flow chart form, and the other data were represented graphically and by tabulation. A description of the findings up to that time in terms of how the OPD was run and tentative ideas for a computer application were given. A meeting was held with Management Committee and Regional Board staff using this document as a basis for discussion. This gave them the chance to shoot down any ideas that they saw as impractical, and to make any arrangements for the continuation of the project.

During the second half of the project more detailed data were collected and further details about procedures were elucidated to allow the ideas that were forming to be further developed. These ideas were tested out as far as possible by discussing them with the OPD staff. One essential item of data that had to be collected was the total number of patient records and X-ray films used by the OPD and affiliated hospitals. This was done by counting the number of folders for each foot of shelf space at various sampling points and then measuring the total footage of shelves.

One purpose of systems analysis is to find out the essential information requirements of the organization so that the system that is designed provides for those requirements and is not a copy of the existing procedures. This is by no means a simple task as it is sometimes found that certain procedures are not part of the basic information-producing structure, but have grown on that structure to cover up its deficiencies. A visit was therefore made to another large OPD within the same region to act as a control on certain points of detail.

The results: existing procedures

In the course of the project it became necessary to explore procedures in the affiliated hospitals where they impinged on those of the OPD. As the interrelations between OPD and hospitals were revealed it became more and more difficult to set a boundary and limit the scope of the investigation to OPD problems. For example, the method of retrieving records obviously embraced more than just the OPD as records are constantly moving between OPD and the hospitals and a large proportion are still stored in the hospitals. On the other hand, although patients are put on hospital waiting lists by consultants during out-patient clinics these waiting lists are kept in hospitals and so the method of maintenance was not looked at in detail.

In a project of this sort it is usually apparent very soon after discussions have started what aspects of the organization are most likely to be available to data processing. This was the case in this project, and although other aspects were explored most attention was devoted to following the main leads. These are now described.

a. Ensuring that all medical records are available. The requirement is that whenever a patient attends the OPD all previous medical information pertinent to his medical condition should be available. Immediate availability is only relevant to those patients arriving without warning; most patients are given an appointment and so there is some time in which to search for the records. What is needed from the record varies from one clinic to another. For instance, in most medical clinics for new patients the consultant wants to know the full medical history, whereas for return visit ENT cases it would generally be the ENT case notes alone that are required. In some cases previous X-ray films are required whereas in many they are not. In order to meet most requirements in the best possible way a centralized record library based at the OPD is being built up, but this process has its own problems.

The formation of the centralized library depends largely on the patient giving correct information about his last hospital or OPD visit when he is admitted or given an appointment. If he does this, and the information is correct, there is a strong chance that his old notes, whether they be at the OPD or one of the hospital records offices, will be found and on discharge they will be filed in the OPD library under a single unit number. If he fails to give this information, the old records are not generally found because of the time and effort involved in searching the various storage places, even though they are mostly indexed. Consequently, whenever a patient fails to disclose a previous visit a new set of records with a new unit number is created. At the other OPD visited during the project all records are under one roof and are accurately indexed. This index is interrogated before every appointment and the staff are just able to keep pace with the demand for records. They said, however, that the index was becoming overloaded and if any further efficiencies are to be achieved it would have to be automated.

Apart from the very unwelcome result that medical facts about the patient become dispersed, multiplication in sets of records also results in more and more shelf space being required. This is further aggravated by there being no method of removing the records of people who have died.

b. Ensuring that investigation reports find their destination. Many investigation reports neither find their way back to the clinic where they were requested, nor are they filed in the patient's notes. The procedure that should be followed is that a clerk inspects each patient's notes prior to a clinic in order to find out whether or not an investigation was requested at the previous clinic. If it was, she looks in the folder relevant to that consultant in which the report is filed, removes the report and places it in the patient's notes. However, the process of inspection for requests is laborious and often exacting, and so many requests are missed. If she had a regular list on which all requests for each clinic were printed, the process of getting the reports to the notes at the right time would be greatly simplified. Some consultants create methods of reminding themselves that they have requested investigations and therefore should inspect the reports; which points to the need for a more foolproof way of doing this clerical task.

c. **Finding the required data in records.** This problem really divides into two parts: extracting sufficient information to conduct a consultation and extracting data for research purposes. In either case it can be a time-consuming task searching for salient information in the voluminous records of patients who have a long medical history.

The requirements for a consultation vary enormously. A physician is likely to want very different information from the notes than a surgeon. Again in some specialist clinics such as ENT and cardiology the amount of information recorded and wanted from the notes is very formalized. The problem of creating a method of record-keeping which makes it easy in each instance for just the right information to be quickly accessible is formidable. However, there appeared to be a certain demand for a brief summary of the chief medical events of a patient's life to be readily available when he arrives for consultation.

If such a summary were maintained for each patient, and it contained details such as the disease diagnosed, treatment given, and operations performed in the course of each admission (both in-patients and out-patients), then a quantity of medical data would become available for research. A number of consultants keep diagnostic indexes as it is; but if the index covered all contacts with the hospital and out-patient services then there would be considerably greater scope. Finding an accurate method of collecting and coding medical information for all patients is no mean problem, however.

d. Allocation of appointments. Appointments are initiated either by written requests from GPs and hospitals, or by verbal requests from the same sources and occasionally from patients, or by the consultant instructing the patient to arrange a return visit at the end of a consultation. All return appointments are arranged by clinic receptionists, whereas other 'old patient' and all 'new patient' appointments are handled by appointments staff in the central office. An exception to this rule is that X-ray, dental, and neurological appointments are made by the respective departments. The definition of an old patient varies from one clinic to another but is usually governed by the date when the patient last attended that clinic.

Clinics can be for old patients, new patients or combined old and new, and there is a folder for each consultant in which the lists of appointments are kept. These lists serve the functions of allocating appointments, checking the presence of records, checking the arrival of the patient at the central waiting area and at the clinic. In fact, clinic receptionists have to copy the lists because they are required simultaneously at the central area and at clinics. A group of patients is allocated to each period during a session, and the consultant's requirements as to size and constitution of the groups and the time intervals are written in his folder. The groupings are largely in line with the recommendations of those who have predicted the best way by queueing theory. However, there still remain practical difficulties in running a satisfactory appointments system.

1. Even when everyone arrives on time, the schedule of appointments can be thrown badly out by one or two extra lengthy consultations. This difficulty is particularly apparent in new patients' clinics; those for old patients being much less prone. The schedule could be arranged to suit the load if it were known at the time of making the appointment whether the case is likely to involve a long consultation.

2. It is not uncommon for patients to get through the initial consultation quickly only to have to wait a considerable length of time to attend a second clinic or have an essential investigation done. In some instances it is possible to predict the services that the patient will need. Thus the appointments could be arranged accordingly and long waits or even return visits obviated.
3. The time when a patient can arrive is sometimes dictated by such factors as public transport (if he lives far away) or ambulance availability. The appointments system there has to take these into account. This is done already to a certain extent, but there is scope for further integration of ambulance services.

e. **Appointment changes and queries.** Appointments staff have to answer queries from patients who have forgotten the date of an appointment or who the appointment is with; and there can be up to eighty such questions, including requests for changes in the appointment date, each day. Servicing such requests involves searching through the lists often with little indication of where to look.

f. **Co-ordination of services.** So as to ensure the best use of ambulance, pathological, and X-ray services, and to reduce as far as possible inconveniences to the patient, co-ordination is required between these services and the allocation of appointments.

The achievement of any such co-ordination rests upon there being advance knowledge of the patients' requirements before the appointment is made. This is generally available in the case of ambulances and a scheduling system could be applied here. It is only the neurology and cardiology clinics, however, that know with any degree of certainty what investigations will have to be done before or immediately after the clinic.

A short survey was conducted to determine whether there is any correlation between complaints being treated and particular sorts of investigation performed. The survey indicated certain trends but much more data will have to be gathered before an appointment system can take into account forecasted investigations. It would aid the scheduling procedure, and thus reduce the number of return visits for investigations, if the GP at the time of requesting an appointment could also request the investigation that he deems to be necessary for the consultation.

g. Statistics of out-patient department usage. A number of statistics are required but are at present unobtainable because of the effort that would be required to gather the data and compile the figures. Such statistics are varied and include breakdowns of waiting lists into 'routine', 'soon' and 'urgent' patients; medical statistics of various sorts; figures depicting the way the OPD is being used such as the incidence of demand from particular age groups and locations; detailed costing figures. Information of this sort is required both for daily operation and long-term planning.

The main procedures involved in 'processing' a patient from when the appointment is requested to when he is discharged are depicted in flow chart form in the appendix.

The results: proposed procedures

Ways and means of using computer techniques were being considered throughout the time of tracing OPD procedures and identifying problem areas. So rudimentary plans for a computer system were forming by the time the first half of the project was complete. These plans were then refined during the second half of the on-site work. Finally, after the on-site work was complete the tasks which were considered suitable for a computer application were decided upon and a system specification was written.

In the opening paragraphs the need to qualify the word 'feasible' was mentioned. The qualifications adopted were that any suggested computer system should not be very complicated or expensive, but should be adaptable, as it would be an experimental venture. Preferably, the system should also be capable of working using a computer bureau.

A small computer with random access backing storage and situated at the OPD would be ideal for running an on-line appointments system, but would not have been suitable for handling large files which was one requirement of the system. The shared use of a medium-sized computer at or near the OPD with inquiry terminals and a random access device reserved for the OPD would be the ideal solution. It presupposes, however, that the computer has the special software needed to service the inquiries. The final choice of system was designed to be run as a bureau application on a medium-sized computer using magnetic tape backing storage. This choice allows the greatest flexibility, and is the simplest to implement.

The system was also designed to accomplish a number of tasks and at the same time be capable of development in ways which could not be clearly defined although their general direction could be seen. It was also designed so that it could be introduced in a number of stages.

a. **The first stage.** The computer system would maintain a master index of all existing records and X-ray films in the hospital group served by the OPD. It could be used to discover whether or not patients applying for appointments have been registered and if so where the records are. All requests within the hospital group for records could also be routed into the system and the computer would print daily lists of the records required from each storage point.

Keeping the index up to date would involve capturing the identifying data of every patient who is newly registered in any of the centres covered by the index. In the case of out-patients this could be obtained from the request form that is sent in for a new out-patient appointment. For in-patients who are admitted from sources other than the waiting list it could be obtained from an admission form which would serve the dual purpose of providing information for hospital activity analysis returns and the master index. The current practice of making out copy index cards for the OPD index would no longer be necessary as this task can be accomplished by the computer. For each new registration it would produce a label which can be stuck on a card to form the new index entry.

The master index file would principally hold identifying information pertaining to every registered patient. This information consists of such items as the surname, forenames, date of birth, unit numbers, street number, GP, NHS number (where known), etc. It serves to identify the patient and whenever requests are made by GPs for new appointments, or data concerning non-waiting list admissions into hospitals is submitted, a programme would attempt to link the patient's details with those of patients on the index. Sophisticated linkage techniques taking into account a number of details about the patient are necessary so as to take into account mis-spellings, changes in name, and erroneous information. If the NHS number were commonly used this could be used for identification; but without it proper linkage techniques are necessary in a population of half a million or so.

b. **The second stage.** Once the index is working satisfactorily the system would be developed to allocate new patient appointments and to print all clinic lists. A file holding details of all appointments made would be created, and details of each visit would be recorded on a patient data file.

Two clinic lists would be produced by the computer for each clinic: the first would appear three days before the clinic as a check-list for ensuring that all records have been assembled; the second would appear the day before the clinic and again would be used by the receptionist to check that all records have been found. If any were missing, her task of retrieving them would be reduced because the last two clinics or hospital visits would be shown on the clinic list thus giving an indication of where to begin the search.

Return appointments would still be arranged by receptionists who would refer to a list of vacancies in future clinics produced weekly by the computer, and enter the time and date on the current clinic list which would act as an input document. The receptionist would also use the list to indicate the patients who attend, whether or not records were found and where they go to after the clinic so that the computer can keep its location index up to date. There would also be provision for entering other details about return visits such as who the patient is to see and any special arrangements that must be made, which would appear on the appropriate clinic list together with a count of the number of times he has attended the clinic.

New appointments would be made differently. The urgency of the GP's request would be assessed by an appointments officer or consultant and from it data prepared and submitted to the computer. The programme would then attempt to link the patient with a record on the master index, failure to do so resulting in a label being printed. This label would bear a unit number allocated by the programme and be used to create an entry on the manual index. Should the clerk find that there is already an entry for that patient it means that the programme has failed to link the data because of erroneous details. Not many mismatches should occur, but in the event of it happening the correct data could be resubmitted.

As soon as the request has reached the computer it would allocate an appointment regardless of whether or not a match was found, and print a notification addressed to the patient. The allocation programme would take account of the consultant's preferences as to how many patients should be grouped, at what intervals, and also the method of coping with different degrees of urgency. It would also take into account ambulance requirements and the distance to be travelled by the patient. Should the consultant make an assessment of the likely length of consultation when the request arrived this would also be allowed for.

Other printed output from the computer would be twenty identification labels for each new patient, alphabetic lists each day of the next three days' worth of appointments, and notifications to GPs stating which patients failed to attend an appointment. The identification labels would, of course, be stuck to request forms when investigations are required. The alphabetic lists would principally be used by appointments staff to answer queries from patients who, at the last minute, want to know when their appointment is due or whether it can be altered. If the patient did not appear on the list his query would be submitted to the computer which would print a reply; these being for appointments more than three days ahead. The letters to GPs of patients who failed to attend would appear in separate batches for each clinic and could be used by consultants to inform the respective GPs. If a patient did not attend for a specified interval after the initial appointment his name would appear on a 'scrapping list' produced periodically and used to single out the unused folders for re-use with other patients.

It would become unnecessary for patients to check in at the booths in the central waiting area as the main purpose which this procedure serves—finding out where the patient last made a visit in the hospital complex to trace lost notes—would be fulfilled by the computer system. Patients would take a seat in the waiting area immediately they arrive until called to individual clinics, and any questions they might have would be answered at an inquiry desk.

c. **The third stage.** The next stage of implementation would be to record all requests for investigations on the patient data file, thus enabling the computer to print on clinic lists details of all investigation reports that need filing or bringing to the attention of the consultant. Under the current system a request is made out at the clinic and taken to the X-ray or pathology department by the patient. There it is entered in a log-book. Under the computer system a carbon copy of these entries would be required, and against each entry the receptionist would write a simple code indicating the type of test. This copy would be used to prepare input data for the computer.

The possibility of recording actual results on the file so that the computer would be able to print the reports was investigated in some depth. This appeared feasible but would entail much work in developing, and obtaining agreement on, the method of coding results; it was therefore considered best left until a later stage of development. The majority of pathology results, at least, are likely to be collected by automatic methods straight from the laboratory machines before very long, and it will then be possible to feed these data straight into the computer system.

At this stage the system would be receiving enough data to produce a number of statistics about the usage of the OPD. These would include all regulation statistics, such as the number of tests done in investigation departments and the number of old and new clinic attendances each month. It would also be able to generate copies of waiting list lengths for each consultant and a number of other statistics such as:

(i) Number of routine and urgent patients seen at each clinic

(ii) The sources feeding the OPD analysed by hospitals and general practice

(iii) The type of patient using each speciality analysed by area of residence, age, and sex

(iv) X-ray and pathology loads generated by each speciality

(v) There would also be built into the system a method of conducting occasional surveys yielding consultation and waiting times for each clinic

Certain requirements that were discussed earlier have not been provided for in the system, up to this stage. This is partly because the requirements are not so clearly defined and partly because the capture of data presents more of a problem. For instance, it will eventually be possible to store a quantity of medical data on computer files and produce the required information at the time of consultation. One way of presenting this information would be in the form of a summary, much the same as a discharge summary, printed on a sheet which could be disposed of at the end of the consultation. Data could be collected at the stage of the consultant writing to the GP for out-patients and at discharge for in-patients. A special letter form would be necessary which would have boxes in which such information as diagnosis, treatment, etc. would be written leaving space for more descriptive material below. A number of GPs in the area were interested in recording their data on computer files. If this came about on any scale it would, of course, provide an excellent means of interchanging information; and in addition, serious attempts could be made in costing the treatment of diseases.

Another requirement that could not be met at this stage is the scheduling of investigations to fit in with clinical appointments. If it were known at the time of allocating an appointment that the patient is going to require, or is likely to require, an investigation that cannot easily be fitted in, then due consideration could be given to this factor when the programme allocates a time. Indeed, if a specific investigation were stipulated—as is current practice in neurology only—then the allocation programme could arrange the investigation appointment too. It appears that methods are beginning to change, more investigations being done before consultation takes place. As these methods become more formalized it will become more sensible to apply the computer to doing the necessary scheduling.

The techniques of implementing a computer system

One essential part of the process of analysing a system is to depict the routine procedures in the form of a flow chart. By doing this it is possible to look at the system as a whole, see how the various procedures connect together, and then proceed to design a computer system which will provide for the organization's requirements.

The appendix contains these flow charts. They are arranged so that the top half of the page shows existing procedures and the bottom half indicates how the computer system would fit in. An explanation of the conventions used to highlight similarities and differences is given in the appendix.

The flow charts, therefore, have a twofold aim: one is to act as a visual aid so that the systems analyst can form a clear picture of the process being studied; the other is to provide the potential user with some indication of how the various processes will compare under the new and old systems. Flow charts are not always used for the second purpose, however.

The implementation of the suggested computer system has been described as a number of stages in which various parts of the system are introduced. Before any computer project becomes operational it normally has to go through a number of processes. These processes may be identified as:

(i) Systems study
(ii) Job planning
(iii) Programme specification
(iv) Programming
(v) Pilot running
(vi) Parallel running

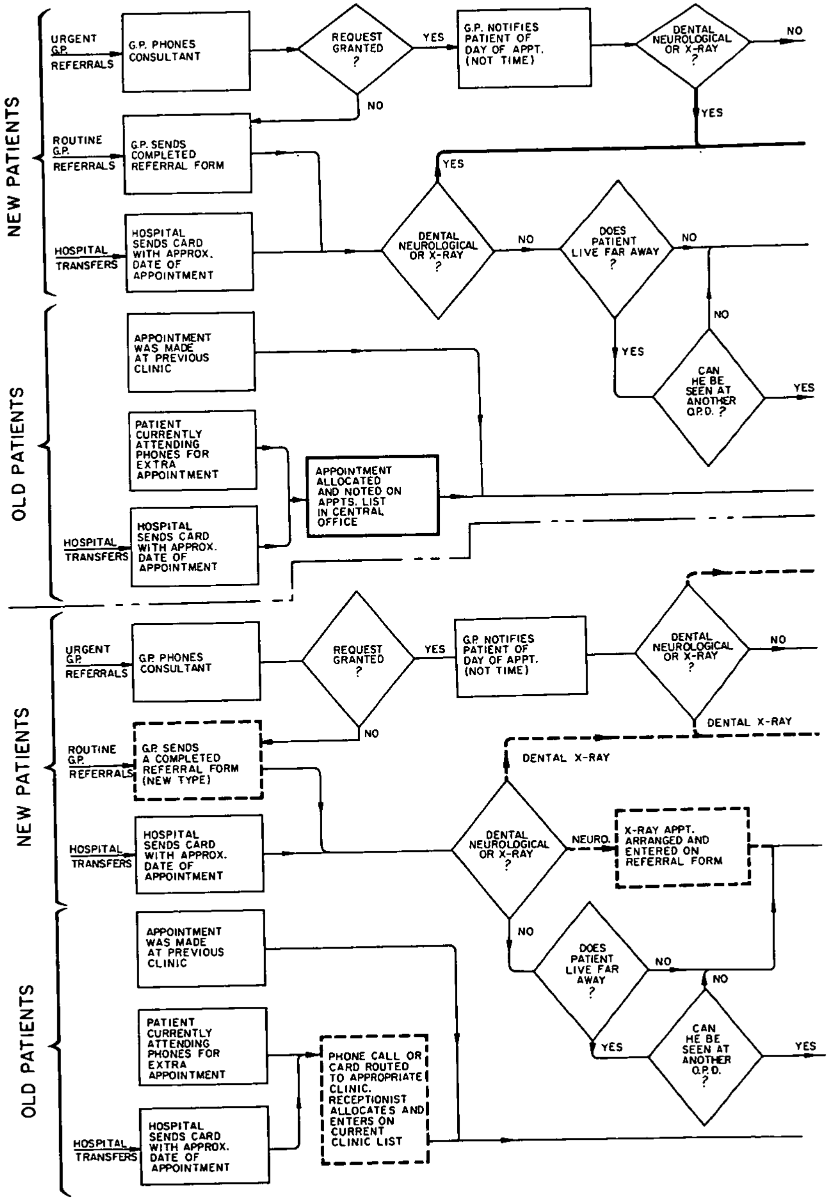
The project described in this article has reached the job planning level for all the stages of implementation. For each stage of implementation the programmes would then have to be specified (iii), written and tested (iv), run on a restricted amount of data (v), run on the full data (vi), and finally released for use. Not all projects would require separate stages of implementation, nor are the processes listed always identifiable as separate entities. It depends on the type, extent, and complexity of the job.

APPENDIX

Flow charts of existing and proposed procedures

On these flow charts the two systems are shown alongside each other, the existing system on top and the proposed system underneath. Markings in heavy continuous type are peculiar to existing procedures, those in heavy broken type peculiar to proposed procedures and the rest common to both. In certain places it has been possible to show where the computer produces a useful output and these places are indicated by a wide arrow. It has not been possible to show certain other advantages such as aids to answering patient's telephoned enquiries and the production of statistics.

EXISTING PROCEDURES



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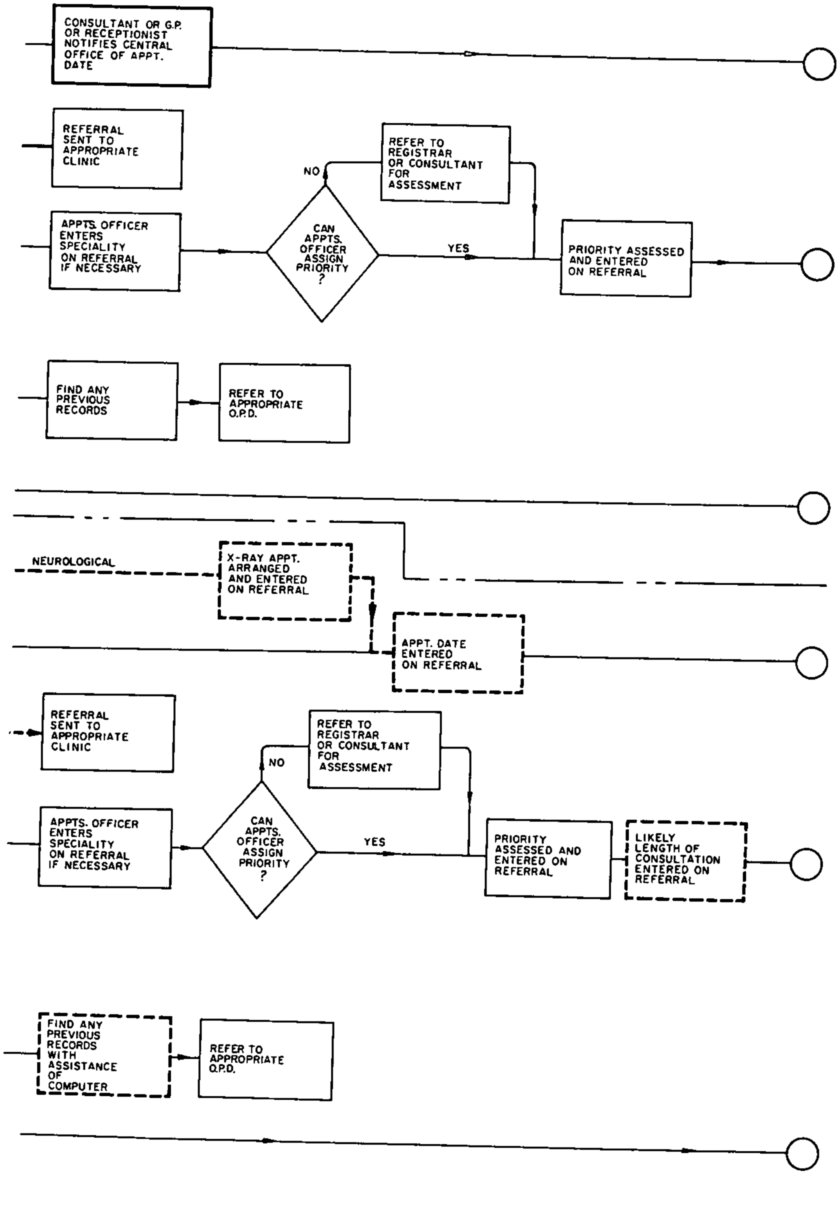

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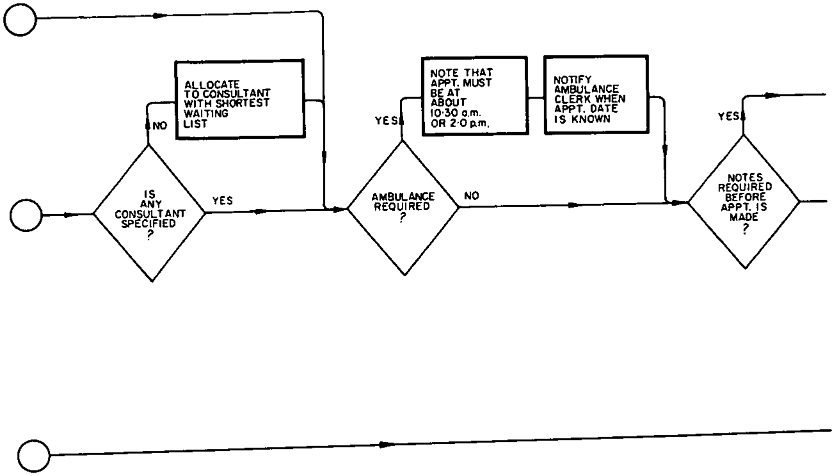

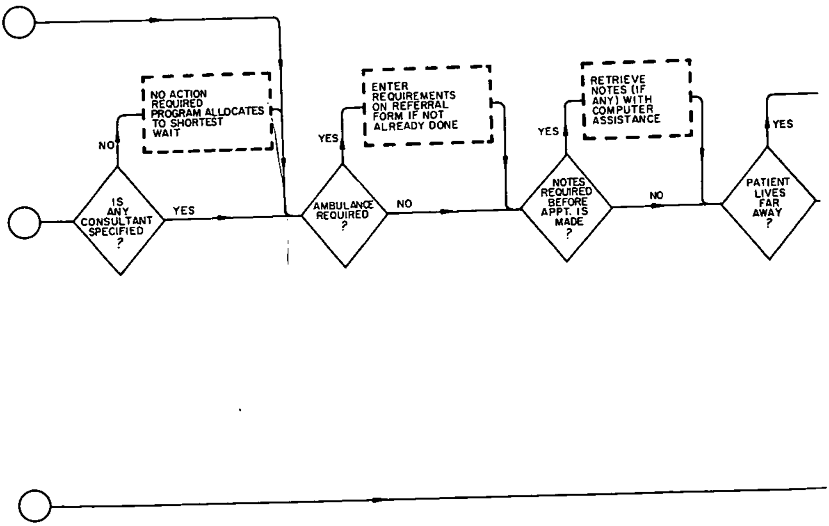

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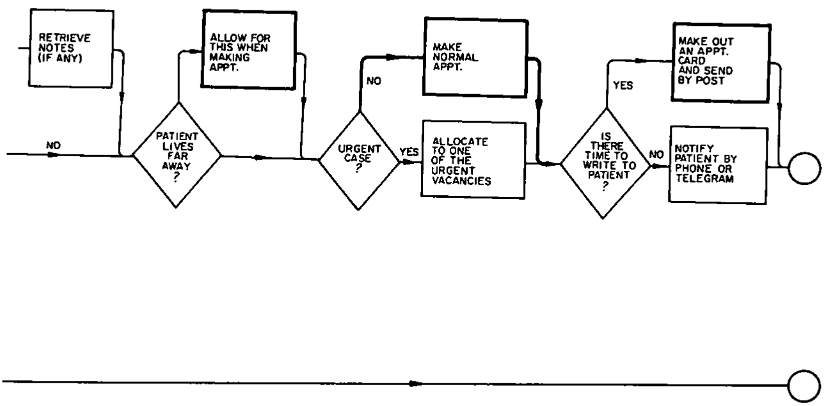

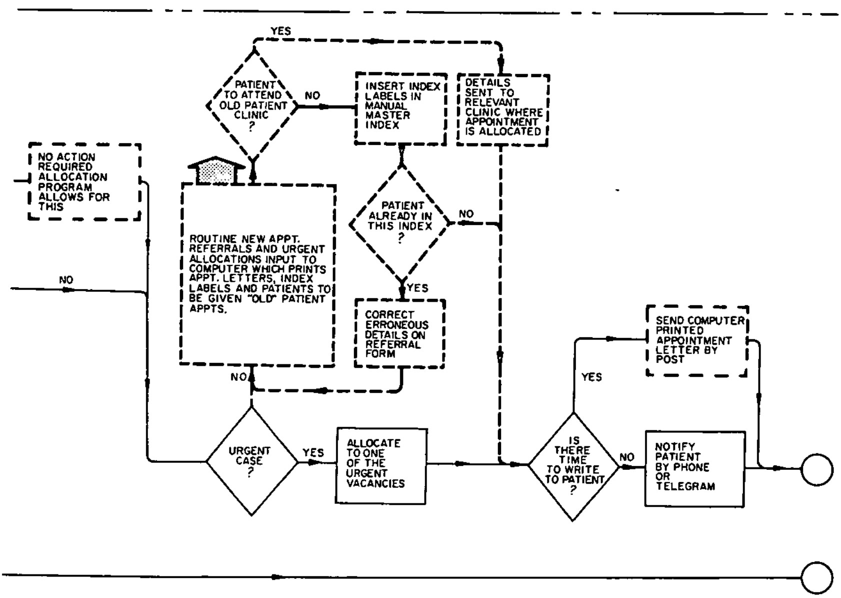

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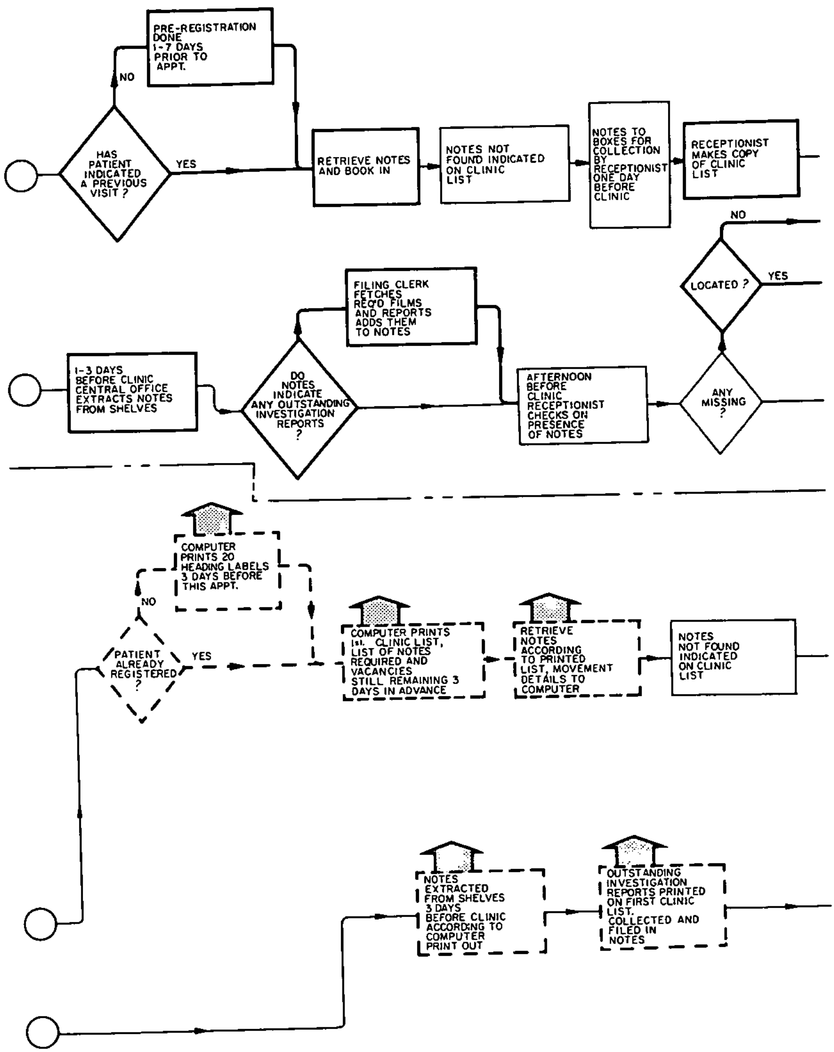

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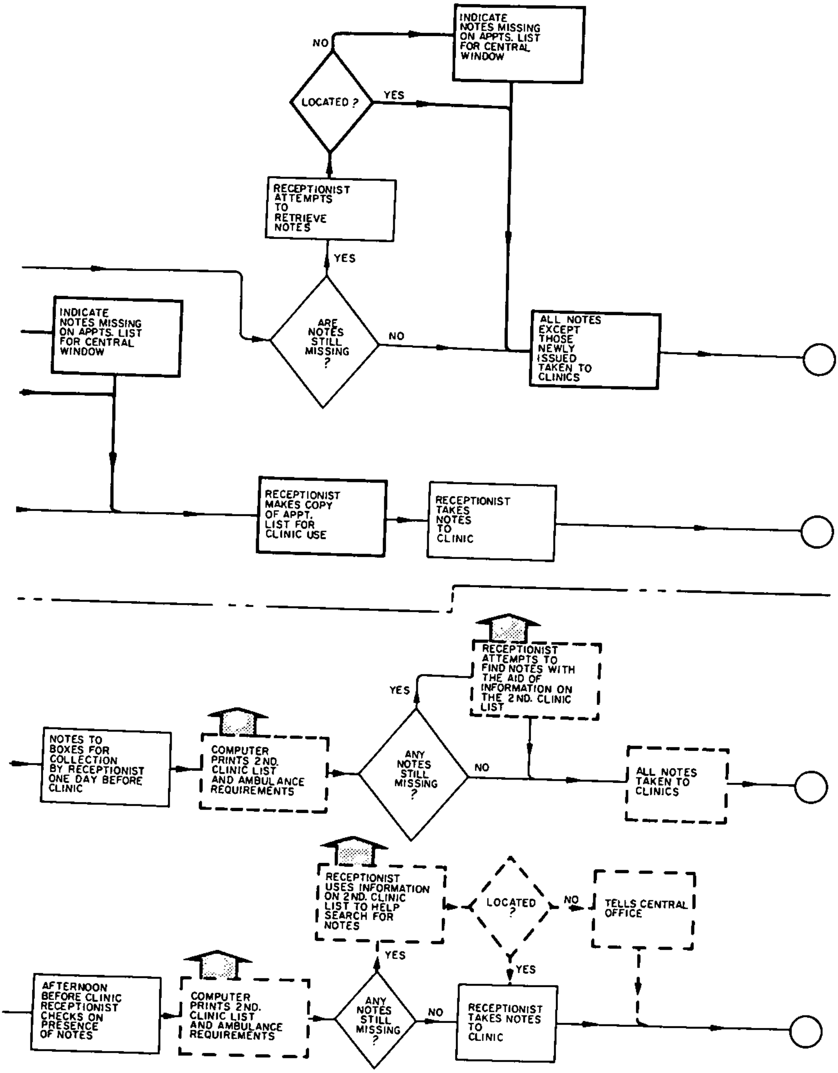

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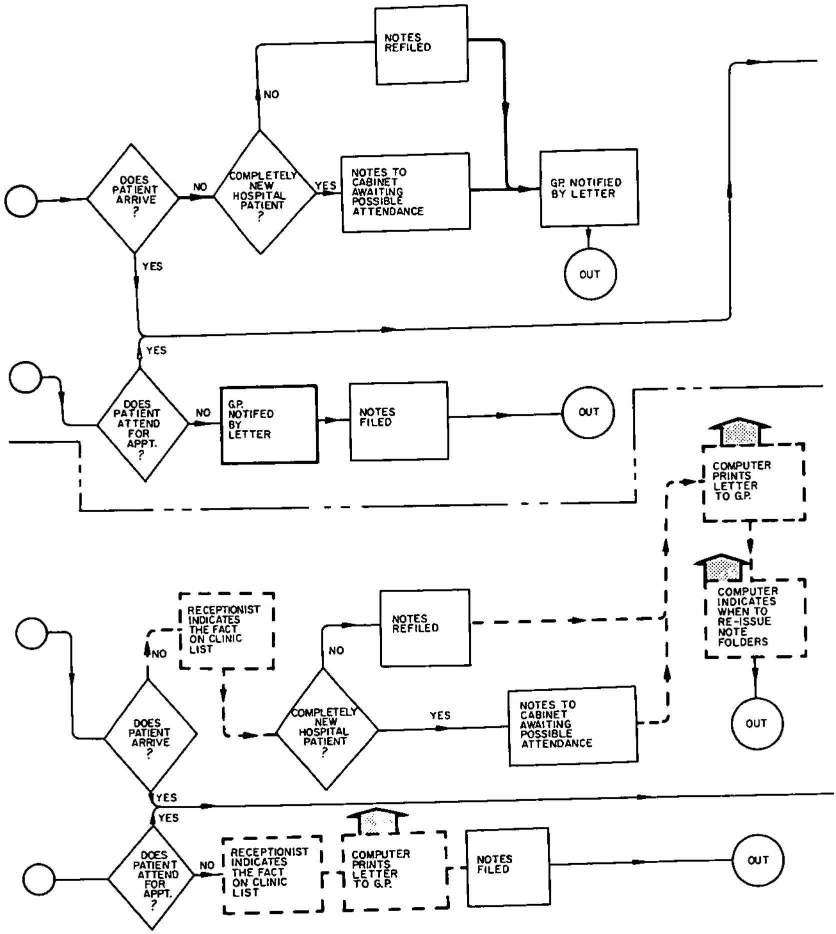

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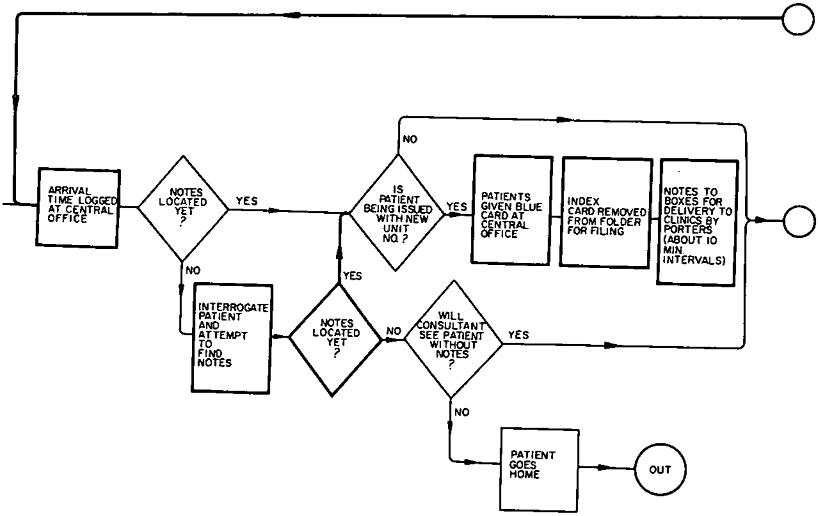

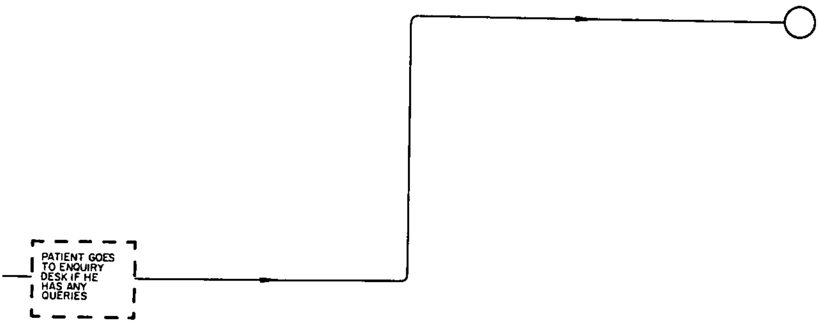

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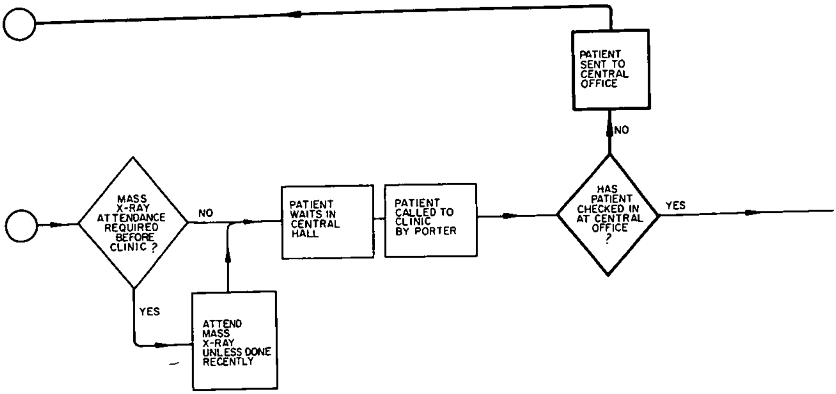

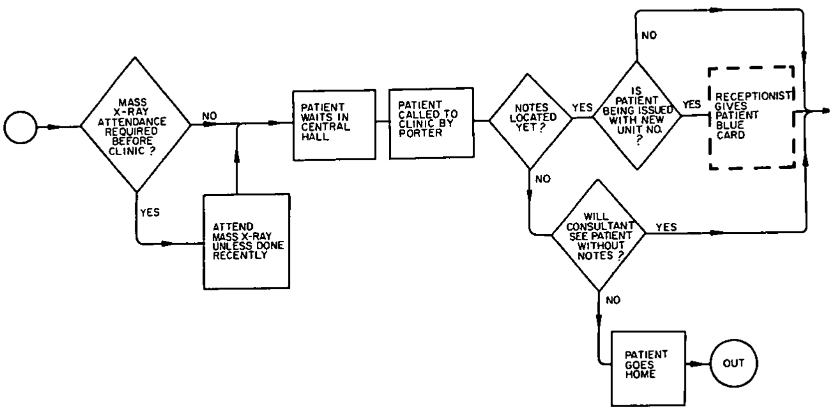

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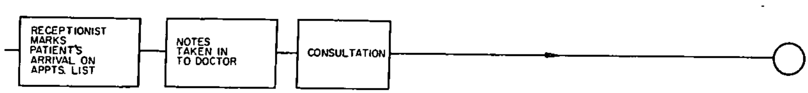

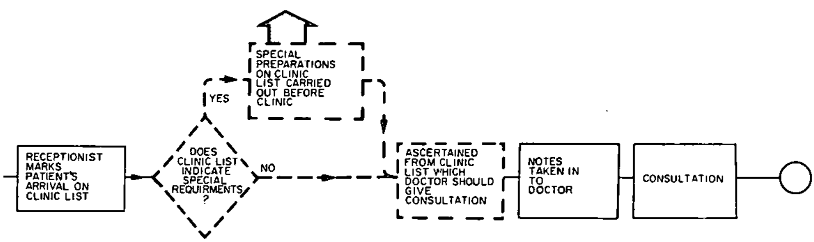

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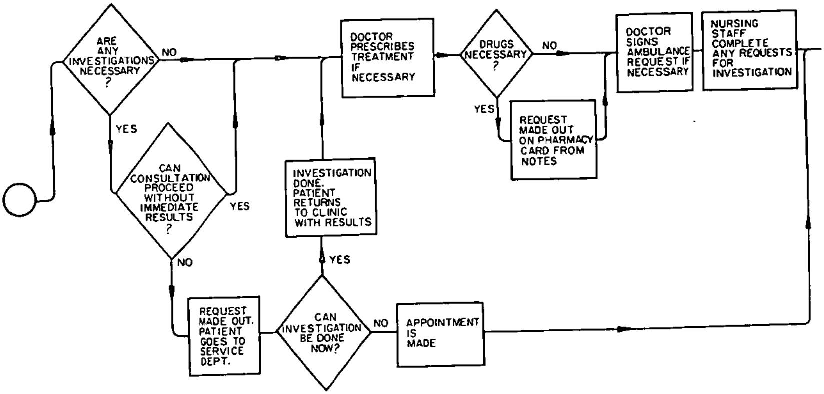
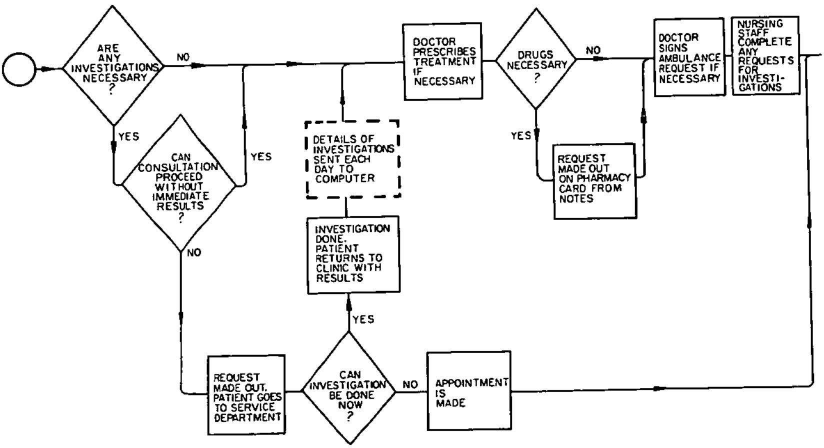
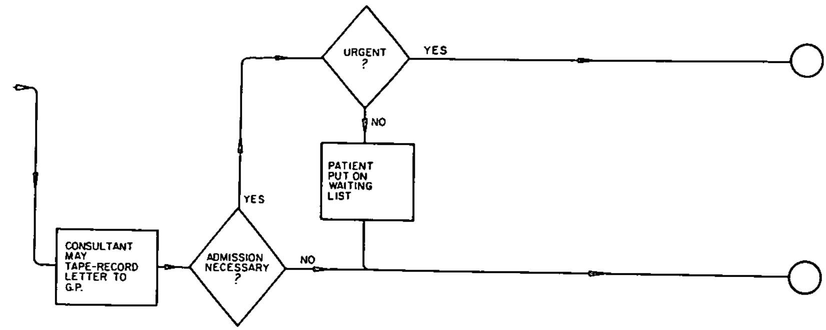
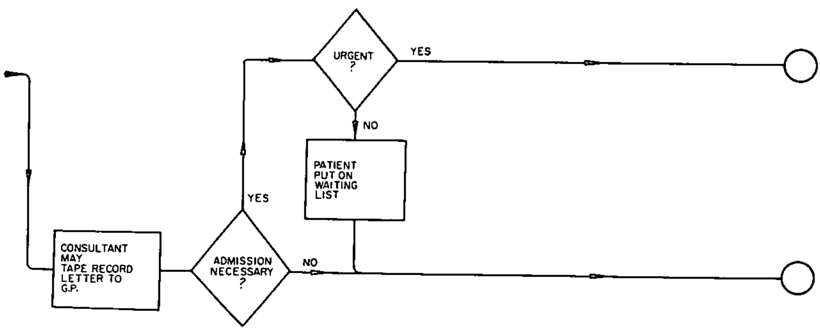




PROPOSED PROCEDURES

EXISTING PROCEDURES





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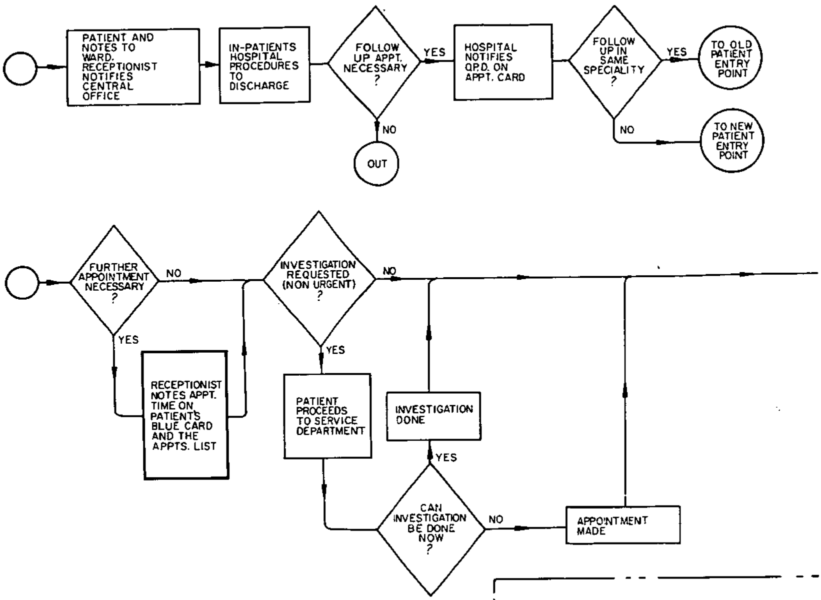

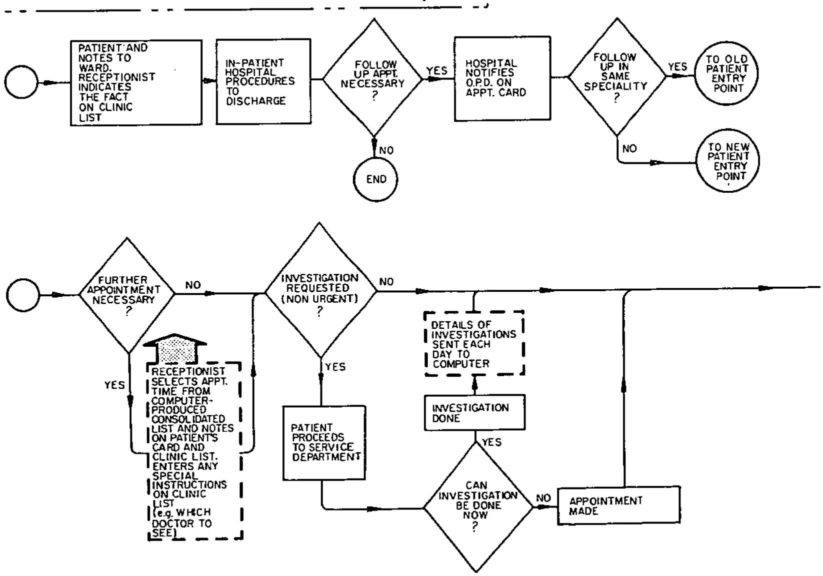

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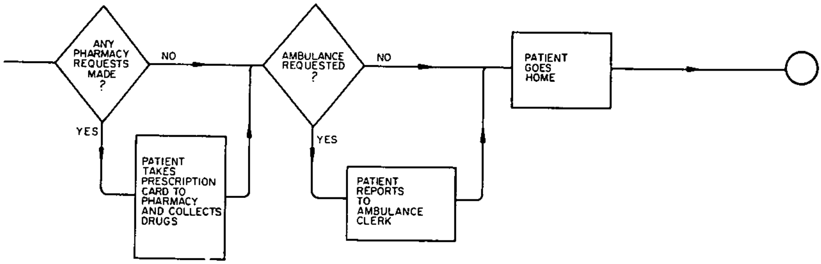

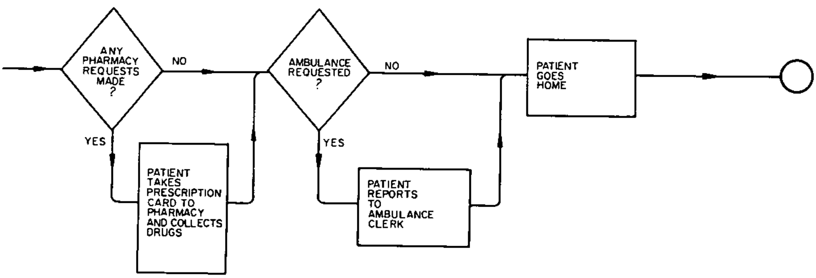

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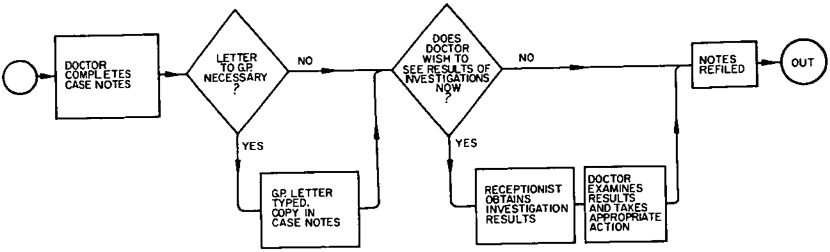

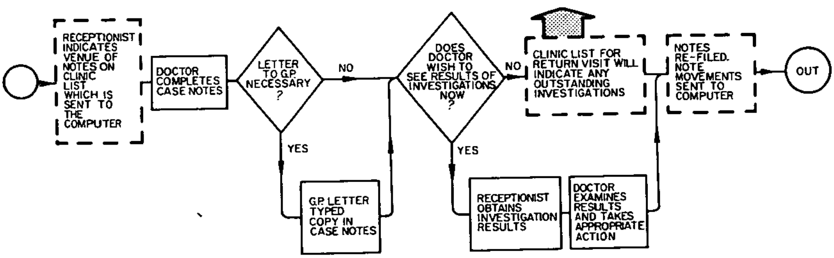

PROPOSED PROCEDURES

14

Systems analysis and hospitals

F. T. C. HARRIS

Critique of a flow chart developing another technique for analysis

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Systems analysis and hospitals

This article outlines a systems analysis language and procedure developed in this unit and discusses its application to a hospital records system. General principles of automatic data processing in hospitals have been discussed elsewhere (1, 2). Here the article falls into two parts, the first discusses the technique being used, the second outlines the results of its application.

I

Some of the difficulties inherent in any systems analysis have been outlined by various authors. Grindley (3) writes: '. . . this task has turned out to be one of major difficulty. . . . No one person knew all of the facts. The clerks did not know how their separate tasks fitted. . . . The managers did not know the detailed work that went on within these separate tasks. . . . Instead of saying what rules they followed in each case, they said it was a matter of experience and judgment.' And again, Grindley (3) writes: '. . . Urwick Diebold . . . found that programmers spent less than half their time writing and testing programmes. The rest of their time was taken up mainly with delays caused by something called "systems queries". . . .' Whilst the proposed solution to this problem has points of interest, it does have a number of disadvantages. Some of these have already been pointed out (4). Grindley (3) appears to assume a very simple approach to systems analysis which he defines as: 'Expressing the relationship between the data fed into a computer and the information to be processed by it', and in discussing the desirability of constructing models of systems, he writes: '. . . the requirements for model building . . . are . . . Firstly, to break down the problem into its component parts. Secondly: to describe precisely the relationship of all the parts with one another.' It may well be that the user does not know what he wants, and a major part of the analyst's work may be directed to finding out not only what it is that the user should want, but also what is feasible. The analyst has first to choose between a number of strategies that are open to him. The two extremes are, on the one hand, to take a restricted and easily identifiable problem within the over-all system and devote himself to the analysis of this, or, on the other hand, to attempt an over-all study of the entire system—or some large part of it. The former strategy has the advantage that it permits rapid description, as of a museum piece exhibited in some chosen display, but here, of course, the display will be in a medium such as 'systematics', flow charts, decision tables, plain language, or whatever. It has the disadvantage that extension of new procedures arising from such a piecemeal analysis to other parts of the system may be obstructed by the design of these new procedures. The latter strategy, of the over-all study, reduces the hazard of incompatibility between sub-systems.

It is this latter approach that has been emphasized in the studies that have led to this article. However, it has its own further disadvantages. The over-all strategy generates a considerable mass of information. This information must be sufficiently detailed to ensure that sub-system incompatibility can be avoided. The bulk of the information so generated poses a considerable problem. Handling, comparing, and up-dating such descriptions are themselves major tasks, particularly where the number of staff available is small.

The use of flow charts as an expository technique in such a strategy is limiting. Flow charts, whilst an excellent didactic tool, involve a great deal of re-drafting as understanding of the system grows and previously unsuspected procedures and interconnections are uncovered. In addition, the system itself will surely undergo

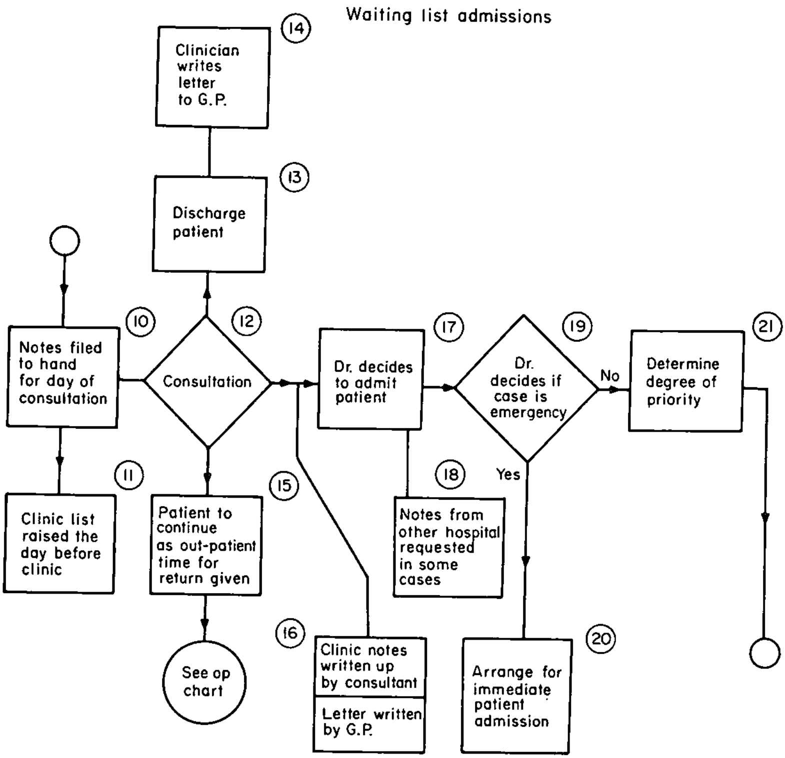

Fig. 1. Waiting list admissions

changes during the period of study and necessitate re-draftings. Similar disadvantages apply to plain language descriptions. Flow charts, however, suffer from an additional disadvantage; they are peculiarly liable to two distinct types of ambiguity. Hence, on the one hand, flow chart blocks may designate quite distinct types of activity with no corresponding change in block format. On the other hand, flow chart blocks mask the degree of analysis of a particular problem that is still necessary. Both of these points are illustrated in Fig. 1, together with many others. The sequence is taken from a most useful analysis of hospital activities undertaken by the Nuffield Provincial Hospitals Trust (5), the preface of which makes it quite clear that the use of flow charts was exploratory. Flow charts have been less extensively used in more detailed studies (6).

The lexicon of blocks incorporated in the N.P.H.T. publication (7) distinguishes 'activity points'—represented by squares—from 'decision points'—represented by diamonds. In the sequence illustrated here, those blocks numbered 11, 12, 14, 16, and 19 do not represent 'activity points', although some of them explicitly embody procedures. The lexicon which informs us that blocks 11, 14, and 16 relate to documents, explicitly informs us that these are not filed in case notes—such documents being represented by another block—but gives no indication of what happens to them, or presumably to their carbon copies. Block 14 appears to indicate a document which is also an operation. It is far from clear how a letter written to the hospital by a GP comes to be associated with the flow, without being incorporated into the case notes at block 16. Block 12 is presumably intended to represent not only a 'decision point', but also to show that procedures are involved. Unfortunately, without previous information, it is difficult to attach any clear meaning to that block. Confusion is not diminished when it is seen that block 17, which indicates an 'activity point' in contra-distinction to a 'decision or option' includes the word 'decides' in its own description.

Blocks 20 and 21 expose a real difficulty in the expression of descriptions by means of flow charts. Flow charts, by nature of their graphical type of representation, emphasize a unidimensional continuum. Thus, they can represent the relation of events in time. It becomes more difficult to represent hierarchically organized structures in which procedures may influence other procedures at a different level in the hierarchy. In the example, block 21 represents an 'activity point' that is certainly prior to, and at a different level from, the 'activity point' illustrated at block 15. It certainly deals with different entities, with statements rather than persons.

One way of escaping from the constraints of flow diagrams, without embracing the alternative ambiguities of plain language, is to use decision tables (8, 9). However, whilst the advantages of decision tables are well known, their disadvantages have been less well publicized. The construction of a decision table, particularly when working on previously unexplored material, is time consuming. Tables have to be continually re-drafted as new material is incorporated, and the conversion of the initial data into tabular form may present difficulties if adequate definitions are to be achieved.

In order to overcome some of these disadvantages and at the same time utilize the advantages of decision tables, we, at the Nuffield Medical Data Processing Unit, have developed a technique that effectively works by stating decision tables as their constituent rules. This has many advantages, of which one is that individual rules can be updated without requiring re-drafting of the whole table.

The technique is still undergoing development. It embraces a number of distinct stages. First, problems are stated as a series of logical conditionals (10) which, if stated loosely, must next be transformed to more precise statements. They are then punched on to cards. A group of such encarded statements, that forms a decision table, is delimited by table identifiers. Examples are given in Appendix B. In a fourth stage, such tables can be up-dated and sorted on unit record equipment or can be manipulated more flexibly if ADP facilities are available. We can automatically trace the flow of logic in a table or a succession of tables.

To give an example of the first stage, let us examine the flow chart that has just been discussed by putting it in the tabular form shown in Table I.

Restatement of Fig. I in decision table rule form

In the following, arabic numerals refer to blocks in the flow chart. Arabic numerals followed by lower-case letters refer to constituent parts of flow chart blocks. Roman numerals are statement identifiers. When followed in numerically ascending order, roman numerals trace the flow of logic. Parentheses enclose comments.

Notice that Table I presents the system as a series of dichotomies, each branch of which can have the value true or false. The flow chart sequence obscures these, for example, statements VIII and XII are the negations of one another within the universe of discourse of this system. Both follow from an unstated negation of statement VI as alternative types of undischarged patient. Statements I, III, IV, VI, VIII, IX, XII, XIII, XIV, and XVI are the antecedents of logical conditionals. Or, in the jargon of decision tables, they are

Table 1

I	11a	If consultation tomorrow.
II	11b	Then raise clinic list.
		(how? What happens to it? What information is listed?)
III	10a	If consultation is today.
IV	10b	If notes are available.
		(What if they are not?)
V	12	Go to consultation procedure.
VI	13	If patient to be discharged.
VII	14	Go to doctor's letter-writing procedure.
VIII	15a	If patient to continue as out-patient.
IX	15b	If time for return can be given.
X	15c	Go to appointments procedure.
		(There is no provision for writing up notes on this appointment, not even if tests are requested in the more detailed sequence no. 37[5].)
XI	16	Go to procedure for writing up doctor's notes.
		(It is impossible to put any clear interpretation on the relation of this block, 16, to the others.)
XII	17	If patient is to be admitted.
XIII	18a	If notes from another hospital are needed.
XIV	18b	Get them.
		(How?)
XV	19	If doctor decides case is an emergency.
		Go to emergency admission procedure.
XVI	20	Unless the case is an emergency.
XIX	21	Go to priority determination procedure.

conditions. The others are the consequents of logical conditionals or decision table actions. It can be seen that all of the actions transfer control to procedures, or other decision tables. This clearly shows both what is required and also that further analysis may have to be undertaken.

Appendix B illustrates a further stage in the statement of this type of analysis. Such a listing can be generated by unit up-dating or restatement of the results of analysis. A suite of programmes is undergoing development for listing such statements, ordering and renumbering them, calculating and inserting cross-references, and for testing the logic of tables for consistency and redundancy and presenting them in tabular form as well as in rule form.

It is not the aim of this article to describe the procedures that have been developed in any further detail. Instead, we will now look at the outline on its applications to a hospital records system. The procedure is, however, entirely general in its application to any records system.

II

One of our major aims has been to identify common procedures amongst departments having apparently distinct requirements and records techniques. One outcome of the analysis of records procedures has been a classification that groups records procedures hierarchically into the three levels discussed below. They are set out fully in Appendix A.

The highest level comprises four groups:

(i) System maintenance—groups of operations that keep the structure of the system in being;
(ii) System control—groups of operations that regulate the activities of the system;
(iii) System statistics—groups of operations that describe activities within the system;
(iv) System operation—groups of operations of the system itself.

It will rarely be the case that an operator in the system is aware of this type of distinction, however real it is. A records clerk may well not regard the difference between cleaning a typewriter, obtaining patient identification particulars, and drawing up a work list, as significant; except that her hands will be dirtied by one job and so generate a further task. On the other hand, I do not wish to reify this particular hierarchical structure; the classification is convenient for this analysis.

The second level consists of a series of sub-groups which, with minor changes, describe both in- and out-patient records procedures. They specifically group together events resulting from transactions relating to particular patients. These groupings are shown in Table 2.

The point of this second-level grouping is to identify procedures,

Table 2. *Decision table groups*

A	Maintenance procedures	B	Control procedures
C	Meta-documentation	D	File preparation
E	Taxonomy	F	Requests—services
G	Requests—other	H	Appointments/admissions arranging
I	Attendance/admissions preparation	J	Registration
K	Attendance/admissions procedures	L	Post-attendance/admissions procedures
M	Attendance/admissions	N	Security
O	File and record manipulation	P	Interaction with other systems
R	Special instructions preparation		

which whilst predominantly associated with a particular records function, may nevertheless play a part in other sequences of record activities.

I shall diverge a little in order to indicate the assumptions from which I am working in drawing up this description. Let me over-simplify the functions of records clerks and appointments clerks in records systems. Then using the terminology of simulation (11), an analogy can be made between the tasks of a records clerk and a parallel processing entity, or storage. That is to say, the operations of the records clerk might have been designed to provide a buffer area within which transactions can be stored up to a limit—a limit that is never in practice explicitly defined. This storage then permits the accumulation of transactions, for instance requests for services, without affecting the over-all flow of transactions in the system. On the other hand, the appointments clerk acts as a unit processing entity (a facility) in that, when dealing with patients, only one transaction can be processed at a time. Storing patients in a buffer area may cause irritation at least and may generate unnecessary expense. The *raison d'être* of both entities is the processing of particular transactions correlated with specific patients. Such transactions generate records so that the pathway followed by a series of events, or generated records, literally forms a paper-chase. Of course, both types of entity may also have non-specific functions such as extracting the data that provide populations for statistical analysis.

For both types of entity, the stimulus to any activity is provided by a request. Even though some requests may present themselves as commands, it is not an unreasonable extension of the concept to include these as requests. Thus, although there are many types of transactions in records systems, the events which initiate procedures in the system are requests. Thus requests are events generated by the occurrence of transactions at appropriate storages or facilities. I wish to emphasize that requests play a crucial part in this description.

The request tables are set out as decision table names in Appendix A, in two of the second-level groups. In group F, requests for services, the tables take the form of a classification of requests. The sole exception to this is the first table, number 38, which is entitled 'Initial communication error'. When set out this way, they form a set of 'open' tables (8) whose actions solely reference other tables. This set of tables first distinguish requests on a criterion of immediacy, is a request being made by someone now present, or by a document or telephone call? They then discriminate between the kinds of persons making requests, between patients, medical staff, records staff, etc. Finally, they distinguish between the various kinds of request themselves. The group G, requests—other, is in fact an extension of the procedures for distinguishing between the aims of requests. This distinction of groups of requests illustrates a third feature of this description of records procedures, namely the relative importance of logical and material factors throughout the description.

Logical factors define the essential and minimal structure of the system. For example, it is formally necessary that a request happens if the system is to operate at all. On the other hand, there are other contributions that must be available if the system is to be able to operate: for example, paper. It is for this reason that table 38, 'Initial communication error', has been grouped with requests; rather than in the group entitled appointments/admissions arranging. In an ideal world, all communications would be error-free. In practice, it is materially essential to allow for error. Again, it may be materially difficult to describe procedures that are distinguishable on logical grounds, a feature that is illustrated in the second table of Appendix B.

All of the tables of group G refer to one or other of a pair of priority allocation tables, tables 15 and 16. As these are control procedures, they fall into a different second-level grouping on logical grounds. Many of the request tables also refer to second-level procedures, grouped together as N, security. These are procedures which provide an operator with a decision on whether or not documents or information can be made available to a petitioner. They also provide checks on the integrity of files in one of the constituent procedures of several of the groupings of tables, for instance, this is the procedure that answers the question 'have we got the files of all of the patients attending this clinic?' For this reason, their material relationship to patient notes has been emphasized by placing them adjacent to the second-level group of tables which describe the handling of patient records.

This last group of records procedures, O, file and record manipulation, have been grouped together on logical grounds. Materially, they will be directly referenced from procedures classified under other groups. For instance, the recovery of files from store for a patient's first attendance, tables 76–7 are associated either with procedures relevant to preparation for a patient's attendance or with admission, group H of Appendix A or with the procedures relevant to the attendance or admission of the patient. This will depend on the variant of admissions procedure that is actually, or 'materially', operated by a given department. In the system studied in practice, this variation has been found in one hospital between the procedures operated in different out-patient departments. On the other hand, just these same tables may be associated with table 50 and also with table 81, when files are sent to other hospitals. In such a case, table 72, case-note security, will also be referenced. Of course, in all of these cases, the sequences of interconnections of tables will have been initiated at one of the request tables.

An emphasis on material requirements provides a more familiar description than an emphasis on logical requirements. Even when the analyst bears in mind the need for parsimony in his description, material requirements may lead him into an unnecessary duplication of procedures. In table 2, group M, procedures dealing with the completion of case-notes are distinguishable from those that are generated by an actual patient attendance. This latter group are described as post-attendance or admissions procedures: in second-level group L. In fact, the completion of records is a special case of up-dating entries, covered in procedures 69 and 70. The entry of a diagnosis is a special case of up-dating medical entries, a procedure which may also be logically related to table 83, the insertion of sub-files and to 53 and 54, requests from medical staff for investigations or for treatment such as physiotherapy. Similarly, the processing and transmission of a summary or discharge letter to a GP is a special case of the general processing of correspondence that is demarcated under table 71.

Seven of the second-level groupings have now been touched upon, in outlining the assumptions that underlie this description. The remainder of the second-level groupings will now be related to them.

J. Registration. This procedure is here conceived in a very restricted sense as just the establishment of a one to one correspondence between a hospital number and a patient's records. The current usage of the term includes this, but also extends to the completion of the non-medical record: name, next of kin, address, and so forth, and consequently lends itself to misinterpretation. Thus it is possible for the operators of different records systems to hold that their 'registration' procedures are irreconcilable with those of others. Here, the patient identification information may be collected during the procedures associated either with arranging for an admission or appointment, or with the admission or appointment attendance. This point has been emphasized elsewhere (12).

D. File preparation. The physical preparation of files such as case-note folders, appointment cards, and so on. This may require the integration of a series of blank forms into a case-note folder together with the stamping of a hospital registration number on that folder before the number has been allocated to a specific patient.

Q. Special instructions preparation. Every patient should have a case-note folder or an appointment admissions document, but only patients attending particular consultants will receive special instructions.

F. Taxonomy. Procedures involving the classification of documents entering the system or its sub-systems. Whilst such procedures occur prior to a written request becoming effective, it is requests that have a crucial status in the system.

H. Appointments/admissions arranging. Relates to those procedures that inform the patient when an appointment has been arranged for him. It thus includes reappointments as well as initial appointments and alterations to previously arranged appointments. There appears to be no logical requirement for differences in out-patient procedure between departments. However, material requirements may necessitate differences as in departments dealing with venereal disease. At this stage, it is rarely possible to complete the non-medical component of the record. Any pre-registration procedure will be initiated here.

Some procedures that are materially connected to this group have been separated on logical grounds. For example, any record of a particular event such as the receipt of a written request for an appointment is here grouped under C. Meta-documentation, table 19. Again discrimination between patients that have or have not previous attendances, involves reference outside this group to table 20, the alphabetic list of patient records and to table 76.

I. Attendance or admission preparation. In those departments in which this group of procedures is materially distinct, there will not only be the entry of such non-medical records as are available into appropriately corresponding files, but in addition patient identification labels may be prepared and the location of ward or clinic identified for each case-note file. In addition, files may have to be recovered from storage, tables 76, 77, 78, 79, and 80. In the case of attendances subsequent to the first and of ward rounds, it is immaterial whether we regard the up-dating of medical entries, table 80, as belonging here or to the post-attendance and admissions procedure. In some cases, however, such a grouping might result in the preparation of attendances preceding the procedures involved in arranging for them. This topsyturvy state would happen when checking the fulfilment of some required group of tests, see table 75, is a pre-requisite for an attendance. This favours grouping the up-dating of entries with group L.

K. Attendance/admissions procedure. In some departments there is no distinction between attendance preparation and the procedure on attendance. Again, establishing whether or not the patient has attended previously can be left to this stage if the number of patients is relatively small.

L. Post/attendance or admissions procedure. This involves filing copies of letters, preparing and sending letters, and for the reasons set out under I above, the up-dating of medical and of non-medical entries. The up-dating of medical entries may appear to be inappropriate as a records activity. However, it involves records staff where it is departmental policy to type case-notes and notes of ward rounds. To this extent, a ward round is logically the equivalent of an out-patient clinic, although there are, of course, obvious material differences.

M. Attendance/admissions completion. The group of procedures or tables, associated with the closure of case-notes after a period of attendance as out-patient or in-patient. We have already seen (p. 45) that these procedures, whilst materially kept as distinct procedures, are logically variants of procedures described under L above and set out in tables grouped under L in Appendix A.

Similarly, groups N, security, O, file and record manipulation, and R, special instructions preparation, have already been discussed (p. 44).

P. Interaction with other systems is a necessarily heterogeneous collection of procedures, some of which, such as Road Traffic Accident Reports, are wholly carried out by records staff, whilst others may involve other departments such as that of the almoner. In some cases, in the system under study, some of the functions carried out by the very small almoner's staff were independently performed by medical secretaries. This did not involve duplication of work.

C. Meta-documentation. The last group to be discussed. Meta-documents stand to documents as do meta-languages to the languages that they describe. Of the two sets of this sub-group, one is formed of procedures 25 to 32 which provide records of other, basic, records. These basic records mirror transactions in the operation of the system. Such procedures are, of course, essential for the over-all control of the system and as such fall into the third of the highest level categories. It is these procedures that provide the essential data for communication between hospital and group (see p. 55) or for communication with Regional Board. There is, however, another important sub-set of these procedures that provide records that are essential for the day-to-day running of large departments, although small departments can do without them. For example, the entries into the file index, table 20, relate patient case-notes which are listed alphabetically to corresponding patient names which are listed numerically. It may well be that some of the meta-documentary tables, for example 57, 59, that are listed under system operation, on material grounds, might be grouped under category II, system control, with greater justification.

III

I now turn to a discussion of the decision tables set out as headings in Appendix A. Whilst we have stated many of these tables fully, it is not possible to illustrate them all in this article. The principles of their construction have been set out in Part I of this article, and two tables are set out in full in Appendix B. I am indebted to Mr. R. J. Stevens, formerly of Middlesex Hospital Medical School, London, and now of I.C.T. Ltd., for his assistance in drawing up many of the tables that we have now formalized.

The first of the two tables is a statement of table 41 of Appendix A for a particular department. In formalizing the second illustrated table, we thought it best to combine tables 44, 45, 49, and 50. The reason for this is that the records activities of this particular department are so arranged that they form a sub-set of the activities of the central records department of the hospital under study, but whilst some departmental activities are effected by central records, others are carried out by one operator who combines the activities of both appointments and records clerks. Incidentally, this illustrates the flexibility of this development of the decision table technique, which makes it simple to combine statements from other tables.

Another feature of the two tables illustrated in Appendix B derives from differences in their semantics that are reinforced by the formal character of decision tabular presentation. The first table contains consequents which only reference other tables. That is to say, none of the consequents describe how an action is performed. Instead, they direct attention to where the description of an action can be found. This is a feature also common to a number of other tables, for instance, 14, 15 and 16 which schedule tasks and allocate priorities. There are two ways in which tabular descriptions can be drawn up in this way. That of example 1 of Appendix B emphasizes the executive status of the table in distinction to the operational status of a table in which actions are stated in such a way as to show how they are performed. Thus, the kinds of tables drawn up in this way are semantically distinct in that they fall into different strata of the operations of the system. This stratification does not necessarily conform to the three levels on which the second part of this article is structured. The second way in which tabular descriptions can be drawn up without containing detailed descriptions of actions is where the analysis is of such a kind that it is only necessary to identify the procedures of a system without describing them in detail. It is not possible to identify procedures without prior knowledge of the system, however, an unfortunate fact that poses considerable problems for the analyst.

In table 55, Q1 indicates a file holding the identifiers of a notional queue. This file is operated upon in tables 57 and 58 or 59 and is transformed into a file recording the expected appearance of patients, files, or laboratory tests. For example, in table 64, store 1 represents the main long-term file, or data set, of the central records department. In paper records systems it has a single physical location. It may be spread about in different rooms or huts but is *the* store. Store 2 represents ephemeral stores set up for specific functions. For example, the case-note folders of in-patients currently on a ward, or of out-patients currently engaged in a course of out-patient treatment. There are very many physical locations for these in the system under study. This dispersal engages a great deal of the time of records staff, particularly table 79, which is a variant of 78, no matter how diligently records staff may operate the file status techniques embodied in table 22. In a paper system, it is all too easy for some member of staff to pick up a file, perhaps even inadvertently, and walk off with it. Despite the fact that this is done for essential medical reasons, it often ensues in a missing file and consequent mayhem.

Table 67, the location of patients for ambulance drivers, is not a records function, and does not appear to be an activity that is officially recognized. Nevertheless, it consumes an inordinate amount of time of records staff.

I am not yet convinced that the separation of the allocation of priorities to requests, tables 15 and 16, should be legitimately separated from the work schedule, 14. We have made only a superficial attempt to analyse these tables so far. There is, undoubtedly, a material difference between an operator scheduling tasks in a work queue and the allocation of priorities to randomly generated requests. However, it may be that the logical equivalence of these apparently disparate procedures should be permitted to override their material dissimilarity.

Table 19, whilst attributed to incoming mail, is in fact constructed, in this analysis, to cover all procedures requiring a check on the flow of transactions and is thus related to tables 75 and 55.

Table 23 provides information for the regional board or group, when it feeds to table 29. It may also provide an unofficial vehicle for keeping medical staff informed of the servicing of their lists.

Table 32 varies widely between different departments from, on the one hand, a highly formalized file holding cross-references to the main index, table 20, and hence store 1, to dependence on the inter-hospital medical grape-vine. It does not apply, presumably, to non-teaching hospitals.

Whilst much of the logical form of the appointments/admissions procedures is common to in- and out-patient procedures, there are, of course, considerable material differences. Table 59, TCI list procedures, differs logically from tables 55, 56, etc., because of the greater degree of medical intervention in allocating priorities.

Table 71, the processing of correspondence, differs materially

```
  O Table   19101 Request%not contact%telephone/document%ministries     19101
A                 etc%aim□□□□ Sort                                      19102
  %CP               Request for appt.                                   19103
       Tgoto  946     Priority, not contact                             19104
       Tgoto  289     Appointments                                      19105
&                       In this case the letter %if any□                19106
&                       requesting an appt. is not shown                19107
&                       to the consultants but an appt.                 19108
&                       is automatically made by records                19109
&                       clerk for the pat. to see Mr.                   1911
&                       XXXXXXXX %always this consultant                19111
&                       □                                               19112
  %CP             Not request for appt                                  19113
  %CP             Request for information                               19114
       Goto  19104                                                      19115
       Tgoto  876      Security, information                            19116
&                       If this is a form on which inf.                 19117
&                       is to be entered the records                    19118
&                       clerk places form in a pending                  19119
&                       file %to be filled in by house                  1912
&                       man□                                            19121
  %CP             Not request for information                           19122
  %CP             Request for document                                  19123
       Goto  19104                                                      19124
       Tgoto  862      Security, document                               19125
  %CP             Not request for document                              19126
       Tgoto  942      Else                                             19127
       Tend  19101                                                      19128
```

Fig. 2

between departments, dependent upon secretarial or medical predispositions about the use of Dictaphones.

I have argued 1. that this decision tabular approach to a hospital records system clarifies the analysis of the system in principle by drawing out its hierarchical structure and directing attention to the distinction between logical and material precepts, and 2. that the decision tabular approach in practice economizes description by making it easier to identify apparently diverse, but essentially common procedures and hence reduce the amount of description, and again 3. that the decision tabular approach, in the form that I have developed, eases the methodology of analysis by simplifying the task of continually up-dating descriptions.

In Part II of the article, I have outlined the results of applying this technique in the present study of the Liverpool Royal Infirmary. In approaching the analysis, I have borne in mind the formal units of one particular simulation technique. The results so far indicate that in developing any fully automated records system, the programming of those modules that control the allocation of priorities and also—depending upon the storage and speed of the configuration—the scheduling of work, may both present considerable problems. There has been no attempt to discuss records procedures associated with pathology and radio-diagnosis, these are dealt with elsewhere in this publication. Consequently, there has been no attempt to discuss problems with which we are all, presumably, familiar: such as the establishment of a correct correspondence between patient, patient-record, and specimen.

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References

1. BURNET, E. H. (1966). *Hospital Industrial Engineering*, p. 416 ff. (eds. Smalley, H. E., and Freeman, J. K., Reinhold).
2. CHAMBERLAIN, JEANETTE (1966). *National Hospital*, 11, p. 19.
3. GRINDLEY, C. B. B. (1966). *Computer Journal*, 9, 124.
4. KING, P. J. H. (1967). Ibid. 10, 116.
5. *The Flow of Medical Information in Hospitals* (Oxford University Press for the Nuffield Provincial Hospitals Trust 1967).
6. BENNETT, A. C., BURGER, E., DEVLIN, M. M., VARNUM, V., STAPLETON, M. E., MARGSAMEN, M., and DAVIS, A. V. *The Admitting System* (United Hospital Fund of New York, 1965).
7. *The Flow of Medical Information in Hospitals* (Oxford University Press for the Nuffield Provincial Hospitals Trust 1967), p. 8.
8. *General Information Manual. Decision Tables. A Systems Analysis and Documentation Technique* (IBM, Technical Publications, 1962).
9. KING, P. J. H. (1967). Op. cit., pp. 135–41.

10. QUINE, W. V. (1947). *Mathematical Logic*, chap. 1 (Harvard University Press).
11. *General Purpose Systems Simulator III*, Introduction (B20-000-01, IBM, Technical Publications, 1965).
12. ANNETT, M. J. M. (1965). *Hospital*, 61, 316.
13. *System 360, Principles of Operation* (IBM A22-682).
14. OPLER, A. (ed.). *Programming the IBM 360*, Appendix D (Wiley, 1966).

APPENDIX A

Over-all system

SUMMARY

	I.	System maintenance.
A		System maintenance.
	II.	System control.
B		System control.
C		Meta-documentation.
	III.	System statistics.
C		Meta-documentation.
	IV.	System operation.
D		File preparation.
E		Taxonomy.
F		Requests—services.
G		Requests—other.
H		Appointments/admission arranging.
I		Attendance/admissions preparation.
J		Registration.
K		Attendance/admissions procedure.
L		Post-attendance/admissions procedure.
M		Attendance/admissions completion (closure).
N		Interaction with other systems.
O		File and record manipulation.
P		Interaction with other systems.
Q		Special instructions preparation.

TABLE HEADINGS

A System maintenance.

1. Engage staff.
2. Study procedures.
3. Change procedures.
4. Order equipment.
5. Train staff.
6. Design forms.
7. Order stationery.
8. Repair/maintain equipment.
9. Trace equipment.

B System control.

10. Allocate clinic locations.
11. Re-allocate work on staff shortage.
12. Re-allocate work on machine breakdowns.
13. Allocate staff functions.
14. Work schedule.
15. Allocate priority to tasks (non-contact requests).
16. Allocate priority to tasks (contact requests).
17. Store tasks in work Q.
18. Search work Q.

C Meta-documentation—(SYSTEM CONTROL).

19. Index of communications (post book, etc.).
20. File index (main index).
21. File index (department).
22. Records tracer file (RT card).
23. Waiting times (Patient Q2 control).
24. Attendance, Record of.

(SYSTEM STATISTICS).

C

25. Statistics, IP/OP (dept. returns to CR).
26. „ Research.
27. „ HAA.
28. „ Cancer registry.
29. „ (CR returns to group).
30. „ (Departmental, for own information).

31. Up-date diagnostic index.
32. Up-date teaching cases index.

D ile and sub-file preparation—(SYSTEM OPERATION)

33. Prepare case-notes file.
34. Prepare appointments record card.

E Taxonomy.

35. Input documentary sort.
36. Output documentary sort.
37. Intra-departmental document sort.

F Requests for services.

38. Initial communication error.
39. Requests, method sort.
40. „ contact, subject sort.
41. „ non-contact, „ „
42. „ contact, pat., aim sort.
43. „ „ GP, BFA, aim sort.
44. „ „ staff.
45. „ non-contact, this hosp., not this dept., aim sort.
46. „ „ „ this dept.
47. „ „ „ other hospital.
48. „ „ „ pat., GP, BFA.

Categories of operations in records systems procedures.

G Requests—Servicing non-appt./admission.

49. Documents, from other hospitals.
50. Treatment, investigation, appointment, information.
51. Send documents to other hospitals, dept.
52. For information, certificates from Ministry of Social Security, solicitors, insurance companies, societies.
53. Medical Staff request (order) treatment.
54. Medical Staff request (order) investigation.

H Appointments/admissions arranging.

55. Add request to appropriate Q1 (after classification).
56. Communicate appointment/admission place, date, time.

57. Cancellation of Q1 (or appointment).
58. Re-order Q1.
59. To come in (TCI) list procedures.

I Attendance/admissions preparation.
60. Enter records (non-medical) in files.
61. Prepare patient identification labels.
62. Find clinic location.

J Registration.
63. Registration.

K Attendance/admission procedure.
64. Arrange for storage of patients in Q2.
65. Emergency procedure.
66. Complete or up-date identification entries.

L Post attendance/admissions procedure.
67. Locate pats. for ambulance drivers.
68. Follow up unkept appointments.
69. Up-date non-medical entries.
70. Up-date medical entries in CSF.
71. Process correspondence.

M (Attendance/admissions completion—special cases of L).
Complete records, 69, 70.
Process discharge letter. (71).

N Security.
72. Case-note security.
73. Document security.
74. Information security.
75. Check integrity of list or Q2.

O File and record manipulation.
76. Search file record procedures.
77. Recover files from store 1, for first attendance.
78. Recover files from store 2, for subsequent attendance.
79. Recover files from clinics, wards, med. secs., etc.
80. Obtain files from outside hospitals.
80.1 Arrange documents, etc. (cf. K).

81. Send files to outside hospitals.
82. Collect (or deliver) documents from (or to) entry (or exit) points.
83. Insertion of sub-files.
84. Re-house case-notes.
85. Store appointees case-notes in store 2.
86. Store files at completion of attendance in store 1.

P Interaction with other systems.

87. Road traffic accident reports.
88. Issue certificates (cf. 52).
89. Arrange non-ambulance transport.
90. Bed bureau.
91. Ambulance transport.
92. Ask other hospital to accept referral. } cf. 71
93. Convalescent homes, obtain places. } cf. 71
94. Local authority housing department. } cf. 71

Q Prepare special instructions.

95. Prepare special instructions.

Abbreviations

BFA	Bona-fide agent.	HAA	Hospital activity analysis.
GP	General Practitioner.	RT	Records tracer.
IP	In-patient.	Q, Q_1, Q_2,	Queues.
OP	Out-patient.		

APPENDIX B

Brief explanatory notes on the syntax

In the first statement of the first table, read as follows:

O = 'Open' table of sub-system number 3, statement 1, system identifier is A followed by sub-system number and statement number.

Statements 2, 5, 6, and 8 are decision table conditions indicated by %CP in this form of the syntax.

Statements 4 and 9 commence with an ampersand indicating comments.

Statements 1 and 11 define the block, module, or sub-routine.

In the second table, there are again block delimiters, statements numbered 98 and 191, decision table conditions, statements numbered 99, 101, 102, 111, etc. As this table has been made up from tables from other systems, the system numbers are 3, 4, 5 or have been left blank. I have left it thus for illustration, although I have an ADP facility for replacing them with a new system number.

Statements 106, 107, 108, and 109 illustrate a facility for breaking down a decision table into subject = %SP, object = %OP, destination = %DP (origin is an exclusive alternant in the syntax), and action = %AP. The convention is adopted that these syntactic constituents of Actions hold until they are restated. Thus, whilst two further actions are stated at statements 117, 118, and 119, 120, 121, these statements do not contain a restatement of the subject because the same subject, that of statement 106, continues to hold for these statements. The subject remains the same until the first line of the statement that encompasses serial numbers 142–5. At serial number 146, in the next action statement, a new subject is stated. % and ampersand are EBCDIC (13, 14) images of BCD codes and result from this listing having been generated by a tabulation programme of the suite of programmes that have been developed and run on a 360/65 handling BCD punched data originally intended for the Liverpool University KDF9.

```
   AO Table    4 98   Request,%contact/not contact%telephone/document%con  A 4 98
A                     sultant/dr.%aim□□□□□ sort                               981
&                                         Orthopaedics consultant/dr.      A 4 982
    %CP                 Request for cancellation of clinic                 A 3 99
   A   Tgoto   3888   Cancellation                                         A 3100
    %CP                 Request for loan of case notes from other hosp     A 3101
    %CP                 Request is contact                                 A 3102
   A   Tgoto   3870   Priority,contact                                     A 3103
   A   Goto    3106                                                        A 3104
   A   Tgoto   3946   Priority,not contact                                 A 3105
    %SP                 Receptionist                                       A 3106
    %OP                   Case notes                                       A 3107
    %DP                     Other hospital                                 A 3108
    %AP                     Telephones                                     A 3109
   A   Tgoto   3948   Work schedule                                        A 3110
    %CP                 Request for referral of pat. to non orthopaedic    A 4111
A                       consultant                                         A 41115
    %CP                 Request is contact                                 A 3112
   A   Goto    3103                                                        A 3113
   A   Goto    3117                                                        A 3114
    %CP                 Not request is contact                             A  115
   A   Goto    3105                                                        A 3116
    %DP                     Consultant/dr.                                 A 4117
    %AP                     Receives                                       A 3118
    %OP                   Patient appointment                              A 3119
    %DP                       Referred dept.                               A 4120
    %AP                     Telephones                                     A 3121
    %CP                 Pat. present                                       A 4122
       Goto    4322                                                        A 4123
    %OP                   Verbal request for pat. appt.                    A 41231
    %DP                       Referred dept.                               A 41232
    %AP                     Makes                                          A 41233
    %OP                   Verbal request for appt. despatch                A 41234
    %AP                     makes                                          A 41235
&                             I.e. referred dept. is asked to              A 41236
&                             send an appt. to the pat.                    A 41237
       Goto    4110                                                        A 4125
    %CP                 Request for referral of pat. to other hosp.        A 4134
    %CP                 Request is contact                                 A 3136
   A   Goto    3103                                                        A 3137
```

```
  %OP          Patient appointment                    A 3138
  %DP              Dept. pat. is being referred to      139
  %AP            Telephones                           A 3140
 A    Goto  3110                                      A 3141
  %SP        Medical Secretary                        A  142
  %OP          Letter containing case details         A 3143
  %DP              Records Clerk                        144
  %AP            gives                                A 3145
  %SP        Records clerk                              146
  %DP              Dept. pat. is being referred to      147
  %AP            sends                                  148
 A    Goto  3110                                      A 3149
  %CP          Not request is contact                 A 3150
 A    Goto  3105                                      A 3151
 A    Goto  3138                                      A 3152
  %CP          Request for information                A 3153
  %CP          Request is contact                     A 3154
 A    Goto  3103                                      A 3155
 A    Goto  3159                                      A 3156
  %CP          Not request is contact                 A 3157
 A    Goto  3105                                      A 3158
  %CP          Information available                  A 3159
  %OP            Information                          A 3160
  %DP               Consultant/dr.                      161
&                      Orthopaedic dept.              A 41611
  %AP               Gives                             A 3162
 A    Goto  3110                                      A 31621
  %OP            Requirement                          A 3163
  %DP                 Note paper                      A 3164
  %AP               Writes                            A 3165
 A    Goto  3110                                      A 3166
  %CP          Request for document                   A 3167
  %CP          Request is contact                     A 3168
 A    Goto  3103                                      A 3169
 A    Goto  3173                                      A 3170
  %CP          Not request is contact                 A 3171
 A    Goto  3105                                      A 3172
  %CP          Document available                     A 3173
  %OP            Document                             A 3174
  %DP               Consultant/dr.                      175
&                      Orthopaedic dept.                1751
  %AP               Gives                             A 3176
 A    Goto  3110                                      A 3177
 A    Goto  3163                                      A 3178
  %CP          Request for case notes                 A 3179
  %CP          Request is contact                     A 3180
 A    Goto  3103                                      A 3181
 A    Goto  3185                                      A 3182
  %CP          Not request is contact                 A 3183
 A    Goto  3105                                      A 3184
  %CP          Case notes available                   A 3185
  %OP            Case notes                           A 3186
```

```
   %DP                     Consultant/dr.                       187
&                             Orthopaedic dept.                1871
   %AP                     Gives                             A 3188
  A     Goto   3110                                          A 3189
  A     Goto   3163                                          A 3190
   %CP               Request is contact                      A  1902
        Goto   103                                           A  1903
        Goto   1907                                          A  1904
   %CP               Not request is contact                  A  1905
        Goto   105                                              1906
        Tgoto  942            Else                           A  1907
  A     Tend   3 98                                          A 3191
```

15

Errors in a hospital record system

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Implication of human error for a machine system

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Errors in a hospital record system

. . . no pleasure is comparable to standing upon the vantage ground of Truth . . . and to see the errors and wanderings and mists and tempests in the vale below: so always that this prospect be with pity and not with swelling or pride. LUCRETIUS *On the Nature of Things*

Defining error

In our previous paper we gave special meaning to the words 'observation' and 'report'. We used the word observation to mean the act of observation and the word report to mean the means by which the observation was communicated to others. If two or more reports are made of observations which there is reason to believe should give rise to similar reports it is often found that these are discrepant. This discrepancy can be given the name 'error'. In this paper we examine some problems of measuring and reducing errors in medical records.

Reasons for measuring error

The study of error, both in terms of measurement of error, and of methods of reducing error has been the subject of concern in all branches of science for a very long time. In financial accounting a complex system of checking by independent auditors has been adopted and is legally required. Yet in medical practice we rely almost entirely on the efforts of individuals to provide their own audit of medical data. Errors in medical reports are seldom discussed, perhaps because methods of reducing the errors have not been available, and have not been the subject of papers until recently (1, 2, 3). The discussion of errors can only improve the accuracy of medical treatment, and will allow new uses for the medical data as its accuracy is improved.

Interpretation of error

We may interpret error in one of two ways. We may feel confident of our assertion that the observations should give rise to the same or similar reports is true, and in this case we regard the errors as mistakes introduced by the recorder. Or we can allow that there may be differences in the circumstances of the observation which we did not or could not measure, and which the reports reflect. Even if we do not wish to explore these differences immediately because they are too small to affect our action, it has been found a profitable exercise to return to the discrepancies later to attempt to find explanations for them. The history of science affords many examples of how beliefs about the nature of things changed as a result of what were first thought to be errors of measurement and where it was later found that the errors derived from true differences in the observations. Whichever of the two interpretations we adopt it is clearly not a trivial matter to examine how errors in medical records may be appropriately quantified as a first step to evaluating methods of eliminating the errors or of revealing true differences.

Existence of a true value

We have suggested that we can approach the problem of detecting errors in reports without recourse to the determination of any true value of the quality observed or the person to whom the quality is attached by merely noting discrepancies in reports of the same observation. Indeed, we may reject the notion that there is any true observation to be recorded unless we accept the platonic view. At other times it does not seem to us to be inconsistent and operationally it may be convenient to regard one particular report as 'true'. In our previous paper, for example, we have taken this view by defining names as those appearing on a birth certificate (or adoption order as appropriate). Alternatively we may use as 'true' the mean value of a series of measurements, a practice commonly adopted in physics. In each type of situation, however, we may discover a number of discrepancies or errors remain.

Quantifying errors

Error can arise from difficulty in distinguishing the thing to be observed as well as uncertainty as to its value. For example, in astronomy an error may involve the confusion of two stars, as well as the assessment of angles between stars. In medical practice error may occur in identifying patients as well as in assessments of height or weight or some other quality about them. Where an observation is quantitative, errors in the report can be expressed in the same units as the measurement itself. For example, a height may be stated as 72 cm with an error of ± 1 cm. This manner of expression is exact and has a clear meaning. But when we come to measure errors in non quantitative parts of reports we are in some difficulty in choosing our units, if we wish to be exact and meaningful in our statement of error rate. For example, should we count the difference of one alphabetic or numeric character in two reports as making them entirely discrepant, or should we count the proportion of characters in error? The children's game of changing 'black' to 'white' letter by letter should make it clear that a single character difference can be important.

Faced with this type of problem we looked to 'information theory' to provide a solution. But we discovered that 'information theory' by definition cannot help in this situation. For as Bar-Hillel (4) has explained '. . . there is no logical connection whatsoever between . . . the amount of (semantic) information conveyed by a statement and the measure of rarity of symbol sequencies . . .' by which means errors are measured in 'information theory'.

Bar-Hillel also explains earlier in the same paper that only complete statements contain semantic information. 'Apples are red', he regards as an informative statement, but not 'Apples are'. There is a similar problem in a medical report where there is inadequacy of identification details of a patient in one report. One report may contain only a surname, while the other to which it is to be compared may contain surname, first forename, and other details. In these circumstances the first report may have to be regarded just as incomplete, and counted separately from otherwise discrepant reports.

Internal inconsistencies

In medical records we are often faced with two further types of problem; in the internal consistency of information within a report, and the comparison of reports containing similar information. If we receive the following message:

Name	Date of birth	Age	Date of observation	Height in cm
Jackson	060160	4	020265	110

This could be regarded as three logically separate reports:

	Name	Quality	Date of observation	Result
A	Jackson	Event of birth	060160	—
B	Jackson	Age	020265	4
C	Jackson	Height	020265	110

We know that there is at least one error in the message for not all these reports can be true but we do not know which logical report is in error. If we then receive a similarly structured message:

Name	Date of birth	Age	Date of observation	Height in cm
Jackson	060160	6	020367	110

we cannot state where the discrepancy between the reports occurs and can do nothing but say that it exists between the two messages. Depending on whether we regard date of birth, age, date of observation, or height to be in error we should arrive at different degrees of discrepancy between them.

Methods of quantifying error in medical reports

Because of this and similar problems we feel that errors in medical records may have to be quantified in three ways. Firstly, we can count errors in terms of the number of discrepant statements or single reports (as defined in the previous paper) found in the record. Secondly, we can count errors in terms of recognizable parts of the reports in error, for it has become clear to us that different parts of a report are observed by different methods and are likely to have different error rates associated with them. Thirdly, for certain special purposes in discussing the reliability of data-processing equipment or methods where meaning is not involved we can count the errors in terms of discrepant characters (5).

If the distribution of character errors were random and unrelated to meaning, then once a character rate were stated giving the likely discrepancy in characters between two reports, and the length of the reports were known, the chances of any two reports being discrepant could be simply calculated. But the assumption does not hold for medical reports which are assembled in a complex fashion.

Obviously the longer the report the greater the chance of error. But it would be unhelpful to say that a whole patient record were wrong if it contained one discrepant character in one report when the total patient record may extend to some thousands of characters. By this index all patient records would be in error and we would have no unit in which to assess any reduction in error we achieved. We feel that a single report as defined in our previous paper, about fifty characters, is not an unreasonable unit in which to measure error rates, particularly if we further subdivide the report into identifying labels and data. (This separation corresponds to the left-hand side and right-hand side of the data collection card, 6REQ, recommended for standard format data collection throughout the hospitals project.)[1] Each of these parts can then be further subdivided into fields.

The report as defined in this manner is not a fixed unit, for as we have pointed out the identification details necessary to identify the patient will vary depending on the size of the population in which he is to be identified. A report for the registration office will be longer than a report for a service laboratory. However, if we adopt the methods proposed in the previous paper of recognizing only two populations for hospital purposes, the hospital special population and the rest, then we are only using two different lengths of report. It is unlikely we shall wish to compare error rates between these two types of report; moreover within the hospital the results

1. See I, 41–61.

often form such a small part of a single report, that differences in the length of say a serum sodium report and a height can be disregarded. As we shall see the present error rate is so high, that we need not concern ourselves immediately with this imprecision. If we succeed in reducing errors in hospital reports to the low levels current in other fields of scientific or business activity, then a character error rate will suffice to measure these low rates.

Problem of meaning and relationship of reports

Whilst this method of approach helps in defining the area for attack in an error elimination programme it does not satisfactorily deal with the problem of the meaning of errors and in particular the relationship between the meaning of two reports which are compared, and from which a deduction is made and acted upon. One illustration of this troublesome problem appeared in the columns of *The Times* for 11 and 12 October (see Fig. 1). If we regard '1946 8000', '1965 18 000', and '1966 27 025', as three separate reports of numbers of deaths from lung cancer (presumably in England and

---

Lung cancer deaths up by 9,025

Polio figures best yet

BY OUR MEDICAL CORRESPONDENT

Cancer of the lung is again the black spot in the annual report of the chief medical officer of the Ministry of Health which shows that in 1966 the number of deaths from the disease was 27,025, compared with 18,000 in 1965 and 8,000 in 1946.

Fig. 1. *a.* Extract from *The Times*, Wednesday, 11 October 1967

Correction

It was incorrectly stated yesterday that 18,000 people died of lung cancer in 1965. This should have read 1956.

Fig. 1. *b.* Extract from *The Times*, Thursday, 12 October 1967

Wales, although this was not stated in *The Times* news item), then only one of the three reports is in error, giving a report error rate of 33 per cent. If we count the characters in error the error rate is 8 per cent. The two characters in error in the news item are certainly more significant than many other combinations of two characters that might have been in error, and the actual error leads to a complete misinterpretation of the situation regarding lung cancer deaths and perhaps with regard to the significance of these in relation to other death rate changes reported later in the same news item (not illustrated). With the set of figures given in error next year's deaths might be predicted as 35 000 (using a parabola). With the corrected figures next year's results may be predicted as 28 000. We have been unable to accommodate this type of problem in our index of error, although we recognize its importance in medicine.

Measuring errors in parts of the hospital system

In attempting to measure the errors that occur in patient records we have divided activity in the construction of reports into four areas:

1. The primary identification of the patient on registration or on readmission.
2. The passage of identification details through a ward or out-patient department, their attachment to a request form or specimen, and the transmission of these to a service department.
3. The receipt of the request in the laboratory and its passage through the laboratory.
4. The receipt of the report of the investigation on the ward and the action initiated on the patient's behalf.

We set out below separate assessments of the current errors in areas 1–3; we have not yet been able to measure the error in area 4.

Errors in the registration of patients

We have examined the reports relating to all patients registered in a three-month period[1] of operation of the computer-assisted registration scheme described in the paper by Dr. K. W. Cross *et al.* (pp. I, 23-39). In order to check the accuracy of the identification details we compared the data collected for patients who were readmitted during that period with that for the first admission in the same period, and recorded the discrepancies. As we shall see it is in that part of the computer-assisted registration procedure which is substantially the same as the previous hand system used that the majority of the errors occur. We can, therefore, regard the errors found as a good estimate of the errors of the previous hand system in this hospital, and in so far as this registration office is typical, as an estimate of errors in hospital manual registration in general. The electronic data-processing equipment makes the measurement of error possible.

All punched cards pass through a validation program on the computer so implausible reports are detected. For example, a male with a maiden name recorded would be rejected by the program, and the card selected from the pack by the computer. A number of errors made in the admission office are detected by this means.

Of a total of 3346 patients admitted in the three-month period July, August, and September, 45 (1·3 per cent) were rejected by the validation program. We have excluded several Sundays where an inexperienced operator produced cards 50 per cent of which were rejected, and for which the punching was repeated.

From those cards which were valid we separated readmissions in two ways. We first sorted the file into registration number order, and examined all pairs of reports which had the same registration number. For each matched pair we examined with a computer program patient details, and printed out discrepant pairs. We then sorted the file into order hierarchically on surname, first forename, second forename, and date of birth. We then examined all pairs of reports for which these details were identical, printing out those matched pairs where registration numbers were discrepant.

1. The first four months were also checked but have not been used in compiling the statistics in the paper lest inexperience in the use of a new system should lead to an excessive error rate, and consequent misleading statistics. However, the results were very similar.

Obviously the file could have been ordered in other ways, but we felt that the extra readmissions found would not have justified the effort. We should point out that a human reader has difficulty in recognizing discrepancies even when presented in this manner, so the use of a program to do the matching is essential.

A total of 3125 patients were admitted during this period (June, July, August), of which 156 had two admissions.

The following table gives the fields which were discrepant in patient admission punched cards. The fields were counted as discrepant if any characters did not match.

Errors in the registration of patients

Name of field	Number of fields in error	Percentage of total pairs examined (156)
Registration number[1]	6	4
Surname	6	4
First forename	2	1
Second forename[2]	21	14
Maiden name[3]	7	5 (35% total possible)
Date of birth	15	10
Total patient admission reports with one or more fields in error	51	33[4]

1. Registration number is the hospital patient record number.
2. In the case of second forename only the first three letters are punched although the operator in fact types the full second forename. An absent name is treated as three blank characters. If recorded on one occasion and not on the second then this was counted as an error. Initial letters substituted for second forename were accepted if this occurred on both occasions.
3. No male, or single woman, can have a maiden name; this would cause rejection of the card by the validation program. Hence the percentage error has also been given in terms of the married female population.
4. The discrepancy in the percentage total arises because some patients have more than one field in error in their registration details.

It is apparent that first forename, surname, and registration number are better recorded than are maiden name and second forename. These latter can be said to contribute negatively to the identification. For example, John Smith may be the same person as John James Smith, but it is not likely to be the same person as John William Smith.

These errors had been typed on the identification sheet, and used for the label on the patient's arm, and for the spirit master prints. We found no evidence to suggest that the wrong case-note folder had been issued to a patient.

Other errors were detected as a result of our search. Six patients had details which were incorrect (not recorded in the above data), but which were corrected by the nursing staff from the Bed State Control Form[1] printed by the computer at the end of each day. The nurses were not asked to correct erroneous entries, and the detection rate they achieved is very low (0·2 per cent); however, it might be improved if they were asked to check details.

A further pair of admission reports in the sample had the same registration number for different patients. Errors of this kind can be detected only where the erroneous number can be paired with a number allocated to a different patient in the same sample. We found a greater number of these in the first sample. We cannot at present assess the frequency of this type of error except that it must be greater than our present measurement of it.

Error in the passage of patient data through a hospital

It is important to establish how far the identification data provided at registration remains consistent in its passage through the hospital. In the face of the known errors at registration consistency rather than 'truth' can be the only criterion. This conforms to the definition of error that we started with, however; and we set out below an assessment of the current degeneration which occurs in the hospital on the basis of the changes found between registration and the arrival of the information at a hospital laboratory. These were convenient points of collection because both registration and a laboratory in the hospital were using a system of electronic data processing, but linkage between them was at the time still by handwritten request forms.

1. See I, 33 above.

Error in handwritten request forms

The basic identification labels specified for person and record identification on the laboratory request forms were:

1. Registration number
2. Surname
3. Initials
4. Age
5. Ward
6. Date

On one day chosen without warning 160 requests made on the service department were examined. Nineteen per cent had all the above identification labels given on the form consistent with the data punched at registration; a further 38 per cent gave all the labels, but with inconsistencies; the remaining 43 per cent failed to give all labels (see table below).

Errors on handwritten request forms

	Requests	Requests with missing identification data	Requests with no missing data but with inaccuracies	Total requests in error
No.	160	69	60	129
%	100	43	38	81

A detailed table of the fields which were in error follows. It refers to the same 160 requests.

Field name	Missing	Incorrect	Total	Percentage
Registration no.	39	2	41	26
Surname	0	9	9	6
Initials	1	79	80	50
Ward	1	—[1]	1	1
Age	26	6	32	20
Date	19	—[1]	19	≥7

1. Could not be accurately assessed

Errors in the service department

We have now established that the input data to the service department using traditional forms are so full of errors that further assessment of the degeneration of data has very doubtful value. However, after processing by the service department reception, we found that 17 per cent of the requests remained consistent with the registration identifying details. Further errors were involved in recording results and 14 per cent of the report cards punched for the original 160 records were complete and accurate. Thus 83 per cent of the reports produced in the service department could not be matched with certainty to the main computer registration file, and a further 3 per cent if matched had inaccurately recorded results, so invalidating the purpose of the matching (see Fig. 2).

Discussion of error rate for the registration system

The error rate in registration seems high from the figures we have presented and one might well ask what is the practical significance of these indices that we have been so careful to compile. Most of the discrepancies seem trivial. A letter wrong here, a date there, occasional missing data, or transpositions. But we have found that on one day taken at random each of 136 (25 per cent) of the total 544 in-patients in the hospital could have been confused with at least one other patient, if the only identifying item of information were surname. Of these 136, five had surname and first two letters of first forename in common with at least one other patient. On another day, with over 500 patients in the hospital 17 were named Smith. And three of the Smiths had their first forename in common. Two of these were on adjacent wards with similar conditions. The degree of redundancy of English language (6), careful checking with regard to critical treatments and special care with patients having common names like Smith (one in seventy-three of the population of the Midlands, it is estimated, has the surname Smith, (7)) compensates for the errors of commission and omission in any identification system. If the criterion of operational significance of an error rate, however, is the ability to link successive admissions in one hospital on a computer, or to provide computer record

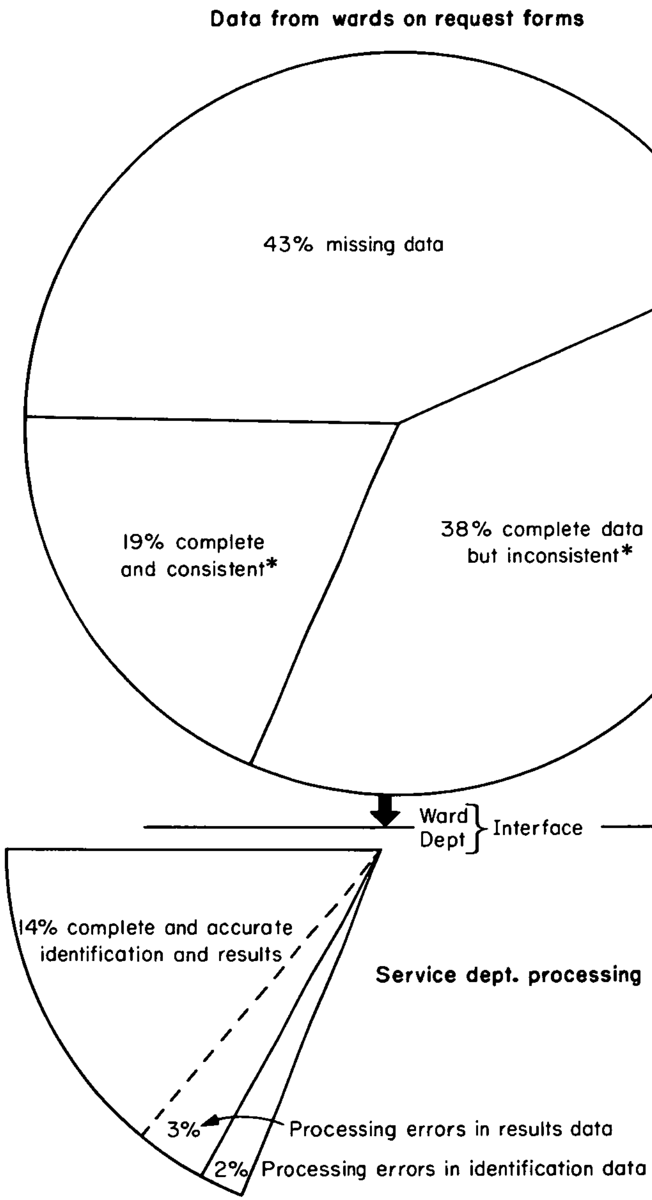

Data from wards on request forms
43% missing data
19% complete and consistent*
38% complete data but inconsistent*
Ward
Dept
Interface
14% complete and accurate identification and results
Service dept. processing
3%
Processing errors in results data
2%
Processing errors in identification data

Fig. 2

linkage with other hospitals, using a perfect match technique on identification details, then at least 35 per cent of matches in the hospitals project would be impossible, or wrong. It has been shown elsewhere (8) that in these circumstances of uncertainty, one is compelled in a research record linkage programme to use the less satisfactory methods of probability matching rather than throw away one-third of the data. If we had to rely on matching by computer in an active treatment situation we would not accept a probability match as sufficient.

Ward and service department

Expressed in terms of errors in identification particulars, 97 per cent occurred between registration and laboratory and very little that can be done within the laboratory is likely to improve this situation.

The majority of these errors will have no effect on the treatment of the patient, but they preclude any attempts at using the records made in a hospital in any other way than to paste them in a patient folder. This analysis, however, immediately demonstrates the importance of developing a data recording and transmission system which provides consistent patient identification data at the point where it is most needed, the ward.

As we demonstrated in the previous paper the traditional method of making out reports and requests in a hospital tends to allow only the writer of the request to be certain of the meaning of the report, he is the only intended 'reader'. In hospitals today we feel that any report should be correctly interpretable by any medical officer in the hospital. For this purpose the error rates we have measured are appropriate to evaluating the failure of the system, and a measure by which we can evaluate improvements. The argument repeatedly put to us that the system is not very inaccurate at the moment is unsound, for many possible uses for the data collected in a hospital are quite impossible under the prevailing error rates, and because of this are not even attempted.

Summary of error rates found

Errors in the traditional hospital information system

	Percentage of reports with one or more errors
At registration	32[1]
Between registration and service department	81
By service department	2[2]
Interpretation of report by ward staff	Not measured

1. In the new registration system a further 1·3 per cent error is produced by the electronic data processing system and a further 1·3 per cent error is detected by the computer validation program.
2. This estimate should be viewed with caution for the reasons given above, p. 67.

Methods of reduction of errors in the registration department

The validation program written by the computer staff detects 1·3 per cent of the errors in registration.

We measured the machine operator error and found errors in 1·3 per cent of registrations punched over one month. These would be eliminated by mechanical verification.

There remains 32 per cent of the reports in error, and obviously we must look for the cause of this in transcription errors of medical records clerks and medical secretaries, and also at the variability of patient testimony of their identification details. We have not yet established the size of the errors contributed from each of these two sources, nor methods of reducing these errors.

It therefore could not be claimed at the time of the study that the electronic data-processing system had substantially reduced the errors in the registration of a patient. It has, however, revealed them, provides some means of reducing them, and shows where the greatest effort in the future needs to be concentrated.

Methods available for reducing errors in the ward

A number of different methods exist already for producing the identification details on a record made on a patient in a hospital.

1. Handwritten forms completed in the ward.
2. Frequently up-dated lists of patients passed to departments by the ward.
3. Master plates for printing on to forms in the ward.
4. Labels for attaching to forms and specimens printed on registration.

Methods 1 and 2 require identification labels to be written down afresh at each identification of the patient. The frequency and difficulty of this process is the cause of the poor quality of the details recorded.

Methods 3 and 4 involve matching an existing accurate record to the patient. This is much easier, but demands that a choice be made between a large number of these plates and labels, and neither is convenient to handle. Each method has been tried with varying success in hospitals, but as methods for computer input they all suffer from the disadvantage of requiring separate key punching for each record, and are not suitable for handling by modern data-processing equipment.

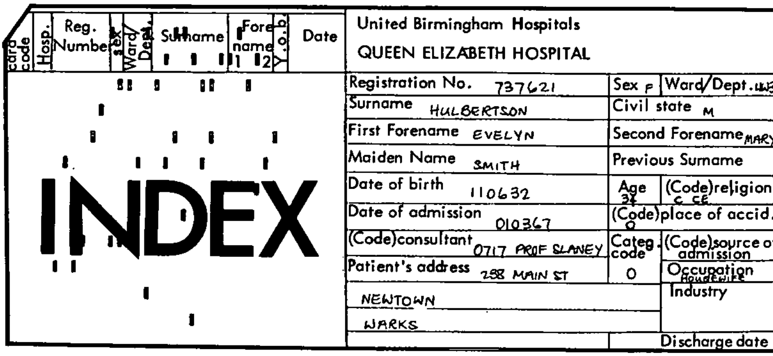
Two electronic data-processing methods

Two new methods are now in use in the hospitals project. In the first method, cards are produced at registration with patient identification details punched and printed upon them. These cards can be used as request forms (see Fig. 3*a*), and can be directly matched with the patient on a ward, or with the forms containing details about him. In this way degeneration of the identification information can be dramatically reduced, only affected by machine copying errors. The cards are easy to handle, can be sorted or printed as is necessary, and at any stage can be matched with the computer in-patient file, and any erroneous cards rejected for hand checking. Furthermore, laboratory results or any other data may be written on and subsequently punched into the remainder of the card (see Fig. 3*b*).

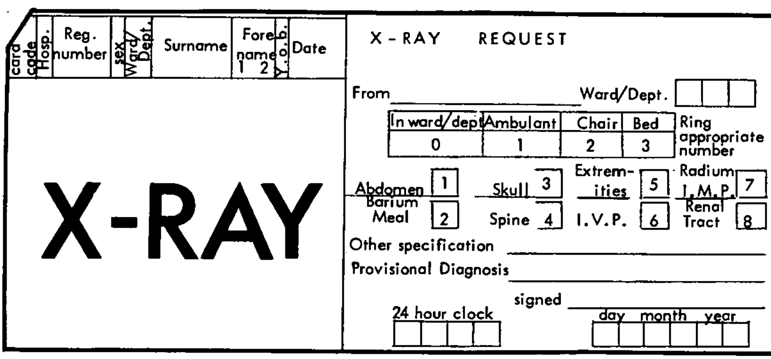
Error rate in 6REQ[1] type cards produced at registration

By means of the validation program written by the central

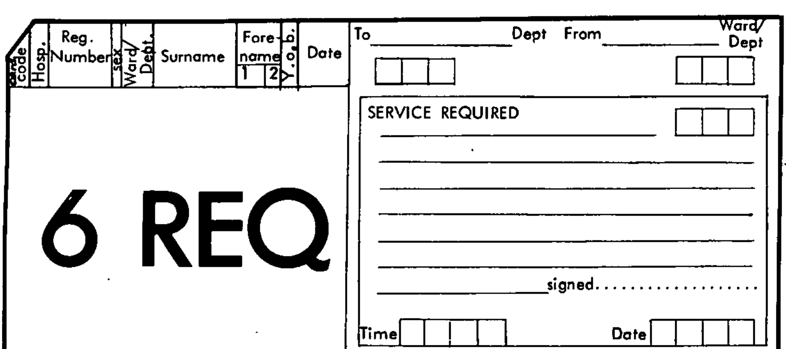
1. See previous paper, I, 23–39.



a. Type 1. Request universal: blood screen



b. Type 2. Request: frequent X-ray



c. Type 3. Request: any test any dept

Fig. 3. (a). Punched cards as request forms

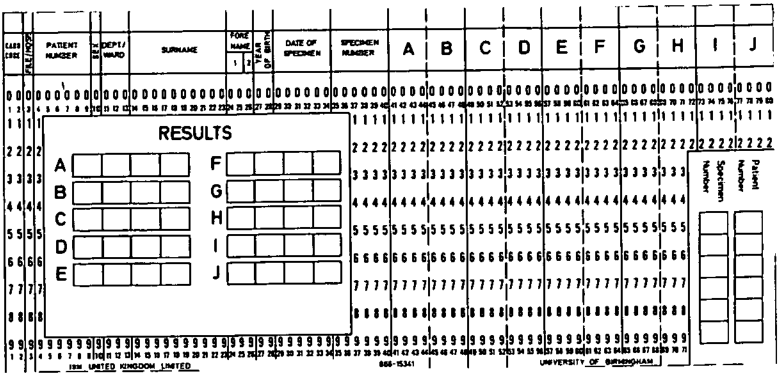


Fig. 3. (b). 6REQ type card for laboratory results to be entered

computing staff we measured the error at registration in the copying of details from the 2ADM[1] card into a 6REQ card using an interpreting card punch. Of 3346 cards, 45 (1·3 per cent) had errors in either surname, initials, sex, or year of birth. As the system develops, more of the 6REQ cards will be used before validation is possible, and other methods of duplicating the 6REQ cards must be introduced, such as an automatic card reproducer.

It is because we have not installed appropriate machinery which can accurately reproduce and interpret large volumes of punched cards that we have been forced to substitute the less satisfactory interpreting card punch. The resulting error rate of 1·3 per cent is almost entirely due to this decision.

Production of computer lists

In the second new method the computer produces lists of patients for the laboratory, ward, and other departments that require them in the hospital. With the Bed State Control Form and the ward bulletins data entries are made directly against the patient's full name and other details. In many ways this is as important a method of identification as is the punched card.

The errors introduced by the computer itself are small and not at present worth measuring. The lists accurately reflect admission details. Between admission we have the error of registration, 35 per cent, within one admission negligible error.

1. See previous paper, pp. I, 23–39.

Other methods using a computer

Mention must be made of two other methods of computer input. The first is punched paper tape and the second the use of computer terminals.

Punched paper tape is a useful medium when data are collected in one place. But medical observations are recorded by many observers scattered throughout the building. Punched paper tape is admirable in a research situation where data are collected in one fixed laboratory, fed into a computer at one time and never required to be read, except by a computer or where paper tape reading automatic typewriter is available. But where a system is being installed to replace a manual system of data collection and processing, as in the hospitals project, the fragmentary nature of the process requires that the medium should be legible to all the readers who must make use of it during its passage around the hospital, transportable, and if advantage is to be taken of peripheral data-processing machinery, readable by that machinery throughout the construction of each individual report. Two years' experience of punched paper tape for the construction of medical records has convinced us that it is not the medium for this purpose.

The second method of computer input that must be mentioned is the use of terminals with particular reference to their possible use on wards. Terminals may employ two methods of input. They may use either a machine and nurse readable medium which must be used to store the patient data (for example, punched card or embossed plate); or the patient data must be entered manually for each report on a keyboard similar to an ordinary typewriter. In both cases the computer may be used to validate the data collected. If all the details were entered manually on an open keyboard it would demand a degree of typing ability beyond that which can be reasonably expected of nursing staff, remembering that even the most junior nurse with perhaps less than six months' experience may be required to enter a report on the terminal. Moreover, the error rate on identification and on data would probably be as high even after validation as that at present found in the hospital registration system.

There are now available terminals which are likely to reduce these errors to a practicable level.[1] Such terminals allow the insertion of standard data by means of a punched card or embossed plate, and variable data may be entered with the help of a series of master overlays and preassigned code keys. We are likely to experiment with the use of terminals in a system being designed for the new maternity hospital due to open on the Centre Site at Edgbaston in mid-1968. Reports from the U.S.A., however, suggest that computer firms have seriously underestimated the software required to support such terminals, especially on third-generation random access machines, and it is unlikely that programs can be written in the short term to provide the necessary file protection and feedback implied by those who have asked for services such as sophisticated error feedback on drug administration (9).

Conclusion

We have discussed the errors that arise in patient identification labels upon registration, between registration and a service department, and within a service department. At registration 35 per cent of the records contained incorrect or missing identification labels; between registration and service department, 81 per cent of records contained one or more inconsistencies with the registration labels; after processing in the service department 2 per cent more records contained inconsistencies.

This measurement took place at the time when EDP equipment had been installed in the registration office and in the service department, while information passed between them on handwritten request forms. This made the task easier and did not depart too far from traditional practice for it to be a reasonable assessment of the accuracy of the traditional system. Whilst the number of inconsistencies remain it is impossible for an EDP system to be developed to provide an information service to the hospital, for within any system it is consistent identification which allows record linkage.

Two new methods of recording patient labels introduced in the

1. It is unfortunate that the computer firms are unable to quote the exact levels of error rate reduction that these devices achieve.

University Hospital's project are discussed, the use of punched cards and of computer printed lists. Their advantage in removing inconsistencies is demonstrated although it is recognized that they do not remove all sources of error.

If we are to introduce aids to processing hospital patient related records we must be certain that we achieve a better standard than was possible by hand filing and processing. EDP methods depart fundamentally from the traditional hospital practice in identifying patients where all the details recorded on a form and remembered by staff are used. It is necessary to acknowledge this fact in assessing the improvement in accuracy provided by EDP methods for matching the patient to a record, as well as in removing inconsistencies between records. The majority of the records in a hospital are filed in the notes on the wards, where the population of patients is very small. In addition the identification method used in a hand method was not only by the use of names and registration numbers. It is highly probable that an optimizing computer program would be better than a filing clerk if they both must use these sorts of data. But identification has been in the past by defining highly specialized populations, and identifying the individual in that population. In a hospital using a handwritten form there will be a great deal of detail which helps limit the population to which the patient referred to could belong; diagnosis, ward, physician, date, handwriting, and so on. It is unlikely that the patient could be mistaken for another with all this additional detail, and if he is, an efficient form filler adds comments such as 'twin 1' and 'twin 2', 'brother'. Also it is probable that the reader of the record would know the patient well and would be aware of likely confusions. It is probable that more trouble is taken to effectively identify each William Smith than each Stefan Ximiner; and that a great variety of source data is used, ultimately always going to the patient and clarifying any doubtful points. If we are to know the operational advantages of EDP equipment we must allow for these added checks that a treatment situation will demand both with an EDP system and without it. For this reason we reject the approach which uses a probable match as a method for EDP linkage within a hospital, for it is in these cases where the probability of match is high that real confusion arises, for example, between relatives, between patients with the same name in adjacent beds or between new-born babies without forenames. In any system added details may have to be given to avoid confusion of these types of cases. But we must always be careful that we do not ask an EDP system to take decisions by probability matching that would never be left to such a doubtful process in a purely manual system.

There are many sources of error in hospital medical records. It is important that in hospital records we recognize there exists the degree of error demonstrated in this paper, and take appropriate action that in other scientific fields has been recognized for a very long time as necessary. Unless we can, real advances in the understanding of change in active treatment cannot be rationally assessed and the potential of EDP equipment at hospital level outside the controlled experiment cannot be fully realized.

The introduction of punched cards as request forms and the use of computer lists of patients' identification to service departments is beginning dramatically to reduce errors from their principal sources. We can now begin to examine the many minor sources of error with more confidence that our time will be usefully spent. In this connection the reflections of a nineteenth-century mathematician (10) on the progress of astronomy in the face of observational error are not without their point for us, 'It would seem in fact that in coarse and rude observations the errors proceed from *a few* principal causes. . . . But when astronomers not content with the degree of accuracy they had reached prosecuted their researches into the remaining sources of error, they found that not three or four but a great number of minor sources of error, of nearly co-ordinate importance began to reveal themselves, having been until that time masked and overshadowed by the graver errors which had been now approximately removed.'

Reliability and accuracy must precede sophistication if we are to achieve any realizable benefits to the patients in the wards. Here is the greatest challenge.

References

1. CROOKS, J., WEIR, K. D., *et al.* (1967). 'Evaluation of a method of prescribing drugs in a hospital and a new method of recording their administration.' *Lancet*, 25 March.
2. HILL, P. A., and WIGMORE, HAZEL (1967). 'Measurement and control of drug administration incidents.' Ibid.
3. SCHOLES, MAUREEN, and WIGMORE, HAZEL (1967). 'Drug error reduced.' *Nursing Times*, 28 April.
4. BAR-HILLEL, Y. (1955). 'An examination of information theory.' *Philosophy of Science*, **22**, no. 2.
5. Midland Gas Board (1966). *Report on Character Recognition*, British Computer Society.
6. RAPAPORT, ANATOL ' "What is information", in Semantic and Signific Aspects of Modern Theories of Communication.' *Synthese*, ix, 167.
7. HOGBEN, L., JOHNSTONE, M., and CROSS, K. W. (1948). 'Identification of medical documents.' *B.M.J.* 1 (April), 632.
8. ACHESON, H. (1967). *Medical Record Linkage* (Nuffield Provincial Hospitals Trust).
9. JACOBS, STANLEY I. (1967). 'Swiftly advancing technology taxes administrative know how.' *Hospitals U.S.A.* (May), Chicago.
10. CROFTON, MORGAN W., F.R.S. (1870). 'On the proof of the law of error of observation.' *Philosophical Transactions* (Royal Society).

16

Automatic coding of a diagnosis

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An example of the problem of mechanical classification

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Automatic coding of a diagnosis

Up to the present time several widely divergent approaches have been made in this country to the problem of storing in a computer and retrieving from it summarized medical records. At one end of the scale is a simple transfer to a computer of data pre-coded to an agreed classification such as already exists on punched cards in many areas and more recently is being collected from all hospitals in Scotland for central processing by the Scottish Home and Health Department. At the other end are the proposals for sophisticated computer techniques of self-generating dictionaries to classify a multiplicity of clinical and pathological observations such as the work being undertaken by the Department of Surgery at the Western General Infirmary in Glasgow (1).

In the Aberdeen project it was decided to develop a relatively simple computer technique which would classify from English language the medical phrases known and recognized as a 'diagnosis' into the numerical system already in standard use throughout the country—the International Statistical Classification of Diseases (2). Once developed, the technique would eliminate all but a very small proportion of the coding routine now done by hospital staff and would facilitate the direct input of a summarized medical report from a ward secretary to a computer as well as making it more readily retrievable when requested.

This article is based on a study that has been made of the problems that had to be resolved before a technique of this nature could be developed and outlines possible methods of overcoming them. The definition of the problems can conveniently be looked at from three aspects: the system of classification; the phraseology of the diagnosis in the medical record; and the most advantageous use of the computer as a link between them.

First, any system of classifying data is based on a set of rules or defined limits for determining each of its classes or codes. The introduction to the International Statistical Classification of Diseases (ISCD) defines the primary purpose of classification of disease data as furnishing 'quantitative data that will answer questions about groups of cases' (2). It points out that the possible axes of classification are manifold—aetiology, site, age, circumstances of onset, and quality of information available on medical reports—and that the published classification represents a compromise between all of these alternatives. The outcome of this compromise is a set of 1526 four-digit code numbers to which may be classified something of the order of 50 000 disease descriptions or phrases. The alphabetical index to these phrases is based on key-words which wholly or partly have an aetiological meaning (for example, abscess or sinusitis). Under sub-headings of these words are listed various qualifying words and phrases relating to site, chronicity, or other discriminants (for example, rectum or acute) which are pertinent to the selection of the correct code number. These qualifying words though also listed at their appropriate position in the alphabetical index carry no code number and the user is requested to first select a word with an aetiological meaning.

This is the classifying system applied routinely by medical and clerical staff to hospital medical records and it would appear at first sight that the existing comprehensive alphabetical index of approximately 50 000 phrases could be stored in a large high-speed computer and the appropriate codes selected automatically whenever a recognizable pattern of words was fed into the machine. The basic assumption underlying this is that the phrases written in the medical records correspond with one of the 'recognizable patterns of words' printed in the alphabetical index.

The first step, therefore, in the study was to examine certain problems presented by the case records to be classified:

(i) To examine the phrases recorded as diagnoses in the medical records;

(ii) To compare them with the phrases recorded in the published classifying index;

(iii) To find some means of measuring differences that occur;

(iv) And to find out how the staff at present overcome the coding difficulties.

In considering computer handling of information, the storage capacity required, and the control programmes needed to operate the machine it is necessary to know not only the size of store needed but also the number and size of patterns of words to be stored and the frequency with which these patterns will be referred to during the coding programme—so that unnecessary searching time is eliminated.

Until this has been achieved it is impossible to assess accurately the feasibility of automatic coding to a standard classification. As a result of the work undertaken in this project a possible scheme for mechanical classification has been developed initially within the confines of a small computer not designed for such work but capable of considerable development with access to the facilities of a more powerful computer.

The object was to discover the extent to which patterns of words in a diagnosis varied not only from the wording of the published ISCD, but also within the framework of each four-digit code. It appeared that instead of attempting to examine case records from all the code numbers the most profitable line of first inquiry would be to obtain a sample of code numbers from the diagnostic index of Aberdeen General Hospitals and analyse a greater proportion of the records classified to the sample numbers. Both the general distribution of cases classified to the seventeen main groups of the International Classification and the ten four-digit categories to which the greatest number of cases had been coded during a twelve-month period were examined. A sample of case records was drawn, as described in the appendix, for the ten most common categories and a list was prepared from the case records of the different phrases ascribed to each code.

Table 1. *Sample of diagnostic index. Aberdeen General Hospitals*

International disease classification	Number of 4-digit codes used in Aberdeen index		Frequency of entries against these codes	
	Number	Per cent	Number	Per cent
I. Infective and parasitic	68	7·0	347	1·1
II. Neoplasm	136	14·0	3924	12·5
III. Allergic, endocrine, metabolic, and nutritional	29	3·0	1123	3·6
IV. Blood and blood forming organs	18	1·9	304	1·0
V. Mental, psychoneurotic, and personality disorders	32	3·3	272	0·9
VI. Nervous system and sense organs	69	7·1	2271	7·3
VII. Circulatory	61	6·3	4257	13·6
VIII. Respiratory	46	4·7	2305	7·4
IX. Digestive	83	8·6	4396	14·1
X. Genito-urinary	46	4·7	3412	10·9
XI. Pregnancy and childbirth	25	2·6	854	2·7
XII. Skin and cellular tissue	56	5·8	418	1·3
XIII. Bones and organs of movement	35	3·6	1244	4·0
XIV. Congenital malformations	29	3·0	253	0·8
XV. Early infancy	—	—	—	—
XVI. Symptoms and senility	78	8·0	2919	9·3
XVII. Accidents	158	16·3	2984	9·5
Total	969	100·0	31 283[1]	100·0

1. The figure does not represent the total number of patients discharged in a year. A number of patients are indexed to more than one condition.

The distribution of cases between the major ISCD groups shown in Table 1 confirmed that the case records of the Aberdeen General Hospitals would not provide data for the whole of the classification system, in fact only 969 out of the total 1526 categories were used to classify these General Hospital cases. The analysis of the ten most common categories, detailed in Table 2, suggested that if the number of diagnostic phrases or 'descriptions' for these codes were representative of all possible codes this would provide a total of approximately 30 000 phrases, as compared with the estimate of 50 000 obtained from the ISCD index. However, at this stage no comparison had been made of the actual wording of the diagnostic phrases with the alphabetical index of the ISCD and it seemed likely that the other factors contributing to the differences in these estimates of the total size of store could be accounted for by the numerous synonyms in the alphabetical index. The need for including a large number of synonyms in the computer store can only be determined by experiment and is likely to vary between general and special hospitals and, indeed, from one area to another.

To arrive at some more tangible results it was necessary to concentrate on a more clearly defined section of the classification. For this purpose the digestive group offered the highest frequency of cases (14 per cent of all cases—Table 1). The more detailed study was therefore restricted to the digestive group. For the purposes of this analysis both tumours and ill-defined symptoms associated with the digestive system were included but diseases of the buccal cavity, codes 530 to 538, were excluded. The frequency of cases coded to this extended group, which will now be referred to as the gastro-intestinal system, was 5220, that is approximately one-sixth of the total frequencies for all categories.

Case records were selected and analysed by the method already described, but in addition punched cards were raised for a more detailed analysis of word content within these records. The actual method is described in the appendix. It was now possible to define more clearly the problems of the corresponding section of the classifying system. In particular an analysis of the size of the 'descriptions' according to the number of words in the phrase that would be needed for a gastro-intestinal dictionary and the possible

Table 2. *Four-digit codes most frequently used in index. Sample of diagnostic index. Aberdeen General Hospitals*

Code number	Frequency of entries against these codes as proportion of all entries in index (per cent)	Number of descriptions covered by code[1]	Total number of words in description	Number of words per description[2]	Number of words[3] per code excluding repetitions of the same word
420·1	3·6	30	98	3·3	19
510·1	2·4	7	16	2·3	8
541·0	2·2	24	82	3·4	20
634·0	1·7	36	93	2·6	33
460·0	1·6	28	127	4·5	20
785·5	1·5	27	104	3·8	36
650·0	1·5	8	15	1·9	7
631·0	1·3	12	42	3·5	15
550·0	1·2	6	14	2·3	8
332·0	1·1	16	56	3·5	21
Total of ten codes	18·2	194	647	3·3	118

1. Description: a word or phrase indicating a diagnosis.
2. Several words are common to more than one description.
3. Several words are common to more than one code.

frequency of referral to phrases of different sizes was undertaken. The results showed that only 2 per cent of the phrases were identical with the standard classification both in respect of individual words and sequence of words. It has to be acknowledged that, in fact, half of these were single words. The individual words of a further 12 per cent corresponded with words in the classification but could not be identified automatically as a phrase without re-ordering the words; 8 per cent of the phrases had words missing which had to be interpreted by the coding clerk from other parts of the medical record. The remaining 78 per cent of the phrases contained words which were extraneous to the classification or words which were not mentioned in the index and had to be interpreted by the coding clerk.

It was therefore impossible to prepare a programme based on the phrase in the alphabetical index without a thorough examination of the sequence of words in these phrases. However, there was no apparent reason why a dictionary of the phrases collected from the case summaries should not be developed, providing, of course, that there was no ambiguity as to which ISCD category they should be classified. This would have a practical application in the present project and would be a testing ground for the use of a computer in this field.

At this point limitations were imposed by the size of computer available. Therefore the automatic coding technique developed is essentially the result of these limitations and in some respects could be simplified if handled by a larger computer.

Within a code number it was found that many of the diagnostic phrases had words in common and very often the phrases were simply a rearrangement of the same words. The individual words for each code were singled out on the record card of that code. For this purpose, individual words were defined as those words which alone or in combination with one or more of the other words on the same card made up the diagnostic phrases classifiable to that code number. These became the key words for the dictionary. Some words are common to phrases classifiable to a variety of code numbers, but by listing in a dictionary each word and all the possible codes in which it occurs, the code for any phrase can be

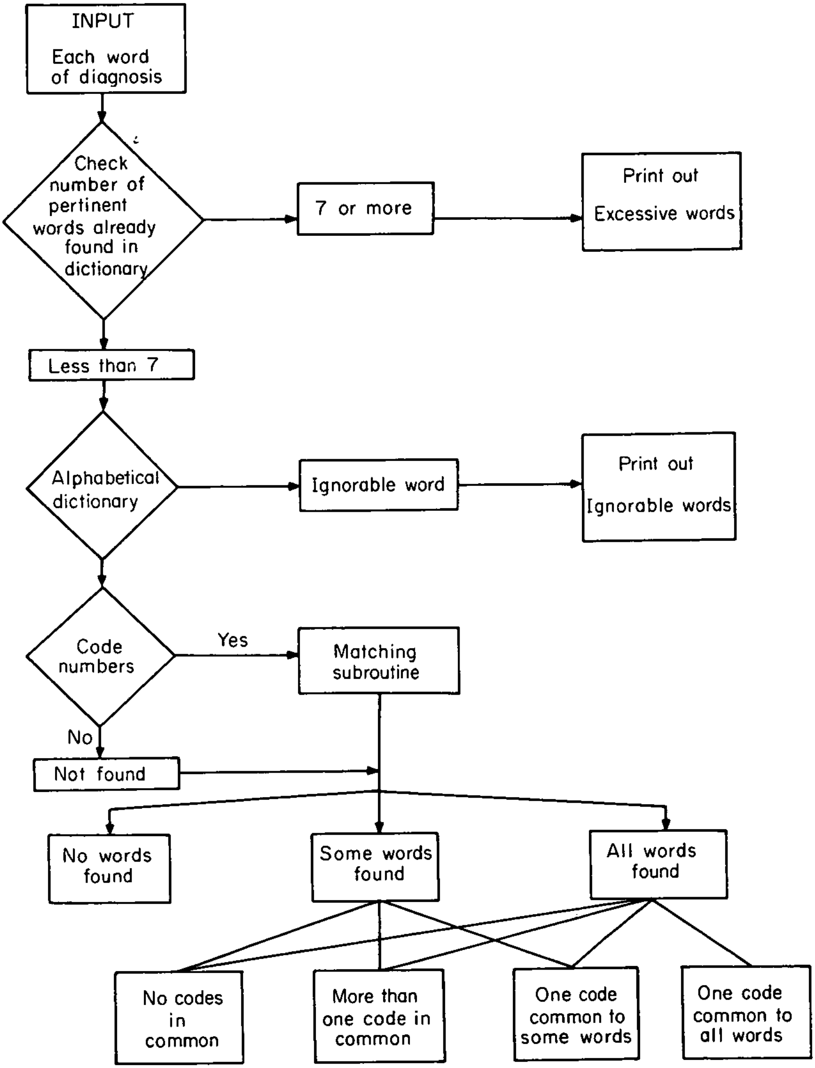


Fig. 1. Flow-chart of matching procedure

selected by finding the code number common to all the words in the phrase. There are some exceptions, mainly 'unspecified' categories, for which special allowance has been made. In the interests of speed, words which are unnecessary in classifying a diagnostic

Words of diagnosis	PILONDAL	SINUS	AND	ABSCESS
Number of codes in store	1	3	0	5
Codes in store	2210	2210		2210
		5740		5501
		5780		5750
				5780
				5870
Resulting OUTPUT	AND ignored			
	ALL words found			
	PILONIDAL SINUS ABSCESS			
	ONE code in common=2210			

a. Success

Words of diagnosis	PILONDLE	SINUS	AND	ABSCESS
Number of codes in store	not found	3	0	5
Codes in store		2210		2210
		5740		5501
		5780		5750
				5780
				5870
Resulting OUTPUT	PILONDLE not found			
	AND ignored			
	SINUS ABSCESS			
	MORE than one code in common 2210 5780			

b. Failure

Fig. 2. Sample of result of matching procedure

phrase are eliminated from the matching procedure. These include articles, prepositions and such words as right, review, investigation, etc. A flow chart of the coding procedure is given in Fig. 1 and it will be noted that only the first six words of a diagnostic phrase are used in the procedure. It seemed unnecessary to allow for more than six because, as shown in Table 3, 99·5 per cent of all the

Table 3. *Gastro-intestinal system related tumours and symptoms. Distribution of the number of words in a diagnosis*

Number of words	Distribution of diagnoses required for gastro-intestinal dictionary (per cent)	Frequency with which these diagnoses are used (per cent)
1	7	14
2	31	44
3	31	24
4	19	11
5	9	7
6	2	1

phrases in the gastro-intestinal records were no longer than six words. Two examples of the automatic coding of a phrase are given in Fig. 2—one successful and one unsuccessful because of misspelling.

Discussion

The application of computer techniques to the automatic coding of medical diagnosis is an experiment in the mechanical interpretation of language. A medical diagnosis in the context of this article is a phrase consisting of one word or several words. This phrase summarizes a series of observations. In its simplest computer terms, therefore, automatic coding of a diagnosis is recognizing and distinguishing between the phrases so that they themselves can be further summarized or classified.

Accuracy in the classification of the contents of any document will be directly proportional to the agreement on the meaning of the words comprising the text. It is too early to attempt to classify the entire contents of a medical record because of the discipline required to reach general agreement on meanings of words and interpretations of observations. While such an achievement may be attainable in a closed and strictly controlled situation it would be difficult to extend the system without redefining its classifications. The International Classification of Diseases tries to provide a system applicable to as wide a variety of situations as possible.

Dissatisfaction with it as a system is frequently expressed and is, of course, the motive in striving for a better method of classification, but the problem lies not in failing to have created the correct classification but in believing that it can be found intuitively. The initial development of a technique of automatic coding of medical information is not concerned with the meaning of phrases nor with evaluating them in terms of the observations which they summarize. It is concerned with handling the differences between the combinations of words in medical phrases.

This difficulty in distinguishing between the practical handling as opposed to the understanding of a classification has caused some confusion in the development of comprehensive computer techniques. The project described in this paper has concentrated on using a computer to handle a standard classification of phrases, which is in itself admittedly inadequate, but which provides a basis for the development of a simple handling technique.

One advantage in using a machine to recognize and classify phrases is that it will be consistent in the decisions it makes. Its memory is for all practical purposes infallible as compared with the human memory which can make mistakes at times of stress or boredom. It can be instructed to recognize and classify only those phrases which it has already stored in its memory and to reject all others. The automatic rejection not only provides information in the early stages about new diagnostic phrases to add to the memory but helps to pinpoint areas of the classifying system where the meaning of a phrase is open to several interpretations—an illuminating experience for the authors of the records.

On the other hand it is argued that the difficulties experienced by doctors in choosing the diagnostic phrase best suited to describe a series of observations can invalidate any subsequent effort to classify the phrase itself. This can lead to the suggestion that it would be preferable to store in a computer's memory the observations on which the phrase was based. This may well be the medical information system of the future but to develop it requires the prospective collection of a mass of observations and the preparation of complex computer-handling techniques which are still in their infancy.

In conclusion, valuable medical and clerical resources are meantime being diverted to perform the simple automatic procedure of coding the diagnosis to a standard classification and this will continue to happen until an automatic procedure is adopted. This article has outlined the problems met in devising such a simple procedure and has described one method of overcoming them.

Acknowledgement

I wish to thank Mr. John Evans, Department of Mental Health, University of Aberdeen, for his helpful suggestions and support in the initial stages of planning the computer procedure.

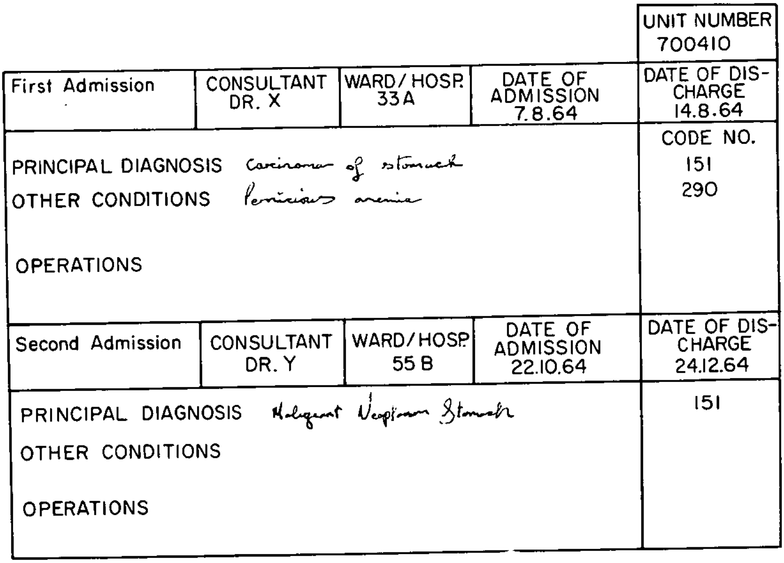
References

1. KENNEDY, F. (1967). Personal communication.
2. World Health Organisation (1955), *Manual of the International Statistical Classification of Diseases, Injuries and Causes of Death* (seventh revision).

APPENDIX

The division headings of the central diagnostic index of Aberdeen General Hospitals are the four-digit categories of the International Classification of Diseases. Up to 1966 this index was maintained on manual record cards. Each year, under the individual four-digit categories, all the cases for that year were listed in chronological order, twenty-eight to a card. A note was made on the case summary sheet in the records folder of the categories to which the diagnosis had been assigned (Fig. 3).

A stratified sample was drawn from the manual record cards by selecting the first six cases from every card in the categories to be studied. This method gave a sample unbiased by seasonal variations and with a better representation of the more rarely occurring diseases than would have been obtained by a strictly random sample. The wording of the diagnosis as written on the case summary sheet was then abstracted from the records folder of these cases. For each four-digit category a special 'descriptions' record card was raised (Fig. 4) on which was recorded the exact wording of all the different diagnostic phrases which were found classified to that category on the case summary sheets. A comparison was then made between the phrases recorded for each category and the definitions for that category as detailed in the ISCD manual and those which were judged to be inadequately specified were deleted, for example, 'perforation' or 'ascites' alone. It was obvious that these inadequate cases had been classified on the basis of information written elsewhere in the case folder than on the summary sheet.



First Admission	CONSULTANT DR. X	WARD/HOSP. 33A	DATE OF ADMISSION 7.8.64	UNIT NUMBER 700410 / DATE OF DISCHARGE 14.8.64
PRINCIPAL DIAGNOSIS Carcinoma of stomach				CODE NO. 151
OTHER CONDITIONS Pernicious anemia				290
OPERATIONS				
Second Admission	CONSULTANT DR. Y	WARD/HOSP. 55 B	DATE OF ADMISSION 22.10.64	DATE OF DISCHARGE 24.12.64
PRINCIPAL DIAGNOSIS Malignant Neoplasm Stomach				151
OTHER CONDITIONS				
OPERATIONS				

Fig. 3. Case summary sheet

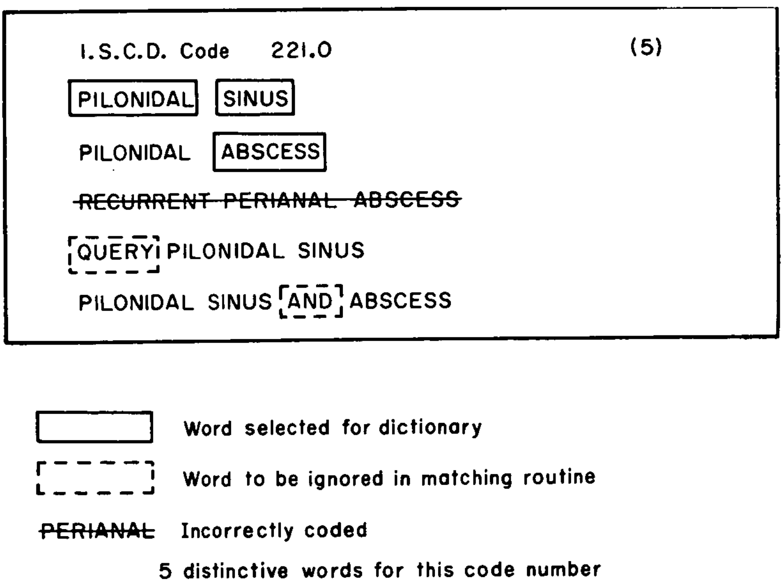


Fig. 4. 'Descriptions' recording card

On each 'descriptions' record card, after exclusion of repetitions, the individual words were ringed and transferred to a pro-forma which detailed the spelling of the word, the number of characters and the four-digit code to which it referred.

At the same time as diagnostic phrases were extracted from the case records, pro-formas were prepared for punched cards for each and every word to enable the preparation of frequency distributions of words used, of the number of characters in the words used and of the number of words in a diagnostic phrase.

17

The economical coding of medical terms

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Another approach to mechanical classification

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The economical coding of medical terms

In this paper, we report progress made with the problem of coding medical terms for use in a medical records system based on a computer. It is important to affirm from the outset that a viable solution to a coding problem must depend not only on the purpose for which the coding is intended, but also on the devices or systems available to process the information being coded.

Ideally, one need not code information at all, and we touch upon this possibility later. We are planning a large information system which will ultimately hold all the patients' records of a large hospital for a reasonable period—five or six years perhaps. We also expect to provide a facility for interrogating the files in a 'conversational mode', that is, a doctor may ask suitable questions and get replies from the computer records almost immediately. The volume of the records, the cost of storage and the problems of man–machine interaction, make some form of condensation and systematization of records almost obligatory.

In the computer store, the fundamental unit of information is the binary digit or 'bit'. These digits are grouped into syllables and words. In the English Electric KDF9 on which we are conducting our experiments, the word in the basic machine language has a length of 48 bits which can be divided into half-words (24 bits), third-words (16 bits), or characters (8 of 6 bits each). There are instructions which allow the programmer to manipulate individual bits or any of these combinations. If the machine could accept say 64 recognizably different symbols—integers, alphabetic characters and punctuation marks—these could be packed as 6-bit characters and the 8-character word then regarded not as a list of symbols but as a number in the radix 64 convertible into any other desirable radix. With a restricted character set, for example, 26 alphabetic characters only, this would allow greater packing, since in radix 64 the most significant digit would always be zero.

In 'fixed-length' working, a definite number of characters or words are grouped into each block. The programmer knows exactly where each group starts. This necessitates the predetermination of a maximum amount of information in each block; if this is exceeded, then the information must somehow be curtailed. Coding of words becomes necessary when the group of characters is fixed since it is possible, albeit rare, to find words of 20 or more letters. To allow 20 would mean wasteful use of storage, whereas to allow only 6 would mean that all words of 7 or more letters have to be condensed.

By adding additional symbols to the set in use to denote 'end of word', 'end of message', etc., one can achieve 'variable-length' working. Every character input is packed successively into the store in a continuous string as on a printed page. Such working avoids the necessity for coding or condensing information but involves the programmer in the task of testing each character to see if it is one of the additional symbols. It excessively complicates the task of picking out individual words, and mitigates against random retrieval of isolated items in the store—a facility which is desirable in the information systems we seek to develop. We seek the smallest fixed-length word we can find, compatible with the need to avoid ambiguity of coding.

Before leaving this necessarily brief account of storage limitations, it is interesting to note that systems have been suggested that use words in full without coding. Human beings do not like to use long words and tend always to shorten them whenever possible. Schwartz (1) records that out of over four and a quarter million words obtained from counting the contents of magazines, the average length was 3·95 letters per word; the 5153 most common words averaged 6·35 letters, and only 38 words, used infrequently, exceeded 12 letters. There is a well-established relationship between the length of words and the frequency with which they are used. This is Zipf's Law which states that if words in a glossary are ranked in order of length and a graph is plotted on log–log paper showing rank against relative frequency an approximately straight line is obtained. Schwartz has investigated Zipf's Law in relation to medical glossaries and finds it is valid for them. Based on this he suggests an information system in which length of word is taken into account in deciding where to store references to it. The shortest and so most frequently used would be on immediate access store, words of intermediate length on quick access stores (drums or discs) and the longest, least-used words on magnetic tape or the slowest accessible storage device.

One common purpose of coding is to impose some logical or systematic structure upon words. Thus there exist internationally accepted 'multifacet' codes for engineering parts. Each facet gives a description of some attribute of the object described. Such codes are widely used in commercial stock-control and production-control systems. They often tend to be longer than the original word itself. Medical terminology is already highly structured. Word endings such as -plegia, -itis, and prefixes such as cardio-, an-, are commonplace and have highly specific meanings. Several terms such as 'alkylosis', 'aneuresis' are built up of stock syllables whose meaning to doctors is obvious. We have carried out extensive investigations of the frequency of occurrence of pairs, triplets, and quadruplets of letters, common affixes and suffixes in medical terms with the object of seeing if we could usefully introduce artificial characters of an extended alphabet so that, for example, an- might become the 27th symbol, etc.

There is no point in detailing these investigations since they can be simply summarized—there are so many recognizable combinations occurring with reasonable frequency that no useful savings are to be made by introducing an extended alphabet or character-set for such combinations.

Another line of investigation which we have tried and abandoned is based on the observation that certain letters occur more frequently than others. For example, in English, E is the commonest occurring letter. We can convert a word to a number by putting A = 1, B = 2, C = 3 . . . Z = 26 treating the result as a number with radix 26 which can then be converted to radix 10. Smaller numbers can be obtained by making the commonest letter equal to 1 and the least common, 26. Even more condensation occurs if we investigate the frequency of occurrence of each letter in each position of the words in a glossary. By suitable choice we can hope to achieve economical codings. However, our investigations indicate that this is not likely to be profitable in the context of the medical information systems we are aiming at. The principal deterrent is that we expect the doctor to communicate with the machine in his own language and make the machine convert the doctor's word to the code form in which the machine retains the information; we find that the necessary conversion routines are expensive both in time and storage.

We have found the most promising results in following up methods of systematically abbreviating words by methods such as those discussed by Bourne and Ford (2), and we will now describe our results in some detail.

We have used 4768 words from the Royal College of Physicians' *The Nomenclature of Disease* in our work. We have ignored spaces, hyphens, and apostrophes, etc., thus BRIGHT'S DISEASE is treated for the purposes of these investigations as the 14-letter word BRIGHTSDISEASE. We have ignored letters after the 24th in any word of 25 or more letters after the removal of spaces, etc. The average word in the glossary is just under 10 letters per word.

We have tested 16 methods. In all of them we treat the letters A–Z as equivalent to the numbers 1–26. (This is a convenience outside the machine; inside a computer this is really irrelevant.) The original word is made up originally of m letters which is to be coded into a word of n letters. The object is to obtain a method of coding which the machine can perform automatically and quickly to give a code word of a fixed length as small as possible without giving an impossibly large number of different words with the same code.

Method 1. Starting from the left, eliminate every second letter and repeat until n letters survive. Thus TUBERCULOSIS first has UECLSS eliminated to give TBRUOI. This has 6 letters and if $n = 4$ we repeat eliminating BU to leave TROI as the code word.

Method 2. Proceed as in Method 1 until $n-1$ letters remain. The letters eliminated are converted to numbers and added up to give a number which has 26 cast out successively until the remainder is less than 27. This remainder, converted to a letter, is added as a check letter to the $n-1$ already obtained. In this method TUBERCULOSIS is reduced to TRO. The eliminated letters are U+E+C+L+S+S+B+U+I = 21+5+3+12+19+19+2+21+9 = 111. After casting out 26s the remainder is 7 or G and the code for TUBERCULOSIS becomes TROG.

These two methods were introduced by Bourne and Ford in whose paper the second method was found to be most effective. We include them here as a basis against which to compare our alternatives.

Method 3. Write down the word in rows, n letters in the first and $(n-1)$ in each of the others until the letters are exhausted. The initial letter is the only letter placed in the first column. Add up the columns as numbers and remove any excess 26s. In this scheme TUBERCULOSIS becomes

T	U	B	E	20	21	2	5
	R	C	U		18	3	21
	L	O	S		12	15	19
	I	S			9	19	
T	H	M	S	20	8	13	19

Method 4. The word is treated as in Method 3 but the column totals are 'carried over' from left to right. Thus the second column total is $60 = 2\times26+8$ so the second letter is H(8) but 2 is carried

to the third column. The revised coding becomes THOT. Any carry from the extreme right-hand column is discarded.

In both Methods 3 and 4 the code word always has the same initial letter as the original word.

Methods 5 and 6. In these methods the columns are of the same length. In 5, the summation follows without carry over to the right as in Method 3, while in 6 carry over is performed as in Method 4. Thus TUBERCULOSIS gives:

T	U	B	E	or	20	21	2	5
R	C	U	L		18	3	21	12
O	S	I	S		15	19	9	19

The total in Method 5 is 1 17 6 10 yielding the code AQFJ while in 6 it is 1 19 7 11 yielding ASGK. The initial letter is not necessarily the same in the original word and the code.

Method 7. Let $m = q \times n + r$. The letters of the original word are formed into n groups, the first r containing $q+1$ letters the rest q. The groups are then summed as in Method 3. Thus TUBERCULOSIS is reduced to a 5-letter code by forming $12 = 5 \times 2 + 2$. There are 2 groups of 3 letters and 3 of 2—(TUB)(ERC)(UL)(OS)(IS) = QZGHB.

Method 8. Omit p letters from the beginning of the original word where p is a predetermined number, provided this does not reduce the word below the desired coded length. Code the remainder by Method 5. If $p = 3$ and $n = 6$, TUBERCULOSIS becomes

E	R	C	U	L	O
S	I	S			
X	A	V	U	L	O

Method 9. Let $m = q \times p + r$ where p is a predetermined number. Drop the first q letters of the original word and code the remainder by Method 5. For $p = 5$, TUBERCULOSIS yields $m = 12$

so $q = 2$. Then the remainder after dropping TU yields for $n = 6$

B	E	R	C	U	L
O	S	I	S		
Q	X	A	V	U	L

Methods 10-16. These are basically the same as Methods 1–7 respectively but with the difference that the number of letters in the original word is added to the last letter of the code word in each.

In all the methods, if the number of letters in the original word is less than the length of the code word, i.e. $m < n$, the original word is extended by using the letters of the original word again: thus if a 6-letter code is required COLD becomes COLDCO which is then coded.

The table on p. 116 gives the results of coding the 4768 words from *The Nomenclature of Disease*. The table shows the number of words which yield repeated codes of lengths 4, 5, 6 letters. We do not give results of 7-letter codes for which none of the methods except 1, 8, and 10 yields more than a few duplications. We see that quite radical improvements can be obtained by small changes in the coding rules. The best of the methods quoted by Bourne and Ford gives 334 repetitions for $n = 4$, our best gives the much smaller result of 54 repetitions in Method 15. Improvement is achieved by lengthening the code word to 5 letters. Bourne and Ford's 334 is reduced to 45 and our Method 15 gives a reduction to 12 repetitions. Our best result for 5-letter codes is only 2 repetitions in Methods 12 and 13. There is no substantial further advantage in going to 6-letter codes.

There is a big advantage to be gained by using 4-letter rather than 5-letter codes in that most computers have word lengths which naturally subdivide into 4 but not 5, so packing information into 4-letter codes is more economical because no part of the word need be wasted. We conclude that using one of our better methods will allow 4-letter coding without undue duplication. Examination

Table. *Number of repeated words remaining after coding from 4768 unique words*

Method	Four-letter code	Five-letter code	Six-letter code
1	951	284	166
2	334	45	12
3	82	8	10
4	83	4	8
5	58	10	12
6	67	10	12
7	106	42	20
8 (1)	134	56	37
8 (2)	290	201	120
9 (8)	77	30	22
9 (10)	64	14	10
10	566	195	124
11	359	56	8
12	88	2	6
13	82	2	6
14	62	8	12
15	54	12	12
16	112	32	12

Note. Number in brackets is *p* (Method 8, p. 114).

of the duplicates shows that many of them occur with words which are very rare diseases, and it might be acceptable to ignore such duplicates, provided users of the system are forewarned that a request for a few specified words might yield information about alternative rare diseases. In the system we are now developing experimentally even this is avoidable.

We envisage an information system in which records are stored in full on magnetic tape, with those of patients actually in hospital held on a large random-access disc. As the records are read into the store key-words which are included in the glossary to be coded are detected and a note of their occurrence is added to a 'term-file' analogous to the index at the end of a book. This term-file is simply a list of the addresses at which the full records containing the key-word are filed. A 'term address file' is used which gives the address in the store at which the term-file for a particular coded key-word starts. The entry in the term address file is one of three kinds. The commonest is a true address showing where the list of records containing references to the key-word starts. The second type is a pseudo-address which is actually the code of a key-word for which the code being inspected is a synonym; this will allow a request for information to be accepted for diseases known by two or more different names. The retrieval programme is arranged to find the address of the term-file for the alternative key-word under which the one asked for is filed. The third kind of entry copes with the cases where two or more different key-words have the same 4-letter code. In this case we use a negative pseudo-address which causes the retrieval programme to re-code the word into a 3-letter code. These are also held in the term address file and the program next consults the 3-letter code entry to find the address of the appropriate term-file. In our best coding system we have not yet found a case in which 4-letter duplicate codes are still duplicates when converted to 3-letter codes. Thus we can achieve unambiguous coding. In the present experimental development of this system we are using the 4-letter code obtained by Method 5.

References

1. SCHWARTZ, E. S. (1966). *Methods of Microglossary Analysis. Data Acquisition and Processing in Biology and Medicine*, vol. 4 (Enslein and Kinslow, eds., Pergamon), pp. 165–78.

2. BOURNE, C. P., and FORD, D. F. (1961). *J. Assoc. Computing Machinery*, 8, 538–52.

18

The medical record and the computer

Part I. The selection of input

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The problem of storing only useful information

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The medical record and the computer

Part I. The selection of input

A case record is compiled to serve a number of purposes. Firstly, it is required for the continuing care of the patient: thereafter it is of value for research, administrative purposes, and medico-legal requirements. However, due to the limitations of present conventional filing systems it has proved difficult to make extensive use of case record data for research or other purposes. Scientific utility implies indexing in depth not just on diagnosis and surgical procedure as is commonly the limit of present systems.

One of the primary motives for applying mechanical or electronic data-processing methods to case records is to make information more readily available for improving the care of the patient, for improving the administrative procedures in a hospital and for research. Such a procedure should result in an improvement in the present quality, legibility and accessibility of information for clinical care purposes. Previous work (Holland *et al.*, 1) has confirmed that a computer could be useful in the handling of medical record data, but it was also quite obvious from this work that the information at present being recorded was not really in a suitable form for highly complex, expensive methods of storage and in addition data were often incomplete and in many cases inaccurate.

There are obviously two main problems in the use of computers in medical record processing:

1. What information is to be stored and what subsequent value has it?
2. How should it be processed?

The technical difficulties of putting information into the computer are being largely overcome and it is now easier to see suitable and simple means of doing this. The first question of what information is to be stored and of its value is harder to solve because it is conceptually more difficult to weight the significance and relevance of data and so decide what has to go in and what has not.

Traditionally the in-patient medical record consists of:

1. A basic sheet with patient identification and chronological information for hospital usage—for example, date of admission, date of discharge, etc.;
2. An initial history and physical examination compiled by one or more physicians attending the patient. This is presented in narrative form with complex organization and is full of syntactic idiosyncrasies;
3. Clinical observations recorded throughout the patient's hospitalization;
4. Therapeutic instructions usually precise in context and in chronological order;
5. Consultation reports comparable to the medical history from the information content point of view but differing somewhat in that they also contain judgements and therapeutic recommendations;
6. Operation reports usually in narrative form except for chronological information and the type of surgery performed;
7. Laboratory data and results of functional tests—for example, pulmonary function studies, electrocardiograms, etc. The laboratory data are usually numerical and well categorized; functional testing data are often complex as they are derived from analogue records;
8. Special reports prepared by hospital departments which provide selective services—for example, radiotherapy, physiotherapy, etc.;
9. A discharge summary which is a final synthesis of the patient's history, examination, course of treatment, and outcome.

Generally, out-patient medical records are constructed separately. A record contains, in addition to identification data, a chronological account of the patient's visits and progress notes written by the physician with indication of treatments provided as well as laboratory test results.

Thus much of both in-patient and out-patient records exist in poorly structured, free language, narrative form. Therapeutic instructions and laboratory results in contrast are precise, concise, and easier to process mechanically. It is obviously possible to put into a computer translatable form most of the narrative record and much work in this field has already been done, for example, Korein, *et al.* (2), Schental, *et al.* (3). But the amount to be processed for each patient is vast and some workers have preferred to record only limited information (Smith and Melton, 4; Bahn, *et al.*, 5) or laboratory data (Jurgens and Rosevere, 6; Smith and Melton, 7). Baird and Garfunkel (8) successfully recorded clinical summaries and laboratory data compiled chronologically but the programme had to be discontinued because of input errors, cost, and lack of data during machine processing.

In Great Britain it is obvious that it will never be possible to store all information that is contained in case records. It is also, of course, questionable whether this is desirable since storage of all information implies that it is all equally valuable. Much clinical information is of little relevance other than at the time that it is collected. An objective evaluation of history and examination data leads one to question much of its precision and value. For example, Cochrane, *et al.* (9) found that four experienced physicians interviewing comparable populations of coal-miners in a pneumoconiosis survey showed considerable variation in history taking. Four symptoms were studied and in three, cough, sputum, and pain in the chest, there was a significant difference in the answers recorded by different observers. Fairbairn, *et al.* (10) found a similar discrepancy in the results from questionnaires for chronic bronchitis. In a study of respiratory physical signs the results of nine observers fell midway between chance and total agreement (Smyllie, *et al.*, 11). Blood pressure measurement is also subject to marked observer bias (Holland, 12; Rose, *et al.*, 13).

Thus no case can be made for recording all information however attractive and simple this may seem. It is, therefore, probable that the only worthwhile approach to the problem of recording case records is to start with the discharge summary. Then only uniform data of practical use need be included and the recording of such data should be relatively easy. An attempt of this method was tried (Bennett and Holland, 14). Information on each patient was coded on special forms which were fed into a Lector photo-electric reading device. The recorded data were then fed directly into the computer. This method was used for six months. Two firms co-operated in the experiment, one medical and one surgical. One Lector form was a general medical sheet for all patients. This contained the patient's identifying details and some general management, diagnostic, and operative details. Space was allotted for recording certain other aspects such as drug allergy. In addition to this general medical sheet, each firm was allowed to include specialized forms containing information of particular interest. Thus the surgical firm which was concerned mainly with genito-urinary surgery designed one form for recording cystoscopy findings and another for details of special investigations. The Department of Obstetrics and Gynaecology designed forms for recording ante-natal and delivery data.

The forms, procedures, and methods devised for the preparation and handling of standard case summaries proved workable, but one of the problems encountered was the difficulty of interesting medical personnel in the procedures. Unfortunately, the lessons propounded by Cochrane, *et al.* (9) in 1951 have not yet permeated the main stream of medical thought. Most physicians still believe that what is written is the truth and must therefore be recorded. It is difficult to persuade them that it is necessary to define exactly what information has lasting value. This is obviously easier in the restricted specialities which have relatively narrow, well-defined limits of interest. General medicine, general surgery, neurology, and orthopaedics do not have these advantages. It is, therefore, necessary to adopt a different approach in order to overcome the difficulty of deciding what information is really relevant for the future care of the individual patient. This it now seems can only be done by experiment and further work is in progress.

To examine the variability of format and content of case summaries, a series of case-notes of patients assigned to the same group of diagnostic codes (ISC 470–527: Diseases of the Respiratory System) was randomly selected. Photocopies of the case histories were distributed to seventeen physicians in different hospitals throughout Britain and the United States. Each physician was asked to write in his usual style a summary of the patient's admission.

An example of variation in style between physicians can be seen in two summaries prepared from the same case history:

SUMMARY A

Male Patient. Age 14. Admitted 7.11.64. Discharged 4.12.64.

Diagnosis. Pneumonia (Staphylococcal).

Present medical history. Malaise, cough, purulent sputum, pleuritic pain in the R. side of the chest for 2 weeks. Failure to respond to oral and parenteral penicillin therapy.

Previous medical history. Asthma for several years with summer exacerbations. No recent asthmatic attacks.

Drug history. Current anti-asthmatic therapy: Orciprenaline 10 mg. bd. daily.

General. Temperature 103 F. Pulse 90/min.

Cardiovascular. B.P. 110/65. Heart sounds normal. No murmurs.

Respiratory. Chest expansion and vocal fremitus normal. There was reduced percussion, reduced air entry and rhonchi present over the right upper lobe posteriorly. There was widespread bronchial breathing.

Progress and treatment. Orciprenaline 10 mg. bd. was continued along with oral penicillin but subsequent to the bacteriological report of a penicillin resistant staphylococcus, erythromycin and novobiocin therapy was instituted. This was supported by vigorous physiotherapy. He responded to this therapy and X-rays showed gradual clearing of consolidation and a disappearance of the abscess cavity which had formed.

Bacteriology. Sputum—Heavy growth of Staph. Aureus, insensitive to penicillin. No AFB in concentrated smears.

Radiology. Chest X-ray—Consolidation of RUL: large cavity with fluid level.

Other. Mantoux tests—negative.

Conclusions and recommendations. This patient's staphylococcal pneumonia responded well to erythromycin, novobiocin and vigorous physiotherapy. At the time of discharge he was well and the radiological appearance of his lungs was satisfactory. He was discharged on orciprenaline 10 mg. bd.

SUMMARY B

Male Patient. Age 14.

Diagnosis. Staphylococcal pneumonia.

This patient was admitted on 7.11.64 complaining of productive coughing for 2 weeks and chest pain on coughing. No response had been obtained with oral and parenteral penicillin prescribed by his own doctor. Past history revealed the presence of summer asthma for the last few years for which orciprenaline 10 mg. bd. was prescribed.

On examination he was febrile with generalized bronchial breathing and added respiratory sounds over the right upper lobe. Chest X-ray revealed consolidation of right upper lobe and a large cavity with fluid level. Sputum culture revealed Staph. Aureus but no AFB.

With antibiotics, antispasmodics and vigorous physiotherapy clinical and X-ray improvement was obtained. The consolidation gradually cleared with healing of the abscess cavity so that he was discharged home on 4.12.64 to continue taking antispasmodics. Mantoux test 1:10.000—negative.

In spite of considerable difference in the form of presentation, the positive content of the two summaries is similar as can be seen from the following extracts:

SUMMARY A	SUMMARY B
Malaise } 2 weeks	Cough } 2 weeks
Cough } 2 weeks	Sputum } 2 weeks
Sputum—purulent } 2 weeks	Chest pain } 2 weeks
R. Pleuritic pain } 2 weeks	
P.H.: Asthma	P.H.: Summer Asthma
O.E.: Febrile 103 F	O.E.: Febrile
Pulse rate 90/min	
Reduced percussion	
Reduced air entry and rhonchi RUL	Added respiratory sounds RUL
Widespread bronchial breathing	Bronchial breathing—generalized
Chest X-ray—consolidation RUL: large cavity with fluid level.	Chest X-ray—consolidation RUL: large cavity with fluid level.
Sputum culture—Staph. Aureus No AFB	Sputum culture—Staph. Aureus No AFB

R.X.: Antibiotics	R.X.: Antibiotics
Physiotherapy	Physiotherapy
Orciprenaline	Antispasmodics
Negative findings:	Negative findings:
B.P. 110/65	
Heart sounds normal: no murmur	
Chest expansion normal	
Vocal fremitus normal	
Mantoux negative	Mantoux 1:10.000 Negative

However, the recording of negative findings is not so similar, and an analysis of the first 150 summaries shows marked variation of practice. Thus cough was recorded positively in 99 (65 per cent) summaries, negatively in 1 (0·75 per cent), and not mentioned in 50 (44 per cent); sputum was recorded positively in 55 (36 per cent), negatively in 12 (8 per cent), and not mentioned in 83 (56 per cent); cyanosis was recorded positively in 36 (24 per cent), negatively in 27 (18 per cent), and not mentioned in 87 (58 per cent); blood pressure was recorded in 41 (27 per cent) and not recorded in 108 (73 per cent). Unfortunately it cannot be assumed that the absence of recording of a symptom or sign implies a negative finding for of the 50 summaries not recording the presence of cough it was present and considered significant in 13; in 87 summaries not mentioning cyanosis it was present and considered significant in 5. In the 55 summaries recording sputum as present only 32 recorded the macroscopic appearance.

This analysis of some common symptoms and signs in respiratory disease only serves to underline that which is already known, i.e. case records and summaries at present recorded are often seriously incomplete. A more important use for these summaries is to establish the basis of a vocabulary of case descriptive terms to be used for case identification and classification. From these summaries it should be possible to choose which items of information are of interest to most physicians for patients with the same group of diseases. It should then be possible to devise standard pro-formas containing this information as a first step and subsequently develop logic flow charts for recording the history and examination. This is obviously looking forward to the time of on-line multi-access computer systems when the physician enters the diagnosis of the patient into the computer and the machine inquires back for the history and different physical signs.

In this way we may ultimately use computers to assist in the long-term collection of valid information about patients, thus improving the general standard of patient care and also making it easier to conduct clinical research.

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References

1. Holland, W. W., De Bono, E., and Goldman, A. J. (1964). *Lancet*, i, 819.
2. Korein, J., Woodbury, M. A., and Goodgold, A. L. (1963). *J. Am. Med. Ass.* 186, 132.
3. Schental, J. E., Sweeney, J. W., and Nettleton, W. (1960). Ibid. 173, 6; (1961), 178, 267; (1963), 186, 101.
4. Smith, J. C., and Melton, J. (1964). Ibid. 188, 958.
5. Bahn, R. C., Schmit, R. W., and Young, G. G. (1965). *Proc. Staff Meet. Mayo Clin.* 39, 835.
6. Jurgens, J. L., and Rosevere, J. W. (1964). Ibid. 39, 818.
7. Smith, J. C., and Melton, J. (1963). *Meth. Inform. Med.* 2, 85.
8. Baird, H. W., and Garfunkel, J. M. (1965). *New Eng. J. Med.* 272, 1211.
9. Cochrane, A. L., Chapman, P. J., and Oldham, P. D. (1951). *Lancet*, i, 1007.
10. Fairbairn, A. S., Wood, C. H., and Fletcher, C. M. (1959). *Brit. J. Prev. Soc. Med.* 13, 175.
11. Smyllie, H. C., Blendis, L. M., and Armitage, P. (1965). *Lancet*, ii, 412.
12. Holland, W. W. (1963). *Epidemiology* (ed. J. Pemberton, Oxford University Press, London), p. 271.
13. Rose, G. A., Holland, W. W., and Crowley, E. A. (1964). *Lancet*, i, 296.
14. Bennett, A. E., and Holland, W. W. (1965). *Lancet*, ii, 1176.

19

The medical record and the computer

Part II. Information analysis

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The problem of making stored information accessible

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The medical record and the computer

Part II. Information analysis

In any system of information storage, methods of retrieval and analysis are also important. In the development of medical records systems it is essential to bear the user in mind.

To communicate with a computer programing languages such as Fortran and Algol have been written to allow the user to write his own programs economically. Unfortunately, even using these languages, writing a program for analysis of any individual investigation is time-consuming. Thus it may take several hours for a programer to write a simple program to analyse and tabulate the presence of, for example, clubbing of the fingers in patients with respiratory disease.

In the first part we have considered methods of medical record storage by computers and have attempted to demonstrate that at least a large part of the discharge summary of patients can probably be recorded in qualitative and quantitative form. Merely to reproduce lists of such items of information, though useful for compiling discharge letters, does not use the capabilities of a computer to best advantage. The computer can, after all, add and subtract—and thus tabulate and perform calculations. Most research utilizing medical records consists essentially of the extraction of relevant items of information, tabulating these and examining associations, survival and results of, for example, a new treatment.

In order to avoid having to write a new program each time an investigator wishes to examine a problem using medical records, a number of general programs have been written and developed. We here give two examples, using as illustrations a prospective investigation in which observations have been made over a period of time, and a prevalence investigation in which observations made at one point in time are analysed. The examples chosen for illustration use records specially compiled for each investigation as we cannot yet use current records!

The first example is the evaluation of the care and facilities in a group of old people's homes. Reports available from the homes included for each person resident in a home during a twenty-six-month period, the date of birth, date of entrance into the home, date of discharge from the home, sex, and whether the individual had been admitted to hospital, experienced a fracture, or died. Information on staff and physical facilities was available for each home. The general method of approach to the problem was to determine whether the rates of deaths, fractures, and hospital admissions were significantly related to the staffing or physical facilities of the homes.

The second example concerns the analysis of data on the prevalence of respiratory symptoms among comparable industrial groups in several widely different geographic areas. A method was required to standardize for possible age and geographic differences so that over-all differences in smoking habits could be evaluated, and conversely, to standardize for age and smoking differences so that over-all geographic differences could be evaluated.

Methods

In order to compare death, fracture, and hospital admission rates in the old people's homes, it was necessary to construct indexes which took into account the differences in age–sex distribution in the individual homes. The method chosen was to apply age–sex specific rates for the entire group of homes to the age–sex specific population in each home to obtain expected numbers which were then summed over all age–sex groups. Ratios of observed to expected numbers were then calculated for each home, and the departure of these ratios from 1·00 was accepted as a measure of the departure of the observed values from the norm. In order to obtain population figures for the calculation of expected values and for the rates, the concept of 'man-years at risk' was used. The entire period covered by the study was twenty-six months, but the individuals at risk may have entered or left a home at any time during the study period. The number of man-years at risk is defined as the number of people at risk multiplied by the length of time at risk (expressed as years or fractions of a year). Thus one-half a man-year at risk might represent one person at risk for six months or one person at risk for two months and another person at risk for four months. In the old people's study, the man-years at risk were accumulated within each of the three calendar years included in the study period and within five-year age groups, by sex. Summed over all homes, these figures were used as denominators for rates based upon observed values in all homes. Summed over each home individually, the figures were multiplied by the rates to obtain expected values for each home.

In order to calculate the man-years at risk it was necessary to determine for each person what fractions of each year he was in the home. These fractions were then assigned to the appropriate calendar years and age-groups. For example, suppose that a 79-year-old male was in a home when the study started on 1 November 1963 and left the home on 31 January 1965. His birthday was 1 July. The table summarizes his contributions to the total man-years at risk.

Year	Age-group	Man-years at risk
1963	75–9	61/365
1964	75–9	182/366
1964	80–4	184/366
1965	80–4	31/365

The man-years at risk method is applicable to any longitudinal study in which individuals may not be at risk for the entire study period, or in which ageing during the study period must be taken into account. 'At risk' must be defined in terms of the context of the specific study. In the old people's study, 'at risk' was defined to mean 'in a home during the study period', first, because the individual was in the environment being studied during this period, and second, because he was at risk in the sense of being under observation so that if a fracture, hospital admission, or death had occurred, it would have been recorded and have been included in the observed values for the study. If a population of mongols was being studied, the individual would have been 'at risk' in the first sense for his entire life, but in the second sense he would have been 'at risk' only if he were under observation so that the occurrence of fracture, hospital admission, or death could have been recorded. If centralized records are available and a computerised record matching procedure in operation, the observed events could be recorded without requiring that the individual be under observation in a special reporting system.

Apart from the labour involved in doing this kind of analysis without a computer, the demands upon clerical accuracy are formidable. In addition, use of a computer guarantees that each case will be treated according to the same criteria and conventions. The development of a computer program to handle this problem required detailed planning and testing as well as documentation to describe exactly what the program does. Intermediate results are printed so that an investigator can see exactly how his own data are being handled and can determine whether incompatibilities between his data and the program will result in invalid results. In the man-years at risk program the print-out includes information from the control cards prepared by the investigator, a table of rates, tables of man-years at risk, expected values, and observed values, and several optional data lists to show how each case is being handled. Examples are shown in the accompanying illustrations (Figs. 1–7).

The study of old people's homes was a longitudinal study of the incidence, that is the *occurrence*, of certain events in a specific environment, and computationally the most difficult part of the problem was the determination of appropriate denominators. The study of the prevalence of respiratory symptoms was a cross-sectional study of the *existence* of certain conditions in a group of people examined at a hypothetical point in time, and the denominator is simply the number of people examined. As in longitudinal

The initial date of the study period is 111 63
The closing date of the study period is 3112 65
The initial age interval is 5 starting with 65 and ending with 99 giving 7 age groups
The initial time period is 1, giving 3 time periods
Each table of expected and observed values consist of 7 age groups, each including 1 of the original groups, and 3 time periods, each including 1 of the original time periods
The basic time period of the study is year
The number of causes of death is 1

Fig. 1. Man years at risk

Data Group 5

Case Number	1071 is not included within study period					
1D	Sex	Birthdate	Entrydate	Lossdate	Status	Cause
1071	1	22 2 69	10 9 156	23 10 163	0	0
Case Number	1554 has inconsistent date information					
1D	Sex	Birthdate	Entrydate	Lossdate	Status	Cause
1554	2	29 8 70	6 2 165	8 12 163	0	491·00

Number of cases read = 58　　Number of cases counted = 55

Fig. 2. Man years at risk

Man-years at risk
Female
Time period code

Age Group	1	2	3
1	0·167	0·	0·415
2	0·688	5·495	6·000
3	0·590	1·669	0·896

Fig. 3. Man years at risk

studies, however, relevant factors not of primary interest must be taken into account before valid comparisons can be made with respect to other factors. The respiratory symptom study was restricted to comparable occupational groups, but they were carried out in several different areas of the United States and Great Britain (Holland and Reid, 1; Holland, *et al.*, 2; Holland and Stone, 3; Deane *et al.*, 4). In comparing the prevalence of symptoms among individuals with differing smoking histories, it was decided to standardize for age and geographic area by using a method analogous to that used in comparing mortality in different geographic areas or different occupational groups. Prevalence rates were first calculated

Data list

ID	Sex	Birthdate	Entrydate	Lossdate	Status	Cause	Entry code	Age	Fraction	Loss code	Fraction
1	2	5 4 80	13 12 157	31 12 165	0	0·	1	83	0·1671	3	1·0000
2	2	12 3 93	23 9 163	31 12 165	0	0·	1	70	0·1671	3	1·0000
3	2	5 3 84	8 9 160	31 12 165	0	0·	1	79	0·1671	3	1·0000
4	2	3 10 81	3 11 161	31 12 165	0	0·	1	81	0·1671	3	1·0000
5	2	28 11 93	24 7 161	31 12 165	0	0·	1	69	0·1671	3	1·0000
6	2	2 2 96	20 6 163	16 12 164	0	434·00	1	94	0·1671	2	0·9577
7	2	23 7 88	11 5 160	21 3 164	0	434·00	1	74	0·1671	2	0·2199
8	2	2 6 88	14 7 162	25 2 164	0	0·	1	75	0·1671	2	0·1516
9	2	4 12 77	27 9 157	25 5 165	0	540·00	1	85	0·1671	3	0·3959
10	2	7 1 79	14 5 162	31 12 165	0	0·	1	84	0·1671	3	1·0000
12	2	17 5 75	1 8 157	14 3 165	0	434·00	1	88	0·1671	3	0·1986

Fig. 4. Man years at risk

Data list of observed values

ID	Sex	Age	Age grp	Time per	Time grp	Cause
6	2	95	4	164	1	434·000
7	2	75	2	164	1	434·000
9	2	87	3	165	1	540·000
12	2	89	3	165	1	434·000
1407	2	79	2	164	1	170·000
1775	2	78	2	164	1	332·000
2806	2	88	3	164	1	434·000

Fig. 5. Man years at risk

Expected numbers
Cause group 1
Female
Summary time period

Age Group	1	2	3
1	0·	0·	0·049
2	0·029	0·769	0·772
3	0·091	0·252	0·118

Fig. 6. Man years at risk

Observed values
Cause group 1
Female
Summary time period

Age Group	1	2	3
1	0	0	0
2	0	0	0
3	0	3	0

Fig. 7. Man years at risk

within age–area cross-classifications for all individuals regardless of smoking history. These rates were then applied to the numbers of individuals within corresponding age–area cross-classifications in each smoking category. Observed to expected ratios were calculated and converted into standardized rates. A generalized computer program had previously been written to calculate specific and standardized death rates and standardized mortality ratios, and this program was adapted for the survey data. In contrast to the man-years at risk programme, which accepted records on individual cases, the rate calculation program required input consisting of

Expected values and standardized ratios

	CGH 0	CGH 1	Ex CGH 2	PHL 0	PHL 1	PHL 2
M						
Observed	247	13	15	235	21	19
Expected	186·208	43·170	45·622	188·024	41·397	45·579
ST ratio	132·648	30·113	32·879	124·984	50·728	41·686
ST rate	897·980	47·200	54·675	852·421	76·662	69·555

Total population for which these values are calculated = 275

Fig. 8. Man years at risk

Standardized rates (direct method)

	CGH 0	CGH 1	Ex CGH 2	PHL 0	PHL 1	PHL 2
M						
Expected	1621·435	78·823	79·742	1529·757	146·039	104·204
Popul	1780	1780	1780	1780	1780	1780
ST rate	910·918	44·283	44·799	859·414	82·044	58·542

Fig. 9. Man years at risk

punched cards giving the numbers of individuals with symptoms and the numbers of individuals 'at risk' in each age, area, and smoking category. These were obtained from output from a generalized tabulating program (Massey, 5). The output of the rates program consisted of tables of numbers, age–area specific rates, observed to expected ratios, and rates standardized by the direct method. Standard errors were obtained for the rates and ratios by hand calculator. Some examples of the computer output are shown in the illustrations (Figs. 8 and 9).

Discussion

Before a computer program is written to solve a specific problem in the analysis of medical data, the need for a generalized program should be weighed against the added cost of writing one. If a few general principles are followed, however, the generality of a program can often be increased at little cost. Although such a program may not be usable by an untrained person, a trained programer may be able to adapt the program to other sets of data relatively easily.

Appropriate documentation is one of the most important principles. This should include program descriptions telling exactly what the program does, how it accomplishes this, and how to use it. Flow diagrams are useful in summarizing the general structure of a program. Comment cards inserted in the program itself can clarify the flow of the program and can be used to define the variable names.

Segmentation of a program can greatly simplify alteration of a program. Input and output should be accomplished by separate sub-routines which can easily be replaced without requiring alteration of the main program. Calculations and manipulation of the data should also be separated into reasonably self-contained sub-routines.

Variable tape names should be used instead of tape numbers both for scratch tapes or data sets as well as for input–output statements to simplify transition from one computer installation to another as well as to allow the user to use his own data tapes. Variable format addresses should be used for input and, in some cases, for output.

Adherence to these principles will not replace the development of truly generalized systems of programs, but should help provide a temporary solution to the shortage of computer software.

All the programs described here have been run on IBM 7090 series computers. Storage requirements may vary according to the amount and complexity of the data being run. In most cases the control cards can be prepared within several hours by an experienced person. The control cards described apply only to the specific examples considered here. Other optional calculations or output are available for some of the programs, in some cases requiring additional control cards. Unfortunately, generality and flexibility of programs is usually gained only at the expense of ease of use.

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References

1. HOLLAND, W. W., and REID, D. D. (1965). *Lancet*, **i**, 445.
2. —— —— SELTSER, R., and STONE, R. W. (1965), *Archs. Environ. Hlth.* **10**, 338.
3. —— and STONE, R. W. (1965). *Am. J. Epidemiol.* **82**, 92.
4. DEANE, M., GOLDSMITH, J. R., and TUMA, D. (1965). *Archs. Environ. Hlth.* **10**, 323.
5. MASSEY, FRANK. Personal communication. XTAB computer programs.

20

The prediction and simulation of surgical admissions

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The provision of a more efficient service to the patient?

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The prediction and simulation of surgical admissions

Introduction

One of the continual problems facing both the nurses and doctors in charge of hospital wards is the efficient use of the beds at their disposal. Perhaps because of the apparent urgency of the problem an undue proportion of the work to ensure effective bed utilization has been concerned with the provision of a sufficient number of beds to accommodate emergency cases arriving during the admitting period covered by particular wards or units. While it must be acknowledged that such admissions represent a substantial variable, both in numbers and in degree of uncertainty, they by no means represent the total problem since few hospitals, or units within hospitals, deal with emergency admissions alone. In determining an effective admission policy it appeared that one way would be to incorporate all types of admissions into the estimate of bed needs. Discussions with ward staff revealed that although some account was taken of the clinical progress of patients already in the ward an arbitrary admission system was used in the majority of units. By and large an attempt was made to keep a consistent number of beds for emergency admissions and by custom a fixed number of waiting-list patients were sent for prior to each receiving day. The rigidity of this method was more noticeable in surgical units where the requirements of optimal operating lists directed the admission policy. Of course, some account was taken of the bed state when sending for waiting-list patients. If the ward was full fewer patients were sent for but such was the delay between the decision to admit and the day of admission that gross fluctuations in bed occupancy occurred. This frequently resulted in what appeared to be a 'stop–go' policy, perhaps more usually associated with faulty predictions in another connection, and although the over-all monthly bed occupancy figures might appear satisfactory, marked daily variations existed. The problem was to maintain or improve bed occupancy and to reduce the daily fluctuations in the figures.

It was hoped that by an examination of the factors associated with length of stay in hospital an estimate could be made of the probability of an individual still occupying a bed on a given date in the future. If this prediction was then related to the number of emergency admissions expected during the intervening period the optimum number of waiting-list patients could be notified at least seven days in advance of their date of admission.

This paper deals with three aspects of the approach to this problem. First, it was necessary to accumulate details about a considerable number of hospital patients and to evolve a system of prediction; the collection and handling of these data are described briefly. Next a simulation of ward admissions based on these predictions was devised. This exercise, which is described in some detail, was initiated for two purposes: to test the accuracy of the predictions and to discover whether it was indeed possible to run such a simulation; initially on simple manually operated lines and then, possibly, in the light of the experience so gained to advance to a more refined technique involving the use of a computer. Finally the practical application of such a system in ward management is discussed.

The collection of data

Following the discussions on the problems of ward management an attempt was made to collect and analyse data that could be used initially in the control of admissions to a surgical ward. From 1963 onwards medical and social details of all patients admitted to one surgical ward were recorded on punch cards. Most of this information was available at the time of admission and, with only a few minor exceptions, is now routinely collected for the Scottish Hospital In-Patient Inquiry.

It was realized that if the scheme was ultimately to be extended to other wards only the most simple and readily available information compatible with reasonably efficient prediction could be used. Part of the problem, therefore, was to effect an acceptable compromise between these two requirements. The associations between the length of time patients had stayed in the ward and various social factors recorded were measured, using the twelve months' admission records then available. In addition the clinical details that could most readily be obtained within a few days of admission to hospital were also scrutinized. On the basis of these preliminary analyses the 1964 records were next used to evolve preliminary 'prediction tables'. At this stage, the only factors incorporated in the calculations were age, mode of referral for admission, and certain diagnostic categories and surgical procedures. It was then decided to test the use of these simple tables before proceeding to design ones of more complicated structure. These later, and more sophisticated, tables are being based on the much larger amount of data accumulated after several years of recording information for the purposes of prediction. It is also hoped that these new tables will provide additional refinements by the incorporation of further parameters and the use of progress notes prepared by both nursing and medical staff. In order to test the operation of the existing tables it was decided that initially a simulation of ward admissions based on these predictions should be undertaken.

The simulation study

Since the basic aim of this stage of the project was to test the accuracy of the predictions it was necessary to simulate the admission and discharge of patients. Although the simulation obviously had to be run on a day-to-day basis it was important that in the early stages the model should be as simple as possible. The daily events that had to be included were the admission of both waiting-list and emergency patients and the discharge of patients already in the ward. The simulation was run manually so that it could be more easily modified in the light of experience. Later, when additional refinements complicate manual operation, the possibility of computer control will be investigated.

A waiting list was constructed from the list patients actually admitted to the appropriate surgical ward during 1964 and 1965. From randomly arranged punch cards details of unit number, age, sex, and diagnosis were printed in a continuous list. Since the average size of a surgical list was approximately 300 this number of patients was used to start the waiting list, and as patients were sent for, the corresponding number were added from the top of the print-out.

In practice the speed of admission for some of the patients classified as waiting list was more like that for emergency cases; for example, those sent to the ward directly, or within a day or two, from surgical out-patients. Such patients could not be distinguished from other list admissions from the information on the punch cards. Investigation of the time on the waiting list for a random sample of 100 list cases for 1964 and 1965 indicated that approximately 200 of these list cases were admitted each year. The admission of such patients was simulated by admitting the person most recently added to the waiting list on four given days each week.

Punch cards for all the emergency admissions of 1964 and 1965 were also arranged in random order. Although the majority of emergencies were admitted on specified days a few were also admitted on other days of the week. Therefore the number of emergency patients admitted on any day was drawn at random from the distribution of the actual numbers previously admitted on the same day of the week.

The simulation was run giving list cases about a week's notice of admission to hospital. Minor cases were admitted on the day prior to operation, major cases two days beforehand. The operating days were assumed to be Monday, Wednesday, and Thursday with emergency admitting days on Wednesday, Saturday, and every third Sunday. Twice a week a prediction was made of bed-state, on Friday for seven and eight days ahead and on Monday for six, seven, and eight days. To determine the number of cases to be brought in off the waiting list, predictions were made of how many free beds there would be in the ward at the time when the patients should be admitted, and the numbers sent for admission were adjusted accordingly. Of course, not all the free beds on a given day are available for list admissions because some must be reserved for the emergencies. The number of beds set aside for these patients was two more than the previous average demand by specific day of the week (Newell, 1). An additional bed was kept free on the four days when an urgent-list patient was to be admitted. In the simulation all list patients sent for were admitted, although in practice a significant proportion cancel their admission. Such a procedure could have been incorporated into the simulation, but as extra patients would have been sent for to compensate it was felt that little would be gained. Patients could also have been cancelled by the ward but this was an unnecessary addition, at this stage, for the purpose of testing the prediction.

The final assumption made in the simulation was that the length of stay in hospital of each patient would be the same as the actual number of days they had been in the ward.

Once the various procedures had been worked out they were combined into a daily routine; although, of course, the normal activity of a ward is not thus neatly partitioned. However, the order decided on was as follows. All those patients in the ward who had completed their actual days' stay were discharged, no account being taken of whether the hospital stay ended in discharge home or elsewhere, or in death. A check was then made of the bed state for comparison with that predicted; this was done in order to test the efficiency of the predictions and was not concerned with the running of the simulation. Next the pre-arranged list patients were admitted. On the days when the predictions were required a list was compiled of all the patients then in the ward, together with the necessary information. Details of waiting-list patients due to be admitted were also added to the list. Figures for future bed states were later returned, on the basis of which patients were selected from the waiting list. As already stated, the random allocation of emergencies was admitted every day and one urgent-list patient on each of four days of the week. At the end of each day the bed state was counted and recorded.

On the day corresponding to the start of the simulation the punch cards of all patients known to have been in the ward at that time were identified. To maintain a flow of list patients during the period before admissions could be brought in on the basis of the first prediction, the actual waiting-list patients admitted during this interim period were also included in the study. Apart from these patients all other admissions to the simulation were made according to the criteria already detailed above. Thereafter a sequence of daily routines was completed and records kept of admissions, discharges, and bed states for comparison with the actual figures achieved by the ward during the corresponding period.

The first seventeen weeks of the simulation have been completed with minor adjustments to the procedure in the ninth and thirteenth weeks. A run of this length was required for several reasons. First of all it took about two weeks for the ward admissions to have been solely determined by the simulation procedure. Secondly, the effect of an unusual set of circumstances affecting bed state may take some weeks to be resolved. For example, if the admissions of several patients with longer than predicted lengths of stay coincide, a series of consecutive predictions will be affected in a way that may well out-last the actual stay of those patients. Running the ward for several months minimizes the risk of drawing conclusions from what might subsequently prove to be a relatively infrequent occurrence. Thirdly, the longer the simulation is run the more realistic the waiting list will become. In the early stages there were relatively more urgent cases than would normally be expected and nearly eight weeks were required to stabilize a list of this size. Fourthly, with a reasonable length of simulation the effect of minor adjustments to procedure could be observed. It transpired that simulated bed state, under inexperienced direction, could also get out of control.

Comparisons were made between the statistics of the simulation and those available for the actual ward performance over a period during which the survey data were collected. Table 1 shows a comparison of admissions and discharges between the simulated and the actual ward performances, the breakdown into list and emergency patients is not given for the actual ward figures because of doubt as to how urgent-waiting-list patients had been classified at the time of admission.

Table 1. *Comparison of admissions and discharges between the simulated and actual ward performances*

	Admissions Waiting list	Emergency	Total	Discharges
Simulated weeks 1–8	182	132	314	313
" " 9–17	196	142	338	334
Total	378	274	652	647
Ward average for seventeen weeks in 1964 and 1965	—	—	616	615

Since the number of emergency admissions was fixed, any increase in the total number of patients admitted by the simulation had to be gained through additional waiting-list admissions. Although a larger number of patients were admitted under the simulation than occurred during a similar length of time in the actual running of the ward, this was due to an excessive number of waiting-list admissions during the fourth to seventh weeks. From the ninth week on the numbers correspond quite well, with 338 admissions and 334 discharges in the simulation compared to averages of 326 admissions and 326 discharges for any nine weeks in 1964 and 1965. The simulation, even in its simple form, was admitting much the same case-load as that borne by the ward in practice. Despite this apparent success the accuracy of the early prediction tables was not as great as had been hoped and these are now being revised.

Table 2 shows the bed occupancy achieved during the simulation. Percentage bed occupancy is the number of beds occupied expressed as a percentage of the possible total. The high figure during the fifth to eighth weeks reflects the overcrowding in the simulation. During the last nine weeks the bed occupancy was 83.5 per cent, which is only slightly higher than the figure of 82.7 per cent actually achieved in 1965 over comparable periods.

The range and distribution of bed occupancy levels in the simulation were also compared with those which occurred in the

Table 2. *Comparison of percentage bed occupancy between the simulated and actual ward performances*

	Percentage bed occupancy
Simulated weeks 1–4	80·4
,, ,, 5–8	90·9
,, ,, 9–12	85·6
,, ,, 13–17	81·9
Ward percentage over a comparable period in 1965	82·7

ward. There were more patients than beds on five occasions during the seventeen weeks of the simulation, but none during the last nine weeks. In 1965 the ward experienced such an overflow on average only once in thirteen weeks. On the other hand, during the simulation daily bed occupancy fell below 75 per cent on only five occasions compared with a figure of twice this size for the comparable period in the ward. The general pattern of bed occupancy is shown in Fig. 1 for both the simulation and for the comparable ward experience.

Discussion

Operational research techniques of this type have seldom been used systematically in ward management. This is partly explained by the absence of quick access to the relevant information upon which decisions should be made. The quantity and utilization of information have never really been explored beyond the immediate and individual needs of the people initiating particular records or returns. Related to this is the division of responsibility between staff in the hospital service; nurses, doctors, and administrators, by training and tradition, all work within separate hierarchical structures. This has led to rigid lines of communication isolating the clinical and managerial responsibility of nurses and doctors from the knowledge and techniques of the professional administrator. Until some means is found of making possible the interchange of

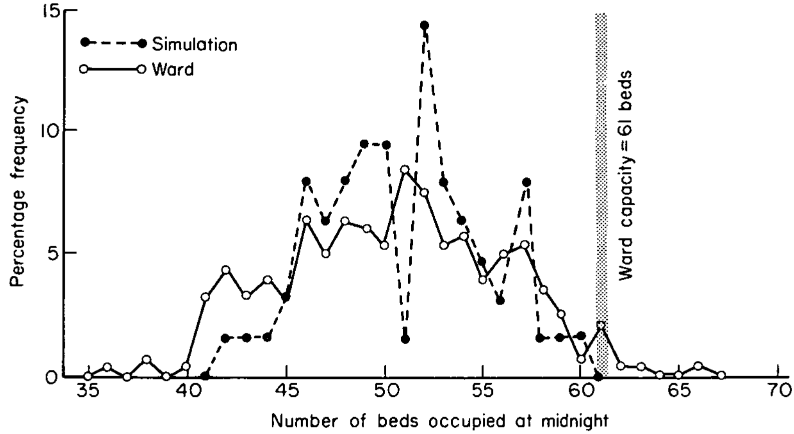

Fig. 1. Percentage frequency distribution of bed occupancy in the last nine weeks of the simulation and in the actual ward experience during a comparable period of 1965

essential information between the different sections of the hospital staff, improvements in patient management and the efficient use of resources will be frustrated. The project described in this paper aims at making better use of existing resources for the benefit of both individual patients and the hospital by the demonstration of operational research techniques.

For this purpose information, easily, quickly, and often routinely obtained, within a short time of admission to hospital, was used to predict the likely length of hospital stay. Since there is, in fact, a limit to the accuracy with which predictions can be made under these circumstances a simply operated scheme, balancing the maximum precision against the least information, is preferable. As a result of the pilot studies, however, it has been decided that the accuracy of the predictions could be improved by the addition of further data. For example, if information indicating an apparent complication in a patient's post-operative recovery were incorporated a further improvement in prediction might be obtained. This decision complicates the data collection; at present both clinical and social data concerning patients are kept on the ward either in the record folder or some similar file until after discharge from hospital. To carry out the predictions at the appropriate stage relevant items of information have to be abstracted or recorded separately. The additional work involved is quite feasible during the pilot stages: this would not be the case if the scheme were routinely to cover a number of wards. Therefore an entirely new recording system is being devised to simplify both the collection of information and the feedback of processed data to the wards. The importance of collating data for these purposes became apparent at an early stage of the simulation. The admission of waiting-list patients in numbers appropriate to the probable bed state at the time of admission is a complex problem and requires careful planning not only for the collection of the relevant information but for its meaningful presentation. During the simulation a special form was designed for this purpose and it is remarkable that in practice wards manage to collate such information without similar aids.

In view of the possible disruption to ward procedure that might be caused during trials of the system, it was decided that before involving wards directly the initial predictions would be made and tested in an experimental situation. The simulation described in this paper is an extremely simple model which is now being developed by the inclusion of additional factors affecting ward management. The preparation of a diary of the actions and decisions required to run the simulation was a useful exercise in determining the information and improvements that had to be added to the system. The intention is to gain sufficient experience on this manually controlled scheme before attempting to incorporate more of the information already routinely collected at various points within the hospital. As this coincides with the installation of new computing facilities in the area an opportunity has been presented of preparing a suite of simulation programmes for demonstrations and training in simple operational research methods applied to hospital management.

Complicated though the writing of even such simple programmes may be and accepting the possibility that the results of simulation experiments cannot always be directly applied, there is still a great need for this type of project. For example, simulations could be run to determine the most efficient sequence of operating, admitting and out-patient clinic days either for a single ward or for a complete surgical division. It appeared during the course of the present simulation that the coincidence of an emergency receiving day with the first of two consecutive operating days did not allow the most efficient use of beds. Although a considerable amount of work in hospital management techniques has been carried out recently, very little has actually been applied within the Health Service. When added to the fact that the major computing developments over the next ten years are likely to be concentrated on treatment aids in the clinical field and on the commercial side of administrative work, the importance of sponsoring continual management studies and their applications becomes apparent.

There is at present an unfortunate and ill-defined suspicion between nurses, doctors, and administrators of each other's motives and objectives in criticizing ward and patient management. Yet it must be remembered that similar anxieties are frequently found in other professions when faced with reorganization and technical innovations. Despite this, these very innovations create the opportunity for representatives of the entire hospital staff to experiment in the development of a team approach to these problems and offer, perhaps, the quickest method of overcoming this prejudice. In such experiments a simulation of hospital problems and a practical demonstration of the results of different actions will allow staff to observe both the range of problems to be overcome in effective ward management and the danger of isolated attempts to resolve these difficulties. Examples such as the choice of operating lists without regard to the composition of the waiting list or the ways in which high bed occupancy figures can mask inefficient use of resources can all be demonstrated by such techniques.

In this way computer applications can contribute directly to improvements in patient care. The importance of this type of approach must not be underestimated; one of the reasons for the slow development of health service organization has been the lack of facilities and purpose in bringing staff together. Projects of this nature which depend upon the contribution of a team help to bridge the gap. The experience afforded of operational research techniques and the opportunity to test adequately innovations before their introduction will greatly speed acceptance of modern management methods in the hospital service.

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Reference

1. NEWELL, D. J. (1954). *Brit. J. Prev. Soc. Med.* 8, 77.

21

The development and implementation of a computer-based hospital information system

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Stages in setting up a computer system

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The development and implementation of a computer-based hospital information system

1. Introduction

In considering the use of the computer as an aid to clinical management in hospitals, it is worth while reviewing the applications that could arise throughout the hospital. The use of any form of aid can only be justified if some benefit accrues in the form of an improvement in patient care, however directly, or indirectly, this arises. At first sight it may appear that the use of computers in hospitals lags behind their use in other applications, but there are two reasons to question this observation. Firstly, there has been delay in many applications because of the failure to realize that the computer has non-calculating abilities and, secondly, there has been little attempt to educate hospital personnel in the possible uses of computers. In these matters medicine does not significantly lag behind other non-numerate specialties.

In discussing the uses of computers in hospitals the preparatory steps will be considered and three areas of operation delineated. Finally a scheme for the implementation in stages of a large computer-based information system will be described.

2. Preparation

It is unlikely that a complete economic justification for hospital computing will be demonstrable but rather that benefit will accrue in many areas, not least by the removal of tedium in the day-to-day work of hospital staff. For example, if facts gathered by one person can be made available to others some saving inevitably results by removing the necessity for the re-collection of the information.

Indirectly this benefits the patient who is spared the frustration of repeated questioning. This is not a new concept as there are already many examples of such savings but a thorough examination of procedures will show if further reductions can be made and it is this process which must be undertaken in hospitals. It is not good enough merely to transfer existing methods on to advanced automated systems as these methods have been developed over a long period to solve problems in a non-automated, or partially automated, environment.

The examination of procedures may be undertaken by a team of people of widely varying disciplines each bringing his own knowledge and experience to a new task—a technique which has its origins in the operational research teams of the Second World War—but it is mandatory that they work jointly with all levels of hospital staff. In this way considerable help is gained from people who have worked with existing procedures and who are aware both of the reasons for these procedures and of any failure to meet the requirements of the patient. Frequently the obvious solution cannot be realized as there is a deficiency of staff, money, or time.

The examination and subsequent analysis of procedures by hospital and computer staff fosters an improvement in education in the needs of patients and the best way to achieve this. Whether a computer is required to implement this solution can be gauged only in this manner. In later paragraphs a range of applications in which a computer may be used are discussed and it is shown how, by building these into a major system over a period of time, unified control results.

3. The computer and communication

The principal commodity passed round a hospital is information and this may be required by one or more people on either a temporary or permanent basis. Some information is of interest to a number of people who require it in different formats or who require only part of it. Such operations are the basis of a message switching system, which would be of considerable use where teletype and visual display terminals could be interconnected to pass large numbers of messages, requests, and facts. This is the first requirement for a hospital computer but, in itself, it requires only the minimum of 'computing power'. Even if editing and multiple addressing facilities are required only the most elementary processor will be required. Such a system provides a distribution network for information but lacks any power to store or originate messages.

The second stage of an information system is provided by the addition of a storage facility to act as a buffer to queue messages for terminals which are occupied at the time of origination. This storage does not need to be high speed in nature and could, for example, be a magnetic drum. No long-term storage is required unless a history is to be maintained for record purposes.

It is unlikely that in setting up a hospital system these two stages would be separated but even when both are implemented the computing power required would still be small. This information system is rudimentary but it reduces both the time spent by staff in distributing information and the multiplicity of inquiries.

4. The computer and administration

There is already some application of computers to administrative problems in hospitals, notably in finance and stock control. These are the conventional applications in commerce and industry and are well developed and documented. Almost no work has been carried out in the control of hospital affairs on a day-to-day basis and, all too frequently, it is found that very little is known about patients and their demands on the services of the hospital until after they have ceased attendance. With knowledge of admissions, discharges, and waiting lists a hospital may be utilized nearer to its optimum capacity than otherwise possible and equipment and services planned accordingly. Much of this information is of use to several people within the hospital—for example, the lay administration and medical social staffs need to share a considerable amount of information already acquired by the records staff. If it is possible to maintain a central file of information about a patient and make it available to all those concerned a considerable alleviation of tedium will result. This is the basic idea underlying the case history, but it is difficult to pass the information around without recourse to copying as the history is always required on the ward, resulting in additional files in various departments. The computer-based information system provides a modern solution to this problem.

The provision of 'hospital statistics' for day-to-day control is a task to which the modern computer system is well matched provided that the required input data can be assembled. The problems of collection are vast and no discussion is intended here other than in noting that the message switching facility previously described will provide basic capture devices. Messages of known format can be intercepted by the computer and information abstracted from them for record purposes.

It is essential to consider the computer as an integral part of the hospital control system rather than an isolated machine. Other elements of the system will involve an efficient form of patient documentation and registration, together with a flexible appointment-booking facility. To avoid as much unnecessary work as possible information regarding identity and requirements of the individual patient must be established as soon as possible after initial contact is made.

5. The computer and retrieval

Two types of computer-based information retrieval system are under development. Firstly, the abstract retrieval type where abstracts are stored and have relevant key-words associated with them. A number of such systems are in use; the best known in the field of medicine being MEDLARS. Arguments can be put forward for storing medical records in this form and preceding each record with a list of significant key-words relevant to the record in question. On searching such a file for one or more key-words only those records containing the appropriate words would be indicated or printed out. No selectivity within the record itself would be permitted and the whole would be printed. The second form of retrieval system is that known as fact retrieval. Here searches are carried out for records containing specific facts in some combination. This permits more detailed searching of records for, in effect, every word becomes a key-word and reasonable, logical combinations of words buried in the record can be identified. This type of retrieval system is currently under development but few satisfactory methods have been suggested. For major research purposes in medicine it is a fact retrieval system which must be developed. Here computer technology is not developed sufficiently for direct application to medical records at this time. However, the information in records themselves is similarly not developed sufficiently since the absence of a finding may be as significant as a stated positive or negative result. For, if no mention is made of some symptom or state this may mean that it was not present, was not found or even that no attempt was made to establish its presence.

In considering the possibility of applying an abstract retrieval system to medical records it should be realized that if sufficient detail is required a vast number of key-words is required. Additionally, if research is to be attempted on sequences of disease it will be necessary to separate key-words into groups—previous illnesses and current illness, for example. If extreme detail is required this could result in the list of key-words approximating to the size of the record.

Some alleviation of the problem is achieved by using fixed-format records in which coded answers are required for every entry. The retrieval, in this case, is straightforward but the form of the record increases considerably the amount of work necessary by the user and diminishes its use as a document for other purposes. The part fixed and part free record format represents a compromise with, initially, some advantages.

The problem of retrieval is a vast task and will require the most sophisticated of computer techniques which, like the files of patient records, must be built up over a period.

6. The implementation—files

To maintain records in retrievable form it is necessary to gather, from many sources, information about patients currently associated with the hospital and make this available to a number of people. The access to these records must be controlled for ethical reasons and this raises a security problem. By structuring of record files, a task ideally suited to modern concepts of file handling by computer, this is readily undertaken. It is comparatively easy to ensure that information, designated as available only to a certain class of people, will be far more difficult to obtain illegitimately from computer files than from conventional paper files. The problem of identifying legitimate users is already well known and is not unique to hospital systems.

An 800-bed hospital generates files of considerable magnitude and with approximately three-quarters of a million case histories the master index alone will occupy about six million words. The diagnostic index for such a hospital could be about half this size. These two files must exist from the start of any computer system whereas the main files of case history details are unlikely to be converted *en masse* if only because of the magnitude of the task.

It is convenient to consider the implementation of a patient record file structure consisting of four groups of files:

1. Index files—typically, the master index and diagnostic index
2. Files relating to the current population associated with the hospital
3. Files relating to people who have recently been in attendance
4. Main history files of all past attendances

Some definitions of terms are required at this stage. By 'current population' is meant all those known to be coming to hospital in the immediate future, actually in hospital or attending clinics and those recently discharged—both in-patients and out-patients. By 'recently in attendance' is meant those who have been discharged more than two weeks and less than some period (possibly a year) to be determined by experience.

To illustrate these groups consider the necessary actions when a patient is to be admitted as an in-patient. He is identified through the master index and his last discharge date identified. File store 3 or 4 is then searched for his case history and transferred as necessary into file 1. It is then available for use as needed.

By a structure as outlined above it is possible to use differing classes of storage of varying access time and to move records from one to the other without any urgency—except in emergencies. For the day-to-day operation of the hospital it is necessary only to use files 1 and 2 and thus avoid the tremendous search times required in files 3 and 4. File 4 and, to a lesser extent, file 3 need only be searched for updating purposes and research investigations and access can be controlled as required. In determining the structure within the files work is being done to establish the preference for storing complete files by patient or by specialty. In file 2 it is probable that the various sections of a patient's record will be stored 'separately' and, in files 3 and 4, that entire records will be held as a series of complete episodes. By segregation of the record, during attendance, in various areas of store it is possible to limit access by utilizing the file structure itself. The editing required on discharge is not significant as it is probably outweighed by that required to eliminate detail that will not be required on subsequent readmission.

For research purposes or simple occurrence queries it is probably necessary only to search files 2 and 3. A complete search of file 4 would be a large undertaking and before accepting such a request all other methods would have to have been attempted. More detailed discussion of the permitted searching techniques and the magnitude of searches to be attempted will result from the completion of further work.

7. The implementation—computer or computers

In previous paragraphs discussion has been made of three stages in the development of a computer-based hospital information system:

1. A simple communication facility using typewriters and an extension of this to include some storage in case any terminals are in use when a message 'arrives'
2. The development of record files by the abstraction of information from suitable communication messages
3. Access to record files at their various levels to provide search and retrieval facilities

For simplicity in both software and hardware, all these facilities should be available from a single system and it is probably not acceptable that there should be two separate types of terminal—one

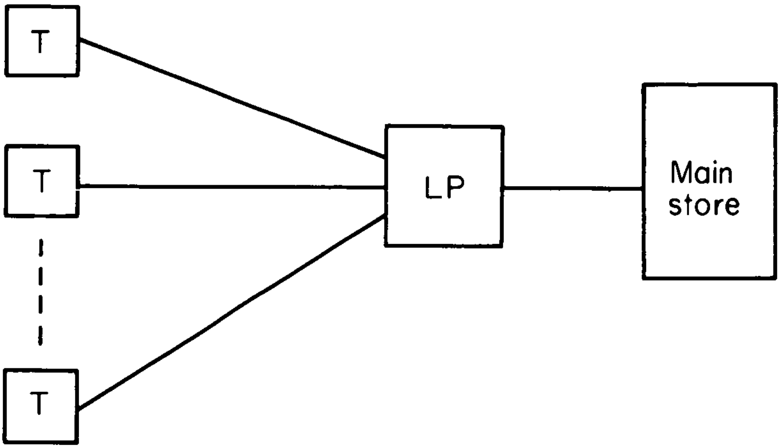

Fig. 1. Single processor
T: Terminal SP: Small processor LP: Large Processor LS: Local store (duplexed)

for communication and one for retrieval. Such a system will appear as in Fig. 1, although a number of interface devices, such as modems and multiplexors, have been omitted for simplicity.

From an operational point of view, however, there are advantages in developing a system based on that shown in Fig. 2. Here a two-processor complex is shown without any shared storage, and the large processor behaves as a peripheral to the small processor. By communicating processor-processor very high speeds can be obtained relative to those obtained using the system shown in Fig. 3, where access is provided via the small processor local store. It is arguable that the latter system has the advantage that in the event of failure of the small processor the large one can take over the control of all terminals. This will lead to some complex software and hardware switching problems which appear not to be justified, in view of the second requirement in the next paragraph.

Fig. 4 shows the combination which seems most promising on reliability and simplicity grounds. It is identical with Fig. 3 except that the large processor is linked direct to the small processor and not to its storage.

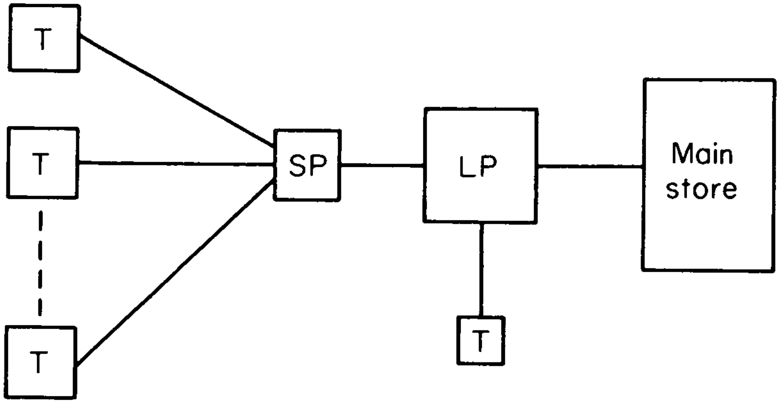

Fig. 2. Double processor

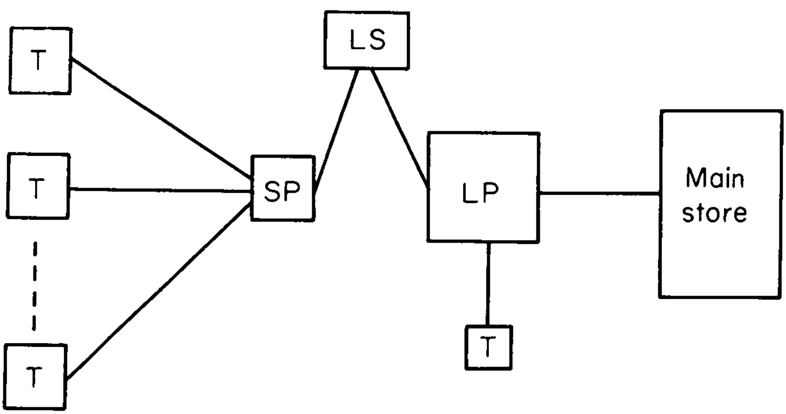

Fig. 3. Common store double processor

There are two factors which arise in hospital applications which have special relevance here. First, modern administration would appear to intend to provide a service throughout the hospital from 9.0 a.m. to 9.0 p.m. and it would appear that computer operating staff are going to be difficult to find who will work outside these hours. Secondly, it is not permissible to have a computer blackout

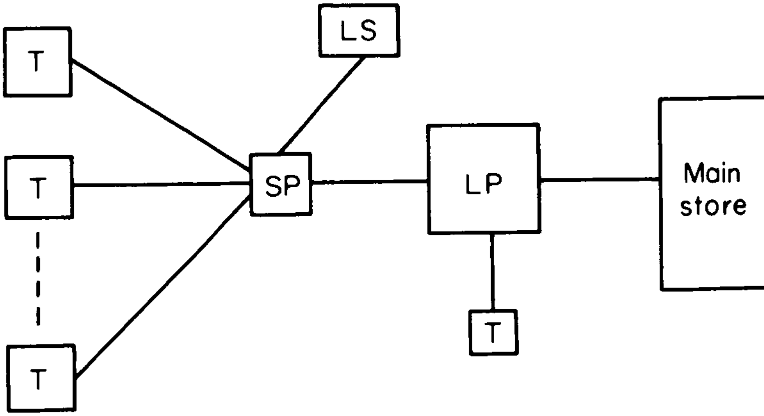

Fig. 4. Local store double processor

on any but the most rare occasions. These conditions lend weight to the arguments in favour of a two-processor system:

1. A small and very simple unattended process-control type local computer run on a twenty-four-hour basis. This machine should have a disc or drum for message storage and this should contain the main patient master index. In the event of a storage failure this would cause loss only of message storage facilities and access to the master index. This could be avoided by duplication of the store. By using micro-miniature components it is unlikely that processor failures will occur except exceedingly rarely and duplication here is superfluous. Terminals on this machine would be either teletype or visual display.
2. A large computer with very large long-term storage devices probably including drum, disc, and tape stores. This machine can be run on a restricted time-scale and is thus easily maintained and complex terminals can be linked to it directly. When breakdown of this large computer occurs the small one will store requests for transmission on resumption of service, and it will appear to the inquirer that there is a delay in answering queries. Failure messages can be

provided by the small computer and routine communication between terminals will continue undisturbed.

This two-processor system will provide a continuous communication service together with access to all the files held on the main machine.

There is considerable scope for investigation into the use of simple satellite computers elsewhere in the hospital but it is essential that these should have only elementary stores and be operated unattended.

Although the main computer can be operated either off-line or on-line, it is assumed that on-line conversational techniques will be used. This permits of simple satellites and a good fast service oriented to the user's requirements. It removes from the user the difficulties of programming and the necessity of remembering long strings of procedural operations.

8. Summary

The development of a computer-based hospital information system could proceed in four stages.

1. Provision of a reliable communication system together with some elementary operations—maintenance of master index, say.
2. Provision of limited off-line computer services in many areas, input being prepared via the communication computer.
3. Upgrading of the main computer service to a small on-line multi-access system.
4. Expansion of main computer to handle very large files resulting from initial working.

The rate of development is, of course, difficult to suggest except in particular cases, but stage 3 should be achieved within a few years of commencement of investigatory work in a hospital and subsequent progress should consist of specific jobs being developed and tried out via stages 2, 3, and 4.

The next ten years?

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Priorities for progress

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The next ten years?

During the past ten years numerous papers emphasizing the potential of computers have provided convincing evidence of the need to apply these techniques in medicine. As with the promotion of any idea, a certain excess of enthusiasm and a tendency to exaggerate are both understandable and permissible. But there is a danger that the theoretical presentation, as in other areas of computer development besides medicine, has far out-paced the practical applications. Somehow, this gap must be bridged and the quickest method would be to theorize less and experiment more. Despite this injunction it would appear that to predict the advances of the next decade it is necessary, as a first step, to list the problems that must be overcome in medical computer applications and then to estimate the extent to which these will have been solved in ten years' time. In trying to answer this question a number of quite distinct groups of problems can be identified.

a. First there is the need for non-complex information about computers and for acceptance of computer methods by the medical profession; this would create a desire on the part of individual doctors to become actively involved with this new technology—all this implies a great deal more than the mere acknowledgement that computers are now an essential part of any potentially efficient organization and therefore inevitably must become a feature of the Health Service.

b. Once the potential of computers has been acknowledged the next question is the type of work that should be undertaken and the type of computing equipment that should be obtained. However, the choice of work that may be carried out is frequently limited and fortuitously determined by the computing facilities that are immediately or easily available.

c. Such a random development of computing interests and facilities has a number of national implications. The Health Service is in need of a reliable and rapid information system initially functioning within its individual units and regions but ultimately integrated to form a national network. The difficulties of achieving this aim will be greatly increased if it is found later, that regional systems have developed using entirely different equipment and perhaps incompatible control languages.

In trying to predict the likely achievements of the next ten years this method of classifying the computer problems in medicine has the added advantage of reviewing the various stages through which the computer developments must pass. The detailing of problems in this way should not be mistaken for a council of despair. It would be naïve to believe that the way ahead is clear, and these difficulties have to be resolved if computer applications are to be used in the provision of better medical care. It is because of the tremendous increase in the complexity of medical practice today that computer facilities must now be seen as an essential component of good patient care.

1. The acceptance of computing methods

This is the stage from which most centres in the United Kingdom are emerging or recovering. While the potential of this type of equipment has been at least partly grasped, the actual exploitation is not so easy. It is now quite apparent that although in the early stages the introduction of large-scale computing facilities will be uneconomic, these costs must be faced because of the long-term benefits that will result. Firstly, there is the large capital expenditure; secondly, the need for specially trained staff to handle the machine and prepare the programmes; and thirdly, the provision of an assured volume of work for processing. Strange as it may seem, money is likely to be the least of the problems. When a genuine need is shown there is little doubt that money will be forthcoming but the other two requirements may not be so easily provided.

Computing in medicine will rapidly become a speciality in its own right and at least some of the people ultimately running these services must be medically trained. Few doctors at present are in a position to take on this role and as yet there is no provision for the education of medical students in computing science. Such a contention immediately lays one open to the oft-repeated charge of expecting even more of an already overloaded curriculum. Yet there is no alternative, young doctors must not only understand how a computer works but must appreciate how it can be applied in medicine. Unless this awareness is fostered amongst undergraduates and opportunities for learning about computer facilities are provided, the rapid development of data processing in medicine, essential for a new information system, will not be possible. Even if a modest attempt were made now to train small groups of students or recent graduates there would be a gap of five to seven years before the influence of this new generation would affect the Health Service.

The requirement of assuring a continuous flow of work for computer handling is perhaps the most difficult problem of all. The present organization of work both in hospital and in domiciliary practice is based primarily on the concept of numerous small units working independently. The development of large hospitals, the continued growth of specialization and the remarkable increase in therapeutically active drugs have created far more complex problems than the original organization was designed to meet. This is particularly true of the newer techniques of treatment such as intensive care, where the provision of expensive equipment and highly trained staff is well-nigh impossible in an organization based on small independent units. Similes, if carried too far, may lose their point, but it is worth considering briefly the development of civil aviation, where the introduction of new information systems is well established.

Today an airline pilot, as a member of a large and complex organization, is quickly provided with accurate information relevant to any decision he is required to make. So that he and his passengers may benefit from these technical advances, the pilot must concede a measure of independence and now has to conform to prescribed patterns of work. He must check, and is himself checked, at various stages of his work, and although always responsible for the final decision, his dependence on complex equipment and the skills of others is very great. If similar benefits are to be achieved in medicine, then certain concessions will have to be made. Changes in the traditional work pattern of doctors will not be easy to effect but the introduction of an efficient information and processing system in medicine is closely related to such a reorganization. One of the most important features is the development of alternative forms of recording and communication. The traditional methods and the accustomed form of existing medical records are quite unsuited for high-speed handling. This problem can only be resolved slowly, because so great will be the changes required, and so inevitable the complications, that it would be unrealistic to envisage such innovations unless spread over many years.

There is still one further potential complication related to the introduction of electronic data processing by doctors in which such a delay would be an advantage. It has always been the hope that one day a medical history could be stored and retrieved by means of a computer, but the realization of this goal has always been pushed into the future. Now, however, the time is drawing nearer, information retrieval in subjects outside medicine is developing quickly so that the application of these techniques will soon become a practical possibility and this raises an important issue. Medical records, at present, are maintained essentially like a library service, information relating to an individual patient is stored in one place, and apart from a small amount of the record which is indexed, the accuracy of the information is irrelevant to the working of the system. It is not possible, on any scale, to compare similarly indexed data relating to different patients, but with computer storage such comparisons will become possible. It is likely that contradictions will be found between data previously assumed to be the same. It is already known that the findings required by different doctors to make a particular diagnosis vary considerably, but the extent of these inconsistencies may be much greater than doctors expect. It has never been practical to test these variations with the present methods of recording. This problem will undoubtedly delay the establishment of a retrieval system based on facts contained within the record and will require that once these areas of disagreement are defined a considerable amount of time be spent on devising ways to assure the accuracy of the information being recorded.

2. The choice of work and equipment

Few centres would now deny the potential application of computers; however, the access to such equipment within the health services will be achieved in a number of different ways. There are three main alternatives:

a. The provision of a small laboratory-type machine, for monitoring or specialized research work, easily used, easily justified, and easily maintained;

b. The purchase of a medium-capacity computer primarily for proven commercial applications within a hospital or region and available, as a by-product, for the development of medical programmes; and

c. The establishment of a hospital computer for medical applications alone and, in the case of large installations, the provision of remote multi-access terminals and other types of specialized equipment.

All three methods are important but each leads to an entirely different form of development. Small machines are easily purchased and resolve specific problems. Within limits they can be extended, by analogue to digital conversion or by the addition of specially designed input devices. These are the machines most likely to appear in hospitals over the next few years, and while there is no doubt that this would provide an immediate practical solution to some of the present data-handling problems, it is not necessarily the best investment as a long-term measure.

The second most likely development over the next decade will be the availability of computing machines used mainly by the accounting and administrative sections of the hospitals. Unfortunately this equipment will be some distance from the clinical departments, will be programmed for commercial applications, and will seldom be immediately available. Valuable though such experience will be, these difficulties of access and the absence of suitable input media will limit routine service applications but, certainly in teaching centres, such a facility could be of considerable importance in training.

It would appear that the first large, remote, multi-access installation solely for medical work in a hospital is still many years away. Experience of multi-access facilities will soon be available in a number of university and research centres, and the applications developed there will be of great benefit in the design of a comprehensive hospital system.

The question of multi-access has other important implications, at the present time most of the hospital-based projects use paper tape or card input and even envisage tape output with off-line printing. This type of approach is in part explained by the need to abstract existing clinical records, but this step must be eliminated if hospitals are ever to become large-scale users. The amount of input required by a hospital in the routine transfer of information would make any such system completely unmanageable. The reorganization of medical records in relation to developments of input and display devices are therefore relatively urgent problems. This raises the whole question of methods of communications, in particular the need for man to communicate with machines. It is this necessity and the conformity that it will require that may prove the greatest stumbling-block to the present generation of senior medical staff. One of the delays associated with the introduction of electronic data processing has been the need to translate information into a form which can be recognized by machines. As already indicated, this is most frequently achieved by the transfer of information to paper tape, punch card, or magnetic tape as an intermediate step. This restriction may initially create difficulties as far as universal applications are concerned. A certain measure of freedom can be obtained by introducing keyboard operation, but even this degree of licence is not a natural method of communication for many doctors, without help. Other alternatives do exist, such as optical character recognition, magnetic ink character reading, lector reading, and other forms of mark sensing, but despite the ingenuity of these methods there are still many operational disadvantages. An audio response system is yet another possibility but unfortunately rather an unlikely one during the next ten years.

The most intriguing potential lies either in the 'light pen' system of activating selected areas on cathode ray equipment or, alternatively, the use of a 'touch-wire' technique when again particular areas of a display screen may be selected merely by touching a wire to complete the appropriate circuit. The combination of these systems with a keyboard for calling up on the display screen computer instructions or check-lists and the subsequent selection of commands or appropriate descriptive phrases by means of the 'light-pen' or 'touch-wire' offers considerable scope for development. This is not an unnatural way to communicate and, though sophisticated, would have a certain nostalgia for man as a method of creating records.

Even if the input difficulties are resolved there is still the problem created by the vast amount of information contained in a medical case history. In the early stages of a new medical record this will not constitute too great a burden as only restricted information or summaries will be committed to storage. However, it is likely that as the system develops the predominance of coded data in the early summaries will be increasingly supplemented by commentaries in English language. This type of record will be extremely wasteful of computer storage and although initially within the large capacity of the most recent generation of computers, it will only be a matter of time before some form of automatic binary translation, uniquely representing the words to be stored, becomes essential. Work towards such a facility is under way, but clearly it will be a considerable and complicated task. Another technique that could help with the storage problem would be a dynamic system based on the length of time since the information in storage was last used. This has often been suggested as a method of overcoming the accumulation of paper in existing medical records systems by placing the folder further and further from the current store the longer the lapse of time since it was last requested. The disadvantage of this method is the amount of manual handling and searching that would be required. In a computer-based system with a series of backing stores, decreasing in accessibility, but also in cost, an automatic method of relegation and recall could be devised.

3. A national network of computers in medicine

The greatest benefit from the introduction of electronic data processing on a large scale would be the possibility of integrating the regional centres into a national medical information system.

Before such a network could become a reality a number of issues would have to be settled. First of all, a balance will have to be struck between the sponsoring of unrelated and perhaps incompatible computer installations over the next few years, and the establishment of a nucleus of equipment and systems ultimately capable of integration. Although this may seem wasteful there is no alternative in view of the different systems soon to be established throughout the country, and it is essential, if computing in medicine is to develop in the United Kingdom, that the scope and range of applications over the next few years should be as wide as possible. It may be that too much is being made of this problem, yet the computer manufacturers themselves speak of waste on an international scale and of the need to standardize. One can only hope that there is someone in authority somewhere within the appropriate health service who will have the information on which to make this decision. The argument that this possibility is so far away that when the time comes the problem will have been solved is not convincing and certainly has not happened in other fields of communications. The Scottish Health Service, although by no means irrevocably committed, will soon be using three different computer systems and as a result at least two computer languages, neither of which will be fully developed until 1970 or later.

This raises complex problems, by no means settled within the computer industry, on the choice and development of higher languages. If medical information is to be handled on a large scale then the most convenient medium, at least for the next few years and despite its disadvantages, would appear to be Cobol. The news that the Ministry of Health is to look into the question of the need for a special medical language is encouraging and it might be worth reflecting upon the advantages that would accrue were this linked to a British computer system. It is hardly surprising to find that in America the more advanced medical programmes are being written in PL–1, but as this language is by no means perfected an alternative is still a worthwhile consideration.

The essential developments for the successful application of computers in medicine may be summarized as follows:

a. The education of medical students and young doctors in computing techniques at an early stage of their careers

b. The availability of computer facilities and experience of multi-access operation

c. The reorganization of medical work and the emergence of the concept of management by clinical staff

d. Changes in methods of recording and linked to this the development of input devices

e. The development of large capacity, low-cost storage

f. The creation of a special medical language for data handling and the ancillary programmes required for medical work

4. The likely achievements

Even by 1977 the establishment of a large multi-access machine working solely within a hospital in the United Kingdom is by no means certain. Offsetting this will be the availability of computer facilities in all regions. Many boards and some hospitals will have their own machines and the majority of hospitals will be equipped with small computers for specialized work in resuscitation or complex forms of investigation. These facilities coupled with the acceptance of a formal training for undergraduates will see computing techniques firmly established in the hospital service.

Some techniques, it must be acknowledged, are already in use; these include the calculation of radiotherapy dosage and fields of radiation, the control of monitoring equipment with patients requiring dialysis, resuscitation or other forms of intensive care, and the rapid interpretation of special investigations, particularly those needing complex or lengthy calculations. This is the area in which the greatest progress will be made in computer applications during the next few years. There are, in fact, few hospital departments that could not benefit, and the only major limitations will be a lack of imagination in recognizing the opportunities or a lack of ingenuity in devising the equipment. That neither are really lacking is shown by the plans for automated laboratory processing based on the auto-analyser and the reading of cervical cytology smears developed from industrial image analysis.

At first the growth of such applications will merely aggravate the present recording difficulties by generating even more information. However, it may also provide the stimulus for change, if electronic data processing is to be effectively used on a large scale as an aid in both patient care and ward management, then some means of assembling the relevant information and an organization within which to apply it must be devised. Even in restricted fields the application of these new techniques in patient care, with the resulting interdependence of specialities in the utilization of equipment, may well force the reorganization that is so urgently needed.

The relevant advances over the next ten years in the general field of computing are much more difficult to review. There are three areas of considerable interest to medicine. First the provision of large-capacity storage, some such facility undoubtedly will become available, but it is likely that initially this will be an uneconomic proposition for the handling of medical records on a large scale. With new types of design, new production methods, and increasing markets, costs will ultimately fall and the final answer to this problem must lie in the use of such equipment coupled with the careful selection of data for storage and some form of binary translation.

The provision of input and display devices is again largely a matter for the manufacturers, and the appearance of such equipment, solely designed for medical applications, is likely to be delayed. The commercial and industrial requirements in this country are by no means saturated and the computer industry, understandably, will attend to these needs before turning to the harder market in the Health Service. Set against this is the willingness of the computer firms to co-operate with both universities and hospitals in the preparation of software and specific projects. This will result in a marked increase in the routines available, particularly in the field of operational research.

There is little doubt that during the next few years a considerable number of medical or paramedical computer projects will be initiated and that thereafter the increase will be dramatic. The only way to improve patient care in the face of the increasing complexity of medical treatment is to make use of modern computing techniques and in ten years' time few major hospitals will be without at least access to these facilities.

The applications of computer methods primarily in the field of immediate aids in patient care are likely to be the most decisive factors in improving the scope and quality of medical care in this country. It is these developments that will promote the revolution in all forms of management technique so urgently needed in the health services. The equipment and knowledge necessary are now available and what is lacking is the stimulus to demand a change. No large organization can function effectively without an accurate information system. Progress in medical care today is closely related to the efficiency with which medical knowledge is processed and made available. The creation of such an information system depends upon changes in the organization and staffing of clinical units. The stimulus for these changes must come from within the Health Service itself and will only follow very practical demonstrations of the advantages of new methods of working. For this reason the immediate need is not for complex computing equipment but rather for quick and easy access to quite simple installations, and it is on the success of these initial applications that the ultimate achievements of the next ten years depend.

Twenty years after or cloud nine attained

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Many a true word . . .

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Twenty years after or cloud nine attained

The introductory chapter of A New Look at the National Health Computer Service, *a video-tape published by Oxford University Press for the Nuffield Provincial Hospitals Trust, April 1988.*

A reminder of developments in the past twenty years may serve to put into clearer focus some of our present problems.

It is now obvious that the crucial event in NHS computer developments was something quite outside the Service's control: the agreement in 1972 with France and Germany that the francling-mark should replace the pound sterling as an international reserve currency. This relief to the British balance of payments led, only two years later, to the lifting of the stringent restrictions on social service expenditure, which in the late 1960s and early 1970s so severely confined computer developments. With this relief, the experiments of the first five years of the medical computing era began to bear fruit.

Twenty years later it is easy for us to criticize the somewhat ill-advised, because premature, emphasis that the Health Ministry (as it then was) put on 'on-line, real-time' computers—which in plain English meant connecting many parts of the hospital, health centres, even surgeries, directly to a small computer located at some central point. The first such computer to be installed—the King's Stokefield Hospital IEA40, now in the Computer Museum at Little Gidding—quickly demonstrated that acceptance and use of key-board and visual display devices as a means of communicating with the computer could not be achieved by rudimentary training of potential users, whether they be nurses from overseas, or post-graduate medical researchers from the Medical Computing Centre at Oxford. For some years, therefore, these expensive devices were only half used, and the frequent resort to pen and telephone, and continual *cris de cœur* from hysterical ward managers created much chaos and despondency in hospitals with the first experimental computers.

This problem was not solved until 1972, when the first system operator was recruited. Here was the forerunner of the familiar figure who now, seated at his console in each ward complex, each administrative suite, and each laboratory block, or fingering his microwave communicator as he tags along with the houseman on his rounds, seems so obvious an answer to the need for efficient communication. It is salutary to recall that it was another seven years before the Association of Medical Systems Operators rose phoenix-like from the ashes of AMRO, so slowly did Area Health Boards realize the importance of converting into system operators the record officers whose unique and comprehensive knowledge of record management ideally suited them for the task. To them, above all, goes much of the credit for the present success of the Computer Service.

In its insistence on getting population health records on to the computer, as an essential nucleus for other computer-based procedures, the Health Ministry has been shown by events to have got priorities right. Much can be traced back to this insistence. We can now see, for instance, that the surplus of beds which is a country-wide feature of the current scene and which reflects today's high clinical and administrative efficiency, can truly be attributed to the use of computers as devices for comprehensive information, instantly communicated. So, too, can much of our world lead in preventive medicine; for the gradual accumulation of health data, readily accessible, gave epidemiologists their first real chance—which accounts for the fact that thirty-three out of the forty-five Area Medical Officers of Health in England and Wales are *alumni* of the College of Epidemiology set up in 1974.

Computers as communication devices have had a substantial influence on hospital and health centre design in the last ten years. They pointed the way to the present functional separation of patient care, administration and laboratory services into separate blocks—and whatever one's opinion of today's ward towers with their polarized, polysilicate cladding, the removal to separate buildings of all services other than nursing—and, of course, consultant suites—has improved immeasurably the conditions in which patients are cared for.

Indeed, visitors to a modern hospital must find it hard to realize that there must be kitchens, pharmacies, laboratories, and all the other paraphernalia of nursing support services, unless by chance they have seen through an open door the system operator at work or the multi-conveyor in use.

A visitor would be equally surprised to learn how substantially the staff who inhabit the laboratory blocks have changed their functions in the last twenty years. The apparently rudimentary first attempts at laboratory automation in the late 1960s established a successful pattern of automatic laboratory services. They also stimulated so much interest among technicians that there followed almost a decade of experiment with and development of new devices for the measurement, analysis, and communication of laboratory data, the laboratory technicians becoming either experts in automation or laboratory researchers, according to temperament and ability. The rapid and astonishing achievements in automation quickly produced the first Area Laboratory to which all parts of the NHS (some will recall that at that time local authority, general practice, and hospital services were organizationally distinct) had continuous access. This in turn introduced a greater element of presymptomatic diagnosis into general practice and created a context in which rapid expansion of health screening techniques was economic. But no-one foresaw that the very process of automation would make laboratory technology a disappearing profession and result in the present dependence on complex and occasionally unpredictable electronuclear equipment, with little or no manual expertise to rescue us from emergencies. Until we solve this problem, the tendency of highly-paid clinicians to waste their time on technicians' work in their private little laboratories will certainly increase.

In the administrative block there are still plenty of staff to be found. The computer-based management system that runs the modern hospital has done little to reduce the numbers of staff, although in many instances the work has changed considerably. For example, the time the assistant superintendent once spent in allocating her nurses she now spends either in convincing them that they must undergo computer system operation training or in persuading them that sister/nurse relationships have really been written into the management programme suite. (Is this a gain or a loss?)

Again, the time that the deputy house governor used to spend on minor managerial problems, such as the consultant's failure to arrive for his clinic, or a breakdown in the hot-water system, he is now able to spend on genuine strategic decision-taking, in moulding the use of staff and equipment to meet varying pressures in the demand for patient care.

One aspect of his work today that could not have been conceived two decades ago is the amount of time and energy he has to spend on influencing professional staff inter-relationships (primarily, of course, computer staff *versus* the rest) and in coping with the ever-increasing problems of adjustment to automation. One would have hoped that over the last twenty years computers might have become respectable and acceptable, but it seems that the average man's failure to accept a machine as a controlling influence is a permanent feature of his personality. It is these problems which have forced the hospital administrator to give more and more time of his professional training up to advanced studies in sociology and psychology. Without a thorough background in the behavioural sciences an administrator today would be utterly lost. And so his role changed from 'Clerk to the Governors' or 'Secretary to the Board', that is, a mainly desk-bound occupation, to Hospital Arbitrator where, aided by changing professional attitudes amongst nursing, medical, and technical staffs he is able to play a central role in the organization of local health services.

However, one should not underestimate the importance of the development of the other kind of administrator who was unknown in the 1960s. The Area Co-ordinator has grown from an inherent lack, in the original conception of the National Health Service, of somebody who is able to provide services over an area in the interests of economy, but this role could not have developed without the swift transfer of information which the computer network made possible. In the old Regional Boards some services like the physics service or a blood bank were provided for a large number of hospitals, but this, of course, cannot be compared with the ever-increasing list of area services (transport, ambulance, pharmacy, catering, pathology, record storage, and so on) which are now under the control of the Area Co-ordinator.

It is curious that the biggest problem still unsolved is that of the siting, organization, and management of the computers themselves; and the several solutions attempted in the last twenty years are worth a brief recapitulation. Initially the Health Ministry's policy was fragmentation: a dozen or so small discrete computers were installed in hospitals (mainly) 'regional' boards (as they were then) and health centres. No attempt was made to link them; and although data banks had conceptual existence they were not evolved at that time. But that was admittedly an experimental period, and it is likely that official papers due for release from the Public Archives in 1992 will show that the possibility of national health databanks was considered, only to be dismissed as impracticable in the current state of the computing art.

Computers increased in number only slowly until about 1975 when, as was noted above, readier availability of public funds facilitated a substantial expansion of data-processing services in the NHS. Two years earlier, however, there had been the prolonged and virulent public debate about the charges being levied by the Computing and Communications Corporation (then still known anachronistically as the General Post Office) for the use of its data-processing grid. The Corporation, it was alleged, was using its quasi-monopoly position to levy extortionate charges for computer services. This row culminated in the famous Treasury instruction that no organization wholly or mainly financed from public funds should use the CCC grid. Three months later, the GPO went completely commercial and this effectively barred the NHS from the computer grid—since no social service can afford commercial rates for anything.

The Health Ministry at once announced its intention to establish a National Health Computing Grid, consisting of forty-five interconnected, medium-sized computers, one in each NHS area. (The 'regions' had been split up in 1974, the year local authorities were reorganized on the same area basis.) But at once a new outcry arose; surely, argued the Keeper of the Population Data Bank, this would perpetuate the ridiculous division between health and social security data on the one hand, and the vast accumulation of other sociological data in the Population Data Bank. If the NHS needed a computing grid, the Data Bank grid could easily accommodate it.

The riposte was immediate: for once the public, the medical profession, and the videocasters were on the same side and unanimously opposed the association of health and economic security data with records of national identity, citizenship, police events, licences, income and expenditure, foreign travel, Gallup responses, and credit ratings. By comparison the debate in 1970 of the problem of the confidentiality of computer-based medical records was as mild as the chatter of old friends over a bottle of mescalager at a drug-house.

With a Euro-election imminent, there could be only one outcome: the National Health Computing Service got its computer grid—and for nearly ten years public health research workers wanting to associate health with other sociological data depended on the monthly data summaries made available, initially, on magnetic tape and, after 1980, on microgravitic wire. (The activities in 1978–9 of the data-grid line-tappers, who were reputed to have made their fortunes out of blackmail and illicit data sales, have been referred to elsewhere. It will be recalled that some unaccountable research statistics were published in *Preliminary Communications* at that time.)

By 1983, seven out of every ten hospitals, ninety out of every hundred health centres, and nearly half of the 9000 doctors remaining in individual or group practices, were directly connected to the grid. All hospitals, and a few large health centres, had intermediate satellite computers. Today the proportion so equipped has not changed materially, mainly because the remaining buildings and staff are not adaptable enough. But in the last three years, the development of sub-molecular storage systems has (as Chapter 5 will show) at one blow made computing grids obsolescent and uneconomic to sustain. Yet here is a capital investment of more than Fm 250m. and a complex of communications and staff whose abandonment would ravish careers and disturb the present pattern of efficient patient care so painstakingly established. Whether the NHS should forego this tremendous technological advance, and in doing so soon forfeit its world-wide lead in medical computing, is discussed in later chapters. Here only one conclusion can be drawn: if the decision is in favour of re-equipping, it is odds-on that by the turn of the century some further development in computing technology will demand a further agonizing decision.

This brief survey of major developments has so far ignored some other happenings that are important to any historical account of the National Health Computing Service. One such was the Health Ministry's attempt to establish a medical computing 'language'. To anyone who has come to computing in the last fifteen years—and seven out of eight F and MRECS (Fellows and Members of the Royal European Computer Society) have—the concept of a written computer language will be hard to grasp. Until the early 1970s, however, it was customary to instruct computers in terminology that started as hand- or typewritten symbols. In the first decade or so of computing, such instructional languages were indeed symbolic: that is, far removed from the vernacular; but gradually new instructional languages were developed that approximated more and more closely to plain English. Even so, they still tended to be fairly esoteric, and most of them tended to have variations that facilitated their use with particular computers (there was little equipment standardization then). By 1968 it was clear that the NHS would be a large user of computers, not confined to one manufacturer; and the Health Ministry thought there should be a plain-English medical computing 'language' that would enable any NHS computer user to question or instruct any computer to which he had access. And so, in solemn conclave, a group of experts produced a plan for such a language, the Health Ministry produced some money, and other experts set to work to define, compile, and specify. Three years later a standard medical computing language was indeed introduced; but two years after that, PAR (phoneme analysis and recognition) transformed man's relationship with computers. Within another two years only *data* was being presented to computers in 'written' form, *instructions* were oral, and written instructional languages superseded—although the need for a concise universal vocabulary remained.

EsPARanto began to be available for all Euro-computers in 1978; and the substantial degree of international agreement on medical vocabulary helped to ensure that MEDESPAR was the first sub-vocabulary to spread through Europe and, later, the Americas, parts of Africa and Japan. To this day, the Sino-Arab Pact countries, to the extent that they use computers at all for other than process-control applications, prefer written or keyboard communication; and it is a curious tribute to the group of experts mentioned above, that the one sub-set of instructional languages still to survive almost as it was designed nearly twenty years ago is their medical computing language—odd though it looks in Chinese ideographs.

Many computer-users in the NHS now believe that MEDESPAR has outlived its usefulness and, indeed, that the rapid development of direct ECN (encephalonucleonic) transcription makes any attempt to produce a more sophisticated version of it superfluous. However, the intense mental self-discipline that encephalonucleonic transcription at present demands makes it unlikely to supersede oral man/computer communication for many years. After all, it is precisely twenty years since the first reports appeared of a rudimentary cortex/computer interface: by any standards this would be slow progress, probably slow enough to justify an investment in one more generation of oral instructional vocabularies.

Academic effort in one area of medical computing brought lasting benefits to medical practice. Few people today realize that the adroom that is a standard feature of clinics, health centres and modern surgeries originated in the badly named (and therefore much maligned) concept of 'auto-diagnosis'—hence ad-room, an ante-room where a patient can answer in an unembarrassing situation a succession of carefully programmed diagnostic questions, a process that increases clinical efficiency by reducing time-wasting and often irrelevant questions, and providing objective data effortlessly, and also has its own therapeutic value to the patient. Initially a development of 'programmed learning' machines (since superseded by autoinstructional aids and later by hypnocturnal absorption), the so-called auto-diagnostic devices were originally located in sound-proofed cubicles in health centres, and connected directly to a central computer. By means of elaborately branching interrogatory programmes, interspersed with careful instructions, appearing on a video-screen, patients were conducted through a part-symbolic, part-factual diagnostic routine.

Initially the questions, and indeed the whole routine, were crude and occasionally even offensive. After a session with such a device, patients tended to approach the doctor in a frame of mind that varied from the sardonic to the sacrilegious. But an increasing research and development effort was put into these devices, and more particularly the diagnostic programs, during the 1970s and their value and acceptability increased rapidly; and by 1980 hospitals had begun to use them, usually as combined teaching and diagnostie aids.

One feature introduced experimentally in 1975 by a group practice in the south-west of England was a print-out of the machine's summary of the patient's condition, with suggested possible diagnoses, which the patient was asked to give to the GP or consultant who interviewed him. Patients were free to read this document, which was always couched so far as possible in lay terms. The ad-machines were programmed to suppress, or code, information about patients with potentially serious diseases—but since such patients were rarely in a condition to attend either hospital or health centre as out-patients, this restriction affected less than 1 per cent of cases. The experimenters expected, and got, increased patient confidence in the medical services generally. Their own performance and self-confidence increased too. So did the price of the shares quoted for the company manufacturing the equipment. The only sufferers were the hypochondriacs; but since this led to a closer understanding of the basically social problem of hypochondria, society as a whole benefited.

One amusing fashion—short-lived, naturally—was a device called

'The Happy Hypochondriac', which was a pocket-sized self-monitoring device. Six interfaces could be attached to specified parts of the owner's anatomy, and the device purported to monitor continuously certain physical parameters. If the owner suspected a deterioration in his physical condition he went to the nearest chemist with an on-line link to a commercial computer where, for a small charge, he could obtain a summary of his condition in the form usually provided by an ad-machine. The device was soon laughed out of existence, partly because an unidentified computer videozine bribed a system operator at one of the on-line computer centres to instruct the computer to reply, randomly, 'You're dead. Proceed to nearest mortuary' or 'Don't waste my time'.

This summary of developments in medical computing will be the background against which we shall next consider a number of contemporary problems.

[*The theories and visions in this article are the outcome of various psychedelic experiences of the author and in no respect reflect the dreamworld of the Ministry of Health.*]

Computers in the service of medicine
VOLUME II

In this second volume, the theme has changed to the range of problems met in analysing those medical procedures which must be clarified if the systematic use of computers is to be developed to full advantage. In the concluding articles two of those deeply experienced in the field select some lessons for the future and one speculates how the problems might appear if current dreams are fulfilled.

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