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A data processing system for hospital bacteriology

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SYNOPSIS A system for the automatic capture and retrieval of information contained in routine bacteriology reports is described. The system depends on the preparation of reports on an electric typewriter producing punched paper tape as a byproduct.

Periodically the information contained on the tape is analysed by computer. The potential value of the system for the analysis of the results of antibiotic sensitivity testing and for the study of the epidemiology of hospital infections is briefly discussed.

The structure of any data processing system is determined by the nature of the facts with which it has to deal, by its objectives, and in practice by the available resources. The main determinant in the present case was the intention to collect data as an automatic byproduct of the normal procedure for preparing reports and without the intermediary of a computer, as it was felt that any system suitable for general use at the present time would have to satisfy these basic conditions. The second major consideration lay in the fact that the conventional bacteriological report consists, at least in part, of English text. In the absence of a computer to turn codes into words, the chosen equipment had thus to be capable of handling efficiently text of variable length, for which task paper tape has definite advantages over the punched card.

Implicit in the decision to limit the study to the information contained in the report as finally issued was the exclusion of the results of tests used in identifying organisms. In fact, the collection of data was restricted to the nature and provenance of the material and the organisms (if any) which had been isolated, together with their sensitivities to standard ranges of antibiotics, with the intention of applying the information thus acquired to a study, first, of prevailing patterns of antibiotic sensitivity and, secondly, of following fluctuations in the bacterial flora from different sources in a hospital.

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Data Preparation

Specimens are accompanied throughout their course in the laboratory by the original request form, identified by name and laboratory accession number. Details of identification tests for organisms are recorded manually on the back of the request form, the report proper on the front. To achieve consistency in the final stage of reporting, a variety of conventions for the expression of results has been agreed. It has been made a rule to confine the report of the presence of an organism to those organisms regarded as pathogens in the context of the history and other findings. Antibiotic responses are reported as 'sensitive' or 'resistant' without qualification. It is felt that this form of expression is both proper as a guide to clinical practice as well as facilitating the analysis of the data; there is, however, no limitation inherent in the system which would prevent grading of sensitivity on any suitable scale. Free comment is possible and appears at the foot of the typed report.

The completed reports are received by the

data processing clerk and sorted into batches by type of specimen. Typewritten reports are then prepared on a Friden Flexowriter 2301, which is a typewriter fitted with paper tape punch and reader. By means of a program tape and control keys, the movement of the carriage may be controlled automatically with predetermined halts for the insertion of data, text may be reproduced (including alternative statements, eg, 'AAFB seen', or 'AAFB not seen'), printing may be suppressed while punch codes on the program tape are reproduced by the tape punch or punching suppressed while printing continues. Program tapes have been prepared for all the main classes of routine reports. The programs allow the first part of a report to be typed simultaneously with the production of a paper tape containing a numerical code which identifies the type of specimen, the hospital registration number and age and sex of the patient, and the hospital, ward, and consultant, or general practice concerned (Fig. 1). At the present stage of development of the system, no record is made on the tape of the results of chemical tests or of microscopy, although this information appears on the typewritten report. The second part of the report, relating to organisms isolated together with their antibiotic sensitivities, is completed by removing the program tape and substituting one or more program edge-punched cards, a separate card being used for each organism. The programs contained on these cards have the effect of transferring the name of the organism onto the report but onto the tape a numerical code which then identifies the organism. The machine halts for the growth density to be recorded and then continues under control to appropriate points where sensitivity test results are entered. These are recorded on report and tape in the form of 1 for 'sensitive' and 0 for 'resistant'. The punch at this point is switched off by the program, so that typed comment may be entered at the foot of the report without being reproduced on the tape. The typed report is then issued, the original request form with working details is filed alphabetically, and the tape accumulated for computer input.

Computing

Storage and retrieval of data were initially carried out on the IBM 1401 installation of Birmingham University Medical School and subsequently on the Elliot 4100 system of the Computer Unit of Warwick University. Programs were written in variants of Fortran IV. The data contained on the paper tape is read on to a magnetic tape file in the sequence in which it has been produced, a roughly chronological order. The input program submits each record to a series of tests before

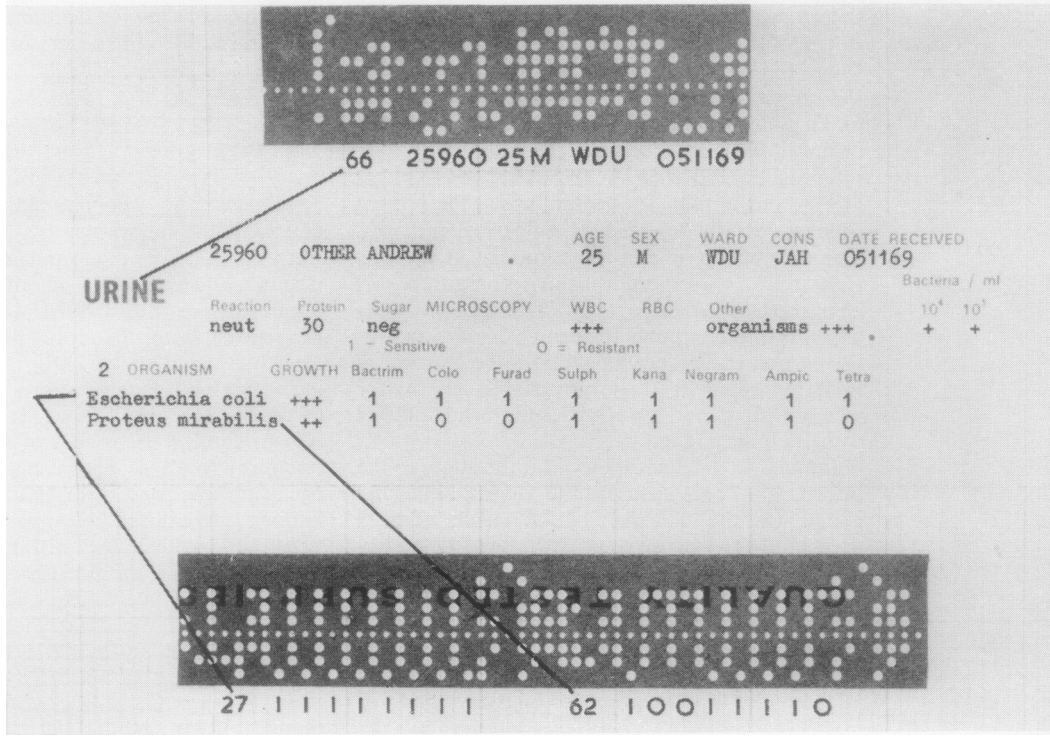

Fig. 1 *Report and byproduct tape.*

accepting it for transfer to magnetic tape. Incorrectly punched records are rejected and listed for amendment and a list of all acceptable records is produced.

To increase the speed and efficiency of subsequent analysis, only positive records are preserved, ie, those containing one or more organisms tested for antibiotic sensitivity. The program, however, analyses the work load by type of specimen and origin of all valid records, classified as positive or negative on the result of culture.

Retrieval and analysis of the stored data have so far been conducted by two types of program. The first (Table I) consists of an analysis of the patterns of sensitivity to a standard set of antibiotics. The right hand column consists of the decimal form of the sensitivity pattern treated as a binary number: it provides a useful shorthand reference to the individual patterns.

E.Coli										
Total	*Fre.*	*Cl*	*Co*	*Fu*	*Su*	*Ka*	*Ne*	*Am*	*Te*	
272	139	1	1	1	1	1	1	1	1	255
	26	1	1	1	1	1	1	1	0	254
	20	1	1	1	0	1	1	1	1	239
	19	1	1	1	0	1	1	1	0	238
	13	1	1	1	1	1	1	0	1	253
	.	.	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.
%		100	92	99	74	97	97	85	71	

Table I *Analysis of the patterns of sensitivity to a standard set of antibiotics*[1]

[1]The table is abbreviated by the omission of less frequently occurring patterns and column totals.

The second type of program yields a tabulation of the frequency with which selected organisms are isolated from different types of specimen from the wards of one hospital. After examining the table it is possible to select blocks of results for more detailed study by means of a subsidiary program which prints a full list of the records concerned. All of the programs may be applied to records accumulated over any desired period.

The first program is designed to perform a number of functions. By giving a statistical indication of the effectiveness for different types of specimen of a given antibiotic *in vitro* against bacterial species considered both individually and collectively, it is intended to provide guidance in the selection of appropriate therapy before the definitive sensitivities are known. Secondly, once the prevailing sensitivity patterns have been established for each organism by the analysis of a sufficiently large number of strains, periodic analyses, eg, monthly, quarterly, or half yearly, will provide a means of detecting the appearance of newly resistant strains. Thirdly, the table may be used as an instrument of quality control by listing anomalous patterns of response for an organism. For example, some improbable results of sensitivity testing of strains of *Proteus mirabilis* against ampicillin which had escaped notice at the time have led to a review of techniques and to a decision to use a lighter inoculum, with consequent improvement in accuracy.

The second program is intended to provide periodic estimates of the prevalence of infections by a particular species in different hospital wards and thus assist in the detection and control of cross-infection.

Discussion

The present study was conceived as a first approach to the practical problems involved in devising a system for the automatic processing of routine hospital bacteriological data and should be assessed in that light. It is a truism that no data processing system can be better than the quality of the data entered into it, and the selection and formalization of those parts of the report destined for the computer record called for a number of difficult decisions. As will be evident, the problem has been met partly by restricting the data collected to limited parts of the report without interfering with freedom for interpretative comment.

The distinctive feature of this method of data preparation is the production of an automatically coded computer input simultaneously with the preparation of a routine report. A variety of other approaches have been used, including the assembly of a report for printing from prepunched cards (Lindberg, 1968), the encoding of data on punched cards either as a preliminary to the production of a report by a computer (Whitby and Blair, 1970), or as a separate exercise (Stirland, Hillier, and Steyger, 1969), mark-sensing punch cards at the bench (Lamson, 1966), and direct entries to a computer memory from keyboards sited in the laboratory (Lindberg, 1968). The present method is advanced as a means of securing computer input together with a typed report which is relatively economical in time and labour and does not require a computer on site.

The objectives have so far been limited to the production of what is in essence a monitoring system for use in epidemiological studies of hospital infections. In practice, it has also proved to be a valuable means of raising the standard of laboratory work. There are, however, no obvious barriers to its extension to include other classes of pertinent data or to link the information produced with other types of laboratory or hospital records.

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