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An assessment of one year of computer-assisted microbiology reporting at Charing Cross Hospital

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SYNOPSIS The pilot scheme began in August 1972 after three months of running parallel with a conventional system. In October 1972 the system was moved from Fulham Hospital into the new Charing Cross Hospital. Sixty thousand routine bacteriology requests have been processed satisfactorily by the computer system, about 70% of the total received. The cost for a computer-printed report is 32p compared with 6p for a typed one.

In July 1970, outline proposals for a pathology requesting and reporting scheme were discussed. Briefly this was as follows.

1 Requests are made by telephone to a group of operators who print out the request data.

2 In the laboratory the samples are logged in on a keyboard on-line to the computer and optical mark reader (OMR) report forms are printed (fig 2).

3 Optical mark reader reports after completion and checking by the technicians are read on the mark reader.

4 The pathologist checks and edits these reports on a visual display unit (VDU).

5 The accepted reports are available on demand to the requesting doctor or member of the firm at any terminal in the hospital or by telephone from the operators.

6 Overnight a cumulative report is printed for all patients on whom requests have been reported and distributed to the wards or medical records.

7 Cross infection data are printed out routinely.

The effort in developing a system was considerable for all laboratory staff and could not be sustained. We were anxious to have some experience with a computer terminal before moving into new laboratories in 1972. We therefore chose to press on without points 1, 4, 5, and 6 above, and to restrict the system to single samples for bacteriological examination (70% of all samples received).

Description of the Present System (fig 1)

One OMR document with pre-barred serial number, including a check digit (fig 2), is allotted to each specimen and stapled to the request form. The serial number, identification data, and specimen type from the clinician's request form are keyed in on a teletype with paper tape attachment in the reception area. The serial number of each specimen is written on the request form by hand.

In the laboratory the technician marks the appropriate boxes on the OMR form with a felt tip pen to indicate macroscopic appearances, microscopic findings, and cultural results. The area to the left of the framed area of the OMR document is not machine readable and is used as a work sheet to record media inoculated, biochemical reactions, etc.

Organism codes are based on those of the Association of Clinical Pathologists' Working Party (1968). The OMR form provides space for four different organisms to be coded, quantitated, and sensitivities recorded.

The OMR document is passed through the document reader, which punches the data onto paper tape, to be read into the computer by a teletype later.

The OMR document data and request form identification data are linked by the serial number and the full report is printed out on the termiprinter. An example is shown in figure 3.

A commercial time sharing bureau (Leasco) has supplied the computer power so far. The response is slow when more users are competing for time (especially between 10 am and 5 pm) resulting in the terminal operating at one third of its capacity, with a coefficient of variation of 0·45, ie, if the average time to produce a report is one minute, on 50% of the occasions it will be produced in half a minute or longer than one and a half minutes. This has made it difficult to keep to a tight time table for work throughput. The cost of computer time alone for a

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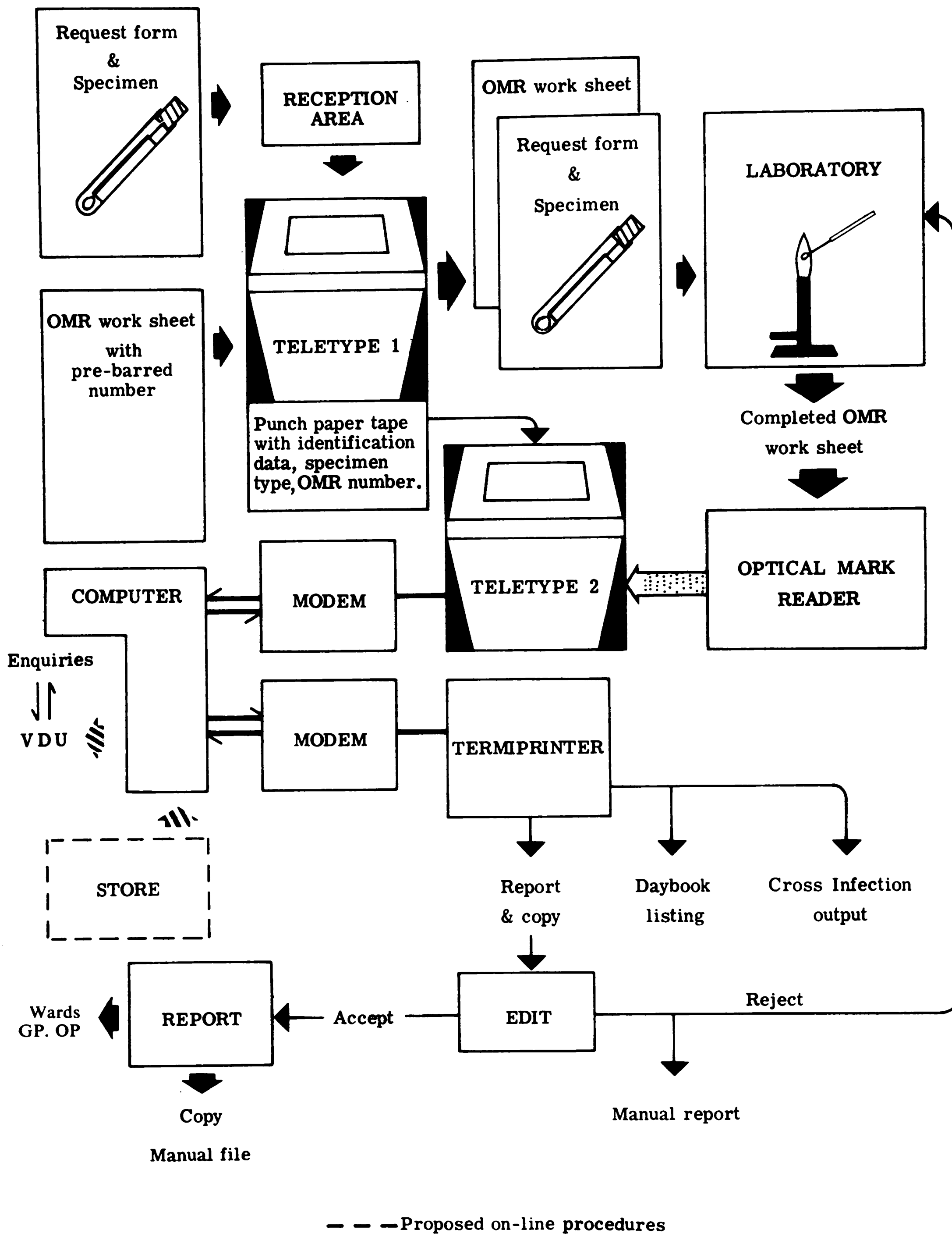

Fig 1 *Diagram showing work flow in a microbiology computerized reporting system.*

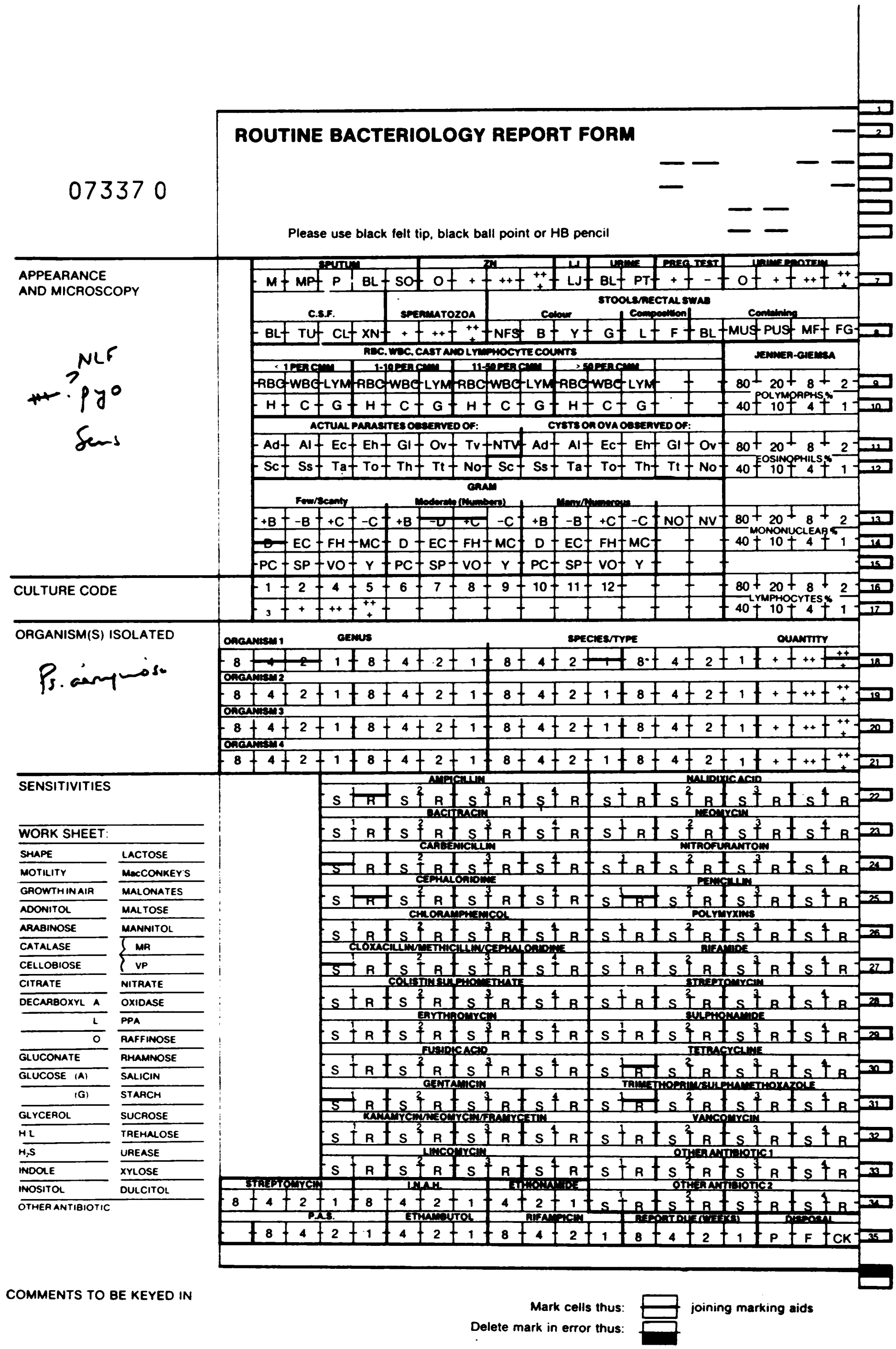

Fig 2 *OMR work sheet. The lettering inside the boxes is in red on the form in use. It is not detected by the mark reader but is helpful when filling in the form.*

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CHARING CROSS GROUP OF HOSPITALS—MICROBIOLOGY REPORT

Name:   DEBORAH                             Hospital No:
Age:                                        Consultant: Dr. Baker 31
Sex:              NEW CHARING CROSS         Ward/Dept: GP

Specimen: Ear Swab R                        Date Received: 19. 9.73

MICROSCOPY:
   GRAM        Moderate numbers of Gram negative bacilli
               Moderate numbers of Gram positive cocci,   Debris

CULTURE: ORG 1 Heavy growth of Pseudomonas aeruginosa(pyocyanea)

SENSITIVITIES:  4 3 2 1
                      R Ampicillin
                      S Carbenicillin
                      R Cephaloridine
                      S Colistin sulphomethate
                      S Gentamicin
                      R Penicillin
                      R Tetracycline
                      R Co-trimoxazole (Septrin)

    Final Report Ear Swab R        Sample No: 7537  Date: 21. 9.73
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Fig 3 *Routine microbiology report produced by the computer.*

report has varied between 11p and 54p (average 22p). The budgeted figure was 11½p.

Specimens arrive throughout the day and one person is almost completely occupied keying out the identification data off-line on to paper tape. The paper tape can be put in at a faster rate in batches, on-line through a second terminal, which was installed after three months because of the slow and variable response. We can now put data in on one machine while the other is printing out reports from the previously input batch. This gives greater satisfaction to the operator, and, because the reporting and data input can be simultaneous, reports can be printed from work sheets received as late as 4.30 pm. The interval between specimens being received and being passed into the laboratory ready for the technicians to work on varies according to the number of specimens received at once and would probably average about an hour, most of them arriving in the morning and being worked on in the laboratory in the afternoon after the previous day's work has been dealt with. Specimens arriving in the afternoon can be dealt with a few minutes after receipt.

Reports are delivered to the wards by laboratory porters who deliver at 2 o'clock and 5.30 pm. The majority of OMR reports from the laboratories are ready for machine reading by 10.30 am and are printed out by noon. If signed by a pathologist before lunch they will be distributed at 2 pm but otherwise will be delivered with the remainder of the reports at 5.30 pm.

A disadvantage of keying in identification data off-line is that errors are not immediately obvious to the operator. Short periods of working on-line are helpful in reducing the error rate.

The advantages of using a commercial bureau during the pilot phase have been that the whole aspect of machine management, including computer installation, computer operation, systems generation, and file recovery, are catered for by the bureau. In this way a hospital computer project is relieved of a difficult and expensive area of activity, particularly at the start of a project. The break-even point financially for a switch to an in-house computer would seem to be one to two years.

Our own in-house computer, a Rank Xerox Sigma 6, is scheduled to be brought into use during 1974. A line printer (200 lines/minute) will replace the termiprinter, and the OMR document reader will be used on-line for request forms and OMR work sheets.

Costs

CAPITAL COSTS (EQUIPMENT)

	£
2 Teletype + modem	1200
1 ICL Termiprinter (30 cps)	2500
1 Data recognition Dataterm 3 OMR reader + punch	4500
1 Decollator	500
Total	8700

REVENUE COSTS (BASED ON 60 000 REPORTS PER ANNUM)

	£
GPO telephones	1200
Computer time	13 200
1½ terminal operators	1800
1 teletypist	1200
OMR documents (60 000)	450
Request forms (60 000)	300
	18 150
£8700 capital cost depreciated over 7 years	1243
p.a.	19 393

These costs may be better appreciated by considering the costs per report.

BREAKDOWN OF COST PER REPORT

Computing time	22
Operators	5
Telephones	2
Equipment	2
Stationery	1
Cost per computer report	32

This is to be compared with the manual cost per report 6p.

It is clear that equipment cost (2p) is almost negligible compared with running cost which itself is mainly computing cost. This is directly calculable here because the computer time is bought commercially from a computer bureau (Leasco). In most computerized laboratory reporting systems the computer costs tend to be underestimated or even ignored because it is considered too difficult to apportion computing unit capital and revenue costs to particular applications.

Discussion

PROBLEMS

Equipment problems and failures

During the six months from 1 January 1973 there were 16 machine failures. Only three lasted longer than two hours and required an engineer to do repairs before further terminal work could be carried out.

	Total Failures	*Failures Lasting > Two Hours*
Termiprinter	6	
OMR reader	5	1
Modems	2	1
Telephone lines	2	
Computer	1	1

Mean time between failures = 2-3 weeks
Mean repair time once a failure has occurred = 2-4 hours

Termiprinter

This proved to be reliable but difficulties in adjusting the report length caused intermittent overrunning onto adjacent reports.

OMR document reader (Optical Mark Readable document reader)

Once set up correctly the OMR document reader proved reliable in practice. Misreading of documents may be difficult to detect but such intermittent faults allow adjustment of the machine before a complete breakdown occurs.

Telephone

Initially the lines went through the hospital switchboard. Frequent disconnexion at £2 each (taking into account the need to re-input data after the disconnexion) proved too disruptive so that two direct outside lines were installed. Even so at least one line failure still occurs daily. Programs have been written so that when such failure occurs records up to the one currently being updated are not lost. The current one is either re-input or completed manually.

Computer

Extremely slow response caused withdrawal of the computer facility for two weeks while programs were drastically modified to take this slow response into account. During this time all reports were typed.

PERSONNEL

Technical staff found no difficulty in marking the documents. Work in the laboratory is divided by specimen type and this restricts the number of codes used by a technician at one time. Slightly more space is required at the bench because of the larger form, and it takes longer to mark the forms than to use bacteriological shorthand. Twice daily semi-alphabetical day book listings are produced.

Secretarial staff have required some additional training in the use of the codes and teletype, usually becoming proficient in a few days.

Medical staff have accepted the computer-assisted reports (fig 3) which are better laid out than our average typed reports. Errors in transcription will continue until the new request forms designed to be machine readable are read by machine. Identification data are still handwritten on 10-20% of request forms. One unfortunate byproduct of our machine-readable request forms is the loss of clinical information, now entered on only a third of forms. Attempts to codify clinical information have in practice been unsuccessful so far.

PROGRAMMING

Programming and program testing are time consuming and involve close cooperation between the bacteriologist and programmer. To date only initial and early further reports, eg, identification of a Klebsiella reported initially as a Gram-negative bacillus with sensitivities, are reported by computer because data storage in a commercial bureau is too costly. Further and final reports of blood cultures, LJ cultures etc, are therefore reported manually. Cross infection data are produced by punching tape automatically each time any of a selected list of organisms is reported. This tape and program are then processed at the University of London computer each fortnight. With an in-house computer it is expected that computer storage of data will be for a period of three years initially.

At present handwritten comments and corrections on the report do not enter the system, although they do reach the patient's notes if identification and destination are adequate.

MULTIPLE SAMPLES

Multiple samples from cytotoxic patients (20% of our requests for bacteriology), screening for a particular pathogen, eg, for gonococci in the Special Clinic, serology and virology have been excluded for the present.

Sampling surveys and large numbers of the same type of sample generate much more paper than a work list when individual reports are not required. The system is cumbersome for multiple samples from the same patient, for example, patients on cytotoxic chemotherapy who have four to six sites sampled twice a week. A new work sheet has been designed for these and we are waiting to try it out.

CUMULATIVE REPORTING

This has been deferred.

ADVANTAGES AND BENEFITS

The manual system of reporting was dependent on experienced secretaries interpreting a bacteriological shorthand. Holidays, sickness, and increasing work load made it precarious, despite the use of stamps to cut down repetitious typing. There has been a shift to machine minding and we hope it will be easier to fill temporary and permanent operator posts than it has been to recruit experienced secretaries.

Transcription errors are reduced and well laid out legible reports are produced. Some errors are picked up by the program and drawn to the pathologist's attention. More pressure of work makes for more typing errors in the conventional system but not in the computer system. Wrongly marked codes, eg, for organisms, are obvious to the pathologist at once because the usual bacteriological shorthand is entered on the work sheet to the left of the machine-readable field.

The twice daily semi-alphabetical day book print-out is much quicker to check for answering queries about specimens.

Proposed lists of 'further reports due' have not yet been produced because of the data storage problem but will be helpful when our own computer is in use.

Cross-infection statistics are produced routinely, similar to those at University College Hospital (Dr Joan Stokes, personal communication). This saves time compiling the statistics but it is too late to help the bacteriologist with current day-to-day problems.

Clinicians are alerted to the reporting of certain pathogens, eg, AAFB or a methicillin-resistant staphylococcus, by a programmed row of asterisks in the report. In practice, however, the bacteriologist always contacts the doctor directly in case the report goes astray.

The development of software took much longer than anticipated and data storage was inadequate for the project as originally planned. Updating of programs will continue to be a time-consuming process requiring close collaboration between bacteriologist and programmer.

FURTHER DEVELOPMENTS

The workload in clinical laboratories doubles every five to seven years but staffing lags behind. This leads to high pressures of work which in a conventional system causes the error rate to rise. A computerized system cannot be hurried and the error rate remains low and stable. We estimate that the capacity of our system is at least 150 000 requests per year, which should allow for the next five years' growth.

Many permanent secretarial posts in this hospital remain vacant or are filled by temporary staff. We are confident that we can double our throughput while maintaining an improved standard of reporting without doubling the need for secretarial staff and without loss of accuracy or delays in reporting. None of these advantages is susceptible to simple cost analysis. During a two-week period when the computer facility was not available, the secretaries were working two to three hours late each evening even though negative further reports for LJ cultures, etc, were deferred. With the terminal working again the reports were despatched at the usual time.

The move to a new hospital has brought three laboratories' work into one. The larger file of copy reports is slower to use and easier for misfiling. An operator using a visual display unit (VDU) to answer telephone queries for results is starting shortly. This will enable us to abandon manual filing of copies when adequate data storage is available in 1974, with large savings in time and frustration for us and enquirers for results. Problems of confidentiality and reliability have not been entirely solved. Editing and checking reports by the pathologist using a VDU will enable verified data to be used for this purpose and for cross infection data. The VDU is to be installed in the next few months.

The central problem of patient identification persists as approximately 30% of request forms bear no hospital number. Recent installation of the addressograph system is improving this figure. Inclusion of identification data in machine-readable form on the request form will eliminate transcription error in the reception area and speed the throughput of specimens into the laboratory.

The next phase will include multiple samples from patients treated with cytotoxic drugs (20% of workload), serology, and virology requests.

Recording of biochemical test data perhaps on the back of the OMR work sheets which would be passed through the OMR document reader a second time to permit computer identification of organisms and quality control does not seem likely to be programmed within the next two years.

Conclusion

Sixty thousand bacteriological requests have been reported using a computer system. Clinicians were consulted during the design of the layout of reports and are pleased with the format. Secretaries have been relieved of very considerable pressures which our conventional system induced.

Improvements envisaged in the next six months including the installation of our own Rank Xerox Sigma 6 will take care of the next five years anticipated increase in workload with further improvement in the speed and efficiency of reporting results without loss of accuracy.

Friends have said that our bacteriological computing like 'a woman's preaching is like a dog's walking on his hind legs. It is not done well; but you are surprised to find it done at all' (Boswell, 1763).

Improvement is planned along the lines suggested and there is no longer any element of surprise. Despite the comparative expense of computing time at present some form of computerized reporting is desirable if not essential for any routine microbiology laboratory handling more than 100 000 requests a year.

We are grateful to Tony Ridgwell, Senior Chief Technician, and to the staff of the microbiology and medical computing departments for their enthusiasm and hard work, to Paul Ward, Dick Davies, and Alf Linington who built up the programs, to Maria Marron, our first terminal operator, and to Antony Rollason for the diagram.

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