The computerized documentation of septicaemia

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At St Thomas’ Hospital for the past 20 years, medical microbiologists have documented all cases of septicaemia, as part of the routine service offered by the department. These records are used in the day-to-day management of patients and have provided much research and teaching material. When the number of paper records became so large that manual extraction of data was impossible we computerized the records. In 1986 information from the paper charts was transferred to a microcomputer, and since the beginning of 1988 the details of each new case have been added to this computer file at the end of the septicaemic episode. At present, collection of data during the course of a patient’s illness continues on paper, but it is hoped that in future this process will also be computerized. Apart from our own data, little computerized information is to be found on patients or the treatment they receive, both within our hospital and nationally. The present system can be viewed as a prototype for other groups of patients.

Introduction

Information on patients with septicaemia resides in several areas of the hospital: the patient’s hospital record, nursing and operating theatre records, investigative and pathology departments, including microbiology. Computerization of information is an obvious answer to the problem of handling large numbers of data and is well established in many pathology departments. However, the fully computerized patient record remains a very distant prospect for most British hospitals. Less unusual is the computerization of details of small subgroups of patients by those with a particular interest in those patients. At St Thomas’ Hospital for 20 years paper records have been kept on all patients with septicaemia. The records have formed the basis of a series of major studies of septicaemia caused by Staphylococcus aureus (Gransden, Eykyn & Phillips, 1984), Streptococcus pneumoniae (Gransden, Eykyn & Phillips, 1985), coagulase-negative staphylococci (Gransden, Eykyn & Phillips, 1989a), Escherichia coli (Gransden et al., 1990) and septicaemia in an Intensive Therapy Unit (Forgacs, Eykyn & Bradley, 1986). They have also formed the basis for several more limited reports (Humble, Eykyn & Phillips, 1980; Eykyn, 1982, 1984, 1988; Phillips & Shannon, 1985).

As the files became increasingly laborious to analyse they were computerized and now readily yield data of excellent quality, currently used in the management of new patients, in the education of trainee microbiologists and others and in research. This paper outlines the processes involved in documentation, the results of which appear elsewhere in this supplement (Eykyn, Gransden & Phillips, 1990; Phillips et al., 1990).
Materials and methods

Paper records

Medical microbiologists visited all patients with septicaemia as soon as it was detected in the laboratory, and usually daily thereafter until the patient had recovered or died. The significance of a blood culture isolate was based on the micro-organism, clinical findings, and the presence of the same micro-organism in other specimens or blood cultures. Trainee medical microbiologists gathered the data under consultant supervision. From 1969 to the present, the clinical and microbiological details of each patient were recorded on two paper charts. One contained patient demographic information and microbiological results on blood cultures and samples from other sites, and the other documented clinical progress and antimicrobial therapy on a daily body temperature chart. For ease of access to the records, the charts were microfilmed, thus reducing the wear and tear on old paper records during the times they were consulted after filing and during the retrospective stage of computerization. With two microfilm copies of the files stored in separate sites, the records were secured from accidental damage or loss.

Information recorded

The information we recorded is shown in Table I. Basic demographic data were obtained from registration documents and noted for each patient. Common underlying diseases or conditions ('disease(s)' in Table I) that could predispose to, or influence the outcome of, the episode of septicaemia were charted when present, although only in broad terms e.g. diabetes, chronic renal failure, haematological malignancy. Less common conditions were recorded as 'other'. An assessment of the patient’s prognosis ('state of health' in Table I) at the clinical onset of septicaemia was made and patients assigned to one of three prognostic groups: 'good' (non-fatal underlying conditions, or previously healthy), 'poor' (rapidly fatal underlying disease or state and unlikely to survive the admission), and 'intermediate' (ultimately fatal underlying disease but likely to survive the admission). This classification follows the slight modifications of the criteria described by McCabe & Jackson (1962) used elsewhere (Bryan, Reynolds & Brenner, 1983). An episode of septicaemia was defined as community-acquired if it began before the patient was admitted to hospital, irrespective of when a blood culture was performed. An episode was hospital-acquired when the onset of septicaemia occurred at any time after admission to hospital. Before 1984 these individual assessments were retrospective, but thereafter they were made at the time a positive blood culture was detected. Haematological indices were recorded when available and included the haemoglobin concentration, peripheral white cell count and differential and the erythrocyte sedimentation rate. Serum creatinine, urea, and liver function test results were also noted when these were abnormal or could influence the management of a patient.

Relevant notes on the clinical course of the patient’s illness, investigations, and items of epidemiological interest, were recorded. The antimicrobial therapy was documented, together with serum concentrations of antibiotics, if measured. Other therapeutic manoeuvres such as surgery, drainage of an abscess or removal of an infected intravascular device were also recorded. The outcome of the septicaemic episode was defined as survival or death and the latter subdivided into death attributable to infection or to the underlying disease.
### Table I. Information on septicaemic patients at St Thomas' Hospital

<table>
<thead>
<tr>
<th>Information</th>
<th>Computer records</th>
<th>Microbiology and other laboratories</th>
<th>Hospital*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Microbiologists'</td>
<td></td>
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</tr>
<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td>microbiology</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>microcomputer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>name</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>hospital number</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>age</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>sex</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>disease(s)</td>
<td>+,*</td>
<td>+</td>
<td>(+)</td>
</tr>
<tr>
<td>state of health</td>
<td>+,*</td>
<td>+</td>
<td>(+)</td>
</tr>
<tr>
<td>speciality</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>community/nosocomial</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
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<tr>
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<td>+</td>
</tr>
<tr>
<td>clinical notes</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Blood (and other) cultures</td>
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</tr>
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<td>laboratory number</td>
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<td>+</td>
<td>+</td>
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<tr>
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<tr>
<td>date positive</td>
<td>+,*</td>
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<td>+</td>
</tr>
<tr>
<td>organism(s)</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>sensitivity (MIC)</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>typing</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>source</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Treatment and outcome</td>
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<tr>
<td>antimicrobials</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>dose/route</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>levels</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>duration</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>appropriateness</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>other manoeuvre(s)</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>daily temperature</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>outcome</td>
<td>+,*</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

*Patient administration system.
*+, Information available; (+), limited information available.

**Microcomputer records**

In 1974 an attempt was made to computerize the records of a limited number of episodes. This proved laborious and expensive and was entirely reliant on outside computer facilities and expertise. It was abandoned after 200 records had been computerized and will not be discussed further here.

Starting in 1986 the charts from 1969 onwards were reviewed and data, indicated in Table I, were transferred to a microcomputer. Initially an Olivetti M24 computer with a storage capacity of 30 megabytes was used and ran dBase III plus (Aston Tate) software with Wordstar Professional (MicroPro) as the text editor for programming. These were subsequently updated to a Compaq 386 machine (with a 100 megabyte hard disc) and dBase IV.
The dBase system is a popular relational database management system designed for use on microcomputers. It permits the entry, storage, sorting, analysis and display of numerical and textual information in files created by the user. A file consists of a number of individual records (up to 1 billion), each composed of up to 255 items of information (called fields). The composition of new files is readily defined by the user. Entry of data is facilitated by arranging and labelling the fields on the computer screen. This screen format can be made to resemble a paper pro-forma. Once data have been entered, dBase can sort the information for almost instantaneous retrieval. Information in one file can be related to one or more other files. While some analysis and basic calculations can be performed with almost no computing knowledge, the dBase programming language allows the user to amalgamate a series of simple commands into increasingly sophisticated programs. This process is made easier through the use of a word processor but requires considerable computing skill.

Procedure for documentation

Collection of the data by hand on the paper charts continued. From 1988 to the present, at the end of a patient episode the completed chart was reviewed and data entered on to computer by a medical microbiologist. The individual records were edited and updated as necessary when more information subsequently became available.

Antimicrobial sensitivity data

Minimum inhibitory concentrations (MICs) were available routinely from 1980 for Enterobacteriaceae and *Pseudomonas* spp. and were measured for viable organisms and added to the computer file retrospectively for the years 1969 to 1980. MIC determination was not completely automated and so data were entered by hand at a computer terminal. For staphylococci, initially the results of disc sensitivity testing were added, but we are currently measuring and computerizing the MICs for all staphylococcal and enterococcal isolates.

Analysis

Programs were written in dBase for the recall of individual patient episodes, groups of patients or organisms, and also for the routine and ad-hoc production of reports. Such reports might be required for specific clinical problems in order to review our previous experience with similar patients, or for postgraduate meetings focusing on particular patient groups such as those with diabetes mellitus, sickle cell disease, neutropenia etc., or those in specific wards such as the intensive care unit, or for undergraduate education.

Expansion

In a pilot project exact details of the patients' antimicrobial therapy and daily temperature response were added to the computer. The dates of positive and negative blood cultures and peripheral white blood cell counts were also recorded. Free text annotation was permitted. A representation of the screen appearance of these data is shown as figure 1.
Validation of data entries

Since addition to the computer of old patient records (1969–1987) was performed by a medical microbiologist each record was carefully reviewed during the process. Since 1988 new records were inserted into a temporary file which was thoroughly scrutinized and reviewed with simple programs. The file was then appended to the main patient file.

The new hardware and the updated version of the software allowed a sophisticated programmable process of validation of data entry while this took place at the keyboard, in order to trap typographical errors. This proved useful during the entry of large quantities of numerical data such as the values of MICs. The system could be programmed to reject those results, or combinations of results, that were unlikely for a particular organism. Thus ‘illegal’ values of MICs which did not form part of our doubling dilution series were not accepted. It was also possible to program rejection of those numbers which although typographically acceptable are extremely unlikely for particular organisms, for example, an MIC for ampicillin of 10 mg/l for *Pseudomonas aeruginosa*, or unlikely combinations of results for an organism, such as an MIC of azlocillin 64 mg/l when the MIC of ampicillin had already been entered within the sensitive range.

Results

Three thousand eight hundred and fifty-one episodes of septicemia were computerized. Three hundred and thirty patients had two or more blood culture isolates during a single episode and there was thus a total of 4268 isolates. The retrospective computerization took two years. Some 50 trainee medical microbiologists have gathered data
Table II. Databases on septicaemia at St Thomas' Hospital

<table>
<thead>
<tr>
<th>File</th>
<th>Contents</th>
<th>Records</th>
<th>Size (Bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient file</td>
<td>demographic and clinical details</td>
<td>3851</td>
<td>922,023</td>
</tr>
<tr>
<td>Organism file</td>
<td>list of all isolates</td>
<td>4268</td>
<td>333,564</td>
</tr>
<tr>
<td>Expanded clinical file*</td>
<td>daily temperature and treatment details</td>
<td>3851*</td>
<td>1,278,257</td>
</tr>
<tr>
<td>Sensitivity file (1)</td>
<td>MICs for Gram-negative organisms</td>
<td>1920</td>
<td>626,114</td>
</tr>
<tr>
<td>Sensitivity file (2)*</td>
<td>MICs for Gram-positive organisms</td>
<td>1898*</td>
<td>139,164</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>3,299,122</td>
</tr>
</tbody>
</table>

*Incomplete.

*Projected figures.

over the 20 years. The current databases, shown in Table II, include one containing patient demographic and clinical information, one with MICs of 32 antibiotics for Enterobacteriaceae and *Pseudomonas* spp., one with MICs of 20 antibiotics for *Staphylococcus* spp., *Streptococcus* spp., and *Enterococcus* spp., and one with daily temperature records and exact details of therapy. All databases were related by a unique field identifying an individual episode so that microbiological data could be related to clinical information on each patient. Over 320 programs have been written for work related to the input and analysis of data.

The initial stage of documentation continues on paper. The addition of completed new results to the computer database by yearly batches has been satisfactory. Increasing sophistication of the programmable validation of data entry can be at the expense of reduced speed of input, so some editing and reviewing of data is still performed by screen review. The expansion of the database to include the temperature and treatment details was temporarily halted after the addition of 800 episodes. It has proved particularly labour-intensive.

Discussion

We have found that medically qualified microbiologists are the most appropriate people to collect the data on septicaemia. They are the first to be informed of a positive culture and can co-ordinate efforts to establish the focus of infection by requesting other specimens or investigations and by reviewing the microbiology in specimens for which small, but relevant, numbers of the blood culture isolate might go undetected amidst other organisms. The microbiologist can also speed the process of identification of blood culture isolates, and in the individual case suggest the most likely focus of infection or even possible underlying disease, as well as helping to predict antimicrobial sensitivities. Close co-operation between microbiologist and clinician almost invariably resolves difficulties in the assessment of the significance of possible contaminants.

Our system has proved remarkably robust and although data collection has been performed by junior microbiologists with varying levels of experience, results have been consistent, largely because of the energetic supervision of the process by seniors. The
Computerized documentation

process is helped by our design of a standardized pro-forma. Many of our trainees have subsequently adopted our method for documentation of patients with serious infections at other hospitals and some have achieved a degree of computerization (French et al., 1990, this Volume). This provides an indication of the transferability of our method.

The items of information we have collected are the minimum required for successful liaison between laboratory and clinician, in the provision of an efficient clinical microbiological service for patients with septicaemia. The data are much the same as those included in other studies (McGowan, Barnes & Finland, 1975; Roberts, 1980; Bryan et al., 1983; Weinstein et al., 1983a; Weinstein et al., 1983b; Ispahani, Pearson & Greenwood, 1987). The process of gathering data may appear labour-intensive but the documentation of septicaemia is an essential part of our training for junior microbiologists and a necessary part of our clinical service. It teaches them to record, observe and collate information on patients with serious sepsis. While at present data collection continues, in the initial stage on paper, we have found the use of a hand-held computer at the bedside with subsequent downloading to the laboratory microcomputer a possible alternative.

An important advantage of the computerization of the septicaemia data is that analysis of groups of patients or organisms has been greatly simplified. We have recently completed an analysis of 861 episodes of *Escherichia coli* septicaemia (Gransden et al., 1990), the previous manual attempt having been abandoned because of its complexity. It may be assumed that computers are now used in the analysis of data in large studies of septicaemia, although few authors mention the fact. Weinstein et al. (1983b) used specially designed computer-printed worksheets to facilitate computerization of data collected from hospital chart review, for only 500 episodes and performed statistical analysis by computer. Our system, which now employs prospective computerization of clinical and microbiological data, has the advantage of allowing instant ad-hoc enquiries and analyses of all septicaemic patients, and because assessment of each case is made at the time of the illness, we avoid the difficulties inherent in retrospective hospital chart reviews. We find that our records of a patient’s previous admission are often more complete than the hospital chart, if, indeed, the latter can be found at all.

The information we have computerized can be used in the selection of initial empirical therapy in septicaemia. Comparison of a new patient’s clinical data, on presentation, with previous similar patients allows the listing of the most likely infecting organisms. When these are related to the computerized sensitivity data it is possible to recommend empirical therapy. Similar processes probably occur in the heuristics employed when experienced microbiologists recommend empirical therapy, but instantaneous access to twenty years of documented cases assists the experienced and inexperienced alike. A computerized link allowing on-line access to this sort of information would be of use to the clinicians who, in practice, most often choose empirical therapy without reference to microbiologists. Programs applied to the septicaemia database can thus be considered a form of computerized decision support system. We intend to analyse the choice of empirical therapy made by clinicians, to identify the most common errors and make available the information that will improve the choice of initial, empirical therapy. Our preliminary analysis shows that mortality from community-acquired septicaemia when empirical therapy is inappropriate is twice as high as when appropriate.

Even when the microbiological diagnosis has been made the database can still help in
listing the most likely source or focus of infection leading to septicaemia caused by a
given bacterial species, so aiding the clinical investigation. We believe that more
detailed analysis of the treatment and temperature details will lead to the prediction of
the future course of an individual case of septicaemia and provide reasons for deviation
from the expected course.

The relatively small numbers of patients with septicaemia (about 220 per annum) and
isolates mean that unusual organisms are encountered only rarely and thus our
experience of them is limited. This could be improved by multicentre documentation.
While the Communicable Disease Surveillance Centre receives information on thou-
sands of cases of bacteraemia each year, the quality of the reports cannot be guaranteed
and clinical information and follow-up are limited (Young, 1982).

Computerization permits rapid and frequent ad-hoc interrogations of the database
and when our pilot expansion is resumed we will have achieved almost complete
computerization of all the information held on paper. Our success with the database
has encouraged us to investigate the application of the methodology to other serious
infections and we are now completing similar systems for patients with endocarditis,
meningitis and malaria. These too are yielding much useful information (Gransden &

References

Gram-negative bacteremia in non-university hospitals: The effect of antimicrobial therapy.
Reviews of Infectious Diseases 5, 629–38.
268–72.
14, 203–8.
100–4.
15 year study of infection. Quarterly Journal of Medicine, new series 60, 773–9.
Infectious Diseases 10, 1228.
endocarditis. Quarterly Journal of Medicine, 73, 1135–42.
diagnosed at St Thomas' Hospital. British Medical Journal 290, 505–8.
bacteraemia with coagulase-negative staphylococci in St Thomas' Hospital. In Abstracts of
European Society of Clinical Microbiology and Infectious Disease.
staphylococci, an emerging problem. In Abstracts of the 4th European Congress of Clinical
Microbiology, Nice, 1989. Abstract 1011, p. 442. European Society of Clinical Microbiology
and Infectious Disease.


