The paper describes the development, implementation, and review of a daily reporting system using data from two modules of a hospital information system: Kirby-Bauer sensitivity results from Microbiology, and patient drug profiles from Pharmacy.

The system reviews each patient receiving antibiotics and compares that information with the patient's Microbiology findings, looking for and flagging "no cultures," "negative cultures," and "mismatches," i.e., the patient is receiving an antibiotic to which the organism is resistant. Reports are produced daily and reviewed by the hospital's Infection Control nurse who, in turn, notifies the attending physician when appropriate.

In the Fall of 1980, the Infection Control Committee of the Medical Staff at CCH formed an Antibiiotic Review subcommittee charged with complying with the Joint Commission on Accreditation of Hospitals (JCAH) standards regarding antibiotic utilization review. Since both the Pharmacy and the Microbiology departments had computer systems, the Director of Information Systems was appointed to the committee in the hope that the computer could be used to facilitate the antibiotic review process.

One of the persistent problems in clinical medicine is the necessity for the attending physician to prescribe antimicrobial agents (antibiotics) before culture results and sensitivity studies can be performed — in order to relieve symptoms, and in some cases, to prevent complications or even death. Often, the antimicrobial therapy chosen may be:
1. Of a broad spectrum, increasing the risk of side-effects
2. Too expensive or inefficient (two drugs used where one would suffice)
3. Incorrect (the organism is resistant to the drug)

In most clinical practice, it is not until the Microbiology report is finished and delivered to the patient's chart that the clinician can review the culture results and modify the antimicrobial treatment.

The problems of antibiotic utilization have been well documented and reported. In fact, several solution models have been proposed and criteria established for prospective, concurrent, and retrospective review. Nevertheless, few hospitals, if any, have established or have the means to establish comprehensive prospective or concurrent antibiotic utilization review programs.

In addition to looking for "problem areas" in the use of antibiotics and performing regular retrospective audits, it was agreed that the group would make a concerted effort to use the computer systems to provide a concurrent review program in the hospital.

A review of the literature revealed that no systems of concurrent antibiotic review had been reported. The use of computer systems was limited to retrospective reports based upon billing or inventory data, although there was much hope for the use of computers in antibiotic review. "Retrospective reports and audits were helpful, but as Michael H. Stolar suggests in the June 1982 "Quality Review Bulletin," "from a patient's perspective, prospective and concurrent methods of drug utilization review would be more desirable than retrospective evaluation because errors can either be prevented or corrected while a patient is still hospitalized and before irreversible damage is done."
A full-time Infectious Disease (ID) Nurse had been reviewing all patients with significant positive cultures for several years. The focus of this review was upon the culture results themselves, the source of the infection, its relationship to surgery or to a particular nursing unit, etc. The nurse did review the antibiotic therapy while reviewing the patients' charts, but this was somewhat secondary: the nurse was the first to admit that it was not possible to review every single positive culture.

The impetus for developing a concurrent review system was strengthened by a recommendation by the hospital's insurance underwriters that because just one untoward reaction to an antibiotic being given in the face of one contradictory culture sensitivity report could become a significant legal event, all therapy must be monitored. In a hospital with an average census of 240 patients, half of whom are on antibiotics on any given day, manual comparisons of culture results and antibiotic therapy would be overwhelmingly time-consuming. In addition, there was no consensus as to who would perform this task.

Computer Systems

The CCH system uses two Data General Eclipse C330 computers using the MUMPS (a dialect of MUDBYS) operating system. The computers are operated by and applications software developed by Medical Information Technology, Inc. (MEDITECH) of Cambridge, MA. Applications currently on line include Patient Registration, Medical Records Index, Laboratory, Microbiology, Surgical Pathology, and Materials Management.

Microbiology

The CCH Microbiology system was implemented in 1974 as an additional module in the Laboratory system. Culture requests are entered into the system, workcards are generated, and culture and sensitivity results are entered into the CRT in a mnemonic-based coding system. Preliminary and final reports are produced daily. In addition, the system keeps track of drug sensitivity patterns by organism and hospital nursing unit. Reports on these findings are provided to the Medical Staff by the Pathologists on a regular basis.

Pharmacy

The Pharmacy system, implemented in May/June of 1980, is a general purpose information system for the hospital Pharmacy. Drug orders are entered on-line by pharmacists, the system displays the patient's current drug profile and checks for drug or allergy interactions. Unit dose envelopes and pick lists are generated by the system. Other subprocesses include Controlled Drugs and IV/additive functions as well as purchasing and billing.

The Pharmacy system by itself has some capabilities for drug utilization monitoring. It can produce lists of patients on particular drugs or drug classes for specified time ranges (up to 30 days), sorted (if they are antibiotics) by "reason for ordering." These reports have enabled the Medical Care Evaluation physician to select specific groups of patients from the general database for specific, timely review.

Linking Pharmacy and Microbiology

The committee established a set of goals and specifications for the concurrent review program:

1. To provide a daily report of those patients on antibiotics which would be able to be easily compared to his/her microbiology findings, preferably on the same page.
2. To have the computer examine the pharmacy and microbiology data and provide some meaningful analysis of that data.
3. To provide a report which could, with as little (human) intervention as possible, be able to be presented to a clinician.
4. To provide a report which would be acceptable to a practicing clinician without being perceived as being "Big Brotherish" or punitive.

Meditech agreed to share in the development costs for the project, and assigned a programer to the project (CCH has no programming staff).

Some logistical problems surfaced immediately, the most important of which was the fact that nowhere in the computer system (and usually nowhere else) was there solid information linking a specific drug order with an individual culture. The two orders were issued to two separate "systems" and had no specific common element. It was agreed that, recognizing this difficulty, the system would print cultures and drug information side by side if they had order dates within 48 hours of each other.

Within a couple of months, the first combined Pharmacy/Microbiology reports were produced, and with a few relatively minor program modifications, the program was presented to the Infection Control Committee. The program had been long awaited in the hospital and was implemented immediately.

How It Works

When the interface between the Pharmacy and Microbiology systems is activated, the sorting program loops through the locations (nursing units) in the hospital and finds each patient in alphabetical order within each location. As each patient is found, the program first checks for active antibiotics in his/her Pharmacy profile. If an antibiotic is found that has been active for 3 days or more, a comparison with the patient's Microbiology findings is triggered. At this point, a query is put to the Microbiology system for a file of the Microbiology findings in a printable format as well as the file of the specific sensitivity results for the internal manipulations. Once this information is received from the Microbiology system (which in this case resides on a different computer), each antibiotic is compared to the Kirby-Bauer sensitivity results. If a result of "resistant" is found for that antibiotic in any of
Microbiology results, it is flagged for a message of "Please Review" on output. Cross-referencing of sensitivity 'drugs' and Pharmacy profile 'drugs' is accomplished through a field in the Pharmacy system drug master file which allows the user to specify to which antibiotic type (Kirby-Bauer) any particular antibiotic corresponds.

The Report

The system's output is produced with the Microbiology and Pharmacy profiles printed on the same sheet. Micro specimens that are logged into the system within 48 hours of the start date of an antibiotic are printed opposite that particular prescription information in order to visually coordinate ordered drugs with ordered tests.

In order to limit the amount of output that can be produced by a report run, three sort options are available to the user:

- **Sort 1**: Prints all patients on antibiotics (72 hours)
- **Sort 2**: Prints all patients on antibiotics (72 hours) with either Microbiology sensitivities on file or "mismatched" antibiotic/sensitivity results
- **Sort 3**: Prints only "mismatches"

In addition, a special routine allowing patient-specific inquiry into Pharmacy/Microbiology results is available with output the same as previously described.

Exhibit 1 shows a section of one patient report. The "Please Review" was triggered by the "Resistant" result for Ampicillin in the Microbiology sensitivity report.

### Concurrent Review Procedure

The integrated computer program accomplishes the comparison between antibiotic orders and cultures automatically and daily. The "Sort 2" report is run daily and includes 10-15 patients.

Since the program does not check for coverage of a resistant organism by a second antibiotic being received, the ID nurse reviews each report. Other causes of insignificant "mismatches" include:

1. Sensitivities not performed on the specific antibiotic (Gantrisin and anti-fungal drug sensitivities are not routinely performed). Sensitivity to Penicillin is another example which the computer reads as a "mismatch.

2. Multiple organisms from one culture (a clinically insignificant organism will be resistant while the other clinically significant organisms will be well covered).

"Mismatches" which remain after this initial review are deemed significant, and the ID nurse reviews the patient's record. If this review confirms the clinical significance of the "mismatch," the nurse notifies the attending physician. This notification is done in the same manner that the Lab would report a positive blood culture as soon as the results are known; the attending is notified in person or by telephone. The ID nurse reviews the case the next day to ascertain whether or not the antimicrobial therapy has been changed. If the nurse has a question or concern about the therapy (including no change in therapy after notification of the "mismatch"), she may refer the case to a physician member of the Infection Control Committee for review.

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**Exhibit 1**

<table>
<thead>
<tr>
<th>ID#</th>
<th>Patient Name</th>
<th>Diagnosis</th>
<th>Allergies</th>
<th>Antimicrobial Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0071002703</td>
<td>Smith</td>
<td>Allergy</td>
<td>None</td>
<td>Ampicillin Capsu 250 mg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>OIC 473273</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Start: 3/9 # 1445 500 mg</td>
</tr>
</tbody>
</table>
Program Evaluation

An evaluation of the program's results for the month of May 1982 revealed the following:

Average daily hospital census: 272
Patients receiving antibiotics for 3 days or more: 32 (average/day)
Total number flagged: 193
- No cultures: 98 (17 patients)
- Negative cultures: 72 (38 patients)
- "Mismatches": 40 (12 patients)

Since the computer system starts "from scratch" each day, a patient with negative or no cultures will appear each day; that is why, for example, 17 patients generated a total of 98 on the monthly tally. Since the primary use of the system is daily monitoring, this is not a significant problem. It can, in fact, act as a reminder to the ID nurse. Also, since one of the patients were flagged for more than one category, the total number flagged is less than the sum of the categories.

One of the first insights provided by the system was documentation of the fact that although 50% of the patients are receiving antibiotics, only about 10% receive them for 3 days or more. This was a confirmation of other data suggesting that much of the use of antibiotics in the hospital is for surgical prophylaxis.

64 physicians had patients flagged for review in this study. The majority of flags were for no and negative cultures. Only 4 physicians had more than one "mismatch," 2 had 2, and 2 had 3. 9 of the 10 physicians with more than 5 patients flagged were surgeons.

Of these 193 flagged for review, 32 were reviewed by the ID nurse in more detail; the chart was reviewed at the nursing unit. 7 of these patients were determined to have significant "mismatches" and the attending physician was notified by the ID nurse. All notifications resulted in immediate change in antimicrobial therapy or additional documentation in the chart by the physician of the rationale for the use of the particular use of the antibiotic was provided. All cases were reviewed in 24 hours by the ID nurse. No case was referred by the ID nurse to an ID physician. In fact, in nearly 12 months of operation of this system, no referrals have been made by the ID nurse to a physician other than the attending or his/her designee.

Physician acceptance of this notification of "bug/drug mismatch" has generally been good. There is an occasional huffy response to the ID nurse, but most accept the program as a new service, the earlier reporting of significant laboratory information.

By limiting the computer selection to only those patients on antibiotics for 3 days or more, the focus is on those patients whose treatment is presumably based upon culture results. In order to sharpen the focus of these studies, however, the hospital implemented an Antibiotic Order Sheet which requires the physician to indicate one of the following reasons for ordering:

1. Surgical prophylaxis
2. Suspected sepsis
3. Documented infection
4. Non-surgical prophylaxis

The reason for ordering is entered into the computer with the order and allows data searches based upon this additional parameter.

The review of "mismatch" data allows the hospital to look for changes in drug utilization patterns. For instance, a January 1983 study showed fewer "mismatches" and more no and negative cultures than in the May 1982 study, prompting an in-depth audit with pre-set written criteria of those patients by "reason for ordering."

Conclusions

These computer programs allow us to screen large, changing populations of inpatients and to select, concurrently and retrospectively, specific groups of patients for medical care evaluation and quality assurance review.

The concurrent review program has decreased the chance of an individual mishap going undetected for more than 24 hours; several of the retrospective studies have increased the Medical Staff's awareness of the costs of treatment; and the programs have increased the documentation of systematic, concurrent review of antibiotic utilization. The process is ongoing and self-generating.

The Antibiotic Utilization project at Cape Cod Hospital has demonstrated that the concerted effort of an interdisciplinary group of physicians, other members of the healthcare professions, and systems analysts and programmers can put operational and administratively oriented systems to use in ways that can directly impact the quality of the care our patients receive.

References