

# Computer-Generated Management Tools for the Clinical Pathology Laboratory

## II. Computer-Generated Graphic Work Flow

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### INTRODUCTION

Utilization of computers in the clinical laboratory improves patient care by enhancing communication of laboratory test results to clinicians. At the same time, however, it also provides the capability to the clinical pathologist to make the laboratory operate more effectively, and thus it can be viewed as a management tool. A recent example of its use as a management tool is in providing the ability to monitor and improve turnaround time for test results.<sup>1</sup>

Although laboratories operate more effectively when work is batched, test specimens and phone calls for results are received at any time of the day or night, making the laboratory into an "upon demand" operation. Indeed, the laboratories operate more effectively for good patient care in this way. Recognition of this fact coupled with limited resources places the clinical laboratory in a difficult position. Unless a method can be found to improve efficiency of the laboratory without decreasing the effectiveness, operations cannot improve. One way that this can be done is to be able to predict physician usage of the laboratory and adjust staffing to the work load. Inadequate staffing obviously contributes to slow turnaround time of laboratory tests. This paper gives an example of how actual work flow of a clinical laboratory can be determined. These work flow patterns were used to adjust staffing of one part of the clinical laboratory—Central Distribution, where specimens are received and accessioned into

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the computer, and where phone calls for test results are answered. Such work flow patterns also have application in the laboratories themselves.

## MATERIALS AND METHODS

The University of Michigan Medical Center is composed of five hospitals with a total of 970 beds, 25,000 inpatient admissions, and 325,000 outpatient visits per year. Nearly 6 million tests or 18 million weighted College of American Pathologists work load units are performed in the pathology laboratory each year. A laboratory computer system (LCS) has been in operation since 1976. The following laboratories report results through the LCS: Hematology; Biochemistry, Microbiology; Immunology; Radioimmunoassay; Cytology, Surgical Pathology, Toxicology; Coagulation; and Nuclear Medicine. The LCS is a PATHLAB system manufactured by the Medlab Company, a division of Control Data Corporation. The main-frame is a CDC 1784 with 160K bytes of core memory and 275M bytes of disk memory. Currently there are 66 peripheral instruments, including 34 CRTs and 5 on-line medical instruments.

The phlebotomy team makes frequent sweeps of the wards using computer-generated collection lists. The laboratory also receives specimens collected by physicians throughout the day and night in an area called Central Distribution (CD). Approximately 800 samples per day are received and entered into the LCS using a program called TEST REQUEST (TR). In this same CD area approximately 900 phone calls for test results are received each day using a program called PATIENT INQUIRY (PI). The same personnel that do TR also do PI. On the day shift there are three to four people staffing the CD area. With such a work load, the CD area is obviously very busy.

A program called TRIP was written by our programming staff to study the work flow through the CD area. Its name is derived from the transactions that it studies: TR and PI. It captures the time of day every time the PI and TR programs are used in CD. These data are stored on disk, and each day a histogram is generated that plots the number per hour of TR, PI, and total transactions. When 4 months of data had been accumulated, they were transferred by magnetic tape from the LCS to the Michigan Terminal System, where files were constructed. The MIDAS statistical package was used to analyze the data. Graphs showing the average work flow pattern for the Sundays, Mondays, Tuesdays, and so on were produced (Figures 1 and 2). Visual inspection of these graphs for each day was made to determine the number and times of the peaks of activity as well as the cause. Peak activity is defined here as 40 or more transactions per hour for either TR or PI. When each has 40 or more per hour, the peak is considered as being composed of both activities. The threshold of 40 per hour was chosen because experience has shown that CD personnel perceive themselves as being busy at this level of activity. The time of day and cause(s) for every peak found in each of the seven daily average work flow patterns was used to construct a CD peak activities chart (Figure 3).

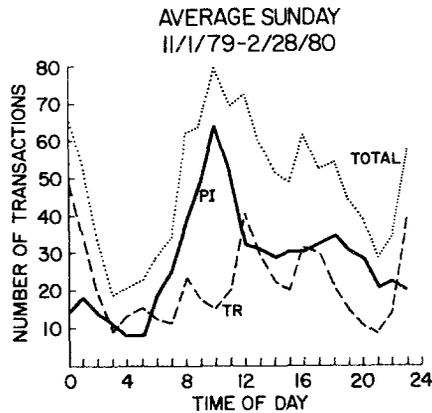


Figure 1. Profile of the average work flow on Sundays in the Central Distribution area. TR represents entry of the test order into the computer and PI represents phone calls by physicians for laboratory results.

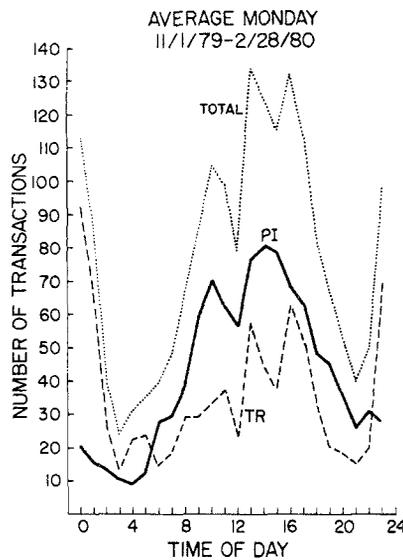


Figure 2. Profile of the average work flow on Mondays in the Central Distribution area. TR represents entry of the test order into the computer and PI represents phone calls by physicians for laboratory results.

## RESULTS AND DISCUSSION

Comparisons of the graphs of the average work flow pattern for each day of the week (Figures 1 and 2) revealed two important points of interest. First, weekdays and weekends are clearly separable. This is true not only from a quantitative aspect (i.e.,

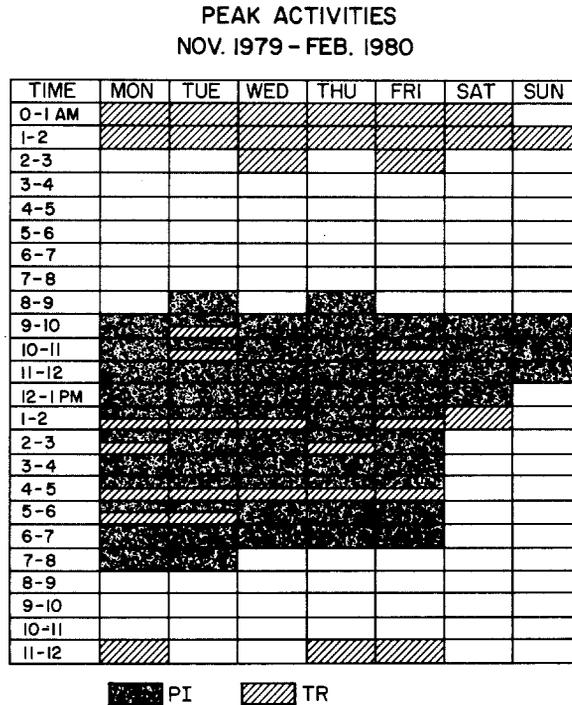


Figure 3. Peak activity in the Central Distribution area. TR represents entry of test orders into the computer. PI represents phone calls by physicians for laboratory results. Splitting of time slots, such as 10:00–11:00 a.m. on Fridays, represents a peak composed of both activities instead of two separate half-hour peaks. Absence of a peak does not imply absence of activity, since a threshold of 40 transactions per hour was used to define a peak of activity.

height of the peaks of activity) but also from the time occurrence of the peaks during the day. No peaks of activity occur after 1:00 p.m. on weekends. The second point noted was that each day had roughly the same number of peaks, six for weekdays and three for weekend days. Both of these observations prompted the construction of the peak activity chart (Figure 3). Once this chart was made, it was immediately obvious that there are stable and predictable patterns of activity in CD. What initially had seemed to be a random “upon demand” operation turned out in reality to have a structure. Although we previously knew that certain times of the day were more busy than others and that weekends were generally less busy than weekdays, the reproducibility of the patterns was not obvious from observing the activity in CD. Thus, given that stable and predictable patterns do exist, one could utilize this knowledge to adjust staffing needs. We have begun doing this by moving shift changes, removing extra staffing on slower days, and spreading out the coverage throughout the week. The timing of coffee breaks and lunch breaks was changed so that they now occur during the relatively quiet periods. We are not aware of any previous reports of laboratory computers used to determine peaks of activity in clinical laboratories.

After determining when the peaks and valleys of activity occur and using it to adjust staffing patterns, the next logical step is to determine the causes of the peak

activity and ask why they occur at those particular times. For some of the activity peaks, the answer is simple. For example the TR peaks at midnight to 2:00 a.m. and 11:00 p.m. to midnight represent requisitions collected from nursing stations late at night and entered into the LCS by our personnel in order to generate collection lists to be used by the phlebotomy team the next morning. The small TR peak at 4:00 to 6:00 a.m. represents specimens received from the intensive care units (figures 1 and 2). The fact that phone calls decrease on weekends after 1:00 p.m. provides a clue to explain the overall pattern of phone calls. On weekends physicians make patient rounds sometime between 8:00 a.m. and 1:00 p.m. After that time the few remaining physicians are those assigned to weekend duty. Thus, most phone calls for the weekend day are done in conjunction with these morning rounds. During weekdays the physician rounds are made twice per day, one being between 7:00 a.m. and 10:00 a.m. and the other between 3:00 and 5:00 p.m. We therefore suspect that the peak of phone calls on weekdays beginning at 9:00 a.m. represents physicians collecting laboratory results for morning rounds, and similarly, the peak of phone calls between 1:00 and 5:00 p.m. represents physicians collecting data for afternoon rounds. During their morning rounds ("patient rounds") physicians are not near the phones and calls to CD should decrease. During afternoon rounds ("chart rounds"), on the other hand, they are closer to the telephones. A preliminary investigation of this possibility suggests that this may be the case since the most frequent time for patient rounds to start is 7:00 to 8:00 a.m., which is a quiet time in CD. A more in-depth follow-up will be required before this hypothesis can be accepted. Westlake has identified physician rounds as one key factor in determining the optimal time for phlebotomy sweeps of the wards.<sup>2</sup> However, aside from this, we are not aware of other clinical pathology literature discussing the importance of physician rounds in the work flow of a clinical laboratory. If physician rounds are responsible for the structure of the work flow into the CD area, it must also be responsible for similar effects in radiology, pharmacy, and nursing services. Thus, it is a point well worth pursuing.

After the two times each day that interim reports are printed and delivered to the wards (by 12:30 p.m. and 4:30 p.m.) the number of phone calls decreases, suggesting that physicians utilize them when they arrive instead of calling CD, and further, that the large number of phone calls at other times represents additional needs for laboratory results not being fulfilled by the current twice-daily printing. On the other hand, the LCS cannot continually print interim reports. Some other means of transmitting the results to physicians at whatever time is best for them must be found. To this end, we are currently developing an interface between the LCS and the hospital computer to immediately pass laboratory results so that physicians can inquire directly on hospital computer CRTs in each ward. It will be interesting to see how the phone call pattern changes when this interface becomes operational.

The fact that there is a peak of phone call activity from 9:00 a.m. to noon or 1:00 p.m. on weekends suggests that interim reports should be printed earlier on these days, say, at 10:30 a.m. Even though fewer of the laboratory tests will appear on them, since some work will still be in progress, it should alleviate a large number of the calls, as apparently most laboratory results are transmitted to physicians by phone on these days. We will begin printing interim reports earlier on weekend mornings and it will be interesting to compare differences in phone call activity after this is done.

The final point to be discussed is the occurrence of TR peaks at 1:00 to 2:00 p.m. and at 4:00 to 6:00 p.m. We believe that this represents a second physician order cycle each day. One main purpose of a LCS is to speed up reporting of results, and the logical outcome of this is to speed up the generation of additional or follow-up tests based upon the results of the first physician order cycle. Further support for this is gained from the observation that the work load within the laboratories has gradually shifted from the morning to the afternoon since the introduction of the LCS in 1976. Whether this represents a leveling out of one day's work or a shift of the work load from the morning to that of the previous afternoon is not clear. In a manual reporting system the usual physician order cycle is 24 hours, whereas with a LCS it is shortened to 4 hours. By increasing the speed of the physician order cycle, this speeds up the diagnostic process and improves patient care.

In summary, the LCS can serve as a management tool to document work flow through the laboratory. This may be used to adjust staffing to optimize for the observed work flow and improve the efficiency of the laboratory without decreasing its effectiveness. One important result of this study has been the suggestion that the physician rounds are linked to the work flow through the laboratory. Further work should be done to test this hypothesis since it has implications for work load in other areas such as radiology and pharmacy.

## REFERENCES

1. Bloch, D.M., Computer-generated management tools for the clinical pathology laboratory. I. Throughout report. *J. Med. Syst.* 4:367-380, 1980.
2. Westlake, G.E., Optimum turnaround time for laboratory information. *Automation and Management in the Clinical Laboratory* (G.E. Westlake and J.L. Bennington eds.), University Park Press, Maryland, 1975, p. 109.