

Adding A Microcomputer Bar-Code Network to a Minicomputer-Based Radiology Information System

George David and Scott Gregory

A bar-code terminal network under software control of a microcomputer was added to the minicomputer-based radiology information system at the Medical College of Georgia in Augusta. The bar-code network was specifically installed to address the inherent inaccuracies occurring when procedure information was entered at the time of registration before procedures were actually performed. Technologists now enter procedure data into bar-code terminals after procedures are performed, substantially reducing database errors. This approach allowed us to take advantage of a microcomputer product without the necessity of completely converting our highly customized information system software from mini-to microcomputer.

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THE COMPUTERIZED information system in the Department of Radiology at the Medical College of Georgia Hospital and Clinics (MCG) was originally placed in service in February 1982, operating on an IBM Series/1 minicomputer (IBM, Armonk, NY). Software for this system, custom written for MCG (Charles May and Associates, Jacksonville, FL), was primarily used to facilitate billing and to maintain patient procedure logs. The original system operated on 512 Kbytes of memory and supported four registration terminals and one billing/system terminal. Since going into service, the operating software has been substantially customized and enhanced by inhouse expertise in the radiology department and hardware and memory have been upgraded.

One serious shortcoming of the original system was the method used to add procedures to the patient database. All procedure data were being entered as part of the registration process based on the procedure(s) requested by the referring physician. This was done as the patient entered the department and before any procedures were performed. This approach resulted in many errors because, as is the case in any radiology department, the procedure performed frequently differs from the one that is requested. For example, procedures may not be performed at all if patients are found to be inadequately prepped, or

the radiologist may alter an roentgenographic request to a more appropriate procedure.

Entering procedures before they were actually performed resulted in numerous errors in the database, degrading system efficiency, usefulness, and accuracy of information. Often errors were not corrected until billing was performed. System operators located errors by comparing the procedures entered at the time of registration with those actually performed as indicated by the text of the radiology results report. Although technologists attempted to call system operators when changes were made, many changes were not noted until billing, several days after the date of service.

Because of the inherent inaccuracies of this approach, database procedure logs were often inaccurate. Facilities or hospital charges (nonprofessional) could not be billed until after reports on each procedure were completed and cross-checked by system operators. In the case of those films removed from the department by other services before being read by a radiologist, patients were never billed for facilities services.

METHODS

In order to address these problems it was decided that procedures should be entered into the information system after being performed. Technologists were selected as the most appropriate people to make these entries because they are the individuals who render services and thus know exactly what each patient receives. It was recognized early that any system that required busy technologists to enter data into a computer would have to be fast, easy, and accurate. Bar-code technology was selected as the best means of having technologists interact with the information system. Bar-coding technology is not new to radiology. In addition to its use in the registration process, bar codes have been used in applications ranging from automating film library checkout to the generation of radiology reports.¹⁻³

Bar coding is simply a typing aid, a quick, convenient, and virtually error-free method of data entry. A number of codes

From the Department of Radiology, Medical College of Georgia, Augusta, GA.

Address reprint requests to George David, MS, Department of Radiology, BD-341, Medical College of Georgia, 1450 Laney-Walker Blvd, Augusta, GA 30912.

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Fig 1. Bar code for character "0".

have been developed for various applications. One of the most popular is the three of nine code or code 39.⁴ Each character of this code is represented by nine elements, five bars, and the four intervening spaces. For any valid three of nine bar-code character, three of these nine elements are wide and six are narrow. The bar code for the character "0" is shown in Fig 1. For this character, the third and fourth bars from the left and the second space from the left are wide. Because all characters have this three wide, six narrow attribute, the process of reading a character contains an inherent validity check. In other words if the bar-code reading device misses a bar due to a printing error, for instance, the reading will be out of synchronization by one bar, rendering it virtually impossible that all remaining characters will pass their validity check.

In addition to each character containing a check of validity, each valid bar code is appended with the asterisk (*) character both at the beginning and end. By using the same start and stop character, wanding of a bar code may be performed in either direction and internally compensated. If an invalid character is read or if valid start and stop characters are not detected, the bar code is rejected and the reader will not respond. On detection of a valid bar code, its contents (minus the start and stop asterisk) are then transmitted (followed by a carriage return/line feed, if so programmed) just as if the data had been typed.

Bar-code equipment is commercially available in several configurations, as add-on devices for many existing terminals, as stand-alone terminals with and without display or keyboard, or as multiplexed networks. Because of the size and physical extent of MCG's radiology department, approximately 12 bar code stations were required for the entry of between 400 and 500 procedures performed daily. Rather than tie a number of stand-alone bar-code terminals to the expensive and limited number of minicomputer ports, it was

decided that connection of a multiplexed bar-code network to a single minicomputer port was the most reasonable approach.

The function of the multiplexer is to control simultaneous activities, relaying the data of one station at a time to the radiology information system while putting other stations requesting access on hold until the line is available. Because technologist interaction with the bar-code system was to be made as fast as possible, it was felt that 12 terminals sharing a single access port to the information management system would not often incur simultaneous activity and that in the case of simultaneous activity a user would need wait for only 1 or 2 seconds for database updates.

A search for a commercial bar-code network yielded an exclusive product offered by Computerwise (Olathe, KS). Instead of using proprietary hardware, Computerwise uses a unique scheme where its "smart" bar-code terminals are connected together through a standard microcomputer (personal computer [PC]) under software control. Each terminal is assigned its own address through built-in firmware. Terminals are tied together in parallel using an RS-422 protocol. Using an RS-422 to RS-232 converter (Computerwise, Olathe, KS), the terminals are connected to the PC through a standard serial interface.

The Computerwise network included sample software for sending data between PC- and bar-code stations and handling simultaneous accesses. The software consisted of a simple BASIC program (GW-BASIC, MicroSoft, Redmond, WA) that calls assembly language drivers. This software was modified inhouse to additionally perform front-end processing of entered data. In addition to multiplexing chores, the PC was programmed to check for proper syntax and sequence of entered data, to send the appropriate prompts to terminals, and finally to forward database updates to the departmental information system, monitoring the response. A second PC serial interface connects to the radiology information system. The configuration of the bar-code system is shown in Fig 2.

Bar-code terminals with two-line, 40-column displays and membrane keypads were installed in various technologist work areas throughout the department. Procedure informa-

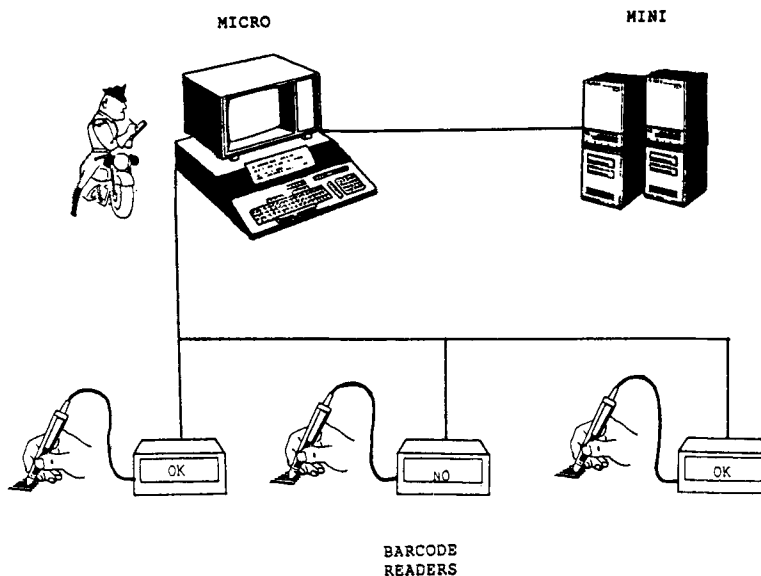


Fig 2. Bar-code system configuration.

tion is no longer entered on the information system at the time of registration. At registration the patient is identified and the referring clinic and physician are entered. The information system then prints a flash card followed by a bar-code label on an inexpensive dot-matrix printer located by each registration terminal. The registration bar code identifies the patient and encounter.

After a procedure is performed, the technologist first wands in the registration bar code (Fig 3). The information system responds by displaying the patient's name on the bar-code terminal. The technologist is then prompted to enter the procedure performed. The information system responds to each procedure by displaying the patient's name followed by the procedure description. Multiple procedures are simply entered one at a time following the first. The process is ended when the technologist enters his or her bar-code identification number. The information system displays the patient's name, followed by the technologist's name, and finally the number of procedures entered. The system is now ready for the next registration bar code.

Having an improved registration process also has allowed better administrative monitoring of activities.⁵ System users can monitor incomplete registrations, those patients who have been registered but for whom no procedures have been entered. This list is provided by registration site from oldest to most recent and indicates patient waiting time. Registration clerks also may delete incomplete registrations for patients who leave the department without receiving a procedure. Technologist workload statistics are generated at the end of each month, allowing managers to more closely monitor departmental activities. Patient tracking is also enhanced because personnel can determine if a patient has been registered in a particular area or if a procedure has been completed.

DISCUSSION

Using a standard microcomputer with software control over multiplexing offered significant advantages over the traditional method of multiplexing through proprietary hardware. Although multiplexers are expensive and if not working may need to be sent off for repairs, a malfunctioning PC could be quickly swapped with another, minimizing downtime. The only proprietary hardware other than bar-code terminals is the RS-422 to RS-232 protocol converter. Both the



(287-914 01) DAVID, GEORGE S
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Fig 3. Registration bar code.

terminals and protocol converter are low enough in cost to keep a spare unit on the shelf.

The most powerful gain in using a PC-based bar-code network over hardware multiplexing is the flexibility of software. The microcomputer is able to do all terminal polling, collision handling, syntax checking, and front-end processing, freeing the information system minicomputer to handle only database updates. As we had found in previous endeavors,^{6,7} integration of microcomputer applications with our minicomputer information system resulted in an application where each computer is allowed to do what it does best. We were able to take advantage of a microcomputer product without the necessity of rewriting our highly customized information system software.

The bar-code network was specifically installed to address the inherent inaccuracies of our old registration system and thus to increase the accuracy of the database. Having the technologists enter procedural data after the procedures have been performed has substantially reduced database errors. Technologists must now perform the additional duty of logging procedures, but minimal time is required, and many actually seem to enjoy performing bar-code entry. Future enhancements being considered are logging patients into rooms, associating more than one technologist with a procedure, printing technologists' initials on the roentgenographic results report, and generating patient-tracking statistics reports.

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