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Review Article

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Review of computer applications in institutional pharmacy—1975–1981

Ken W. Burleson

A literature review of computer applications in institutional pharmacy, covering papers published from 1975 to 1981, is presented.

Articles are categorized as computer concepts, applications to administrative functions, controlled substances, drug distribution systems (including on-line and off-line services, intravenous admixture services, and ambulatory services), drug information, clinical services (including drug-use review, drug interactions and therapeutic incompatibility surveillance, and pharmacokinetics), and pharmacy-related applications developed by nonpharmacists.

Before 1975, computer applications in institutional pharmacy reported in the literature were largely single-use applications. After 1975, many reports described the integration of individual applications into sophisticated systems that supported many functions. There is still a need for good cost justification studies of computerization in pharmacy.

Index terms: Administration; Automation, data processing, computers; Controlled substances; Drug distribution systems; Drug information; Drug interactions; Incompatibilities; Pharmacy, institutional

In the past 20 years electronic data processing (EDP) in hospital pharmacy has grown from applications that improved accounting procedures to sophisticated multifunctional, integrated systems for institutional drug control and clinical pharmacy support. Early innovators were hospital pharmacists who applied computers to accounting and billing functions. However, as pharmacists became aware of the benefits of automation and as they gained expertise in the field, applications of EDP became varied. Innovative approaches to pharmacy practice have been instituted that, without automation, would be too time-consuming, too costly, or too difficult to implement. Automated drug control systems, medication delivery systems, and support of clinical services are examples of these applications. Interest in automation for pharmacy practice has stimulated vendors of commercial systems to develop hardware and software packages designed for pharmacy.

The expanded use of electronic data processing in pharmacy practice has been due to both the development of more sophisticated hardware and software during the past 20 years and the experiences of individual practitioners in applying EDP to various segments of practice. The literature has contributed substantially to the increased awareness of the individual pharmacist of the benefits of automation. In 1975, Knight and Conrad[1] published an extensive review of pharmacy applications of electronic data processing made to that time. This article reviews those applications made from 1975 to the present.

Ken W. Burleson is Director, Pharmacy Services, Catawba County Memorial Hospital, Hickory, NC 20601.

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Computer Concepts

Data processing concepts and technology are areas in which few pharmacists have had formal training. They should become familiar with fundamentals of systems analysis, design, and computer technology prior to involvement with application development. A number of articles have described the basic concepts of data processing for the pharmacist.

Nelson[2] presented an introduction to computer hardware that could be used in a pharmacy system. He described the various hardware components, including the central processing unit (CPU), input devices, and data storage devices. Advantages and disadvantages of different components were presented. Downtime, system security, and vendor systems evaluations were discussed. He also presented a dictionary of computer terminology. Mehl[3] outlined the minimum requirements for a pharmacy data processing system. He compared advantages of centralized versus decentralized systems, and examined the methods of data entry and types of drug coding for developing a data base. He also emphasized the need for order verification to prevent errors.

Computer hardware configurations range from the large mainframe computer to the minicomputer to the most recent development in the field, the microprocessor. Given the premise that the pharmacist has a choice in the selection of hardware, an understanding of the advantages and disadvantages of each can be essential to the development of a successful application. Knowles[4] explained the differences between mainframe systems and minicomputers. Lauer et al.[5] explained the apparent and subtle differences between a mainframe computer shared with other users (shared system) and a stand-alone dedicated minicomputer system for pharmacy, particularly in regard to ambulatory pharmacy practice. Advantages and disadvantages of each configuration were presented. Data storage was found to be the most serious drawback to a stand-alone system, a disadvantage that could be minimized with a properly designed system. The authors concluded that in most situations for pharmacy practice, either configuration could provide adequate support.

Another configuration is a pharmacy application developed as a part of a total hospital information system (HIS). Ball et al.[6] examined the past, present, and future developments in hospital data processing systems, from stand-alone pharmacy systems to large hospital information systems. The authors predicted that in the immediate future, many physicians would have terminals in their offices interfaced with hospital information systems. Mecklenburg[7] described the expanding applications of hospital information systems, including pharmacy and other clinical applications.

An important concept for the pharmacist to understand before developing an application is the methods used to justify the need for and cost of a computerized system. Although many articles have been written describing the varied applications of computerization, few articles have described controlled documented studies to justify the cost and evaluate the effects of a computerized system. The fact that evaluation of systems and intensive cost-benefit studies have not been accomplished may be a major reason why there has not been a greater acceptance of pharmacy systems by hospital administrators or pharmacists. In 1975, Gouveia[8] reviewed the few studies to date that had attempted to analyse the effects of computerization on hospital costs, medication errors, and patient care. He found that the few studies published actually raised more questions than they answered. He emphasized the need for research to establish adequate cost-benefit ratios to justify computerization to hospital administrators, patients, and third party payers.

Since that time, other studies have been published describing the steps involved with analyzing and justifying the need for and cost of computerization. Freibrun[9] analyzed a traditional pharmacy system in a 360-bed hospital. He identified procedures needing improvements and examined alternate manual and automated approaches for change; areas in which automation would offer potential savings; developed a rating scale for vendors; and described steps involved in successful operations analysis in a pharmacy. Kay et al.[10] described the method used to analyse a hospital pharmacy's need for automation and identify the various areas where automation would benefit both pharmacy and the hospital. The impact of the proposed system upon other areas of the hospital were also listed. Cost justification for a dedicated mini-computer was developed. The authors were successful in justifying automation of the pharmacy department, based upon a potential cost savings and an improved medication delivery system.

Neal[11] developed an in-depth cost proposal to justify to hospital administration the computerization of a hospital pharmacy. He identified seven areas of tangible cost savings (reduction in costs, elimination of salaries paid, increased revenues) and two areas of intangible savings (reduced overhead, labor reallocation). He was able to project tangible dollar savings to each of these areas. He found that automation of the department would result in a substantial cost savings. He also described the various steps in developing and presenting the analysis to hospital administration. Gray[12] evaluated the cost of computerization of an i.v. admixture service in a hospital pharmacy. Staffing analysis and life cycle cost projection were determined. Workloads and staffing patterns both with and without the computer were calculated. The basis of the study was to determine the amount of money that could be invested in a computer system as justified by staffing reductions and other savings. The author's conclusion was that the computer was cost effective and, therefore, should be purchased.

Lauer[13] gave an overview of the need for automation in pharmacy practice and the benefits to be realized from computerization. Three areas of savings as a result of automation—time, space, and personnel costs—justified the cost of computerization.

Two authors have described the methods of dealing with vendors of computer systems. Olsen et al.[14] described the method used to select an upgraded computer system that would support an automated clinical department in the hospital. Although the article dealt specifically with an automated laboratory system, the authors presented a general discussion of vendors, vendor selection, systems requirements, terminal requirements, and hardware and software that could be used by the pharmacist in selecting a pharmacy system. Cutely[15] presented an extensive list of questions a pharmacist should ask a hardware or software vendor of a commercial system when considering the purchase of such a system.

Before beginning development of any automated applications, the pharmacist must develop a data base, or drug file, listing all the drugs to be found in the pharmacy, along with any information pertinent to the description of each drug. The method in which a data base is developed can mean the difference between a flexible system with the ability for expanded applications and a rigid, single application system. Hanson et al.[16] have described the development of a master drug file that was developed by examining an existing computerized drug data file to determine which existing fields of information should be retained for the new data base. The new data base was developed to support increasingly sophisticated pharmacy applications. Twenty-seven data fields for the master drug file were identified. Programs were written to permit entry and maintenance of the file by using punched cards input to an offline computer. The authors envisioned using online entry of data through a cathode ray tube (CRT) in the future. Programs were written that permitted machine verification of data according to predefined specifications. Any errors detected were rejected for correction. This editing feature resulted in a high degree of accuracy of the stored data. Strand et al.[17] developed a master drug file after comparing commercially available data bases which they found to be deficient. Twenty-seven different data fields were identified and information for each drug entered to a coding form which was used for data entry. Entry was online via a cathode ray tube. The data base was used to support certain administrative and drug distribution programs for both inpatient and outpatient services. The authors also examined the cost of the development of the file. They found that more than 900 hours were involved with the development, at a total salary cost of $8451. This calculated to $7.43 per line item in the data base. Although this cost was twice that of a commercially available data base, the authors thought that the additional data fields that were available to them justified the cost.

The American Society of Hospital Pharmacists provides a computer-generated, machine-readable data base called Drug Products Information File (DPIF)[a] for use by pharmacists in computerized systems. Frankenfeld[18] examined the problems associated with the National Drug Code (NDC) system as a pharmacy data base and the potential for interfacing it to DPIF. He explained the advantages of cross-referencing the information in the two files.

Administrative Applications

Because of the computer's inherent ability to quickly tabulate numerical data, and to store, retrieve, and compile statistical information, certain administrative functions are ideally suited to automation. Among these functions are patient billing and accounting, drug use review, and inventory control. A number of articles have described applications of EDP in these areas.

Silverman[19] described the administrative functions that could be automated using a dedicated minicomputer. Among these applications were personnel management, patient billing and accounting, and inventory control.

Wuest and Schaengold[20] described an automated accounting system shared by two hospital pharmacies, using a time-shared computer system. Data were entered from dispensing records showing all transactions for each pharmacy. The system generated a monthly report of expenses for chargeable patient drugs and nonchargeable floor stock. Drug use statistics from this report were used for purchasing and inventory control. The system also printed a formulary for each hospital.

In a hospital without data processing capability, Elliott[21] contracted to use the computer services of a local drug wholesaler to develop an inventory and purchasing system. The wholesaler's programs for inventory control were modified to adapt to the special needs of the hospital. All drug issues to stock from inventory were manually recorded on an inventory master list by a clerk and this was sent to the wholesaler for keypunching into the system. A weekly computer-generated report summarized the use of each item, and this list served as a stock status report and purchase list. Each item that had reached a predetermined order point was flagged. Items supplied by the wholesaler were automatically shipped and entered into the computerized inventory. Orders to direct vendors were completed by the pharmacist, working from the report. The system also generated a hospital formulary by use of therapeutic category coding. Both an alphabetical listing and a listing by therapeutic categories were available.

Pickup et al.[22] utilized the Massachusetts General Hospital Utility Multi-Programming System (MUMPS) to develop programs to control ward stock levels and contribute to workload analysis in a quality control section of a hospital pharmacy. The system was programmed to determine each hospital ward's minimum stock levels, based upon historical demand and the ability of the pharmacy to respond to the needs of the various wards. Results showed that the system could reduce the inventory of drugs on the nursing units, thereby effecting a cost savings, without any deterioration of service or inconvenience to the nursing units. The system also handled data concerning raw materials in the quality control section. It was determined that a time savings could be realized by automating some of the reports in this area.

Automated patient billing has been a feature of hospital computer systems for many years. This is one of the earlier applications to which EDP was applied in pharmacy. Trudeau[23] modified an existing time-shared payroll and accounting system to provide drug use review and patient drug billing. The time saved from these applications was used to permit the pharmacy to complete a hospital-wide traditional unit dose system. The author did not use the computer directly to support the unit dose system. Priest[24] used computer-printed gummed labels to be attached to intravenous fluids and other pharmacy patient charge items that were kept as floor stock on the nursing units. These gummed stickers functioned as a charge voucher as well as a stock replenishment mechanism. The author concluded that the system aided in the capture of more charges, while simultaneously saving personnel time.

Fish[25] described a computerized patient billing system that was based on a combination of a percentage markup of drug costs plus a dose fee. Seven different dose fees (factors) were used, depending upon the type of drug product administered to the patient; e.g., oral unit dose, injectable unit dose, and i.v. additives. Manual patient profiles were used for a unit dose medication system, and cumulative charges for each patient were maintained on these profiles. At the time of patient discharge, the profile for the patient was inactivated and all drug charges were added. A pharmacy technician also entered the patient number, computer drug code, and dose factor for all drugs. The profile was then sent to the pharmacy pricing area, where the charges were entered into the computer via a cathode ray tube. A final patient bill was produced as a result of data entry. The system offered advantages of an accurate, itemized statement; charges were equitable, based upon the type of drug administered; and the system produced useful statistical reports. The time required to enter charges manually into the system was a drawback, and the author proposed an automated unit dose system that would eliminate much of the manual data entry.

Gurtel et al.[26] projected drug use review statistics for a pharmacy and therapeutics committee to use in determining the benefit of adding a new drug to the formulary of an ambulatory patient care clinic. A computer-supported ambulatory pharmacy system was used to determine if a new drug, ticrynafen, a diuretic with uricosuric properties, would benefit patients in the clinic. The computerized patient profile was used to determine the number of patients taking a diuretic who were also taking a uricosuric agent, to determine how many patients could benefit from the new drug which offered both therapeutic actions. Computer analysis revealed that only 8% of the patients on a diuretic were simultaneously receiving a uricosuric agent. In view of the cost of the new drug and the limited application, as shown by computer analysis, the pharmacy and therapeutics committee chose to add the drug only on a restricted formulary status. The drug was eventually prescribed for four patients. Later, the drug was recalled from the market because of its adverse reactions. The computer was used to search the patient profiles for those patients receiving the drug at the time of recall, so that their physicians could contact them and make appropriate changes in therapy. The authors concluded that the use of the computerized patient information system enabled the pharmacy and therapeutics committee to prevent the potential exposure of more than 160 patients to the adverse effects of the drug.

Not all administrative applications of data processing must be developed on a computer. Word processing equipment is similar to a computer, with the exception that word processing equipment ordinarily has no built-in logic. The system is used for storage of small amounts of data and retrieval and printing of this information on a repetitive basis. Letcher[27] compared three different commercial brands of word processing equipment to various applications in hospital pharmacy. The applications studied were label production; storage of personnel information; scheduling of repetitive tasks; and composition of narrative information, such as drug bulletins and procedure manuals. The evaluation included keyboard design, disk storage capabilities, software, print format, and security of data. One of the three systems was clearly superior to the other two because of its flexibility of applications. The author summarized the results of the evaluations of each machine.

Controlled Substances Applications

Controlled substances are defined as those drugs which have the potential and liability for abuse; i.e., narcotics and barbiturates. Federal and state laws require that practitioners who dispense these medications maintain records of disposition for all drugs under this regulation. Because of the large number of drugs in this category, proper recordkeeping has been time-consuming for both the pharmacist and nursing personnel. Automation of this segment of practice can reduce time involvement for both the pharmacist and nurse, while maintaining accurate control and accountability records as required by law.

Petoletti[28] used an off-line system in an outpatient clinic to monitor for potential abuse of controlled drugs by patients. Dispensing data were entered on a source document for each prescription dispensed. These data were keypunched weekly, and reports were generated that notified the pharmacist of those patients receiving excessive supplies of controlled drugs.

McDaniel[29] modified an existing patient accounting system to develop an automated recordkeeping system. All controlled drugs were assigned specific service codes within a designated group of service numbers. A separate file was set up in the computer for this group designation. As charges were posted to the patient's account, records of controlled drugs dispensed were created. Daily and cumulative monthly reports were printed, which showed distribution of controlled drugs. Nazzaro[30] developed a program on an off-line computer to provide accurate records for controlled substances accountability, while reducing manual transcriptions involved with record maintenance. The system was used for both inpatient ward stock and outpatient prescriptions in a military hospital. All prescription transactions were recorded manually on punched cards, and included patient number or hospital ward code, physician's identification code, drug code, and quantity of drug dispensed. All data were later keypunched and entered into the computer. Various records were generated by the system, including perpetual records of each drug by patient or ward, monthly inventory of all controlled substances, and ward monitoring lists of excess stock of controlled substances. The system could also search for prescriptions by patient or prescriber.

Shaver et al.[31] described a system for an inpatient and outpatient military hospital pharmacy which used limited computer hardware. The system was run on a remote mainframe computer through a telephone hookup. A pharmacist or technician entered all transactions daily via a cathode ray tube. After data entry was complete, all transactions were verified before the update program was run, to ensure accuracy of information. The system generated a number of reports, including transactions by drug and current inventory balances. It also permitted patient drug use screening and physician prescribing screening to monitor for potential drug abuse. The system was capable of tying in terminals at other military hospitals.

Finally, Dickinson[32] reported how the Drug Enforcement Agency used computers to map entire states to show drug distribution, to pinpoint areas of potential drug abuse. Data are obtained from two sources—the Automated Reporting and Consolidated Order System (ARCOS), which shows drug distribution from manufacturers and wholesalers to pharmacies; and the Drug Abuse Warning Network (DAWN), which tracks drugs from selected hospital emergency rooms. All data were entered into the computer and analyzed. The resultant output was distributed to DEA field offices and other local and state law enforcement officials for follow-up.

Drug Distribution System Applications

Traditional manual drug distribution systems are time consuming, involve much clerical work for both pharmacist and nurse, and tend to be error-prone. Automation of the medication cycle can provide substantial benefits to the pharmacist, nurse, and patient by reducing the amount of clerical work involved with maintaining a medication system, reducing errors, improving administrative control, and freeing the pharmacist for more clinical involvement. Much work has been done in automating various segments of the medication cycle. Many pharmacists have automated one or more procedures involved in medication delivery. However, prior to 1975, only a few systems had integrated the various components of the cycle into a completely automated medication delivery system. Since that time, several articles have described the development and application of total systems for automated medication delivery. This increased development has been due, in part, to the reduced cost of hardware necessary to support an automated medication delivery system and to the entry of vendors that provide hardware and software packages. Yet, the use of EDP in the medication cycle is not extensively employed by hospitals. Stolar,[33] in a 1978 national survey of hospital pharmacies, found that of the 738 reporting hospitals, only 13% of the large hospitals and 5% of the small hospitals used computer systems in the drug dispensing process.

The importance of EDP in hospital drug delivery systems and the role of the pharmacist in implementing its use has been recognized by the American Society of Hospital Pharmacists (ASHP). The ASHP Statement on Hospital Drug Control Systems[34] states, "The pharmacist should utilize EDP to decrease the many traditional paper-handling chores so that his clinical role may be effectively expanded and his talents utilized properly." This position statement also outlined the many applications of EDP to pharmacy practice and the role of the pharmacist in systems development.

Off-line Medication Systems. Prior to 1975, many automated medication distribution systems were developed utilizing off-line systems, usually by modifying an existing batch process accounting system to provide pharmacy applications. In recent years, more and more pharmacists have had access to on-line computer systems, and only a few authors have described the development of systems using off-line computer hardware.

Swift[35] described a semi-automated approach to a unit dose system, in which punched cards were used to provide information for medication cart filling. Each drug order was transferred in writing by a pharmacy technician to a punched card, called the master dose card. After verification of the transcription by a pharmacist, the data were keypunched onto cards. The cards for each patient's medications were then placed in the proper medication cart drawer. These cards were color-coded by drug type and alphabetical name to simplify cart filling. The technicians filled a 24-hour supply of medication from the information on the cards. The daily charge data were then entered manually on each card for the amount of drug dispensed. After the pharmacist checked the medications in the cart, using the master dose cards, the cards were sent to the data processing center for daily charging. The cards were then returned to pharmacy for subsequent use in the medication system. The system was cumbersome, since the cards were often misplaced and daily maintenance of the patient records involved a substantial amount of paper handling. The cards were not used to generate a patient profile; therefore, monitoring of patient medication records was not possible.

Gilbert et al.[36] described a batch mode order entry procedure on an off-line computer. The pharmacist reduced all drug orders to numeric codes on punched cards. Once each eight hours, the coded orders were batch keypunched. The computer printed a drug distribution log for unit dose cart filling, a cumulative patient profile, and a daily medication charting document for nursing. Automated patient charging and census control were features of the system. The author overcame the lapse between profile printings by sending doses of medications for new orders to cover the interim until the next cart exchange.

On-line Medication Systems. On-line systems allow the operator to interact directly with the computer, allowing immediate access to data stored, thus overcoming the time lapse in information processing which occurs with off-line systems. Thus, on-line systems lend themselves to more flexible programming. For this reason, on-line medication systems have usually involved more sophisticated applications. A number of such systems have been successfully implemented, both as dedicated pharmacy modules and as subsystems of larger hospital information systems.

A series of articles has described the medication distribution system at The Johns Hopkins Hospital. Two gener-

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