

The Medical Record: A Comprehensive Computer System For The Family Physician

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Background: Despite the early excitement regarding the possible uses of computers in medical care in the 1980s, the computer has not had much effect on routine outpatient medicine except for billing and accounting.

Methods: An emerging comprehensive ambulatory care computer system, The Medical Record (TMR), is used extensively in a large family practice, the Duke Family Medicine Center. TMR is the central system for accounting, appointments, billing, and reporting of laboratory results, radiographic findings, and medications. TMR also records problem lists and generates prompts to the clinicians for needed health maintenance, laboratory tests, and reminder letters. The most innovative function of TMR is the computerized obstetric patient record, which can be accessed from multiple sites. Cost savings compared with a manual system were found to be in excess of \$7 per patient visit or approximately \$500,000 per year for the Duke Family Medicine Center.

Results and Conclusions: A comprehensive computer system in a large family practice is cost effective and facilitates better patient care through improved access to patient data. (J Am Board Fam Pract 1994; 7:324-34.)

The use of computers in the medical care of patients has been a topic of discussion since the 1960s. Previous reports on computerized medical systems have dealt with both hospital and ambulatory care systems.¹⁻⁶ In the past 15 years there have been extensive reports on comprehensive office-based computer systems, which were used predominantly for billing, appointments, case summaries of patient care, clinician prompts, and queries of the computerized data base for quality assurance audits.^{1,2,5,7} Much has been written on the advantages and disadvantages of comprehensive office-based computer systems in the outpatient setting and the application of these systems to research.^{2,5,8,9} The benefits of a fully operational comprehensive computer system have been described as legibility, accessibility of data for display, and reduction in time spent recording data. For example, one entry of a prescription medication can replace the manual tasks of entering the data in the progress note, the medication list, and the prescription blank.^{3,8} The reduction in manual repetitive tasks and the possibility of better data management are considered the major strengths of the computer.

There have also been concerns about the effectiveness of a comprehensive ambulatory medical computer system, primarily centering around the cost of data entry, accuracy of the computer data base, and whether the computer can have an impact on patient outcome.⁹ Recently reports of computer use in primary care offices have focused on the generation of health maintenance prompts for clinicians and patients,¹⁰⁻¹² the effectiveness of a clinician-interactive system on cost reduction in a geriatric clinic for veterans,³ and a review of two microcomputer-based office systems.¹³

This article describes the advantages and cost savings associated with using The Medical Record (TMR), a comprehensive state-of-the-art medical office computer system,¹ in the Duke Family Medicine Center (DFMC), a large family practice clinic.

Methods

Study Site

The study was performed in the DFMC, a large free-standing practice operated by the Department of Community and Family Medicine at Duke University Medical Centers. The practice is open to all employees of Duke University and their families, Duke students, and patients from the wider Durham community. Practice volume exceeds 70,000 visits per year, with each of the patient groups comprising approximately one third of the practice. The DFMC also serves as a teaching site for medical, physician assistant, and

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pharmacy students. In July 1991 the practice became the residency site for the Duke Family Medicine Program. In addition to 30 residents, the DFMC is staffed by 18 family physicians, 2 nurse-practitioners, 2 physician assistants, 2 psychologists, 1 psychiatrist, 1 nutritionist, and 1 obstetrician-gynecologist. TMR was developed at Duke University in the 1970s and has been used since the mid-1970s in the DFMC, where further applications in primary care have been developed.

Computer System

TMR is designed with multiple modules each of which can be utilized as needed by the practice. The modules include demographics and insurance, accounting, appointments, requests for ancillary studies and reporting of their results, pharmacy, problem lists, encounter or procedure notes, and a wide array of reports. During the initial development of TMR in the early 1970s, the system was funded by a Robert Wood Johnson grant. Since the mid-1970s, TMR development has been supported solely out of operational dollars. TMR is currently operating on Digital Equipment Corporation's family of VAX computers under the VMS operation system and is being rewritten in C+ and C++ to run under Windows NT.

Access to TMR requires both a personalized identification code and a password. The identification code is specific to one user and the password is changed every 6 months by the user. TMR has the capacity to limit privileges and access to sensitive portions of the medical record based on the personalized identification code. For example, medical record personnel are unable to access accounting information; likewise, physicians are unable to change laboratory or billing information. To date there have been no problems with unauthorized access to the practice data base.

The practice data base is backed up each night, and TMR, similar to bank and finance computers, is designed with comprehensive mirrors and backups to prevent unanticipated downtime. During the past 2 years unplanned downtime during clinic hours (7 AM to 8 PM) has been very rare and limited to 1 to 2 minutes. Planned downtimes occur when new innovations are brought on-line. All of these innovations are brought on-line in the late evening or weekend hours.

The functions of TMR in use at DFMC can be divided into two levels. Level 1 functions handle the day-to-day tasks of an outpatient office that are traditionally accomplished with a manual system, such as appointments, accounting, and billing. These functions are basic and are available on current commercial medical computer systems.^{13,14} Level 2 functions are the newest and most innovative and perform tasks that are difficult or impossible to do manually. Examples of level 2 functions are routine reminders to clinicians for needed health maintenance based on a patient's age, sex, health problems, and results of previous health maintenance tests; reminder letters to patients of health maintenance needs; and remote access from the hospital ward or emergency department to medical record information.

Appointments

Computerized scheduling of appointments is extremely important in a large clinic and is a standardized part of medical office computer systems.¹⁵ A computerized system has the advantage of being able to schedule a large number of patients simultaneously with multiple clinicians at multiple sites. In addition, the clinic schedule can be viewed in its current form from any computer terminal.

When the reception staff at the DFMC make a patient's appointment, TMR prompts the receptionist to update the patient's demographic record and indicates whether the patient has an outstanding bill or special needs, such as a complicated medical problem, that require a longer appointment. TMR allows the receptionist to locate the patient's primary clinician quickly and schedule the appointment with that provider or a team member. While making the appointment, the receptionist can choose a variety of appointment lengths to accommodate the patient's needs or the issues to be addressed during the visit. For example, complete physical examinations or procedures can be allotted 30- to 45-minute appointments. If a patient needs to schedule an appointment for more than 3 months in advance, TMR will store the patient's name, social security number (used as the patient identifier code), the month the appointment is needed, and any necessary comments, such as a note to "follow-up cholesterol." When the clinician's schedule for that month becomes available for appointments, the

reception staff retrieves the patient's name and number by computer and calls the patient to schedule the appointment.

During the past 3 years the family practice clinic has customized TMR, creating different appointment slots to fill in the clinic schedule more efficiently. The appointment system now has five appointment types: (1) routine care or health maintenance, (2) follow-up appointments, (3) same-day appointments, (4) walk-in clinic appointments, and (5) specialty clinics, such as travel and colposcopy clinics. To improve further appointment efficiency, the computer generates a report at the end of the week that shows how well the various appointment slots have been used and tracks patient no-shows and overbookings. Based on this report, the distribution of the appointment slots is changed on a seasonal basis to meet the clinic needs.

Encounter Form

TMR generates a 5-page patient summary, the encounter form, either the day before a routine or follow-up visit or the day of an acute care visit (Figures 1, 2, 3, and 4). The encounter form lists the patient's age, sex, address, insurance data, appointment time, primary clinician, and treating clinician for that visit. The encounter form also displays a list of the patient's active and inactive health problems, current medications and drug allergies, the status of all screening tests indicated for the patient, and laboratory and radiology flow sheets for the last nine visits.

The first 3 pages of the encounter form are used as a work sheet and routing sheet for the patient visit. When the patient requires laboratory work or radiographs, the clinician orders the tests on the first page of the encounter form and sends the patient to the in-house laboratory or radiology facility. Patient follow-up appointments, visit changes, and referrals are requested on the first page of the encounter form; the visit diagnoses are recorded on the second page. Prescriptions are written on the third page of the encounter form. By approval of the North Carolina Board of Pharmacy, the encounter form serves as the permanent record of the prescription in place of the traditional prescription.

Clinical data and billing information on the encounter form are entered into TMR by the receptionist as the patient leaves the office. The en-

counter form is used as an adjustment to the chart during the patient visit. For most patients the chart contains dictated clinic notes, as well as consultant notes, and electrocardiograms and duplicate copies of laboratory and radiograph results.

Accounting

The TMR accounting module allows the business office to communicate directly with Blue Cross and Blue Shield and other insurance carriers by tape-to-tape billing. This computerized billing allows the practice to eliminate lost charges and take advantage of instant billing and same-day claims filing, thus expediting collections while reducing the number of personnel necessary to file claims. TMR also tracks accounts receivable, prints receipts for preparation of third-party insurance claim forms, and prints bills with mailing addresses for patient billing.

Laboratory, Radiology, and Pharmacy Modules

The laboratory and radiology modules of TMR are used to store test results. These reports are printed on the encounter form at the time of each patient visit (Figure 4). In addition, the ordering clinician receives a paper copy of the test when the result is entered into the computer. Because these reports are available at any time from any computer terminal, providers can view a laboratory or radiology report during off-hour visits without the patient's paper chart. The TMR laboratory and radiology modules allow direct communication with outside laboratories and radiology departments by directly down-loading the results of outside tests into TMR. This direct communication between computer systems reduces the errors, personnel time, and costs that are associated with a manual system. The laboratory tests performed on-site in the DFMC clinic also are entered into TMR directly from the equipment performing the specific test using the computer software product "The Laboratory System" (TLS).¹ This equipment-computer linkage alleviates the need to enter the laboratory data manually into TMR, thereby reducing staffing costs, transcription errors, and lost reports.

Radiology reports are entered into TMR electronically using a network linkage between the Department of Radiology and the DFMC. As reports are generated in the radiology department, they are transferred to TMR, where they are

COMMUNITY AND FAMILY MEDICINE
 Category: DUKE HEALTH SERVICE
 Primary MD: SEVERNS(2)
 Occupation: med lic prac nurse
 Employer: BOX 3176 MED CTR
 3 No show/cancel, last 07/06/92
 Ins:DHS (23 -44-7 -0-)
 Apt:900W SEVERNS(2)

RV DBT 23 -44-7 MA UDE 14 FA ST DURHAM, NC 27705 919-2 -05 /919-6 -24 Date of birth: 07/24/31
 62 yo bl si female

Date apt: 07/28/93 Printed: 07/27/93 16:51
 MD: PA/NP: STU: HLTH ED: NOTE DICTATED? Y N
 APPT W/: WHEN: COMMENT: RV/ TIME:15 30 45 OBK
 RV/TEST ONLY: TEST/PROB:
 REFERRAL W/: WHEN:

NEW 99201(193) 99202(194) 99203(195) 99204(196) 99205(197)
 EST 99211(32) 99212(2) 99213(3) 99214(5) 99215(6)
 (TEST ONLY)

HISTORY PF EPF D C C
 EXAM PF EPF D C C
 MED DEC MAKING SF SF/LC LC/MC MC HC

OTHER: DUKE OJI: NON-DUKE OJI IN-B L I E C; RV-M B L I E C

LAB-ROUTINE	XRAY (L,R,B)/REASON NO REVIEW	PROCEDURES
LAB-WAITING	STUDIES EKG IPPD VISION(485) OTHER:	SUPPLIES INJ/IMMUNIZ(THERAPIES)

QUALITY ASSURANCE RECOMMENDATIONS

CATEGORY	TEST	RECOMMENDED	LAST DONE	F/U DATE
STUDY	CHOLESTEROL	AGE 18-70 ONCE IN 1 YR	237 07/14/93	
	LIPID PANEL	AGE 18-70 ONCE IN 1 YR	237 07/14/93	*DUE NOW*
VACCINE	DT	AGE 18+ ONCE IN 10 YR	03/26/90	DUE 03/25/:0
STUDY	GUAIAAC	AGE 50+ ONCE IN 1 YR	NSR 07/06/92	*DUE NOW*
STUDY	PAP	AGE 18+ ONCE IN 2 YR	NORM 07/14/93	DUE 07/14/95
STUDY	MAMMOGRAM	AGE 50+ ONCE IN 1 YR	1. N 07/14/93	DUE 07/14/94

QUALITY ASSURANCE DATA COLLECTION

TEST	PLACE	DATE	RESULT
LIPID PANEL			D N
GUAIAAC			D N

Figure 1. The first page of the DFMC patient encounter form with health maintenance prompts for a 62-year-old woman.

stored permanently, and are also printed for physician review and filing in the chart. The conclusion section of each radiology report is also printed on the patient's encounter form.

The pharmacy module of TMR contains a list of each patient's prescription and nonprescription medications including drug strength, date started, the prescribing provider, and unit prescribed, as well as the initial number of refills and the number of refills used to date (Figure 3). As are the laboratory and radiology data, the pharmacy data are avail-

able from any terminal and are printed on the encounter form. New data are entered by the in-house pharmacy and are updated at each office visit or prescription refill. New prescriptions and refills at the in-house pharmacy are entered while the pharmacist is processing the prescription. Deletions and discontinued drugs, such as antibiotics, and prescriptions to outside pharmacies are indicated by the clinician on the encounter form and are updated by the pharmacy the next day, thus alleviating the need to maintain a manual medication

ONSET	RESOLVED	SEEN	CODE	ACTIVE PROBLEMS
10/24/91			303	ACUTE UPPER RESP TRACT INFECTION
10/24/91			439	MENOPAUSAL SYMPTOMS
11/29/91			639	FATIGUE
11/29/91			622	ABDOMINAL PAIN
12/19/91			109	ANEMIA
12/19/91			720	CHRONIC PANCREATITIS
12/20/91			695	HEALTH MAINTENANCE
01/06/92			263	HYPERTENSION
02/24/92			937	S/P CHOLECYSTECTOMY
08/14/92			1229	GYN EXAM
10/02/92			519	OSTEOARTHRITIS
10/02/92			1756	DRUG ALLERGY
01/08/93			1265	POSTOPERATIVE PAIN
07/28/93			1751	S/P SPLENECTOMY
07/28/93			1370	UMBILICAL HERNIA

VISITS/YR: 6/93; 9/92; 4/91

	92 SEP 03	92 SEP 08	92 SEP 18	92 OCT 02	93 JAN 08	93 JUL 28	93 AUG 16	93 SEP 21	93 SEP 27	93 OCT 27
PRIMARY PROVIDER	MIC	MIC	NOW	CRD	CRD		CRD	CRD	CRD	NOV
SECONDARY PROVIDER	NUR	NUR	NUR							
ENCOUNTER PROBLEMS										
V70.0 HEALTH MAINTENANCE	*	*								
401.9 HYPERTENSION			*	*	*		*			
715.90 OSTEOARTHRITIS				*						
995.2 DRUG ALLERGY				*						
998.9 POSTOPERATIVE PAIN					*					
553.1 UMBILICAL HERNIA						*				
S/P SPLENECTOMY						*				
XX RX ONLY								*		
627.2 MENOPAUSAL SYMPTOMS									*	
NO SHOW/ERROR										*
ENCOUNTER THERAPIES										
PROCARDIA XL							*	*		
PREMARIN							*	*		
PROVERA							*	*		
PNEUMONIA VACCINE									*	

Figure 2. The second page of the DFMC patient encounter form with the problem list for a 56-year-old woman with a drug allergy to penicillin.

list. Patient drug allergies are recorded on the encounter sheet and entered into TMR by the pharmacy. Drug allergies appear in the problem list (Figure 2) and in the medication list (Figure 3).

Patient Problem Lists

A list of diagnoses for each DFMC patient is stored in TMR. The computerized patient diagnosis list serves as both the problem list and source of billing diagnoses for the office visit. The list of active diagnoses with their onset date is

printed on the encounter form (Figure 2), and the clinician indicates the diagnoses for the office visit by either writing in a new problem or checking an old diagnosis already printed on the problem list. When the receptionist enters the visit diagnoses and the professional fees, the computer updates the patient diagnosis list and files the insurance claim.

A clinician can update the diagnosis list by deleting errors, resolving inactive problems, adding new specificity to a problem (e.g., pharyngitis can become streptococcal pharyngitis), or adding new

COMMUNITY AND FAMILY MEDICINE

Category: PRIVATE

Primary MD: DENNISTON(1)

Occupation: retired

4 No show/cancel, last 09/01/93

Date apt: Printed: 10/27/93 13:17

RV SBP 1 - 0-5 V
DA D C
60 ANDE DR
DURHAM, NC 27
919- 7-4 8/919-4 -0 1
Date of birth: 02/ /37
56 yo mar female

*** CURRENT THERAPIES ***

THERAPY	DISP	RF	OFFICE START	END	
SELDANE-D 1 T	60	0/0	03/24/93	04/22/93	S R C
T 1 TABLET BID					
PROCARDIA XL 30 MG TAB	30	5/3	08/16/93	02/11/94	S R C
T 1 TABLET QD					
PREMARIN 0.625 MG TAB	30	5/3	08/16/93	02/11/94	S R C
T 1 TABLET QD					
PROVERA 2.5 MG TAB	30	5/3	08/16/93	02/11/94	S R C
T 1 TABLET QD					
DISALCID 750 MG TAB	120	5/5	08/17/93	02/12/94	S R C
T 2 TABLETS BID					

* allergies: penicillin vk-urticaria and bronchospasm, pen-urticaria and
bronchospasm

Drug mg. No.

Sig: _____
Drug mg. No.

Sig: _____
Drug mg. No.

Sig: _____

Figure 3. The third page of the DFMC patient encounter form with the medication list and prescription sheet for a 56-year-old woman with a drug allergy to penicillin.

problems. A resolved problem prints in the cumulative problem list located on the fourth page of the encounter form.

Clinician Reminders

One of the modules of TMR is used to remind clinicians of the health maintenance screening tests needed by the patient. Computer systems of this type have been reported in the literature with increasing frequency.^{2,5,10-13,15} TMR health maintenance prompts are generated from an algorithm based on the patient's age, sex, previous diagnoses, risk factors, and previously completed

health maintenance activities (Figure 1). The reminder is printed routinely on the encounter form and allows the clinician to determine quickly the patient's health maintenance status and needs. If the patient has had a health maintenance test recently, such as a mammogram in the past year, the test date and result are printed, as well as the date on which the test is next due. When a test is due, the computer will note that the test is "due now."

Certain diagnoses will permanently suppress the reminder for a particular test; e.g., "hysterectomy" listed in the problem list will permanently

COMMUNITY AND FAMILY MEDICINE

Category: MEDICARE-DHS

Primary MD: GREENBERG(3)

Occupation: retired

: AGE

1 No show/cancel, last 07/13/92

Ins: MEDICARE (24 -28-7 -), DHS (2

Apt: 1700W GREENBERG(3) FU EXERTIONAL PAIN/CP

RV
DBT

24 -28-7 V78

CAR

V

2 J CIRCLE

HILLSBOROUGH, NC 27278

919-7 -7

Date of birth: 09/06/25

67 yo mar female

Date apt: 07/28/93 Printed: 07/27/93 17:02

06/30/92 08/05/92 08/31/92 11/23/92 07/14/93

PLACE	OFFICE	OFFICE	OFFICE	OFFICE	OFFICE
PRIMARY PROVIDER	CAMPBELL,	GREENBERG	GREENBERG	GREENBERG	GREENBERG
HGB	12.5-18	GMSX	14.2	13.1	
HCT	39-51	%	41.4	38.7*	
RBC	4-6	MIL	4.71	4.16	
MCV	81-94	CU MIC	88	93	
MCH	27-31	MCG	30.1	31.5*	
MCHC	32-36	%	34.3	33.9	
RDW	11.5-14.5		15.5*	14.9*	
WBC	4.0-10.5	THOUS	8.6	7.2	
LYMPH%	16-48		27	31	
MID-RANGE%			8	8	
GRAN.%	42-78		65	61	
PLATE CNT	150-450	THOUS/CUMM	303	282	
SED WEST	0-20	MM/HR	10		
RHEUM FACT			N		
FANA			TEXT1		
//HEMOCCUL		NEGX3			
HEMOCCULT3				NX3	
MAMMO SCRIN			TEXT2		
MAMMOGRAM		TEXT3			

TEXT1 = NEG. FOR ALL STAINING PATTERNS

TEXT2 = NO MAMMOGRAPHIC EVIDENCE OF MALIGNANCY. RECOMMEND ROUTINE FOLLOW UP MAMMOGRAM BEGINNING IN 8/93.

TEXT3 = 1. NEGATIVE FOR MASS IN THE RIGHT AXILLA. 2. NEGATIVE FOR EVIDENCE OF MALIGNANCY. 3. ASYMMETRIC DENSITY IN UPPER OUTER QUADRANT OF LEFT BREAST AND RECOMMEND A 6 MONTH MAMMOGRAM FOLLOW UP.

Figure 4. The fourth page of the DFMC patient encounter form with laboratory and radiology results.

turn off the reminder for a Papanicolaou test for that patient. The report is modified to a limited extent by previous results, e.g., an elevated cholesterol reading will trigger a prompt for a lipid panel. Providers can record laboratory and radiology reports performed outside the clinic, and this information is displayed in both the laboratory section and the health maintenance prompts. The health maintenance prompt system also allows the clinician to modify the prompts for a patient by permanently shutting off a specific prompt or documenting a discussion of a needed screening test with the patient who chooses not to obtain the test during the office visit. The system currently tracks the following tests: Papanicolaou test, cholesterol, lipid panel (if cholesterol level is abnormal), adult tetanus immunization, mammogram, stool occult blood, pneumococcal immunization, childhood immunizations, and rubella titer.

Patient Letters

Informing patients of laboratory results can be a time-consuming and costly process. TMR has the capacity to generate personalized letters to patients using information stored in the system. This module has been used to generate both "birthday letters" and letters reporting laboratory results. The birthday letter alerts patients to needed screening tests and includes the information listed in the health maintenance prompts but written in a fashion that is understandable to patients. Laboratory report letters are generated to inform patients of the results of screening cholesterol readings, Papanicolaou smears, and tests for occult blood in the stool. One of six different cholesterol topic letters is automatically selected depending on the patient's cholesterol level and the results of previous cholesterol tests. Letters are generated for normal or near-normal results on

Papanicolaou smears and negative findings for occult blood in the stool. These letters are sent to the ordering clinician and can be signed and mailed, revised and retyped, or omitted.

Computerization of the Chart Notes

TMR has the capacity to store both free text and coded forms of patient data. This computerized patient data can be used to generate a note to document the office visit. The note can be viewed from any terminal or printed for storage in the paper chart. Currently this function of TMR is being used for two different groups of patients. Nursing home patients' charts are exclusively computerized with backup paper copies kept at the nursing home and in the office chart. Before each nursing home visit, the clinician is given a specialized encounter form for the patient that contains the usual encounter form information plus the most recent chart note. During the nursing home visit the clinician hand writes a visit note on the encounter form; updates the medications, allergies, and the problem list; adds new diagnoses and laboratory tests if performed outside the family practice; and records the billing code for the visit. At the end of the visit a copy of the encounter form is placed in the nursing home chart as the official note, and the note for the visit is transcribed by the DFMC medical transcriptionists into TMR along with the updated diagnoses, medications, allergies, and other pertinent information. Transcription and data entry of diagnoses and billing codes require about 10 minutes of data-entry personnel time per nursing home visit, but this procedure decreases physician time spent writing duplicate notes.

Perhaps the most exciting innovation of TMR is the integrated obstetric record system. In 1991 the physicians at the DFMC began delivering babies at Duke University Hospital. In planning for the new service, it was clear that an obstetric record was needed that would track prenatal care in a large and busy practice and ensure that needed information was also available in the labor and delivery suite when patients were admitted. Likewise, the information from the labor and delivery suite needed to be transferred rapidly to the family practice office for follow-up and postpartum visits. As a result, a computerized medical record for obstetric patients was developed with the assistance of the Department of Obstetrics and Gy-

necology, which already had a TMR data base for its obstetric patients. This new TMR system maintains more than 90 percent of the obstetric data in computerized form, with the paper chart used mostly for backup copies. The system is based upon an extensive new obstetric encounter form, which is completed by the nurse and the physician on a multiple page fill-in-the-blank format. This information is entered into TMR and is used to create the computerized obstetric record. Before all subsequent visits, a prenatal summary is generated, and the findings from the history and physical examination from the visit are entered on a flow sheet with comments entered as free text. Data are entered each day, and each night the data bases of the DFMC and the Department of Obstetrics and Gynecology records are mutually updated. When a patient is admitted to the labor and delivery floor, a comprehensive summary of the prenatal course is immediately available, including graphs of weight and fundal height. Data recording in-hospital is done on the Department of Obstetrics and Gynecology system and downloaded at discharge to the DFMC. The discharge summary itself is printed in the DFMC, where it is signed, and then electronically transferred back to the hospital as a completed record.

User Satisfaction

The popularity of TMR at the DFMC has never been formally assessed; however, there has never been any opposition to its use. The computer is often used as a recruiting tool for potential residents and faculty. The one area of disappointment expressed by the faculty is the speed of innovations. Because the DFMC is the pilot site for TMR innovations in primary care, the faculty constantly develop new ideas for improving the efficiency and effectiveness of the practice. Responding in a rational way to the avalanche of suggestions for improvement has become a major task for the computer managers.

Calculating Computer Cost

To date no formula has been published for calculating the cost of a computer system versus a manual system. The cost of TMR at the DFMC for the fiscal year 1991-92 was determined from the practice year-end expenditures, which are calculated separately during the budget process for

each clinical unit, e.g., nursing, reception, and computer services.

The costs of a manual system were estimated by surveying each clinical unit manager. Each manager was asked the question: "How many additional employees would be necessary to perform current tasks if the computer system was no longer available?" They were also asked to define the tasks the new employees would be performing and the average salary. The clinical unit managers were not asked to calculate costs of supervision and space, which is a normal part of each unit manager's budget at the DFMC. The estimates were checked by the administrator who oversees the budget process. In addition, the cost of manually producing reports, such as billing and collection ratios, clinic efficiency reports, and so on, were not included in the estimated costs of a manual system.

The DFMC volume for 1991-92 was 75,645 encounters, which included clinician and nonclinician visits, such as nurse visits, laboratory-only visits, and prescription refills. In 1991-92 the average total expense to the clinic for a patient visit including laboratory, radiographic examinations, and pharmacy expenses was \$71.98. The total cost for TMR for fiscal year 91-92 was \$134,543. Costs for the computer system are charged to each of the clinical units, i.e., laboratory, radiology, nursing, based on a formula that includes both fixed and variable costs (Table 1). The total amount of 1991-92 fixed computer costs for the DFMC TMR system was \$94,640, but the family practice clinic contracted out TMR services to another practice to reduce the fixed costs to \$47,320. The total computer cost per visit was \$1.78, or 2.5 percent of the total clinic expenses for a patient visit.

The costs of operating TMR in the DFMC can be compared with the costs of operating a practice of this size without a computer system. The average total expense for a patient visit with ancillary services would be \$70.20 (\$71.98-\$1.78). To operate the family practice using only a manual system, however, would require an estimated \$669,000 additional per year in staffing costs alone (Table 2). The estimated increased staffing costs of a manual system would raise the base cost per visit (\$70.20) by \$8.84, making the total cost per visit \$79.04 compared with \$71.98 per visit with the computer. The computer therefore saves

Table 1. Computer Costs for the Duke Family Medicine Center for Each Clinical Unit (1991-1992).

Clinical Unit	Total Cost for Unit* (\$)	Cost per Visit by Unit (\$)
Business office	12,615	0.17
Reception	48,463	0.64
Nursing	4,496	0.06
Pharmacy	2,586	0.03
Medical records	5,563	0.07
Radiology	1,502	0.02
Laboratory	11,998	0.16
Fixed costs*	47,320	0.63
Total	134,543	1.78

*Includes salaries for computer personnel, contracts for services, and space costs.

the practice an estimated \$7 per patient visit or approximately \$500,000 per year.

Comparison of the DFMC with smaller practices is difficult because the large size of the practice demands computerization. Some estimation of the cost of TMR in a smaller practice can be made, however. The start-up costs of purchasing both the hardware and software are based on the number of persons who will use the system. On average, the number of persons using the system is twice the number of clinicians in the practice, i.e., a 4-clinician practice would likely have 8 users and a 6-clinician practice would have 12 users. The estimated starting up costs for a 4-clinician practice is \$30,000 to \$50,000, for a 6-clinician practice it is \$65,000 to \$80,000, and for a 15-clinician practice it is \$95,000 to \$125,000. The yearly costs of upkeep of both the software and the hardware are roughly 10 percent of the start-up costs.

Discussion

TMR is an example of one of the emerging computer systems that is allowing the computer's strengths in organizing and presenting data to be used in making outpatient care more efficient and effective. There are other computer systems, such as Regenstrief,⁶ Computer-Stored Ambulatory Record (COSTAR),⁵ and Practice Partner Patient Records,¹³ which have functions similar to those of TMR, including appointments, billing, laboratory, radiology, and pharmacy data bases. In addition, Regenstrief¹⁵ has achieved a network of computerized hospital laboratories that is accessible from

Table 2. Estimated Additional Costs Required to Replace TMR with a Manual System (1991–1992).

Additional Staff	Cost per Year (\$)
3 Licensed practical nurses (staffing floor)	70,000
2 Licensed practical nurses (triage and referrals)	40,000
1 Laboratory technician	22,000
3 Medical records staff	45,000
6 Patient representatives (reception)	140,000
3 Pharmacists or technicians	120,000
6 Business office staff	222,000
Paper and supplies of business office	10,000
Total	669,000

multiple sites. Thus TMR is only one of many emerging comprehensive computer systems that are being used in outpatient practices.

All of these systems offer improved efficiencies of data collection and processing, but all appear to be associated with higher costs. As reported here, however, at least in large practices the computerized system might be less expensive than manual modules. In addition, Regenstrief recently has been shown to have reduced inpatient costs.¹⁶

Goroll, et al.⁵ and Barnett⁷ have reported the cost savings of COSTAR in a partially computerized practice. In 1984 Goroll, et al.⁵ calculated the cost of using COSTAR in a teaching hospital group internal medicine practice. The practice had an average of 50,000 visits per year and was staffed by 115 part-time physicians, including residents and fellows. COSTAR was used in only one-third of the clinic, representing approximately 18,500 visits. The computer cost per patient visit in 1984 was \$1.65 per visit. These calculations included data processing, project management, and supplies. Capital costs were difficult to estimate because the system was subsidized and hardware costs were minimal. Goroll, et al. noted that their cost data were based on the initial cost saving in a subsidized system, and therefore it might not have represented true cost. Barnett⁷ also reported the cost of COSTAR at another site in 1984 as an additional \$0.87 per encounter for conventional medical records tasks. When the additional functions of COSTAR were considered, however, the computer system actually saved the practice \$0.72 per encounter compared with an equivalent manual

system. Unfortunately, comparison of TMR cost savings with COSTAR is limited by the difficulties of comparing two dissimilar practices and the unmeasurable effects of time and inflation.

For this report we compared the cost of using TMR with a hypothetical manual practice in a large family practice. This type of comparison is by nature a gross comparison, not unlike comparing an office that uses a network of personal computers and laser printers with an office that utilizes only typewriters. The true cost of a comprehensive office computer system must be calculated not only in terms of dollars saved in staffing costs, as we have done, but in terms of office space, administrative costs, time saved, and improvements in patient care. The cost savings calculated in this report do not take into account the added cost of space and supervision of the additional personnel or the cost of manually calculating the many financial reports generated by TMR. In addition, the calculations do not take into account savings that are more difficult to measure, such as decreased number of lost billing charges, decreased amount of clinician time spent recording duplicate data, increased access to patient data, and more accurate patient laboratory and radiology data bases. Thus our cost analysis is at best a "best guess," and the \$500,000 savings is likely an underestimate of the true savings of this computer system at DFMC. Still, it appears that a large computerized office could be more cost effective than a manual office.

Summary

This paper describes the successful use of a comprehensive computer system in a large family practice. A rough estimate of the cost effectiveness of TMR in the Duke Family Medicine Center revealed that the computer provides a substantial savings for the practice.

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