sion. Initial testing should be performed on a series of prototypical cases. Next, another computer program [2] should be built to search systematically for inconsistencies in the clinical program. Then, a retrospective review should be undertaken, comparing the program's performance to that of unaided clinicians. Next, a prospective review should be mounted in which the program's suggestions are "overread" by experienced clinicians to be sure that no gross errors occur. Finally, a prospective controlled trial should be performed. In both the retrospective and the prospective trials, the computer's performance should be compared to the performance of unaided clinicians, preferably by a panel of experts blinded to which decision maker they are evaluating. In the final phase of evaluation, the impact of the computer program on health outcomes should be assessed. This final phase can only be allowed once the earlier phases of evaluation have certified the program as "safe" for the patient. The early phases of this evaluation sequence might be viewed as analogous to animal trials in the evaluation of a new drug. In the final phase, the prospective controlled trial, great care must be exercised to avoid the "Hawthorne effect," that is, an improvement in physician performance because his behavior is under scrutiny.

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COSTAR—A Computer-Based Medical Information System for Ambulatory Care

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***Abstract*—The storage, retrieval, and communication of information are key features of both the practice of medicine and the administration of health care. This paper describes a COmputer-STored Ambulatory Record (COSTAR) which replaces the traditional document-based patient medical record with a comprehensive, centralized, and integrated information system. COSTAR meets both the medical care and the financial/administrative needs of a variety of different medical practices (whether fee-for-service or prepaid) and can be implemented and operated without on-site programming support. COSTAR has a modular design to facilitate phased implementation, and uses a comprehensive dictionary of terms to standardize and store data. The physician records medical, administrative, and financial information on a single source document (the encounter form); data are input by clerical personnel; information is retrieved via different computer-generated displays and printouts which automatically select and organize the data. The system provides a high-level language which allows the user to access the database from a logical point of view and perform searches or prepare reports without programming support. COSTAR is available on minicomputers using commercially supported software and will be marketed by commercial organizations.**

Manuscript received December 7, 1978; revised March 20, 1979. This work was supported in part by the National Center for Health Services Research, OASH under Grant HS 00240.
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I. Introduction

THE communication of medical information is a critical element in the practice of high-quality medical care. Traditional recording practices rely almost completely on a manual record folder where physician notes are handwritten or dictated and merged with laboratory data and other

0018-9219/79/0900-1226$00.75 © 1979 IEEE

patient material. This manual system has inherent problems of incomplete data and occasional unavailability of the medical record resulting from different physicians recording data at different places at different times. Even when the medical record is available, poor organization and frequent illegibility may make retrieving the desired information a laborious and time-consuming task. It is usually necessary to record data redundantly to provide the necessary information for patient care, scheduling, billing, and management reports. Quality of care studies and clinical investigation research which depend on the aggregation of data from a large number of individual patient records are particularly cumbersome and require the expenditure of many hours of manual searching.

Although many medical practices have begun to use computer technology to assist in information processing, most of the commercial systems are restricted to patient billing, accounts receivable, and preparation of third party insurance claims forms, and have no impact on the information processing related to patient care. There are a number of research projects where the objective is to use the computer to improve availability of medical data to the physician. Most such projects are dependent on research funds and, although some of these systems have become operational in their local environment and have achieved significant professional acceptance, none have been nationally disseminated [1]-[5]. There have been two recent state-of-the-art reviews of computer-based medical information systems sponsored by the Department of Health, Education, and Welfare [6], [7], and one review by the Office of Technology Assessment [8]. All three of these reviews emphasized that the different experimental projects were designed to meet the particular and often unique needs of a specific site, rather than being a prototype system that could be easily generalized.

The need to introduce computer technology to facilitate ambulatory practice is becoming increasingly acute, both because of the shift in responsibility for ambulatory care from the solo general practitioner to a loosely coordinated team of medical specialists, and because of the increasing complexity and volume of the medical data recorded on each patient. For example, fifty years ago, many physicians might not even record any information on an ambulatory patient visit, and twenty years ago, the note might be only a few lines long. Now ambulatory records may contain lengthy notes written by a multiplicity of different health care providers (primary care physicians and nurses, dieticians, social workers, etc.), large numbers of different laboratory results, and a diverse set of other data elements such as X-ray and pathology reports, and summaries of hospital admissions. In addition the focus of ambulatory care has changed from preoccupation with treatment of episodic illness to an increased concern with preventive medicine and with ensuring continuity of care in the management of chronic disease.

These changes in patterns of medical care have been associated with changes in the administrative structures of medical practice. The dominant organizational format of ambulatory care has evolved from the solo physician's office to health care organizations of considerable size and complexity. The management of any large health care organization—whether it be a fee-for-service group practice, a health maintenance organization, or a hospital-based clinic—requires the optimal scheduling of visits, the ability to monitor the use of resources and the productivity of providers, and the operation of a billing and accounts receivable operation of considerable magnitude. The manual medical record has proven grossly inadequate to meet the administrative needs of such organizations. Management reports and organizational planning often require duplicate data collection of incomplete and sometimes inaccurate information.

For the past decade this laboratory has been involved in the development and implementation of a computer-based medical information system COSTAR (COmputer-STored Ambulatory Record) designed to perform the data management functions needed by a group practice in the care of ambulatory patients [9]-[11]. The purpose of the system is to replace the traditional document-based patient medical record with a comprehensive, centralized, and integrated information system that meets both the medical care and financial/administrative needs of either a fee-for-service or a prepaid group practice.

COSTAR was originally developed by the Laboratory of Computer Science in collaboration with the Harvard Community Health Plan (HCHP)—a prepaid group practice located in Boston and has been operational there since 1969. The fourth version of the system, COSTAR 4, is fully integrated into HCHP operations and is supported from the Plan's operational budget. The HCHP management views the system a success based on the criteria of cost acceptability, improved availability of medical information and of management data, reliability of operation, professional acceptability, facilitation of a higher standard of patient care, and stimulation of research in health care delivery by providing a readily accessible database.

However, COSTAR 4 does not have the potential for use by other ambulatory practices, since it incorporates a number of characteristics which were specifically designed for HCHP needs, and has only a limited set of functional capabilities (e.g., there is only a partial scheduling module and no accounts receivable function). In addition, it was obvious that national dissemination of COSTAR could not occur unless there were national support and marketing by private industry. Therefore, a significantly revised and expanded version of the automated information system called COSTAR 5 has been developed in collaboration with the Intramural Division of the National Center for Health Services Research and with Digital Equipment Corporation [12]. This paper describes the data management characteristics of COSTAR, and discusses the implementation strategies we have chosen.

II. Data Management Characteristics of COSTAR 5

A. Design Goals

The design goals of COSTAR 5 are the following.

1) Facilitate patient care by improving the availability, accessibility, timeliness of retrieval, legibility, and organization of medical information.

2) Enhance the financial viability of the medical practice by providing a comprehensive billing system with accompanying accounting reports.

3) Facilitate medical practice administration by providing the data retrieval and analysis capability required by management for day-to-day operation, budgeting, and planning.

4) Provide data processing support for administrative and ancillary services (e.g., scheduling, laboratories, and planning).

5) Provide the capability to generate standardized management reports and to support user-specified inquiry and report generation on any elements of the database.

6) Support programs of quality assurance by monitoring the content of the database according to user-specified rules

and reporting automatically any deviations from these standards of care.

B. Operating System

COSTAR is programmed in Standard MUMPS (Massachusetts General Hospital Utility Multi-Programming System), a compact high-level interpretive data management system particularly suited for interactive applications which require a large shared database and the rapid, efficient manipulation of textual data [13], [14]. The use of MUMPS has greatly facilitated program development and maintenance since it is not necessary to compile or translate a program into another form before it can be executed and debugged. An interpretive language does have decreased execution efficiency, but the adverse effect of this speed reduction is not prohibitive because few COSTAR programs are strictly processor-bound.

A significant feature of MUMPS is its hierarchical data base system. A MUMPS file may be viewed as a sparse multidimensional array that is global to all users. The minimal space needed to store each variable-length array element is allocated dynamically as needed; records in the data base are not predimensioned. When sections of the file are deleted or changed, released storage areas are returned to the free pool. Dynamic allocation of storage in MUMPS is an extremely important strategy in implementing a medical information system because the size of any individual record cannot be predicted, and because there is wide variation in the size and speed of growth of the different records. MUMPS does not provide the full degree of data independence of a complete data base management system. However, MUMPS does allow the programmer to refer to information in a symbolic fashion and to deal with the data base in terms of a logically meaningful file structure rather than in terms of the physical layout of the data.

MUMPS programs are written in explicitly defined segments (routines), with only the current segment for the individual user resident in core at any one time. In the COSTAR system there are almost 1000 segments, each of which averages over 1000 bytes. In addition, the directories of COSTAR occupy about another million bytes. Because the syntax of MUMPS is very concise, and there is no compilation into machine code, a multi-user COSTAR system can be implemented on a relatively small computer. An equivalent assembly language coded system would have an excess of ten times the amount of MUMPS program code, so that the total COSTAR system in assembly language would be of the order of ten million bytes or more.

Since the original implementation of MUMPS at Massachusetts General Hospital, the language has evolved so that there are currently a number of dialects. Two years ago a standardized version of the language was approved by the American National Standards Institute. Standard MUMPS is now supported by several computer manufacturers. Therefore, COSTAR can be implemented by a number of different computer vendors. In addition, because the MUMPS file structure provides relative independence of the capacity of the physical disk files, COSTAR can be implemented on a wide range of sizes of computer configurations, and can grow modularly via hardware expansion as data processing requirements increase.

C. Medical Vocabulary–COSTAR Directory

The traditional medical record has a virtually limitless vocabulary and only minimal structure. The only standardization of vocabulary currently used in recording medical data are coding systems for diagnoses and procedures. The *International Classification of Diseases, 9th Edition, Clinical Modification* ICD-9-CM is a recently published disease classification system that is being federally mandated for use by all health care agencies and institutions. The size of this nomenclature is very large, with approximately 13 000 primary concepts (many of which have synonyms so that there are over 60 000 different terms). This classification system is primarily designed for statistical reporting on diseases in a population, and the authors of the classification recognize that there are deficiencies in using the system in the clinical management of individual patients' problems. In particular, the ICD-9-CM is not particularly suited for common health problems, complaints, and ill-defined conditions that are common in primary health care.

There are many different coding systems required by the various third party insurance carriers for reimbursement of common surgical procedures and laboratory tests. A commonly used classification, the Current Procedures Terminology (CPT) published by the American Medical Association, has over 5000 different terms.

There has been little practical success in using computer technology to process the narrative text information of medical records. If a computer system is to be used effectively for automatically selecting and organizing medical information, then it is essential that there be at least a minimal level of standardization of the vocabulary. In COSTAR, standardization of information is provided through the "directory," a dictionary of medical terms that are allowed in patient records. A complete coding system for all the detail of all medical information for all types of specialties would be of enormous size; in addition, there is considerable disagreement within the medical community on appropriate taxonomy systems. The COSTAR directory has a limited taxonomic scheme (e.g., all diagnostic codes relating to the cardiovascular system begin with the letter *M*) and no predetermined or maximal number of terms; each medical group may define the lexicon appropriate for the particular medical specialties involved and the type of practice.

Each element in the directory corresponds to a unique COSTAR "code." This code is a shorthand notation for a medical concept, e.g., MHAB1 stands for the term hypertension. A code represents the concept rather than the term itself, in that synonymous terms (e.g., high blood pressure) are assigned to the same code. In addition, terms which are similar but not identical may be grouped together by using one or more "modifiers" to describe that particular code, e.g., MHAB1-A means renovascular hypertension, MHAB1-B means secondary hypertension, and so on. Modifiers can also be used to designate various trade names for a drug, so that the specific prescription details can be retained while at the same time medications of the same generic type are grouped together.

The tradition of medical practice requires flexibility in the structure and content of data associated with various terms. For example, weight is merely a single number; a blood pressure, however, may be recorded from various limbs with the patient in different positions, and, therefore, may be associated with two or four or sometimes six numbers; a urinalysis includes a variety of elements such as pH, specific gravity, color, etc.

The directory is the unifying element that allows COSTAR to deal with these varying details, serving a function analogous to a Data Base Management System (DBMS) schema in specifying the structure of the stored data. However, the directory plays a more active role in the processing of data within COSTAR than that of a DBMS schema. Each code in the directory may have associated with it comprehensive validation criteria for input data based on patient parameters such as age and sex. In addition, the protocols defined for the different categories of codes within the directory specify the encoding and physical layout of the associated data within the record, and the appropriate format for reporting the information in output documents. Further, the practice may specify parameters with each term which guide production of reports and statistics. For example, the practice may specify that certain values of a particular laboratory test are considered abnormal, and should be flagged on all medical output; or that certain diagnoses are considered of such important clinical significance that when they occur, the diagnosis should be flagged on all output documents (e.g., penicillin allergy).

The special functional properties of a code can be specified at three levels of detail. First, every code has a "division" attribute that designates one of several broad medical categories, e.g., physical findings, diagnoses/problems, laboratory tests, medications, nonmedication therapies, procedures, and administrative terms. The data stored in the record varies for each division. For example, a medication code usually is associated with related information about dose, route, frequency, quantity, number of refills, and short textual directions, while a diagnosis may have stored with it only textual description or qualification of the patient's condition.

The second level of detail is provided by a set of parameters specific to a particular code that cause specific actions during processing of patient data associated with the code. For example, a particular diagnosis in the directory could specify that output documents produced for any patient having that diagnosis should include a flowchart of data pertinent to the diagnosed disease. In addition, the directory may specify standard fees for procedures or tests, and may also map COSTAR codes to other coding schemes for claims and reports sent to specific insurance carriers.

The third level of capability provided by the COSTAR directory allows MUMPS program code to be executed during data input, output, or analysis processes. Thus virtually unlimited functionality can be implemented by a programmer with a working knowledge of COSTAR. Few directory entries will contain such application program extensions, but the capability ensures sufficient flexibility to accommodate most problems of data input, validation, processing, and output formatting. Such flexibility is required in a medical information system intended for adaptation to many styles of practice.

The COSTAR directory shares some of the characteristics of a table-driven information system in providing nonprogrammer users the capability to change the content of the table. This allows local variation in recording data and preparing reports. Although a copy of the COSTAR directory is provided to each site, each practice has the capability to add new codes and to modify any of the characteristics of existing codes. The COSTAR system provides the utility programs required to perform code building and modification without requiring the assistance of a programmer. These directory building programs allow each site to tailor the system to local needs and local practice patterns without adding new functions or changing the computer programs.

TABLE I

COSTAR code for Hematocrit: MNBC3	
Long name of the term: HEMATOCRIT	
Short name of the term: HCT	
DIVISION: LABORATORY	
RESULT CHECKING	
ALLOWABLE: 1 to 90	
NORMAL:	
FEMALE 15 and up	37 to 42
OTHERWISE, MALE 15 and up	42 to 47
OTHERWISE, up to 0.2	35 to 50
OTHERWISE	38 to 47
FEE: 3.50	
REVENUE CENTER: LABORATORY	
TRANSLATION DIRECTORY: CPT	
MEMBER OF THE PANEL(S): HEMOGRAM MNAS1	

The actual key to the directory entry is MNB3. The *C* is the checkletter of the code and is stored as data in the directory. COSTAR codes have a limited taxonomical meaning. In this example *M* implies hematology, *N*, microscopic, and *B*3, ordinal assignment.

Directory entries always contain the long name of the term. Optionally, short names may be specified. Either can be used for inputting purposes; some output reports will use the short term if available for formatting convenience.

The division assigned to a code is arbitrary. The laboratory division has rules or algorithms specific to it. Input of a code in this division can only be through the encounter input sequence or the laboratory result entry sequence. The clinical statuses which may apply to laboratory codes are "ordered," "pending," "normal," and "abnormal." These status flags affect output formatting and ordering.

The result checks are specified by each practice site through interactive sequences and stored in the directory itself. In this example the acceptable input must be a numeric value between 1 and 90; the normal ranges are based on age and sex of the patient. Laboratory result entry sequences extract these rules from the directory and automatically apply them in checking the test results. A normal or abnormal status is filed with the result data.

The fee is the practice specified amount to be billed to the patient or third party carrier.

The revenue center, in this case "laboratory," is an arbitrary classification of billable items used by management to analyze the practice's income generation.

Entry of this item in the directory provides automatic mapping of this test to the corresponding entry in the Current Procedural Terminology (CPT) translation directory, where the CPT code is specified and optionally a different term and/or fee.

The hemogram represents a set of laboratory codes often ordered together. Generally panel codes are used to facilitate billing, input, and display of related laboratory tests.

The COSTAR directory provides the capability to process and store data which are very nonuniform in nature. Although there is only a finite set of different types of medical information (e.g., diagnoses, medications, laboratory tests, procedures, dispositions, etc.), the information structure associated with each type varies considerably. For example, the minimal information that is required for each code is the name and type of medical information (e.g., the code "MNBC3" may have the name *Hematocrit* and be a laboratory test). However, as Table I illustrates, it is also possible to define the parameters for this same code much more extensively.

The number of terms and the complexity of information in the directory varies considerably between different COSTAR sites. A typical multispeciality group practice might have about 4000 different codes (about half of which are diagnoses/problems with most of the others being laboratory tests, medications, procedures, and administrative items). On the average each code usually has three to four different names, synonyms, or abbreviations that can be used to access the same term.

The specific form of the COSTAR code is an arbitrary feature of the system, but it is not essential for the practice to use codes as such, since all interaction with the system can be done using either the full name or the abbreviated name of the code. However, all data are stored internally with the code as an index, and all noncoded information is stored associated with a specific code. For example, any information concerned with the diagnosis of hypertension would be stored with "MHAB1" in the patient record. Such information includes each date the diagnosis was used, the clinical status of the diagnosis, the physician who made the diagnosis, and any narrative text associated with the diagnosis.

D. Modular Construction

In order to facilitate transferability of COSTAR 5, we have adopted an explicit strategy of modular design suitable for phased implementation. We have found that the modular design approach offers several advantages. First, it permits a large complex system to be broken down into a number of smaller, more easily handled subsystems and functions. These functions can then be analyzed and specified separately, leading to more rapid implementation. Second, a modular implementation allows the user organization to select a subset of available modules and thus tailor the system to both the requirements of the organization and its current financial resources. Third, a modular organization allows functions to be added or deleted without impacting the integrity of the total system. This facilitates system evolution consistent with an organization's changing needs, demands, and capabilities. Finally, the modular approach allows flexibility in system software configurations. An organization can take full advantage of technological advances and utilize phased incremental growth which is compatible with their economic constraints.

The basic COSTAR 5 system includes modules for security, registration, and a fundamental medical record system. In addition, there are a number of optional modules which at this time include: expanded medical records, generalized flowcharts, accounts receivable, scheduling, and management report generator. Additional modules under development include: laboratory test reporting, quality assurance, and an information retrieval system.

1) Security: A computer system concerned with sensitive medical information requires an effective security system. Security relates to two distinct activities: 1) restricting the use of data to authorized personnel; and 2) protecting the data against loss by backing up all data to allow reconstruction of the database.

In order to protect confidentiality of medical records, COSTAR currently offers three levels of security. The first level requires all prospective users to identify themselves prior to any terminal use. In addition, identification requirements can be expanded to control access to the various system functions. A second level of security is available through line (or terminal) restriction. Any terminal may be identified in terms of the system options available to it. Thus the practice may specify that no medical data are to be available on the terminals designated for registration, scheduling, or administrative functions. A third level of protection is available through implementation of a password system.

The second portion of the security system—data integrity—is accomplished by copying the entire database at specified intervals onto standard backup storage media and writing each transaction onto a transaction log. If a hardware malfunction necessitating recreation of the database occurs, the copy of the database can be restored and the transactions recorded on the log reprocessed, thus automatically rebuilding the COSTAR files.

2) Registration: The basic COSTAR registration sequence included routines for both fee-for-service populations and prepaid practices. The programs collect basic demographic data such as patient name, sex, date of birth, guarantor identification, and insurance or prepaid group information. COSTAR also permits the incorporation of locally specified queries into the basic registration sequence.

Unit numbers can be assigned automatically by the system, or they can be entered manually by the clerk. Registration information is available for interactive inquiry and update at any time.

3) Medical Record Module: The design goal of the COSTAR 5 medical record module is a system that meets the total record-keeping needs of primary health care providers. However, adoption of the total system may evolve over time, and individual installations may initially choose to implement only a subset of the functional capabilities such as a computer-based problem list, which would serve as an adjunct to a practice's current medical record-keeping system.

The module has two sections—*data capture* and *medical output.* Data capture is achieved by means of a printed encounter form. Each practice must design forms to meet their individual needs. All items on the encounter form have unique codes in the COSTAR system. Each site will determine the items printed on the form, the appropriate responses to these items, and the arrangement of the items on the form to meet their requirements.

There are three basic formats for displaying medical information.

a) The encounter report: This is a single visit note that includes diagnoses with associated narrative text, objective data, medications, test results, and consultation requests associated with that visit (illustrated in Fig. 1).

b) The status report: This is an index to, and summary of, the patient's current medical status (illustrated in Fig. 2).

c) Flowcharts: A flowchart is a computer-generated display which emphasizes the temporal course of the disease process or the variation in clinical findings over time. The display is a chronological listing, by date, of all occurrences of particular coded items with associated text and/or results. (An example of a flowchart is illustrated in Fig. 3.)

These reports can be produced on a scheduled basis or on demand, as printed material, or on the CRT display at the time of provider inquiry.

4) Scheduling: The on-line scheduling and appointment module finds open appointments, books patients for given times, displays schedules for both providers and patients, and automatically prints support documents for appointments (such as day lists), chart pull lists, and medical records for the scheduled patients. Small practices may not need a complete scheduling function; a subset of the system may be used to enter names or unit numbers of patients one day prior to their scheduled visit in order to trigger the automatic printing of medical records, or to create chart pull lists and routing slips.

5) Accounts Receivable (A/R): As clerical personnel enter encounter data into the system, the computer automatically files the information for both the medical record and the A/R

```
ENCOUNTER REPORT                UN: 1Ø36X
DEMO,ABRAHAM LINCOLN (M) 66 YRS    (2/12/12)

3/2/78    SITE OFFICE   TYPE NEW PATIENT   ROUTINE OFFICE VISIT
          BILLED TO GUARANTOR  DOE,JUDY,MD

                          DIAGNOSES/PROBLEMS

BHAE1       COMPLETE HISTORY AND PHYSICAL EXAM [REVIEW, RFV]
              LOOKS REASONABLY WELL CONSIDERING HIS MANY PROBLEMS. IS
              WORRIED ABOUT DOMESTIC STRIFE.
MHAB1       HYPERTENSION [R/O]
              STRONG FH. HAD NEGATIVE WORKUP IN ARMY PHYSICAL TWENTY YEARS
              AGO.  WILL START ON DIURETICS.
QGAA7       HEARTBURN
              PARTICULARLY AGGRAVATING AFTER CABINET MEETINGS

                            PHYSICAL EXAM

CAEF1 **    BLOOD PRESSURE          165/1ØØ RIGHT ARM 175/1Ø5 LEFT ARM
CAKH1       WEIGHT                  165

                              THERAPIES

TTAX1       CHLOROTHIAZIDE
              1ØØMG PO QD TAKE WITH ORANGE JUICE
              QTY: 1ØØ REFILL: 2
CWBB1       SYMPTOMATIC THERAPY
              TRY GLASS OF MILK FOR HEARTBURN
QWDN1       SALT RESTRICTION

                              PROCEDURES

BTTK5-N     SMALLPOX VACCINE INJECTION

                                TESTS

CNCJ1       BLOOD UREA NITROGEN                     23
KQBA1       STOOL OCCULT BLOOD                      NEG
MNBN3 **    HEMATOCRIT                              35
```

Fig. 1. The encounter report is equivalent to the "progress note" of the manual medical record and reflects the activity at a single patient visit. The report displays in a standard format both the data recorded via a single encounter form and the data reflecting laboratory test results associated with that encounter (which may be entered separately).

file, if that is appropriate, thus eliminating duplicate posting. The system prepares bills for individual patients or for third party carriers, translating the COSTAR codes to other coding schemes (to ICDA, for example) when necessary.

Additional A/R functions include entry of payment against accounts, maintenance of balance forward, and preparation of statements and reports such as a) batch verification list, b) daily transaction register, c) aged trial balance, d) outstanding insurance list, e) monthly ledger, and f) monthly revenue analysis reports by individual provider and for the practice collectively. All account information is available for on-line inquiry.

E. Paper Form Data Capture

One of the implementation compromises of the COSTAR strategy is that the physician or nurse does not directly interact with the computer system to enter medical information. Instead, both administrative and medical data for each ambulatory visit are recorded on an encounter form, a preprinted checklist with a defined structure and format (a portion of one encounter form is illustrated in Fig. 4). The basic structure consists of classes of recorded items (e.g., diagnoses, medications) and a vocabulary of terms specific to each of those classes. In most of the COSTAR user sites, the majority of information is recorded using a self-encoding format, i.e., there is a unique name and code associated with each item. At a particular encounter, items not covered by codes on the form are recorded in text and later coded by the medical record staff using a master code list (in the HCHP experience, fewer than one in ten encounters require any manual coding). Each form is reviewed periodically and changed to reflect the use of new or different terminology. The coding system used has been developed by the authors to meet the needs of the various specialties and reflects the diseases, problems, and health assessment activities that have been identified in the ambulatory care environment. An encounter form is completed not only for every patient visit in the ambulatory center, but also for many other care activities such as important telephone calls, home visits, emergency department visits, hospital visits, and hospital discharge summaries.

Although for purposes of organization and analysis it would be desirable to collect and store all medical data in a coded form, the enormous variety and richness of medical concepts make this an unobtainable ideal. In COSTAR, the primary topic (e.g., diagnostic name, medication name) is encoded while the bulk of descriptive information is stored in narrative form. Narrative information is recorded either by writing on the encounter form or by using dictation. This text is always associated with a specific item (e.g., a particular diagnosis) and a specific date and provider. Linkage of the narrative information with an encoded item is critical to automatic organization and retrieval of related data. Each clinical code is associated with a "status" at the time of recording to delineate further the clinical relevancy of the particular entity at that time; for example, status flags for diagnostic codes include "major," "minor," "inactive," and "presumptive." This

```
STATUS REPORT                 UN:1036X
DEMO,ABRAHAM LINCOLN (M) 66 YRS    (2/12/12)
PENNSLYVANIA AVE.  WASHINGTON, D.C.  00011
                                          INS:UNKNOWN

NO PRIMARY PROVIDERS

BHAE1       COMPLETE HISTORY AND PHYSICAL EXAM      DOE,JUDY,MD 3/2/78
              LOOKS REASONABLY WELL CONSIDERING HIS MANY PROBLEMS. IS
              WORRIED ABOUT DOMESTIC STRIFE.

                            --MAJOR PROBLEMS--

YJSN1       DEPRESSION                              DOE,JUDY,MD 4/15/78
              INTERMITTENTLY BECOMES VERY WITHDRAWN AND UNHAPPY

                            --MINOR PROBLEMS--

MHAB1       HYPERTENSION                    DOE,JUDY,MD 3/2/78-2-4/15/78
              BP CONTINUES ELEVATED.  SUGGEST EXERCISE PROGRAM
CGDC2       WEIGHT LOSS                             DOE,JUDY,MD 4/15/78
              20 LBS IN PAST YEAR WITH NO CLEAR CAUSE EXCEPT
              ANXIETY ABOUT COMING ELECTION
QGAA7       HEARTBURN                               DOE,JUDY,MD 3/2/78
              PARTICULARLY AGGRAVATING AFTER CABINET MEETINGS

                            --PHYSICAL EXAM--

CAEF1      BLOOD PRESSURE        * 4/15/78       165/100 RIGHT ARM
CAKH1      WEIGHT                  4/15/78       162

                              --THERAPIES--

TTAX1      CHLOROTHIAZIDE                                      3/2/78
             100MG PO QD TAKE WITH ORANGE JUICE
           QTY:100 REFILL:2
CWMF1      EXERCISE                                           4/15/78
           RUN 2 MILES EACH DAY
CWBB1      SYMPTOMATIC THERAPY                                 3/2/78
           TRY GLASS OF MILK FOR HEARTBURN
QWDN1      SALT RESTRICTION                                    3/2/78

                              --PROCEDURES--

BTTK5-N   SMALLPOX VACCINE INJECTION                           3/2/78

                                --TESTS--

CHEMISTRY
  CNCJ1    BLOOD UREA NITROGEN           3/2/78          23
  FNCW5    FREE THYROXINE [ORDERED]      4/15/78
  KQBA1    STOOL OCCULT BLOOD            3/2/78          NEG
HEMATOLOGY
  MNBN3 *  HEMATOCRIT                    3/2/78      *   35
MISCELLANEOUS
  WPAN1    ELECTROCARDIOGRAM             4/15/78
             NSR  LOW T WAVES OVER PRECORDIUM
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Fig. 2. The status report is an up-to-date summary of the diagnoses, medications, and laboratory results which gives the physician an overview of the current state of the patient's medical status. The first part of the Status Report contains identification information, membership enrollment, demographic and personal data of the patient, and scheduled appointments. The diagnostic information is organized according to the current status of each problem, with major problems listed first. Each diagnosis is associated with the most recently recorded status and the most recently recorded narrative text as well as the date when the problem was initially recorded, the date when last recorded, and the number of visits at which the problem was recorded. Other sections of the Status Report display information on physical examination, therapy, laboratory test results, and dispositions.

status flag determines how the information is formatted on medical displays (e.g., whether the diagnosis is on the "active" problem list) and is used to suppress routine display when a clinical entity is no longer active or medically significant. However, no medical information is ever deleted from the computer-based file and all data that have been recorded may be reviewed.

After the physician or nurse completes the encounter form, it is sent to the medical record department where clerical personnel enter the data into the computer system via terminals. The interval between the time of physician recording on the encounter form and the time of entry into the computer is dependent on the clerical staff of the record room; at HCHP it currently averages less than 24 hours. The use of a self-encoding form minimizes errors in coding and transcription by clerical personnel. Routine quality control analysis at HCHP indicates that transcription errors of either codes or text occur in less than one of 400 data elements.

F. Computer-Stored Database

Storage of information in on-line disk files guarantees that it is always available for review either by a printed report or through terminal inquiry. Also, data can be added to the patient's record from multiple sites.

Medical information in the COSTAR database can be automatically manipulated and organized for different styles of retrieval. Because much of the significant information in COSTAR is coded, it is possible to use predefined algorithms to select and organize data for medical record reports. The data are the most current, since the usual strategy in COSTAR operation is to print the record just prior to the patient's visit. COSTAR selects and organizes the information according to the medical significance, so that the content of the medical information reflects the particular medical circumstances of the specific patient.

The size of the patient medical record stored in COSTAR is

HYPERTENSION FLOWCHART

DATE	WGT	BLOOD PRESSURE	CREA	URIC ACID	K+	MEDICATIONS
3/2/78	165	165/100 RIGHT ARM 175/105 LEFT ARM				CHLOROTHIAZIDE 100MG PO QD TAKE WITH ORANGE JUICE
4/15/78	162	165/100 RIGHT ARM				
6/3/78	160	165/90 STANDING 160/95 LYING			4.3	CHLOROTHIAZIDE 500 MG PO QD
8/9/78				* 8.6	3.7	
8/31/78	169	165/90 STANDING 160/95 LYING				CHLOROTHIAZIDE
9/7/78				* 9.2		CHLOROTHIAZIDE 500 MG PO QD QTY 100 TAB X 3 REFILLS METHYLDOPA 250 MG PO BID QTY:60 X 3 REFILLS

Fig. 3. The flowchart lists specific parameters or types of data along a horizontal axis with date of event along the vertical axis. The medical practice may create any number of flowchart formats, or "templates" that specify which COSTAR codes are to be displayed, and the output format of the report. This flowchart would be appropriate for the followup of patients with hypertension. The column marked "medications" includes many antihypertensive drugs, of which only Chlorothiazide and Methyldopa have been prescribed for this patient.

DIAGNOSES / SIGNS / SYMPTOMS

Use the column marked "ST" for the following status codes:
✓ = minor I = inactive D = do not display Y = status post
M = major R = rule out P = presumptive H = history of
Place an "S" in the column marked "S?" if the condition is short duration.

S?	ST	GENERAL
	✓	BHAE1 Initial Health Assessment
		BHBK1 Adult Health Review
		BHPQ3 Rx Refill Only
		BHTM3 Immunization Visit
		BWCE1 Health Education
		DRUG REACTIONS
		CKPZ3 Drug Allergy - Penicillin
		CKPG4 Drug Allergy - Sulfonamides
		CLTZ3 Drug Reaction:____
		CLTJ1 Drug Toxicity:____
		SYSTEMIC
		CGBP5 Fatigue
		CGCZ6 Fever of Unknown Origin
		DKZW9 Viral Infection
		TRAUMA
		GLAY4 Skin Abrasion
		GLCL1 Burn
		GLBJ8 Contusion
		VMZK9 Fracture:____
		VLHP1 Head Trauma
		GLDR1 Laceration
		RESPIRATORY
		JJEV1 Upper Respiratory Infection
		DKYV3 Influenza
		LJEP3 Acute Bronchitis
		LJEM6 Chronic Bronchitis

S?	ST	ENT
		JHJW2 Cerumenosis
		JJGW3 Otitis Externa
		JJGL5 Otitis Media
		___A. Serous
		JLFG1 Rhinitis
		JLFK8 Allergic Rhinitis
		JJDP1 Sinusitis
		JJCJ1 Laryngitis
		JJCM8 Tracheitis
		JJAY1 Pharyngitis
		JJAN3 Strep Pharyngitis
		JGEK8 Epistaxis
		EYE
		HJDM1 Conjunctivitis
		HLAC1 Eye Injury
		HJBR3 Hordeolum
		MUSCULOSKELETAL
		VGAB6 Back Pain
		VGCZ1 Myalgia
		VJJW2 Gout
		VJME1 Bursitis
		VGFN4 Arthralgia
		VJHH1 Rheumatoid Arthritis
		VLGJ1 Sprain
		VLKA1 Disk Disease
		VJCC1 Osteoarthritis

FREE TEXT FOR DIAGNOSES

CODE
BHAE1 Looks reasonably well considering his many problems. Is worried about domestic strife

Fig. 4. The encounter form is a preprinted checklist which is designed by each specialty in each practice to record all medical, administrative, and billing data. Information is recorded by checking the appropriate code, entering the status of the code, selecting any appropriate modifiers, and writing any descriptive information as narrative text adjacent to the coded item. The data on the encounter form are entered into the computer system by clerical personnel.

dominated by three factors: the average number of encounters per year (in most ambulatory practices, this is three to five), the average length of time the patient receives active medical care from the practice, and the amount of narrative text recorded on each visit. There are very large variations in the latter two characteristics: one patient may be a transient who came only for a single episode of care, and another patient may have a major chronic illness lasting a number of years. The limited experience thus far with COSTAR suggests that a visit is associated with an average of about 150–200 characters, and that the average patient record may have on the order of 2500 characters.

G. Flexibility of Surface Behavior

There are no two medical practices which have identical needs and identical specifications for the functioning of an information system. COSTAR programs are written so that each site can choose among available options that determine certain characteristics (for instance, whether a diagnosis is required as the reason for the visit at each patient encounter). In other instances, site-specified table-stored entries determine the content of an interactive sequence (such as the questions on the registration procedure) or of certain output documents (such as the medical items on a hypertension flowchart). Many of these "switches" can only be set by a COSTAR programmer at the time of installation, but some of the options can be selected or changed at any time by the site personnel.

The encounter form itself may be designed to suit the documentation patterns of each specialty (e.g., the pediatrics encounter form may have a very different appearance from the encounter form used in orthopedics in the same practice). Although each specialty selects the items specific to its encounter form, the system as a whole shares a common set of consistent terms.

To assure that the different needs of the different specialties are met with regard to medical record reports, each specialty in a practice can identify which particular encounter reports should be included in the medical output (e.g., the output for a visit for a surgical consultation could be specified to include all encounter reports which contained the code for which the consultation had been requested) or what flow charts would be useful (e.g., a record of immunizations for a visit to pediatrics for well child care, or a temporal display of blood pressure, weight, and height of uterus for a prenatal visit). The primary objective in the use of different criteria in selecting the content and format of the medical output is to ensure that the physician can read and evaluate the relevant medical data in a minimal period of time.

H. Availability of Information

The principal method of providing access to the database is through standardized patient care reports (e.g., status report, encounter report, etc.) as well as through prespecified listings and reports associated with the accounts receivable and scheduling functions (e.g., revenue analysis, lists of currently booked appointments, etc.). However, these reports do not provide the capability for the user to supply the parameters for selective retrieval, analysis, and tabulation of data from the stored records. The effective administration of a complex organization such as a group practice requires the production of a variety of management reports on the characteristics and visit patterns of different patient populations, the types of resources being used by what patients, the costs and income associated with each service provided by the practice, and the workload of different specialties and different providers. These management reports are of increasing importance in facilitating rational administrative decision making, controlling the use of practice resources, appropriate reimbursement of the professional staff, meeting the reporting requirements of third party insurance and governmental regulatory agencies, and planning for growth or expansion of the organization.

In COSTAR 5 there are two different high-level languages that allow access to the database from a symbolic or logical point of view without the need for a programming staff or for the user to have a detailed knowledge of the underlying physical file structure. The first is the COSTAR Report Generator (CRG) which has been developed and is being supported by the Intramural Division of the National Center for Health Services Research. This report generator has been designed to accept commonly understood commands and to permit the user to obtain listings and tabulations associated with any variables indicated by the user. The second retrieval language provides the user with the capability to specify arbitrarily complex retrieval and analysis protocols. Personnel at the local site can use a medically oriented procedural language to specify the parameters for search routines which operate on the database, to format and display patient records selected by the search, and to produce standardized tabulations and cross-tabulations. A further extension of the language will allow the production of user specified reports using the information selected by the information retrieval system.

III. Implementation Strategies

The prototype COSTAR system at HCHP demonstrates the feasibility and potential effectiveness of automation of information processing at a single ambulatory care site. However, the national dissemination of an ambulatory information system to hundreds of sites requires not only a much more flexible system, but also a significantly different implementation strategy. The four major components the implementation strategy for COSTAR 5 include 1) industrial support, 2) installation planning, 3) local site modification, and 4) documentation.

A. Industrial Support

Any information system that is to be used by a large number of different medical practices must be implemented on current state-of-the-art minicomputer hardware in commercially supported systems and application software. The majority of medical practices do not have, and do not want to have, a programming staff who can develop a sophisticated information system or even modify a system obtained from a research organization such as this laboratory. A few very exceptional medical organizations may have the local talent to undertake the development and installation and support of a computer-based system. However, significant dissemination of COSTAR will depend on commercial organizations providing national marketing, local support for selection of appropriate hardware configuration and installation planning, and local site personnel education in customizing the system for individual practice needs.

COSTAR 5 is written in the ANSI certified Standard MUMPS which is commercially supported by a number of different hardware vendors. All of the developmental activity and programming efforts of this laboratory are supported by a research grant from the National Center for Health Services Research, and the COSTAR application programs are available to any organization, commercial or private.

B. Installation Planning

The importance of the installation process cannot be overemphasized, since COSTAR represents an entirely new application area in a marketplace which has little or no experience in automation. Since the installation of COSTAR will affect the methods and procedures not only of providers but of administrators and clerical personnel as well, and since only minimal perturbation of the health care delivery process can be tolerated, the installation process must be carefully planned and executed.

Thus COSTAR installations must 1) blend into the existing procedures and behavioral patterns of personnel, 2) preserve or enhance the efficiency of the normal decision-making processes, and 3) avoid the maintenance overhead of parallel manual or automated systems. In order to facilitate dissemination of COSTAR 5, an installation guide is being developed to cover the installation process from its early preplanning phase through post installation analysis, and to serve as the operational blueprint for the procedure.

C. Local Site Modification

At the time of initial installation each user site must make a number of decisions such as which modules to install and the form of unit number identification. In addition, there are a large number of other features which must be initially defined but which can be later modified, such as password conventions for system access, information requirements for each third party insurance carrier, and the revenue centers to be used. However, the major individual site modifications will be made through changes in the COSTAR directory, such as choosing or defining the codes to be used in the practice, defining the translation of these codes into other coding systems, and setting normal value ranges for the laboratory tests.

It is our hope that there will be only minimal need for modification of the computer programs, and that such programming can be done by the industrial field support group. There is a large cost associated both with the creation of site-specific computer programs and more importantly, the support of a large number of different computer software systems on a national basis. Therefore, it is critical that, as much as possible, all necessary changes in COSTAR be made by modification of the site-specific directory of codes. We expect that a major area of continuing development of COSTAR 5 will be adding enhancements to the COSTAR directory functions so that local on-site programming will not be required.

D. Documentation

The successful transfer of a complex computer-based system depends almost as much on the quality of the associated documentation as it does on the quality of the computer programs. The documentation provided to the user must detail not only how to interact with the system, but also must give the background as to why the different technical decisions were made, and how best to take advantage of the different data recording and display alternatives offered by COSTAR. As much as possible, we have tried to make COSTAR 5 self-documenting in that the system operates in an interactive fashion, wherein the user responds to a series of prompts to control the entry or retrieval of data. To each of these prompts, the user may enter a question mark to learn the meaning of the particular prompt, or to learn the format of the required answer and be given typical examples of possible responses. Ideally, most of the user's documentation needs will be met by this self-documentation so that there will be little need to consult the written user's manual.

There will also be extensive documentation provided to aid in physician education, since it has been our experience that the better a provider's understanding of the different system options, the better the system will be accepted and used. Although we have tried to make the use of COSTAR mimic typical manual recording practices, there are significant differences, and it is essential that the provider appreciate these differences. Changing a physician's recording habits is a challenge; when this must be achieved by an industrial marketing or field support group whose orientation is systems engineering, the task is most difficult and will require an imaginative and comprehensive set of educational materials.

Documentation for the installation and support technical group consists mainly in program and file structure description. The only unique feature of this documentation is the attempt to detail the interaction between the different features of each module and the interactions between modules. We will also try to document explicitly those features and program codes which should not be casually changed because of the possibility of jeopardizing or compromising the integrity of the total system operation.

IV. Technical Evaluation

The evaluation of the impact of all technological innovations in health care has become a topic of great interest to the federal government, primarily because of a concern that many technologies are associated with an increased cost of care without a perceptible equivalent increase in benefit.

The experience of the different sites using COSTAR 5 thus far is so limited that it is impossible to make a definitive evaluation. However, we can extrapolate to a certain extent from the experience at HCHP to make certain observations.

A. Cost

Because of the financial constraints on most medical practices, it is essential that the total direct and indirect costs of COSTAR not be significantly more than the present costs of the manual system and whatever computer support is currently used. The crucial weakness in making such a comparison is the paucity of quantitative information on the costs of information processing in the typical ambulatory practice. Most practices have only a vague idea of the costs of the technology, supplies, and labor directly attributed to the manual medical record and to third party billing, and usually even less data on the other information processing tasks such as scheduling, laboratory reporting, quality assurance, and preparation of management reports.

The relative costs associated with COSTAR are, therefore, difficult to assess, given the degree of uncertainty of comparable costs of manual information processing. It is the judgement of the HCHP administration that the cost of their version of COSTAR is slightly more than the cost that would be incurred in performing the same functions using manual techniques (with the justification for using COSTAR being the much greater effectiveness in performing these functions). It is our expectation that the cost of COSTAR will be comparable to the costs of commercially available systems that deal purely with accounting functions and which have been successfully marketed on a national scale. For a small practice the cost of COSTAR 5 should not be more than $1000–$2000/month; for a large practice the cost should be $3000–$5000/month.

It is our impression that the monetary costs of the computer system are relatively small compared to the large cash flows of even modest sized group practices, and that there are potential savings in time of both clerical and professional personnel. Given the uncertainty in evaluating cost effectiveness of a computer system versus a manual system, we expect that the main driving force for the decision to acquire COSTAR will not be to save money in information processing, but rather to meet the increasingly critical need for more accurate and complete management and financial information.

B. Professional Acceptability

The practice of medicine is traditionally conservative, and any radical change in procedures for processing medical information will not be readily accepted. A dominant reason for using a paper encounter form for data entry, and for allowing some information to be recorded in narrative text, is that this technique allows the capture of considerable coded data and yet has at least a superficial resemblance to the classical recording practice of writing in the medical record. The use of direct terminal interaction with the physician recording information through a menu selection process would increase the cost of the system in requiring more powerful computer processing support and more sophisticated terminals. A more important limitation is that many physicians find interacting with a terminal professionally unacceptable. It may be that as more physicians become familiar with using terminals for inquiring about medical data on a specific patient, this restriction will disappear. However, the optimal strategy at present seems to be a system which does not depend on direct physician interaction with the computer terminal.

A second critical characteristic of COSTAR is that there is no explicit model of medical information recording and no defined data base which the system imposes on the physician. The style and completeness of medical recording is completely determined by local recording practices. It is our belief that the technology should conform to professional standards defined by each site; it is not our objective to reform medical practice by requirements or restrictions built into the technology.

These beliefs have been validated in the ten-year experience with the original version of COSTAR in the HCHP Kenmore Center. A 1975 survey of physicians and nurses at HCHP showed that ninety percent of the providers felt that there was greater record availability in COSTAR, eighty percent felt it required less time to record information in COSTAR, and eighty-seven percent expressed a preference for using COSTAR over a manual record.

C. Flexibility

As of early 1979, COSTAR 5 is in the process of being implemented at seven different sites. In each situation, it has been necessary to make programming changes to meet the specific needs of the practice, although some of these changes were functional extensions that will be useful to other sites. From the beginning, it was planned that the development of COSTAR 5 would be evolutionary, beginning with a basic system (Level One), and progressing with a series of enhancements in later releases. Although the directory functions do support a variety of different surface behaviors at the different sites, the final evaluation of the degree of flexibility inherent in COSTAR 5 cannot be made at this time.

D. Improvement in Patient Care

Although most medical professionals maintain that increased availability of information is associated with improved medical decision making, and, therefore, with improved patient care, there is little experimental evidence to document this prejudice. In an indirect fashion, a computer-based information system has the potential to improve patient care by providing the opportunity to identify patients at high risk because of a particular diagnosis or patients who are receiving an undesirable set of medications. For example, COSTAR has been used at HCHP for a recall program of women receiving a particular sequential birth control pill and for another program to identify high-risk patients to receive flu vaccination. COSTAR can also be used to monitor the patterns of medical practice according to specific standards of care. For example, COSTAR could be used to support quality assurance programs to ensure that all patients with abnormal Pap smears or elevated blood pressure received the appropriate followup, or that all children received the appropriate immunizations. The standards that are used for the automated surveillance in such quality assurance programs are defined by the local policies of each practice.

The advantage of COSTAR over a manual system is that a computer system can be programmed to be algorithmically sensitive to the implications of the medical content of each patient's record as part of routine system operation. In contrast, a manual medical record is essentially passive and oblivious to the significance of the medical information contained in the document. This use of COSTAR is the engineering equivalent of the control system model where the information about the specific deviation provides the feedback loop by notifying automatically the decision maker in a timely fashion, so that action can be taken to correct the deviation. This automatic notification has negligible cost and has been demonstrated at HCHP to improve adherence to the prescribed standards of care [15], [16].

V. Conclusion

It would be naive to believe that any computer-based information system is completely general purpose or will completely meet the needs of every medical practice. In addition, there is always a cost and efficiency tradeoff between a system that is specifically designed for a well-defined set of needs, and a system designed to have sufficient flexibility to support a broad range of functions and provide a great variety of local options. The dominant objective in the COSTAR 5 development is to provide a system that can meet the information processing needs of a variety of ambulatory practices without requiring excessive programming modifications at each local site. Although the experience thus far in installing COSTAR 5 in the different test sites is encouraging, it is premature to claim that the present implementation is flexible and robust enough to be a completely satisfactory system. We do believe that there is a widespread perception of need for an information system that supports both administrative and medical needs in ambulatory care, and that an information system that met these needs and that could be successfully installed and supported by private industry would be rapidly disseminated. We are optimistic that the basic design strategy we have chosen, and COSTAR 5 as it is presently implemented, provide the system capability that can evolve to meet the diverse requirements for national dissemination.

Acknowledgment

The authors acknowledge the contributions of all the members of the COSTAR system team in this developmental effort. In the preparation of this manuscript, the editorial criticisms of Ms. R. Zielstorff and the IEEE reviewers were particularly useful.

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The Technology of PROMIS

JAN R. SCHULTZ AND LAYTON DAVIS

***Abstract*—A network of computers supports many high-speed terminals equipped with touch-sensitive screens. Users make selections on frames displayed at these terminals to interact with a large data base of medical guidance and patient records while performing patient care. Rapid response times for selections (most are processed in about 230 ms) result from a high-speed communications line, a tailor-made programming language, and enhancements to the off-the-shelf operating and file systems. A PROMIS has been used for patient care on a hospital ward for several years with almost no down time.**

I. Introduction

PROMIS embodies a problem-oriented medical guidance system of branching displays and electronic patient records whose data may be subsetted and displayed in many ways. Every information originator interfaces directly with the guidance system. The problem-oriented system revolves about the patient's problem list: a data base is gathered, problems are formulated, and every subsequent action, including tests and treatment, must be justified for a specific problem.

The reliability, responsiveness, scalability, and access to large data files demanded of PROMIS have resulted in the design and use of unique tools, including CRT terminals with touch-sensitive screens, a CATV communication system linking peripherals to a minicomputer and minicomputer "nodes" to each other, application programming languages, software subsystems, a file system, operating system enhancements, and medical data structures.

Manuscript received December 20, 1978; revised February 6, 1979. This project was funded primarily by the National Center for Health Services Research, U.S. Department of Health, Education, and Welfare, with additional support from the Robert Wood Johnson Foundation. The environment for development work was provided by the Medical Center Hospital of Vermont and by the Departments of Medicine and Gynecology, University of Vermont, Burlington.
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II. Objectives of PROMIS

PROMIS Laboratory is developing computer-based systems to achieve:

1) a defined system of comprehensive medical care with a supporting knowledge and logic base for providers;
2) documentation of the care so that outcomes can be studied and the knowledge and logic base can be updated and corrected;
3) a scalable system that can be installed in all types of health care facilities.

The technological innovations described in this paper have resulted from the pursuit of these objectives.

III. Hardware

The PROMIS hardware base is a network of minicomputer "nodes" connected by a high-speed CATV bus. Each node consists of a Sperry-Univac V77-600 minicomputer with 16-bit words, 800-ns cycle time, and 256K word central memory, three Control Data Corporation Storage Module Drives (250 million characters per spindle), and peripherals. The CPU has Writable Control Store (WCS) and firmware developed by PROMIS Laboratory to facilitate rapid execution of common functions.

All hardware, including that developed specifically for PROMIS, is available from commercial sources.

A. PROMIS Terminal

The user interface for PROMIS is a high-speed (307 200 bits/s) CRT terminal equipped with a touch-sensitive screen and typewriter keyboard. By selecting choices presented on the screen, and occasionally by typing in data, the user negotiates the medical guidance structure to retrieve data from and store

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Commentary

The Added Value of the EMR

Reflections on G.O. Barnett's paper:
COSTAR – A Computer-Based Medical Information System for Ambulatory Care

It is always a delight to re-read a seminal paper such as this. Octo Barnett has gone on to become one of the leaders in the field of medical informatics. Not surprisingly, this paper from 1979 contains much that is still relevant today. Although it concentrates on the details of the implementation of COSTAR, in doing so it describes many fundamental issues relating to the implementation of Electronic Medical Records (EMRs). We are still trying to resolve some of these same issues today. Equally interesting are the elements of the paper that show aspects of EMRs we now regard as flawed. As one would expect, the passage of time has changed our views on many things.

The problems of manual records are well described. What is surprising is that these problems are still so relevant today. Why, if there are such problems, has the EMR not moved forward more rapidly? We are making progress but it is slow [1]. The statement that most commercial systems are designed for billing, accounts and third party insurance forms could be made today. This is even more surprising when the reason given for clinicians needing to move to electronic information systems are just as relevant today. These include the increasing complexity and volume of medical data, recorded for each patient, and the shift in emphasis in ambulatory care from treatment of episodic illness towards preventative medicine and continuity of care in the management of chronic disease.

Even the description of the difficulties caused by changes in health care administration is still recognisable. The statement that the manual record has proven grossly inadequate to meet the needs of health maintenance types of organisations is extremely topical in many countries.

The design goals are still valid:

1. *Facilitate patient care by improving the availability, accessibility, timeliness of arrival, legibility and organisation of medical information.*

Goal 1 concentrates on some aspects we would take for granted now. Legibility is no longer seen as a major problem. It is just accepted as a by-product. Today, one would have enhanced this goal by adding elements designed to improve patient care using decision support techniques supplementing better organisation of medical data [2].

2. *Enhance the financial viability of the medical practice by providing comprehensive billing systems with accounting reports.*

This Goal is still as valid but has proved to be a hindrance in developing systems that meet clinicians needs.

3. *Facilitate medical practice administration by providing the data retrieval and analysis capability required by management.*

This seems straightforward, but has also proved a problem. Too much emphasis on administration has failed because the systems have not supported the collection of the underlying data to drive administrative processes.

4. *Provide data processing support for administrative and ancillary services.*

Goal 4 reflects on the concept that data management is handled centrally within an organisation. There has been a tendency to move away from central control via data management departments towards local control on users' PCs, but this trend seems to be reversing. A plea is made for industrial support for the wider implementation of COSTAR. This is stressed due to the lack of computer-skilled staff in a practice. Unfortunately, such limitations still survive today and the overall cost of ownership of current systems is too high for many health-care systems. We now know that training of all staff is an absolute pre-requisite for effective implementation of a system into any health-care facility. In 1979 this was not so well recognised.

5. *Provide the capability to generate standardised management reports.*

We would now call this enabling medical and administrative audit but it is otherwise little changed.

6. *Support programs of quality assurance by monitoring the content of the database according to user specified rules.*

Goal 6 is remarkably far sighted. User-specified guideline or electronic protocol support is growing in fashion throughout the world. It is seen as one of the most effective ways to improve the cost effectiveness of medical care, which is trying to meet an ever-increasing demand. The paper was assuming that most of this activity would be off line. However, in 1979 this was not usually recognised as an issue for computer records.

COSTAR was written in MUMPS. Many legacy systems benefited from the flexibility and power of MUMPS but few would start a new system using it in these days of relational databases, object orientation and document-based records.

Perhaps one of the most far-seeing elements of COSTAR is its sophisticated mechanisms for handling a dictionary of terms. Today we would favour using standardised national or international term sets to allow consistency and data transfer across organisations. However, much of the detail on how such term sets should be handled was first described in COSTAR. Although the term set used within a COSTAR system would have been particular to that system, it could have had many of the elements we now know are needed to ensure that clinical data can be collected in a useful and reliable form. Poorly structured term sets and a reliance on excessive amounts of free text have dogged attempts to replicate a useful electronic medical record. Equally impressive is the ability for the user to program specific responses to specific coded entries. This allows both for data-entry validation routines but also more sophisticated responses.

The arguments described for not using the International Classification of Diseases (ICD) still stand today. For example: "In particular the ICD-CM is not particularly suited for common health problems and ill-defined conditions that are common in primary care." The statement that "there has been little success in using computer technology to process narrative text." is only a little unchanged today. Perhaps the most appealing statement that still runs true is: "there is considerable disagreement within the medical community on appropriate taxonomy systems".

Modular design still remains a major criterion for successful implementations; yet, it is one often forgotten by suppliers who tend to favour monolithic systems as they are easier to build and maintain. However, they are much less flexible in the constant battle to persuade clinical users to use systems.

Confidentiality is catered for by password and specific terminal restrictions. This would be regarded as too little today. A transaction log that records each transaction enhances security. Today, we would expect details of a secure audit trail that would allow the use of the record in a court of law.

Clinician Acceptability

The paper talks a great deal about the administrative information produced from the system. This was the main driver for electronic records at the time. It is now being recognised that it is this concentration on secondary administrative uses which has caused much of the problems currently experienced with trying to introduce such systems to clinicians. Clinicians are not willing to use systems that are only designed to provide off-line results from entering data. It is now recognised that the primary function of the EMR is for direct patient care [3]. Thus, clinicians need information at the point of care [4].

Professional acceptability is put forward as the main reason for sticking to manual entry for physicians. Inevitably, COSTAR is limited by the display and interface technologies available at the time. This made it more difficult to persuade clinicians to use it. Such limitations plus the desire to avoid interfering with clinical practice caused COSTAR to work on the basis of data being recorded onto encounter forms which were then transcribed onto the computer. This produces the need to run manual and computer systems in parallel, increasing the overheads and often a cause for failure. It is interesting that the paper describes the transcription error rate as being very small (<1 in 400 transactions) This may be because the type and quantity of data being collected was limited. However, some of this must have been because of the effort put into the design of the data entry worksheets. This aspect receives much emphasis, which is not surprising considering the importance of collection of data onto paper prior to transcribing it onto the computer. However, subsequent work has shown that the greater the distance in time or space between the collector of the data and the person entering the same data, the greater the chances that the data is less suitable for any purposes other than serving as an aide memoire [5].

One of the features that would be regarded important these days, but which is missing, is the concept of different views on the data to suit both different users and to extract greater value from the record [6]. This is not surprising as COSTAR was designed to be used by recording on paper rather than on screen. This means that the essential elements of data presentation are not relevant.

Another element we would regard as essential today is the concept of a "story". The medical record, if to be used in a real-time environment, has to be able to show its data elements in a way which fits with the clinicians thinking. This is one of the major requirements if one is going to overcome the professional resistance to electronic medical records described in the paper [7]. The other major feature in meeting this challenge is to ensure that the EMR provides "added value". This can be in the form of displaying the data in a form which returns more than the individual elements recorded. It can also be in the form of prompts, alerts and watchdogs, which provide the clinicians with information they may not otherwise have known [8]. Unfortunately, although much more is known about "clinician-friendly" EMRs we have yet to implement them in a widespread enough fashion to achieve better uptake.

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