Review Paper ■

Three Decades of Research on Computer Applications in Health Care:

Medical Informatics Support at the Agency for Healthcare Research and Quality

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Abstract The Agency for Healthcare Research and Quality and its predecessor organizations—collectively referred to here as AHRQ—have a productive history of funding research and development in the field of medical informatics, with grant investments since 1968 totaling $107 million. Many computerized interventions that are commonplace today, such as drug interaction alerts, had their genesis in early AHRQ initiatives.

This review provides a historical perspective on AHRQ investment in medical informatics research. It shows that grants provided by AHRQ resulted in achievements that include advancing automation in the clinical laboratory and radiology, assisting in technology development (computer languages, software, and hardware), evaluating the effectiveness of computer-based medical information systems, facilitating the evolution of computer-aided decision making, promoting computer-initiated quality assurance programs, backing the formation and application of comprehensive data banks, enhancing the management of specific conditions such as HIV infection, and supporting health data coding and standards initiatives.

Other federal agencies and private organizations have also supported research in medical informatics, some earlier and to a greater degree than AHRQ. The results and relative roles of these related efforts are beyond the scope of this review.

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Three decades ago, when the federal government's National Center for Health Services Research and Development began to support research on computer applications in health care, few imagined the impact that information systems and sciences would have on medical care today. For most, the idea of a national clearinghouse of guidelines, available through a computer that sits on a home office desktop, seemed like science fiction. For a few researchers and those supporting their work, however, visions of what could become possible in the management of health care information called for development of computerized systems and the evaluation of their effects on quality, cost, and access to care.

The Agency for Healthcare Research and Quality (AHRQ, from 1999) and its predecessor agencies—the National Center for Health Services Research and Development (beginning in 1968) and the Agency for Health Care Policy and Research (from 1989 to 1999)—have a rich history of funding research, development, and evaluation in medical informatics. Although the grant investments since 1968 total only $107 million ($246 million in 2000 dollars), they supported initiatives that have established a research framework for many of the computer applications now being used today.

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The focus of AHRQ's early research funding in medical informatics was on acquiring patient care data and communicating patient care management information. The goal was not only to improve the quality of care, but also to achieve reductions in costs and medical personnel resource use by processing data more efficiently. Research aimed at improving communication of information was targeted at what we would call today "getting the right information to the right place at the right time." The promise of this research was its ability to provide findings that would guide reorganization of care delivery, take advantage of the more rapid communication of necessary information, and reduce manpower needs.[1] Over time, AHRQ's funding has emphasized the application of health services research methods to evaluations of information technology used in community health settings. This article highlights key accomplishments emerging from AHRQ's funding that have improved the quality of patient care in studied sites and have the potential to improve health care in all settings.

Other federal agencies (such as the National Library of Medicine, the Veterans Health Administration, and the Department of Defense) and private organizations (such as The John A. Hartford Foundation, The Robert Wood Johnson Foundation, and the American Hospital Association) have supported developments in medical informatics, with some having greater research expenditures and earlier histories than AHRQ. Nevertheless, it is the Agency's contributions to medical informatics that are the focus of this study. The purpose of this article is to provide a historical perspective for understanding the benefits of past research funded by AHRQ that supports health care applications of information technology today and that foreshadows AHRQ's medical informatics initiatives for the future.

Method

The AHRQ grant history was searched using internal administrative records for grants pertaining to medical informatics since 1968. Table 1 shows the grants that were discovered, listed by the year of first AHRQ funding, AHRQ grant number, title, principal investigator, and funded institution. Once the grants were identified, a MEDLINE search was performed on articles written by the principal investigators to determine the contributions made to the medical informatics literature by these investments. Articles were chosen on the basis of their illustration of the development and application of computer applications to practical problems and on their findings of effects on quality of care, patient outcomes, health care costs, use, or access. There is no equivalent searchable AHRQ contract history; however, some contract material was discovered, as shown in Table 2. The middle two digits in the contract numbers shown in Table 2 denote the year in which contracts were awarded. A literature review by Kunitz and Associates supplied helpful links to the contributions of AHRQ-funded researchers.[2]

This paper is principally a summary of the fruits of AHRQ grant support of medical informatics, supplemented by selected contracts and intramural resources. In some cases, no attribution to AHRQ (or its predecessors) for funding support was found in the articles. For most of these publications, we did not presume AHRQ support, and the article was not included. Consequently, the articles cited here are a portion of all the articles produced with AHRQ support.

We attempted to link publications and other contributions to specific grants, and have provided grant numbers when possible. The sequentially assigned grant numbers (and, occasionally, contract numbers) are shown in brackets in the text. In most instances, but not all, the sequence numbers indicate the order in which the grants were funded. By citing these reference numbers, we do not mean to imply that AHRQ grants were the only source of funding for cited contributions. Other funders deserve much credit as well.

In 1968, AHRQ (as the National Center for Health Services Research and Development), with Paul Sanazzaro as its first director, was created from several components of the Health Services and Mental Health Administration (HSMHA). Some grants funded by HSMHA were carried into AHRQ but received no additional funding. Those that did receive additional AHRQ funding are included, where this could be determined.[3,4] For example, two health services research centers targeted to health care technology research were initiated in HSMHA with funding continued by AHRQ. The two centers were led by Morris Collen, Kaiser Foundation Research Institute, California [HS00288] and Donald Lindberg, University of Missouri Medical Center [HS00014].[5–7]

From 1973 to 1995, Norman Weissman was the director of the Center for Extramural Research (or its equivalent in health information technology) and, along with Gerald Cohen, Bruce Waxman, Donald Barnes, Richard DuBois, Robert Ullom, James McAllister, Alan Mayer, and others at AHRQ, strongly encouraged the application of health services research methods in medical informatics.[8]

Table 1 ■

List of Selected AHRQ-funded Grants, 1968 to 2000

Year	Grant No.	Title	Principal Investigator	Institution
1969	HS00014	COMPUTER RECOGNITION OF HUMAN DISEASE PATTERNS	LINDBERG, DONALD AB	UNIVERSITY OF MISSOURI
1972	HS00020	EVALUATION OF COMPUTER CONTROLLED PATIENT SIMULATOR	ABRAHAMSON, STEPHEN	UNIV OF SOUTHERN CALIFORNIA
1969	HS00060	COMPUTERS-AUTOMATION IMPACT ON LABORATORY MANAGEMENT	RAPPOPORT, ARTHUR E.	YOUNGSTOWN HOSPITAL ASSOC.
1969	HS00070	DEVELOPMENT OF EMERGENCY LIFE SUPPORT POD	NOBEL, JOEL J.	EMERGENCY CARE RESEARCH INST
1968	HS00075	USE OF COMPUTER TO IMPROVE CLINICAL LABORATORY	SELIGSON, DAVID	YALE UNIVERSITY
1969	HS00089	REAL TIME COMPUTER SERVICES FOR AMBULATORY CLINIC	JESSIMAN, ANDREW G.	PETER BENT BRIGHAM HOSPITAL
1970	HS00093	DEMONSTRATION OF THE INTEGRATION OF ACTIVE MEDICAL RECORDS	ROBINSON, ROBERT E.	BOWMAN GRAY SCHOOL OF MED.
1970	HS00106	COMPUTERIZED PROTOCOL FOR MECHANICAL VENTILATION WEANING	RANDOLPH, ADRIENNE G.	UNIVERSITY OF UTAH
1969	HS00126	COMPUTER ANALYSIS OF NARRATIVE CLINICAL DATA	KOREIN, JULIUS	NEW YORK UNIVERSITY MED CTR
1969	HS00128	ON-LINE MONITORING SYSTEM FOR INTENSIVE CARE UNIT	KEZDI, PAUL	COX HEART INSTITUTE
1970	HS00146	DEMONSTRATION OF COMPUTER MONITORING (SURGICAL)	BELLVILLE, JOHN W.	STANFORD UNIVERSITY MED CTR
1969	HS00175	AUTOMATION OF A PROBLEM-ORIENTED MEDICAL RECORD	WEED, LAWRENCE L.	UNIVERSITY OF VERMONT
1970	HS00188	AUTOMATION OF MEDICAL CONSULTATION	BLEICH, HOWARD L.	BETH ISRAEL HOSP (BOSTON)
1969	HS00238	DEVELOPMENT OF AUTOMATED SYSTEM FOR CRITICAL CARE UNITS	WEIL, MAX H.	UNIV. OF SOUTHERN CALIFORNIA
1969	HS00240	HOSPITAL COMPUTER PROJECT	BARNETT, G. O.	MASS. GENERAL HOSP
1969	HS00288	HEALTH SERVICES RESEARCH CENTER	COLLEN, MORRIS	KAISER PERMANENTE
1970	HS00307	AMBULATORY SCHEDULING: A MANAGEMENT SCIENCE APPROACH	ROCKART, JOHN F.	LAHEY CLINIC FOUNDATION
1968	HS00316	MEDICAL DIAGNOSIS USING SUBJECTIVE PROBABILITIES	GUSTAFSON, DAVID H.	UNIVERSITY OF WISCONSIN
1970	HS00408	IMPROVEMENT OF METHODOLOGY FOR CLINICAL EVALUATIONS	EINSTEIN, ALVAN R.	YALE UNIVERSITY
1970	HS00427	COMPUTER TECHNICS IN PATIENT CARE	CLARK, GLENN M.	UNIVERSITY OF TENNESSEE
1971	HS00646	MISSOURI AUTOMATED RADIOLOGY SYSTEM MARS	LEHR, JAMES L.	UNIV. OF MISSOURI COLUMBIA
1971	HS00659	COMPUTER BASED MEDICAL INTERVIEWING	SLACK, WARNER V.	BETH ISRAEL HOSP. (BOSTON)
1972	HS00685	APPLICATION OF STATISTICAL METHODS TO RECORD LINKAGE	ODOROFF, CHARLES L.	UNIVERSITY OF ROCHESTER
1971	HS00696	DEVELOPMENT OF A DIFFERENTIAL WHITE COUNT SYSTEM	NEURATH, PETER W.	NEW ENGLAND MEDICAL CENTER
1972	HS00714	REGIONAL AL LOCATION OF HIGH COST HEALTH SERVICES	WOLFE, HARVEY	UNIVERSITY OF PITTSBURGH
1971	HS00739	A COMPUTER-BASED DRUG INTERACTION WARNING SYSTEM	COHEN, STANLEY N.	STANFORD UNIVERSITY
1972	HS00830	AUTOMATED AMBULATORY MEDICAL RECOR SYSTEM FOR HMO'S	BRUNJES, SHANNON D.	YALE UNIVERSITY
1972	HS00911	COMPUTER AIDED MEDICAL DECISION MAKING	SCHWARTZ, WILLIAM B.	NEW ENGLAND MED CTR HOSPITAL
1972	HS00929	DEVELOP, TEST, AND EVALUATE PROFESSIONAL REVIEW	BOYDEN, GEORGE M.	NEW MEX. FOUND. FOR MED. CARE
1972	HS00933	THE IOWA HEALTH SERVICES DATA BANK	DUNN, DONALD W.	IOWA HOSPITAL ASSOCIATION
1971	HS01052	AN URBAN COMPREHENSIVE HEALTH CARE INFORMATION SYSTEM	GIEBINK, GERALD A.	HEALTH CARE MANAGEMENT SYST
1972	HS01053	AUTOMATED HEALTH SERVICES	WARNER, HOMER R.	UNIVERSITY OF UTAH
1972	HS01054	CODED LANGUAGE INFORMATION PROCESSING FOR RADIOLOGY	SIMON, MORRIS	BETH ISRAEL HOSP (BOSTON)
1974	HS01195	COMPUTER BASED CONSULTATION IN CARE OF CRITICALLY ILL	SIEGEL, JOHN H.	STATE UNIVERSITY OF NEW YORK
1974	HS01467	EVALUATION OF COMPUTER-AIDED CARE AFTER HEART SURGERY	EDMUNDS, L H.	UNIVERSITY OF PENNSYLVANIA
1974	HS01472	COMPUTER AIDS TO THERAPY IN CRITICAL CARE	MORGAN, ALFRED P.	HARVARD UNIVERSITY
1974	HS01474	MEDICAL DECISION SYSTEM EMERGENCY AND CRITICAL CARE	WEIL, MAX H.	UNIV OF SOUTHERN CALIFORNIA
1974	HS01533	BROADCAST COMPUTER SYSTEM FOR PATIENT HISTORY TAKING	MOLNAR, CHARLES E.	WASHINGTON UNIVERSITY
1974	HS01540	PILOT PROJECT, MUMPS USERS GROUP	ZIMMERMAN, JOAN	WASHINGTON UNIVERSITY
1974	HS01544	COMPUTER-BASED CONSULTATIONS IN CLINICAL THERAPEUTICS	COHEN, STANLEY N.	STANFORD UNIVERSITY
1975	HS01566	COMPUTER MANAGEMENT SYSTEMS FOR DIAGNOSTIC RADIOLOGY	SHEA, FRANCIS J.	TEMPLE UNIVERSITY
1974	HS01569	CLINICAL COMPUTER RESOURCE RELATED RESEARCH PROJECT	BRUNJES, SHANNON D.	YALE UNIVERSITY

1974	HS01571	AUTOMATED PHYSICIANS ASSISTANT	LUCAS, FRED V.	UNIV. OF MISSOURI COLUMBIA
1974	HS01577	QUALITY OF CARE AND AN HMO AUTOMATED MEDICAL RECORD	BRUNJES, SHANNON D.	YALE UNIVERSITY
1974	HS01589	EMERGENCY CARE QUALITY: USEFULNESS OF PATIENT PROFILES	VALLBONA, CARLOS	BAYLOR COLLEGE OF MEDICINE
1974	HS01611	A STUDY OF PREVENTABLE HOSPITAL ADMISSIONS	MCDOWELL, IAN W.	BOSTON UNIVERSITY
1974	HS01613	LABORATORY FOR DEVELOPMENT OF HEALTH INFORMATION SYSTEM	STARMER, CHARLES F.	DUKE UNIVERSITY MEDICAL CTR
1974	HS01621	STUDYING THE IMPACT OF PATIENT DRUG PROFILES IN A HMO	JOHNSON, RICHARD E.	KAISER FOUNDATION RES. INST
1974	HS01646	AN EVALUATION OF A COMPUTERIZED ECG ANALYSIS SYSTEM	WORTMAN, PAUL M.	NORTHWESTERN UNIVERSITY
1975	HS01662	DECISION ANALYTIC TOOLS FOR REGIONAL HEALTH PLANNING	SONDIK, EDWARD J.	STANFORD UNIVERSITY
1975	HS01875	COMPUTERIZED NATIONAL CHRONIC DISEASE DATABANK SYSTEM	FRIES, JAMES F.	STANFORD UNIVERSITY
1976	HS02027	A PATIENT CARE QUALITY ASSURANCE SYSTEM	GALL, JOHN E.	EL CAMINO HOSPITAL
1976	HS02099	ON-LINE CODE-GENERATED X-RAY REPORTING AND DATA RECALL	SIMON, MORRIS	BETH ISRAEL HOSP (BOSTON)
1976	HS02122	THE VALUE OF INFORMATION DISSEMINATION	LAVE, LESTER B.	CARNEGIE MELLON UNIVERSITY
1976	HS02142	COMPUTER-BASED AMBULATORY QUALITY ASSURANCE PROGRAM	WINICKOFF, RICHARD N.	HARVARD COMM. HEALTH PLAN
1976	HS02463	COMPUTERIZED PROTOCOLS APPLIED TO EMERGENCY CARE	GARDNER, REED M.	LDS HOSPITAL
1977	HS02485	CONTROLLED TRAIL OF A QUALITY ASSURANCE MECHANISM	MC DONALD, CLEMENT J.	INDIANA UNIVERSITY
1976	HS02603	COMPUTERIZED INTERPRETATION OF THE ECG - II	COLE, SANDFORD S.	UNITED ENGINEERING TRUSTEES
1977	HS02649	AUTOMATED RECORD SUMMARIES: ANALYSIS OF AN EXPERIMENT	ROGERS, JAMES L.	NORTHWESTERN UNIVERSITY
1977	HS02760	SPECIFICATION AND BUILDING OF AMBULATORY-CARE RECORDS	ZIMMERMAN, JOAN	WASHINGTON UNIVERSITY
1079	HS02764	THE DEVELOPMENT OF CLINIMETRICS	FEINSTEIN, ALVAN R.	YALE UNIVERSITY
1977	HS02839	MACHINE REPRESENTATION OF MEDICAL KNOWLEDGE	BASKIN, A B.	UNIVERSITY OF ILLINOIS
1978	HS03000	COMPUTER INTERVENTION IN CLINICAL DRUG THERAPY	COHEN, STANLEY N.	STANFORD UNIVERSITY
1978	HS03087	AMBULATORY CARE MEDICAL AUDIT DEMONSTRATION PROJECT	PALMER, R H.	HARVARD UNIVERSITY
1978	HS03115	IMPROVING CLINICAL DECISION-MAKING IN ARTHRITIS	LEVY, JOSHUA	UNIV. OF CALIF. SAN FRANCISCO
1979	HS03573	CLINICAL COMPUTER AUDIT: EFFECTS ON COST AND RESOURCE	THOMAS, JAMES C.	UNIV. OF TEXAS HEALTH SCI. CTR.
1980	HS03582	EVALUATION OF A SUMMARY MEDICAL RECORD SYSTEM	SIMBORG, DONALD W.	UNIV. OF CALIF. SAN FRANCISCO
1979	HS03588	EXPERIMENTAL DISSEMINATION OF AN INFORMATION SYSTEM	BARNETT, G. O.	MASS. GENERAL HOSPITAL
1979	HS03650	INTEGRATING MEDICAL KNOWLEDGE AND CLINICAL DATA BANKS	WIEDERHOLD, GIO C.	STANFORD UNIVERSITY
1979	HS03672	HEALTH INFORMATION SYSTEM TRANSFERABILITY EVALUATION	DITTMANN, JAY T.	UNIV. OF MISSOURI COLUMBIA
1979	HS03792	A MEDICAL INFORMATION SYSTEMS DESIGN METHODOLOGY	COX, JEROME R.	WASHINGTON UNIVERSITY
1981	HS03810	BEDSIDE DATA ENTRY FOR MEDICAL DECISION-MAKING	WARNER, HOMER R.	LDS HOSPITAL
1979	HS03834	A MEDICAL DATABASE APPROACH TO EVALUATE TECHNOLOGY	STEAD, E. A.	DUKE UNIVERSITY MEDICAL CTR
1979	HS03896	IMPROVING DRUG PRESCRIBING IN FAMILY PRACTICE	GEHLBACH, STEPHEN H.	DUKE UNIVERSITY MEDICAL CTR
1980	HS04073	COMPUTER-STORED AMBULATORY RECORD (COSTAR)	BARNETT, G. O.	MASS. GENERAL HOSPITAL
1981	HS04080	VARIANCE IN MEDICAL DECISIONS: CAUSES AND CURES	MC DONALD, CLEMENT J.	INDIANA UNIVERSITY
1980	HS04152	AUTOMATED AMBULATORY MEDICAL RECORD SYSTEMS FOLLOW-UP	WIEDERHOLD, GIO C.	STANFORD UNIVERSITY
1981	HS04196	A GENERALIZED NETWORK TECHNOLOGY FOR HOSPITALS	SIMBORG, DONALD W.	UNIV. OF CALIF. SAN FRANCISCO
1981	HS04389	DERIVING KNOWLEDGE FROM CLINICAL DATABASES	WIEDERHOLD, GIO C.	STANFORD UNIVERSITY
1983	HS04604	DECISION SUPPORT SYSTEMS FOR AMBULATORY CARE PROBLEMS	WILSON, EDWARD C.	UNIVERSITY OF VIRGINIA
1983	HS04788	NURSE: A NURSE STAFFING REQUIREMENTS SYSTEM	SMITHWICK, MARY M.	EL CAMINO HOSPITAL
1983	HS04873	USING EXPERIENCE TO IMPROVE CLINICAL DECISION MAKING	PRYOR, DAVID B.	DUKE UNIVERSITY MEDICAL CTR
1984	HS04949	THE IMPACT OF COSTAR ON QUALITY OF AMBULATORY CARE	CAMPBELL, JAMES R.	UNIV. OF NEBRASKA MED. CTR.
1984	HS04996	EFFECT OF COMPUTER FEEDBACK ON PHYSICIAN TEST ORDERING	MC DONALD, CLEMENT J.	INDIANA UNIVERSITY
1985	HS05084	DEVELOPMENT OF EDP PERFORMANCE STANDARDS FOR HOSPITALS	BAILEY, JAMES E.	ARIZONA STATE UNIVERSITY
1984	HS05127	SURVEY OF CALIFORNIA HEALTH DEPARTMENT COMPUTER SYSTEMS	BOGGESS, JANE E.	HEALTH OFFICERS ASSOC. OF CA
1984	HS05135	HOME SURVEILLANCE SYSTEM FOR HYPERTENSIVE PATIENTS	FRIEDMAN, ROBERT H.	THE UNIVERSITY HOSPITAL
1984	HS05261	COMPUTER-BASED SYSTEM FOR LONG-TERM CARE AND RESEARCH	ZIELSTORFF, RITA D.	MASS. GENERAL HOSPITAL

continued

Table 1 ■
List of Selected AHRQ-funded Grants, 1968 to 2000, *continued*

Year	Grant No.	Title	Principal Investigator	Institution
1985	HS05263	MENTOR COMPUTERIZED MONITORING OF THERAPEUTIC DECISIONS	BLASCHKE, TERRENCE F.	STANFORD UNIVERSITY
1986	HS05275	IMPACT AND COST OF A PATIENT CARE INFORMATION SYSTEM	PALMER, R H.	HARVARD UNIVERSITY
1986	HS05319	EVALUATION OF A COMPUTERIZED INFECTIOUS DISEASE MONITOR	GARDNER, REED M.	LDS HOSPITAL
1986	HS05369	PROCESS OF INCORPORATING COMPUTERS INTO NURSING PRACTICE	KJERULFF, KRISTEN H.	UNIVERSITY OF MARYLAND
1986	HS05398	COMMUNICATION NETWORKS AND PHYSICIAN USE OF AN HIS	MCDOWELL, IAN W.	METHODIST HOSPITAL OF INDIANA
1988	HS05406	THE EFFECT OF COMPUTERIZATION ON THE NURSING PROCESS	PRYOR, T A.	LDS HOSPITAL
1988	HS05626	ASSESSMENT OF TECHNOLOGY USE VIA A COMPUTERIZED ORDERING	MC DONALD, CLEMENT J.	INDIANA UNIVERSITY
1989	HS05635	MULTIDIMENSIONAL TECHNOLOGY ASSESSMENT OF PTCA	MARK, DANIEL B.	DUKE UNIVERSITY MEDICAL CTR
1989	HS06028	CLINICAL APPLICATIONS OF AN EXPERT SYSTEM	EVANS, R S.	LDS HOSPITAL
1989	HS06065	CORSAGE—A HYBRID EXPERT SYSTEM FOR MYOCARDIAL INFARCTION	DIAMOND, GEORGE A.	CEDARS-SINAI MEDICAL CENTER
1990	HS06173	ELDERLY OUTPATIENTS, COMPUTERIZED RECORD, AND EFFICIENCY	MARTIN, DOUGLAS K.	INDIANA UNIVERSITY
1990	HS06177	IMPACT OF COMPUTER SUPPORT ON HIV INFECTED PATIENTS	GUSTAFSON, DAVID H.	UNIVERSITY OF WISCONSIN
1989	HS06211	ATHOS—AIDS TIME-ORIENTED HEALTH OUTCOME STUDY	FRIES, JAMES F.	STANFORD UNIVERSITY
1990	HS06283	CONTROLLED TRIAL OF A HEALTH MAINTENANCE TRACKING SYSTEM	FRAME, PAUL S.	TRI-COUNTY FAMILY MEDICINE
1990	HS06288	KNOWLEDGE-BASED RECORDS FOR PATIENTS WITH HIV INFECTIONS	SAFRAN, CHARLES	BETH ISRAEL HOSP (BOSTON)
1990	HS06330	COMPUTER SUPPORT FOR PROTOCOL-DIRECTED THERAPY	MUSEN, MARK A.	STANFORD UNIVERSITY
1990	HS06368	EFFECTIVENESS OF QMR IN MEDICAL DECISION SUPPORT	BANKOWITZ, RICHARD A.	UNIVERSITY OF PITTSBURGH
1990	HS06418	COMPUTER ASSISTED GUIDELINES FOR ADMISSION TESTING	CEBUL, RANDALL D.	CASE WESTERN RESERVE UNIV.
1990	HS06469	MEASURING EFFECTIVENESS OF CLINICAL MANAGEMENT SYSTEM	PALMER, R.H.	HARVARD UNIVERSITY
1990	HS06503	OUTCOME ASSESSMENT PROG. IN ISCHEMIC HEART DISEASE	DELONG, ELIZABETH R.	DUKE UNIVERSITY MEDICAL CTR
1990	HS06512	SCREENING QUALITY OF CARE USING ADMINISTRATIVE DATA	IEZZONI, LISA I.	BETH ISRAEL HOSP (BOSTON)
1991	HS06575	COMPUTER-BASED ACCESS TO GUIDELINES FOR CLINICAL CARE	BARNETT, G.O.	MASS. GENERAL HOSPITAL
1992	HS06594	A RANDOMIZED TRIAL OF COMPUTERIZED ICU PROTOCOLS	EAST, THOMAS D.	LDS HOSPITAL
1993	HS07632	ADVANCE DIRECTIVES, PROXIES & ELECTRONIC MEDICAL RECORDS	TIERNEY, WILLIAM M.	INDIANA UNIVERSITY
1993	HS07719	COMPUTER RECORDS, GUIDELINES, QUALITY & EFFICIENT CARE	MC DONALD, CLEMENT J.	INDIANA UNIVERSITY
1993	HS07763	COMPUTER-BASED PROSPECTIVE DRUG UTILIZATION REVIEW	TIERNEY, WILLIAM M.	INDIANA UNIVERSITY
1993	HS08096	DEMONSTRATING COMPUTER SUPPORT IMPACT ON AIDS PATIENTS	GUSTAFSON, DAVID H.	UNIVERSITY OF WISCONSIN
1995	HS08247	ADOPTION AND USE OF TELECOMMUNICATIONS FOR RURAL HEALTH	MC INTOSH, WILLIAM A.	TEXAS A&M–COLL. STATION
1994	HS08749	SHARING PAPERLESS RECORDS AMONG PROVIDER NETWORKS	SAFRAN, CHARLES	BETH ISRAEL DEACONESS MED CTR.
1994	HS08750	CODES & TCP/TOOLKITS FOR EXCHANGING CLINICAL DATA	MC DONALD, CLEMENT J.	INDIANA UNIVERSITY
1997	HS08814	THE EFFICACY OF TELEMEDICINE COLPOSCOPY	FERRIS, DARON G.	MEDICAL COLLEGE OF GEORGIA
1997	HS08823	PATIENT-CENTERED, COMPUTER-ASSISTED, QUALITY IMPROVEMENT	HARRIS, LISA E.	INDIANA UNIVERSITY
1996	HS09345	SIXTH REGENSTRIEF CONFERENCE	CLARK, CHARLES M.	REGENSTRIEF INSTITUTE
1996	HS09407	COMPUTERIZED DECISION SUPPORT FOR POSTTRANSPLANT CARE	SULLIVAN, KEITH M.	DUKE UNIVERSITY MEDICAL CTR
1996	HS09421	DEPRESSION CARE USING COMPUTERIZED DECISION SUPPORT	ROLLMAN, BRUCE L.	UNIVERSITY OF PITTSBURGH
1996	HS09436	INTERACTIVE, GUIDELINE-BASED DECISION SUPPORT ON THE WEB	LOBACH, DAVID F.	DUKE UNIVERSITY MEDICAL CTR
1996	HS09507	EVALUATING COMPUTER DECISION SUPPORT FOR PREVENTIVE CARE	DOWNS, STEPHEN M.	UNIVERSITY OF NORTH CAROLINA
1997	HS09526	ASSESSING HEALTH DATA NEEDS IN A CHANGING ENVIRONMENT	WHITE, WILLIAM D.	UNIV. OF ILLINOIS AT CHICAGO
1997	HS09567	COMPUTER SYSTEM TO SUPPORT ALZHEIMER'S DECISION-MAKING	GUSTAFSON, DAVID H.	UNIVERSITY OF WISCONSIN
1998	HS09706	EVALUATION OF AN ADAPTIVE PATIENT DATA ENTRY INTERFACE	LOBACH, DAVID F.	DUKE UNIVERSITY MEDICAL CTR
1999	HS10246	IMPLEMENTATION OF COMPUTER-BASED HEALTH SUPPORT SYSTEMS	GUSTAFSON, DAVID H.	UNIVERSITY OF WISCONSIN
1999	HS10363	COMPUTER-BASED DOCUMENTATION AND PROVIDER INTERACTION	JOHNSON, KEVIN B.	JOHNS HOPKINS UNIVERSITY

Table 2 ■

List of Selected AHRQ-funded Contracts

Contract Number	Contractor	Title	Year of Award
110-68-0047	Lockheed Air Corporation, Sunny Vale, California	Analysis of Information Needs of Nursing Stations	1968
110-71-0128	El Camino Hospital Mountain View, California	Demonstration of Existing Hospital Information System	1971
110-73-0331	Battelle Memorial Institute Columbus, Ohio	Evaluation of the Implementation and Operation of the Technicon Medical Information System at El Camino Hospital	1973
106-74-0118	University of California at San Francisco, San Francisco, California	Analysis of Existing Ambulatory Automated Medical Record Systems	1974
106-74-0118	Indiana University, Indianapolis, Indiana	Protocol-based Computer Reminders	1974
230-75-0204	University of Vermont, Burlington, Vermont	Evaluation of the Problem-oriented Medical Record System	1974
233-78-3010	University of Vermont, Burlington, Vermont	Exportation, Expansion, and Dissemination of the PROMIS System	1978
282-91-0015	Kunitz and Associates, Inc., Rockville, Maryland	Data Sources for Ambulatory Care Effectiveness Studies	1991

Areas of Medical Informatics Support

The principal areas of research in medical informatics funded by AHRQ in the past three decades are summarized in Table 3. They include health care information systems, decision support, computerized medical records, and medical informatics standards.

Health Care Information Systems

Medical care is notorious for its immense knowledge base, the vast array of data that are applicable to patient care, and the complexity of those data. Yet many clinicians and hospitals still rely on paper and pen to record data, on charts and files to store data, and on their memories or searching abilities to find—in stacks of charts, files, books, journals, and literature summaries—data and information to support decisions. Early researchers in medical informatics recognized the power of the computer for data storage and retrieval and developed information systems that, they dreamed, would someday replace much of the paper in health care.

Table 3 ■

Three Decades of AHRQ Medical Informatics Support

- Health care information systems:
  - Medical information systems
  - Computerized data banks
  - Automation in clinical laboratory, radiology, and critical care
- Decision support and quality assurance:
  - Computer-aided decision making
  - Patient-centered HIV management systems
  - Quality assurance and improvement
- Computer-based medical records and integrated information systems:
  - Medical information standards
  - Research and development
  - Coordination
  - Health information privacy

Medical Information Systems

Morris Collen led the effort at Kaiser Permanente to collect, format, and store information from more than 200,000 multiphasic health screening examinations in patients' computer medical records [HS00288]. This functioning system had the ability to add information from subsequent encounters using manually encoded forms, optical scanning devices, and machine-readable cards. In 1971, the data bank contained about 1 million patient records in "an integrated, continuous, variable length, variable format record."[9]

Lawrence Weed, who championed the problem-oriented medical record, provided an organizational framework for a comprehensive medical record that included medical mapping of patient data and medical information and feedback loops of information to the physician [HS00175].[10] Based on this framework, the Problem-Oriented Medical Information System (PROMIS) database was developed. This visionary computerized record-keeping system included such features as touch-screen interfaces, which are commonly used in today's kiosks.[11]

Howard Bleich pioneered the automation of computer-based interactive consultation programs that assisted physicians in the diagnosis and treatment of disease states such as electrolyte and acid-base disorders, dermatologic conditions, and hypercalcemia [HS00188].[12–16] Computer-based teaching programs for physicians were developed in the areas of hemostasis and nitroglycerin administration.[17,18] In addition, computer-based instructional programs were designed for patients, such as the proper collection of a clean-caught urine specimen.[19]

Spearheaded by Octo Barnett [HS00240, HS03588, HS04073], the Computer Stored Ambulatory Record (COSTAR) was implemented beginning in 1968. Development of this automated medical record system was a collaborative effort between the Massachusetts General Hospital Laboratory of Computer Science and the Harvard Community Health Plan.

COSTAR is programmed in MUMPS (Massachusetts General Hospital Utility Multi-programming System), a computer language better tailored to modeling the capture, storage, and retrieval of medical data than COBOL and FORTRAN, which were routinely used at the time.[20] The Agency supported the development of MUMPS, contracted with the American National Standards Institute (ANSI) to have this language standardized by the National Bureau of Standards, funded a MUMPS users group to encourage its dissemination [HS01540], and formed a MUMPS Development Committee to foster collaboration among industry partners [HS02760]. MUMPS was adopted by the Department of Veterans Affairs for use in its hospital information systems and is used throughout the world. In 1988, MUMPS became an IBM-supported programming language.

COSTAR supported direct patient care, quality assurance programs, and billing. One quality assurance program monitored treatment follow-up after positive throat cultures for streptococcus. Before intervention, a computer-generated audit of medical records for documentation of follow-up treatment for positive throat cultures found an unacceptable level of missed follow-up, sometimes as high as 17 percent of the patients seen. Once computer-generated reminders were implemented, noncompliance fell to as low as 0 percent. When reminders were removed, the failure rate returned to prior levels.[21] COSTAR has been installed both nationally and internationally in hundreds of sites.

Homer R. Warner led the development of the Health Evaluation through Logical Processing (HELP) system. This integrated hospital information system, conceived in the late 1960s and supported by AHRQ from 1972 to 1977 [HS01053], is used at LDS Hospital in Salt Lake City, Utah, and is distributed commercially by the 3M Company. The main clinical role of HELP was to provide decision support for health professionals and, like COSTAR and PROMIS, demonstrated that computer systems could not only replace much of the paper record but could also improve the process of care by enhancing the use of that information. This system has evolved to include alerting systems (abnormal laboratory results), critiquing systems (blood product utilization), suggestion systems (protocols for ventilator management), quality assurance systems (mammography screening), and more.[22]

In the late 1970s and early 1980s, AHRQ supported the development and evaluation of computer-based patient records. Much of this early work was done in ambulatory settings.[23] In Illinois, use of the Northwestern University Computerized Medical Record Summary System (NUCRSS) was shown to shorten lengths of hospital stays and contribute to better care and outcomes for patients with hypertension, renal disease, and obesity [HS02649].[24] A Summary Time-oriented Record (STOR), developed at the University of California at San Francisco, was found to influence positively a physician's ability to predict the effectiveness of alternative treatment strategies [HS03802].[25] The Agency also supported the study of scientific and operational issues of database technology, its components, and alternatives to actual implementation on computer system advanced applications [HS03650].[26]

The partnership of Clement McDonald and William Tierney in the development of the Regenstrief Medical Record System (RMRS) and the evaluation of its effects on practice provide an example of the optimal interaction of medical informatics and health services research [HS02485, HS04080, HS04996, HS05626, HS7719]. The RMRS serves Wishard Memorial Hospital in Indianapolis and is multifaceted, in that it has the capacity to store patient observations, laboratory test results, and imaging studies as well as generate flow sheets and reminders and capture orders directly from physicians. In a series of controlled trials, RMRS contributed significantly to improvements in the quality of patient care.[27] In one study, computer-generated reminders increased preventive care measures practiced by physicians at least twofold.[28] In a 1993 publication, Regenstrief Institute researchers showed that interventions generated by microcomputer workstations when physicians wrote inpatient test and drug orders saved the hospital's medicine service an estimated $3 million annually. Nationally, this could translate into billions of dollars.[29]

Computerized Data Banks

Researchers anticipated that repositories would permit longitudinal data to be collected and stored in ways useful for the conduct of epidemiologic studies, leading to better understanding of disease manifestations and efficacy of treatment regimens. In the mid 1970s, Frank Starmer at Duke University created a computerized representation of the geometric structure of coronary artery trees, to be used in the classification of heart disease [HS01613]. This technology allowed quantification of findings from patients who underwent cardiac catheterization. The patient workup that included these findings, detailed data about interventions, and the patient status over long-term follow-up were entered into the Duke Cardiovascular Data Bank.[30]

Robert Rosati, Eugene Stead, David Pryor, Frank Harrell, Robert Califf, and others have shown that the Duke Data Bank can function as a time-lapse camera associating cause with outcome. For example, they identified characteristics important for estimates of "the likelihood a patient had significant coronary artery disease" and "the likelihood of disease when applied prospectively to 1,811 patients …" [HS06503, HS05635, HS04873][31]; devised a prognostic score based on the treadmill test, which accurately predicted outcomes (better than did the clinical assessment) in a study of outpatients with suspected coronary disease and which assisted clinicians in determining whether to refer such outpatients for cardiac catheterization [HS05635, HS04873, HS06503][32]; and provided many other significant findings [HS03834].[33–37]

In the 1990s, the Cooperative Cardiovascular Project, a collaborative effort among Duke University, AHRQ, and the Health Care Financing Administration built on this foundation to identify factors that contributed to outcomes of coronary bypass grafting. Risk adjustment and provider profiling methods were studied as mechanisms for service improvement [HS05635].[38]

The Arthritis Rheumatism and Aging Medical Information System (ARAMIS) was developed by James Fries at Stanford University School of Medicine to gather data for epidemiologic purposes and was adapted to help improve health outcomes more directly as a decision support tool.[39] A study published in 1999 used the ARAMIS data bank to evaluate the relationship between the use of non-steroidal anti-inflammatory drugs and gastrointestinal complications in patients with arthritis.[40] The data bank has also been applied to improving outcomes, such as reducing discomfort and lessening the economic impact of arthritic diseases [HS01875].[41] Another example is IDEFIX, a knowledge-based system that produces patient summaries derived from ARAMIS and has been employed for the assessment of patients with systemic lupus erythematosus [HS04389].[42]

The AIDS Time-oriented Health Outcome Study (ATHOS) collected longitudinal data, such as mortality trends, quality-of-life issues, and drug-related toxicities, on this rapidly evolving illness. Patients complete health assessment questionnaires, and their answers are put into a computerized database.[43] Information gained includes a better understanding of HIV-infection progression, the classification of HIV-disease states, and the economic and social effects of this illness [HS06211].

Automation in Clinical Laboratory, Radiology, and Critical Care

The first AHRQ-supported medical informatics projects focused on the clinical laboratory from the late 1960s through the mid-1970s. Once the computer handled most of the information processing, medical technologists could focus more time on performing test procedures, thus decreasing turn-around times.[44] Information systems could then transmit test results directly to physicians. For example, the Direct Input Voice Output Telephone System (DIVOTS) was used to deliver laboratory reports expeditiously by phone. The first live transatlantic demonstration of a computerized audio-laboratory communication system was conducted using this technology.[45]

These early innovations owe much to the work of Arthur Rappoport [HS00060] and David Seligson [HS00075] and laid the foundation for the modern clinical laboratory as we know it today, equipped with sophisticated computerized instrumentation and interfaced with hospital information systems.

The Agency supported research into automating the reporting and retrieving of radiologic consultations during the 1970s [HS00646, HS01054, HS01566, HS02099]. The Missouri Automated Radiology System (MARS), under the direction of James L. Lehr

[HS00646], allowed for swift, computerized delivery of radiologists' interpretations of x-ray reports. In one study, 70 percent of traditionally dictated reports were not available to the patients' physicians until the next day. MARS-generated reports, however, boasted a 75 percent same-day turn-around time, and a 93 percent next-day completion rate.[46]

Morris Simon [HS01054], at Beth Israel Hospital in Boston, developed a coded language for radiologic reporting, referred to as CLIP (Coded Language Information Processing).[47] CLIP accelerated the reporting and retrieval of radiologic results, thus providing physicians with prompt feedback.

Throughout the 1970s, AHRQ supported research in computer-based monitoring of patients in critical care settings [HS01195, HS01467, HS01472, HS01474]. The surgical intensive care unit at Buffalo General Hospital was outfitted with the Clinical Assessment Research Education (CARE) system, which continuously monitored physiologic and metabolic functions of critically ill patients and managed data about fluid and electrolytes as well as cardiac and respiratory functions.[48] In a 6-year observational study led by John H. Siegel [HS01195], the CARE system was credited with a reduction in non-cardiac surgical mortality of more than 8 percent and with a drop in trauma mortality from 25 to 7.5 percent.[49]

Max H. Weil, at the University of Southern California, was another forerunner in this field. His innovations improved computerized cardiovascular monitoring and served as the prototype for the technologically advanced critical care units of today [HS01474].[50]

Decision Support and Quality Assurance

Researchers recognized that computer systems might improve the quality of care by assisting people with cognitive tasks and overload. The Agency funded studies that ranged from interventions to bring information to bear on a problem, through checks for mistakes, to analysis of data to identify quality problems.

Computer-aided Decision Making

Pauker and others[51] investigated the problem of relating medical knowledge to the clinical problem at hand. They developed a computer program that applied principles of artificial intelligence to understanding complex problem-solving strategies to support physician decision making related to patients with edema [HS 00911].

In a hallmark article published in 1976, Clement McDonald[52] discussed the "non-perfectibility" of man. Simply put, human beings have limitations when processing information, and physicians are more likely to commit errors as a result of "sensory overload" than because of inherent "flaws" in their knowledge base. To compensate for these human limits, McDonald and other investigators have designed and tested computer-aided decision-making tools that produce prompts, reminders, alerts, and consultations. As the 2000 Institute of Medicine report *To Err is Human: Building a Safer Health System*[53] concluded, the establishment of systems that remind, support, and correct decisions can often prevent mistakes in health care delivery.

Several grants developed and evaluated the effects of computerized systems in helping clinicians and patients improve the effective use of drugs, avoid their potential adverse effects, and reduce their cost. In the 1970s, Stanley Cohen [HS00739, HS03000] developed a computer-based system that warned of adverse drug reactions at Stanford University Medical Center.[54] Also at Stanford, Leslie Lenert and others [HS05263] modeled a computer program to monitor blood concentrations of drugs and recommend changes in the drug dose when the concentration is outside the therapeutic level.[55] Stephen Gehlbach [HS03896] conducted a study at Duke University in the early 1980s in which physicians were given computer-generated feedback on their prescribing habits, coupled with information on the cost savings that would have occurred if a generic equivalent had been selected instead. As a result of this feedback, the prescribing of generic drugs increased in the experimental group of physicians from 14 to 67 percent.[56]

During the late 1980s and into the early 1990s, the HELP hospital information system at LDS Hospital in Salt Lake City was expanded to include an "automated antibiotic consultant" [HS06028]. The computer program recommended the appropriate empirical antibiotic regimen (a decision made at the time a specimen was submitted to the laboratory but before results were available) 94 percent of the time, compared with the 77 percent success rate of control physicians.[57]

Regenstrief Institute researchers showed at Wishard Memorial Hospital that computerized displays of previous test results, generated at the time of ordering, reduced the number of tests ordered by 16.8 percent and the cost of testing by 13 percent [HS02485].[58] Being able to see quickly, for example, a patient's last three complete blood counts and the intervals at which they were ordered preempted the physician from requesting unnecessary tests. Once reminders were removed, however, redundant ordering resumed.

Coupled with alerts, protocol-based reminders have also been incorporated into automated systems and studied for their effects on patient outcomes and clinical processes [HS06283]. For example, winter morbidity was decreased by 10 to 30 percent during a 3-year trial period from 1978 to 1980, when physicians received computer-based reminders to administer influenza vaccines [HS04996].[59] At Beth Israel Hospital in Boston, in the early 1990s, computerized alerts were implemented to warn of rising creatinine levels, which can indicate kidney failure [HS06288]. Medications were adjusted or discontinued almost a full day sooner on average as a result.[60] A computer-based health maintenance tracking system generated a 15 percent increase in provider compliance with preventive measures such as mammography and Pap smears.[61]

Patient-centered HIV Management Systems

Much of the medical informatics funding by AHRQ during the 1990s evaluated computerized systems that supported the management of HIV infection. The Comprehensive Health Enhancement Support System (CHESS) was developed by David Gustafson and colleagues at the University of Wisconsin–Madison [HS06177]. This interactive computer-based system has an HIV/AIDS module that renders personalized assistance to individual patients. In this study, computers were placed in patient homes for a 3- to 6- month period. Patients infected with HIV who used CHESS had fewer hospitalizations and reported higher quality of life.[62]

The AIDS Time-Oriented Health Outcomes Study (ATHOS) was a national observational database of HIV-infected patients who were seen by physicians at Stanford University [HS06211]. Strategies for improved management of HIV infection, particularly for disease progression and quality of life, were derived from this database.[63] At Beth Israel Hospital, Charles Safran developed a system that linked an electronic patient record to treatment protocols, drug information, alerts, and community resources for the care of patients with HIV infection [HS06288].

Access to this database helped physicians deliver a higher level of care to these patients.[64] The system included a computer-based interview screening blood donors for HIV infection. The computer interviews elicited more self-reports of HIV-related behaviors from potential donors, who indicated that they felt the computer interview was more private.[65]

Mark Musen, at Stanford University, contributed to the creation of "AIDS2," a computerized decision support tool that helps physicians match HIV-infected patients with therapy-related clinical trials [HS06330]. This system allowed eligibility status to be determined more efficiently than before and enabled a greater number of qualified patients to be enrolled and to receive state-of-the-art treatments.[66]

Quality Assurance and Improvement

A major theme behind AHRQ funding of medical informatics projects has been improvement of the quality of care [HS02142, HS02469, HS03087, HS03573, HS05275, HS05635, HS06283, HS06469, HS06512]. Richard Winickoff, at Harvard Community Health Plan, developed a computer-based ambulatory quality assurance program in an early attempt to improve physician compliance in screening for colorectal cancer [HS02142]. This study was one of the first to use peer-comparison feedback, which was shown to be effective in modifying physicians' behavior. It has since become a central component of quality improvement programs worldwide. As a result of this intervention, physicians increased appropriate preventive measures (digital examinations and occult blood screening on patients over 40 years old) from 66 to 79.9 percent.[67]

Heather Palmer, at Harvard University [HS03087], conducted the Ambulatory Care Medical Audit Demonstration (ACMAD), a computerized quality assurance project that monitored activities using medical records to examine whether prescribed treatment protocols were being followed.[68] Tracking was done on tasks such as cancer screening for women, follow-up after abnormal serum glucose findings, and well-child care. In one ACMAD study, deficiencies in care were found that ranged from 6 to 42 percent of the cases, despite prior approval of established guidelines by the physicians in the study.[69] These variations in compliance indicate that physicians do not always translate their beliefs into practice.

Lisa Iezzoni developed and tested computer programs applied to administrative data, particularly payment claims and hospital discharge abstracts. The Complications Screening Program (CSP) evaluated the use, accuracy, and completeness of these data for targeting potential quality of care problems in hospitals [HS06512, HS09099]. Patients with in-hospital complications in 1995 not only were older but were more likely to die, to have longer stays, and to have higher total charges.[70]

The driving question is whether a computerized screening tool based on administrative data that contain patients' diagnoses and procedures can "flag," in hospitals, cases with potential quality problems for further investigation in a valid and efficient manner. Findings revealed mixed but encouraging results—coding completeness was suspect[71]; sometimes flagged cases did not have a higher probability of process problems,[72] whereas other times they did[73]; and validity appeared to be greater when CSP was applied to surgical cases than to medical cases.[74]

Treatment of diabetes has been shown to benefit from computerized feedback systems [HS07719].[75] Computer-assisted applications were helpful in conditions affecting elderly patients, such as depression and alcoholism, and in the use of advanced directives [HS07632].[76] Improving access to care via telecommunication technology was investigated in underserved rural areas [HS08247], and telephone-linked care was successfully used in ambulatory settings to augment office visits and to monitor and counsel patients with hypertension [HS05135].[77]

Investigators funded by AHRQ in the late 1990s began exploring Web-enabled clinical information systems that hold promise for seamlessly integrating clinical data from separate sources [HS07719].[78] With the funding of research studies into computer-based access to clinical guidelines, AHRQ anticipates findings to show the effects of integrating accepted practice guidelines with patient care data at the time and place of service delivery [HS06575, HS08750, HS09407, HS09421, HS09436].

Computer-based Medical Records and Integrated Information Systems

Studies funded by AHRQ contributed to the knowledge base on which computer-based medical records and integrated information systems are built—how to enter and retrieve patient care data efficiently, how to link the data with medical knowledge to improve medical care processes, and how to achieve user acceptance or, at least, user cooperation.

El Camino Hospital received AHRQ-support from 1971 to 1974 [110-73-0128] to study the first implementation of a hospital-wide system that included direct physician order entry. The Technicon Medical Information System served both administrative and clinical functions. Outcomes from implementing this system included a 5 percent reduction in nursing costs, a 4.7 percent shorter average length of stay, and an overall decrease in hospital costs.[79] A peculiarity reinforcing the belief that there were real cost savings at El Camino, as noted by Lindberg, is that "[a]ccording to the installation contract, all costs were to be borne by Technicon, the vendor, who was to be paid a fee only for savings generated by the MIS that were confirmed by all parties."[80]

Analyzing the general requirements for a medical information system (both hospital and outpatient) in 1970, Collen discussed the "extraordinary requirements" of such systems for capital, personnel, and organization, as well as the "stringent requirements for high reliability and user utility" [HS00288].[81] Also at this time, Lindberg presented a model of a statewide medical information system with its advantages, social issues, and technical problems [HS00014].[82]

Robert Robinson, in 1970, examined techniques for acquiring narrative medical record data, finding that speech analysis was not sophisticated enough for everyday use [HS00093].[83] Although natural language processing was felt to have considerable potential, much improvement in technology and abstracting methods had to take place before value would be received.

John Rockart investigated the interesting question of which medical records should be kept in an active file and for how long, based on four scenarios [HS00307].[84] Simulation analysis parameters included active file size, probability that a stored record will be needed (based on distance of patient residence from the clinic and number of previous returns to the clinic), and costs. This method is applicable to paper and computerized medical record storage when active and inactive files have different costs or times for storage and retrieval processes.

In 1972, Startsman and Robinson reported on a survey of seven occupational categories in a university medical center setting, noting at that time an "expressed reluctance of interns to use computers" [HS00093].[85]

In 1973, Rockart built on the work of Collen and others by analyzing computer processing of patient history questionnaires that are filled out by patients at home, where they have better access to such information as drug labels and family records. He studied physician acceptance (most were very favorable—the physicians thought it saved time), patient attitudes (nearly all were favorable or had no comment), and content validity (false positive findings recorded by the automated medical history but not by the examining physician averaged 1.2 per patient).[86]

The PROMIS system was extensively analyzed at the Medical Center Hospital of Vermont [230-75-0204]. Recommendations stemming from this investigation, such as the need to simplify data entry and retrieval, precipitated modifications to the system that improved its functionality in clinical settings and provided "lessons learned" to other system developers and implementers.[87]

James Campbell studied the effect of computerized medical records on personnel in a teaching clinic at the University of Nebraska College of Medicine [HS04949]. Nurses and clerical workers noted a dramatic, and scientifically documented, improvement in the availability of medical records and in patient management, particularly during responses to telephone inquiries.[88]

The capture and management of orthopedic narrative data using special formats to enable its storage and retrieval from a "computer-manageable bank of clinical data" was developed at New York University Medical Center and Bellevue Hospital Center in 1972 [HS00128].[89] MEDPhrase, developed at Massachusetts General Hospital, linked stereotypical phrases used by physicians to a controlled vocabulary [HS06575]. With MEDPhrase, as reported in 1996,[90] physicians have a computerized "memo-type pad," which appears as a window on the computer screen, and are able to link their shorthand notations to predetermined phrases.

Medical Information Standards

Standards for health care data are important because they improve the basic infrastructure for communicating health information, especially information in computerized form. For patient care as well as for research, the uniformity, accuracy, and computerization of health care data are essential for comparing like medical concepts and for understanding the meaning of clinical and administrative health care communications

Research and Development

During the mid to late 1990s, AHRQ collaborated with NLM and the John A. Hartford Foundation to support the development of the Logical Observation Identifiers, Names, and Codes (LOINC) standard [HS05626, HS07719] at Regenstrief Institute and Indiana University. LOINC includes more than 10,000 names and codes and uses a uniform vocabulary for reporting clinical laboratory test results across computer systems.[91] Its ongoing development is supported by a coalition of federal agencies (NLM, Department of Veteran Affairs, Department of Defense, and Centers for Medicare and Medicaid Services). Freely available, LOINC is growing in national acceptance as the standard for transmitting laboratory results electronically and has been adopted by the American Clinical Laboratory Association. This standard simplifies the tasks of data collection and dissemination and minimizes costs associated with these functions.[92]

In the area of lung cancer, AHRQ funded the development and study of uniform taxonomies based on both clinical and functional patient conditions rather than on just the characteristics of a tumor. These taxonomies are useful for investigating the effects of patient differences on estimates of the prognosis of primary lung cancer patients [HS00408, HS02764, HS04101].[93] Uniform recording of clinical history and patient health status is important for estimating prognosis. These studies emphasize the need for scientific investigation of such factors to provide an evidence base for patient classifications [HS04101].[94]

Coordination

An AHRQ report to Congress in 1991 identified gaps in standards development and a lack of coordination among U.S. health data standards developing organizations (SDOs).[95] In response, AHRQ convened a national meeting of these SDOs and invited ANSI to describe its official coordinating mechanisms. The SDOs voted to form a planning panel, approved by ANSI in December 1991. The panel was followed by the Health Informatics Standards Board (HISB), which was approved by ANSI in 1995 as a permanent board for national coordination and continues today.

To reduce administrative health costs by promoting national health data uniformity, Congress directed the Secretary of Health and Human Services (HHS), in the Health Insurance Portability and Accountability Act (HIPAA) of 1996 to adopt (make mandatory) national health information standards in four areas—electronic administrative transactions, identifiers, security, and privacy of personal health information.[96] Assisting with the Secretary's HIPAA mandate, HISB prepared 1) the ANSI HISB Inventory of Health Care Information Standards (January 1997),[97] valuable for locating standards that were candidates for the Secretary's adoption, and 2) the ANSI HISB Inventory of Clinical Information Standards (June 1998),[98] with support from AHRQ and the HHS Office of the Assistant Secretary for Planning and Evaluation. This latter study contributed to the 2000 HIPAA-mandated report of the National Committee on Vital and Health Statistics on standards for patient medical record information and its electronic transmission.[99]

Because health information is exchanged across national borders for patient care, financing, regulatory, and research purposes, the need for a common understanding of medical concepts both nationally and internationally logically demands international coordination of these standards. Working with HISB, AHRQ supported the formation of the International Standards Organization's Technical Committee 215 (ISO/TC 215), Health Informatics, and the formation of the U.S. Technical Advisory Group to ISO/TC 215 in 1998. This coordination maximizes private and public sector input into the formation of U.S. positions and work items on international health data standards.

Recognizing the need for the public health community to be involved in national health data standards processes that make gathering accurate health data more efficient, AHRQ joined the Center for Disease Control and Prevention's National Center for Health Statistics to begin the formation of the Public Health Data Standards Consortium in November 1998.

Health Information Privacy

Standards for protecting the confidentiality of personally identifiable health information is essential for building the public's trust in providers, patients, health service and public health researchers, and others who have legitimate access to this information. Staff of AHRQ provided input for the HIPAA Privacy Rule standard (compliance date, April 14, 2003). With the HHS Office of the Assistant Secretary for Planning and Evaluation as a partner in 2000, AHRQ sponsored a study by the Institute of Medicine. This study, *Protecting Data Privacy in Health Services Research,* identified best practices among the nation's institutional review boards and made recommendations to improve the protection of personally identifiable health information when used by health services researchers.[100]

Prospects for Informatics in Health Care Research and Quality

Many remarkable achievements in medical informatics during the past 30 years have emerged as a result of AHRQ funding and support. Evaluations of medical informatics funded by AHRQ have included a variety of methods from the toolbox of the evaluation sciences—controlled trials with random allocation of patients to groups of physicians; randomized allocation of clinicians and institutions into control and study groups; reversal of control and study groups to analyze information system effects, before and after evaluation; the use of matched pairs of organizations with and without extensive computerized health information systems; and others.

Current Driving Forces

Improving the quality of patient care and minimizing costs, as well as improving access to care, are the underlying goals of research that advances medical informatics. One driving force for more medical informatics research is understanding how links between clinical information and health information (both good and bad) on the Internet can affect patient–physician relationships and patient understanding, compliance with treatment, and health status.

Reductions in the costs of computing, storage, and communication and increases in computing speed and communication bandwidth have revolutionized information management substantially in many industries, but not so much in health care. Addressing this revolutionary gap is a second driving force that must be informed by scientific research findings that show where the most productive information technology investments are to be made in health care.

The need to compare data, codes, and clinical concepts across sites of care and health enterprises is well recognized. Overcoming vocabulary and coding barriers and other data incompatibilities that have long hindered easy transfer and consolidation of clinical information is a third and continual driving force as medicine and technology combine and evolve over time.[101]

A fourth driving force is the demand for medical informatics tools to improve patient safety, not only by preventing inappropriate actions but also by reducing errors of omission.[102]

Responding to patient safety and quality improvement priorities and to many of these driving forces, AHRQ is funding health informatics through two initiatives, begun in 2001 with initial funding of approximately $10 million and carried on through 2002 and 2003. The first initiative supports medical informatics research on improving the delivery of evidence-based information to health decision makers and enhancing the collection of patient and practitioner data, including quality and outcome data, as an integral part of patient care. The second initiative supports clinical informatics research focusing on the role of computers and communication in improving patient safety. These initiatives are in addition to the general investigator-initiated grants funding that also supports medical informatics. The Agency offers guidance to researchers through published requests for grant applications and general program announcements for investigator-initiated research studies (see http://www.ahrq.gov).

Challenges Ahead for Medical Informatics

Many challenges lie ahead for medical informatics research. They include:

- Improving the standardization of clinical vocabulary and coding
- Improving the integration, comparability, and confidentiality of health care data across computer systems and sites of care
- Linking patient care data and medical information accurately to support clinical decision making, while protecting patient confidentiality
- Identifying and overcoming the barriers to the use of medical informatics tools in the medical community
- Identifying the highest valued, most productive uses of information integration and computer and communication system applications in health care

Future directions for AHRQ-funded medical informatics research will be guided by the expressed needs of the users of health information systems and the challenges that face developers of medical informatics applications. Findings from this research are intended to inform the choices that users of health information systems will have to make to satisfy demands for patient safety, quality improvement, and efficiency.

In many respects, computerized medical information systems are an emerging technology whose true potential is yet to be fully realized.[103] As with other emerging technologies, it is critical to evaluate information technology's contributions to improved health, its most appropriate uses, and its risks over time.[104] The Agency will continue to support health services research into applications of information technology in health care, to ensure that high-quality information is available for health care decisions.

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