Fifty Years in Medical Informatics

Morris Frank Collen
Director Emeritus, Division of Research, Kaiser Permanente, Oakland, CA, USA

Summary

Objectives: An overview of personal experiences in medical informatics based on Dr. Morris Collen's 50 years of research in the field.

Methods: A personal reminiscence and historical overview, focusing on the first two decades of medical informatics, when Dr. Collen began working with Dr. Sidney Garfield, the founder of Kaiser Permanente, leading to his involvement in computer-based medical care, through the development of the pioneering Automated Multiphasic Health Testing (AMHT) system, which they introduced into Kaiser clinics in Oakland and San Francisco.

Results: Statistical models for medical decision-making based on consultations with Jerzy Neyman and George Dantzig were incorporated into the AMHT, and tested on a large database of cases. Meetings with other pioneers in medical informatics at the Karolinska Institute led to the formation of the early society Salutas Unitas, and the many national and international collaborations which followed during the first two decades helped coalesce the field as clinicians and researchers investigated problems of medical data, decision support, and laboratory, hospital, and library information systems.

Conclusion: Dr. Collen's research and his many medical informatics activities significantly contributed to the growth of the field. The U.S. contributions are covered extensively in his book, A History of Medical Informatics in the United States, 1950-1990. Washington, DC: Am Med Informatics Association 1995.

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Keywords

History of medical informatics, Kaiser Permanente Automated Multiphasic Health Testing System, pioneering research in medical decision-making, professional organizations and meetings in medical informatics, evolution of research and leaders in medical

Life has brought me many nice surprises. One was being invited by my long-time friends, Reinhold Haux and Casimir Kulikowski, to write this article for the 2006 IMIA Yearbook and share my *personal* reminiscences. As I reflect on my 50 years of involvement in medical informatics, a myriad of faces emerge, and I recall many people that I admire and respect for their significant contributions to the field. My own career owes much to these worthy people. I feel that I was born with an interest in data, beginning with my birth date, a series of three consecutive, two-digit numbers: (mo-dd-yr) 11-12-13. As a teen-ager, I enjoyed playing with electric gadgets, so I decided to study electrical engineering and then go on to graduate school to get a doctorate. However, my life changed when I met and married a nurse, named Bobbie, who advised me to go to medical school. Although I planned to end up in academia, my life again changed dramatically while I was completing my medical residency at the Los Angeles County General Hospital, and Pearl Harbor was bombed on December 7, 1941. Because of my bronchial asthma, I did not join the group of County Hospital physicians sent to India. Instead, I worked for Sidney Garfield in the Kaiser shipyards in Richmond, California. Second only to my wife, Garfield had the greatest influence on my career. Trained as a surgeon, he was the visionary who, with the support of industrialist Henry J. Kaiser, created Kaiser Permanente and instilled it with the principles of prepaid, group practice, medical care.

At the end of the war, I stayed with Kaiser Permanente. I enjoyed being in an organization that allowed me to practice medicine, establish a residency training program, and do research, just as I had hoped to do in academia. Garfield knew that I had training in electrical engineering, so in 1961 he asked me to go to a conference on biomedical electronics in New York City. He thought the time had come for doctors to use computers in patient care. Of course, he was right; and I found this conference to be very exciting. On my return, Garfield established the Department of Medical Methods Research (MMR) in Oakland, California, with the primary objective of developing computer-based applications for patient care.

On considering where to start, I decided that it would be easiest and safest to first use computers in the process of examining persons who come in for a health checkup. The traditional health evaluation is a fairly routine and repetitive process; and for about 80% of Kaiser Permanente health-checkup examinees we usually did not find any significant abnormalities. Furthermore, Garfield was committed to preventive medicine and he advocated periodic health checkups that could categorize examinees as "well", "worried-well", "asymptomatic sick", or "sick"[1]. So I decided to develop a method for automating as much as possible the multiple components of an *automated multiphasic health testing (AMHT)* system. To develop such a system I needed to study some automated clinical labora-

tory systems. I found to be very helpful the writings of George Williams and his associates at the NIH Clinical Center, who developed one of the earliest comprehensive laboratory systems.

I soon visited Octo Barnett, who had developed the laboratory system at the Massachusetts General Hospital (MGH). I heard that the administrator of MGH found the laboratory system to be so efficient he would never give it up, no matter what happened to their other computer systems. A brilliant informatician, Barnett worked with his associates at MGH to develop MUMPS, which became one of the most commonly used programming languages; and COSTAR, a computer-based ambulatory record system for the Harvard Community Health Plan. Barnett also trained many leaders in medical informatics, including Robert Greenes and Jerome Grossman. Octo and I became good friends, who could disagree on many items, such as the best approach to developing a medical information system. He took a subsystem "modular" approach, whereas I advocated a "total systems" approach. History has proven his approach was better. I learned from him that nurses are the best information systems analysts, and have benefited over the years from conversations with Rita Zielstorff, Virginia Saba, Judy Ozbolt, Patricia Brennan, Kathleen McCormick, and Susan Grobe.

I needed an automated chemical analyzer for the AMHT system being developed in our Oakland medical center, so I visited Edwin Whitehead, the president of Technicon Corporation in Tarrytown, New York. Technicon had commercialized Leonard Skeggs' invention of a single-channel, automated chemical analyzer that used a peristaltic-pump to push samples of serum, separated by air bubbles, through plastic tubes. It was not practical for us to have eight of these machines running side-by-side to do the eight chemistry tests I wanted, so I asked Whitehead if he could make me an eight-channel, automated chemical analyzer. After a few moments of thought, he asked me how much was budgeted for this. I replied only $25,000; to my surprise, he agreed to make it. The first Technicon multichannel AutoAnalyzer was delivered several weeks later and became fully operational in our Oakland AMHT system. Soon he delivered a second machine in our San Francisco AMHT system. We used these machines for many years, until Garfield purchased an AutoChemist, developed by Gunnar Jungner in Sweden, that used piston pumps to keep the serum specimens separate; and could do up to 40 different chemical analyses.

We tested several modes of conducting self-administered patient questionnaires, and settled on using a sort-box of punched cards with a question on each card. In the 1960s, when I was visiting my daughter, Roberta, then a medical student at the University of Wisconsin, I met Warner Slack, who was developing a computer-based, self-administered, patient questionnaire using a LINC computer. The LINC was developed at the Lincoln Laboratory at the Massachusetts Institute of Technology by Wesley Clark and Charles Molner. The LINC computer became the basis of the PDP minicomputer series that helped to advance medical informatics. Slack described watching his secretary fill out an early version of the questionnaire. When she came to questions related to sexual activities, she asked him to leave the room until she had finished. Thus, he learned that some patients will confide to a computer personally sensitive information that they would not tell their doctor. Slack soon joined the informatics group at Beth Israel Hospital in Boston, where Howard Bleich developed his famous acid-base algorithms. Charles Safran and Robert Greenes joined them to develop their impressive Beth Israel Hospital information system.

We initiated the first automated multiphasic health testing (AMHT) system in our Oakland medical center in 1962 [2]. My first encounter with a computer was with an IBM 1440 installed in an air-conditioned basement room with a myriad of cables on the floor. We generated a deck of punched cards for each examinee; and as they went from one testing station to another, the test results were entered onto the cards. On completing the health checkup, an online printout of a summary report listed any abnormal tests found and advised secondary follow-up tests to be performed by using simple decision rules: "If this abnormality is present, then do this test." Suggested diagnoses for the physicians to consider were also printed on the summary report. Professors George Dantzig (called the "father of linear programming") and Jerzy Neyman met regularly with us at the University of California at Berkeley during the 1960s and helped to develop our approach to providing computer-aided diagnoses [3]. Although most others used Bayes' conditional probability theorem, we used a likelihood ratio approach because we did not always know the prior probability (prevalence) of a diagnosis Bayes' theorem required. After the completion of the multiphasic health checkup, all of the patient test data were stored in the multiphasic database. We collected data from about 35,000 AMHT examinations each year in this database that is still used by researchers. I am pleased to have lived long enough to see Joseph Terdiman, whom I called the "czar" of our early research databases, now developing a

much larger research database for Kaiser Permanente's national membership of more than eight million. Charles Flagle, then Professor of Operations Research at Johns Hopkins University, visited us several times to help conduct cost-effectiveness analyses.

In the 1970s, "stand-alone" AMHT systems expanded rapidly in the United States and in several other countries. Today, due in part to the advent of large, computer-based, hospital information systems capable of absorbing a health-checkup subsystem, and in part to the general lack of support by American physicians, AMHT systems operate mainly in Japan and in Taiwan.

On studying computer-aided diagnosis programs and clinical decision-support systems, I was most impressed by Ledley and Lusted's landmark paper [4]. I consider this to be the most important medical informatics paper I have ever read since it had such a great influence on stimulating the development of computer-based, clinical-decision support that should be a major goal of every comprehensive medical information system. Robert Ledley, a dentist by training, was a quiet person, a brilliant thinker, and a remarkable inventor honored by a Presidential Inventor Award. While Professor of Radiology, Physiology, and Physics at Georgetown University, Ledley began to conduct research and development on computer applications to dental projects at the National Bureau of Standards; and there he developed in 1973 the first whole body scanner, that he called the Automated Computerized Transverse Axial (ACTA) scanner.

I was also impressed by Homer Warner's early article on computer-aided diagnosis that applied Bayes' theorem to correctly diagnose 95% of patients with congenital heart disease [5]. When I visited Warner in Salt Lake City, I was pleased to see that he had also instituted a multiphasic screening program. I have always regarded Homer Warner as a model informatician. His hospital information system, with its clinical-decision support program called HELP, which I observed operating at LDS Hospital, continues to be one of the best in the United States. The only problem that I ever had with Homer was when we were together at a meeting in Germany. As I guzzled the delicious local draft beer, I learned that he would not join me in drinking any alcoholic beverages. Warner established the first Department of Medical Informatics in the United States at the University of Utah, where he trained several giants in the field of medical informatics, including Alan Pryor, Paul Clayton; and also Reed Gardner who continued to expand the LDS System in Salt Lake City and also made many important contributions to the field of medical informatics. In the 1960s, Homer Warner chaired the National Institutes of Health (NIH) Computer Study Section. About the same time, I chaired the National Center for Health Services Research and Development (NCHSR& D) Health Care Systems Study Section. Being a member of one of these study sections provided an extraordinary opportunity to observe first-hand the development of informatics technology.

This Yearbook's theme, "Assessing Information Technologies for Health", brought back memories of the 1960s and 1970s when AMHT was popular internationally. The International Health Evaluation Association (IHEA) was launched by Fred Gilbert, at the University of Hawaii. IHEA held periodic meetings on advances in health screening in London, San Diego, Tokyo, and in Vancouver, British Columbia. IHEA published selected papers; and Jochen Moehr, at the University of Victoria, played an important role in editing papers published in Methods of Information in Medicine.

In the late 1960s, Kaiser Permanente in the San Francisco Bay area decided to use the AMHT system as a prototype medical information system because it had given us some experience with a computer-based patient record and with many of the subsystem components of a medical information system. Under the leadership of Edmund (Ted) van Brunt, we developed and operated a pilot medical information system in our San Francisco medical center, with a computer-based patient record that had been developed by the manager of our computer center, Lou Davis [6]. However, due to lack of adequate funding in 1973, further development of Kaiser Permanente's medical information systems was delayed for some years.

When I read Paul Starr's book on "The Social Transformation of American Medicine" [7], I was impressed by his characterization of the hospital as the most complicated organizational structure made by man. It was evident that the computer-based systems used by banks and many industries would be inadequate to meet the functional and technical requirements of a *medical* information system (MIS) and that it would take a team, led by physicians and supported by engineers, to develop a successful MIS.

To acquaint myself with evolving computer applications in medicine, I visited several people who were already recognized leaders in the field. To begin, I visited James Sweeney at Tulane Medical School, who with Joseph Schenthal, a clinician, had already begun to use a computer to process data with mark-sense cards for clinic patients [8]. Sweenney became the first Professor of Computer Medicine in the

United States; when I asked him what his title meant, he said that he took care of sick computers.

It was very helpful for me to study the remarkable accomplishments of William Stead, a physician, and Ed Hammond, an engineer, who developed TMR (The Medical Record) at Duke University. TMR was so well designed that it was soon readily transferred to a medical group in California. I was also very impressed with the important accomplishments of Clement McDonald, at the Regenstrief Institute in Indianapolis, who with Marc Overhage and associates developed the Regenstrief Medical Record (RMR) and a clinical decision support program called CARE. I also visited Lawrence Weed, who developed his problem-oriented medical record system (PROMIS) at the University of Vermont, and was a brilliant and entertaining banquet speaker. My most admired and respected leader in medical informatics is Donald Lindberg. When Lindberg was at the University of Missouri-Columbia, he began in 1964 to develop one of the earliest computer-based systems for the reporting of clinical laboratory determinations, using punched cards to enter clinical laboratory data into the computer. In 1965, he expanded his laboratory information system into a comprehensive computerized hospital system. By 1970, he was operating a multi-facility medical information system in the state of Missouri, using long-distance telephone lines. He also provided communication and technology services to a unique AMHT system in a solo-practice physician's office 90 miles outside Columbia, that I was privileged to visit and observe in full operation while processing patients.

I visited Lindberg at the University on several occasions during the 1970s, when we each had federally funded Health Services Research Centers. In the 1970s, Lindberg developed several clinical decision-support programs. His CONSIDER program helped physicians analyze and treat patients with blood electrolyte problems. AI-RHEUM, which he developed with Lawrence Kingsland, was one of the earliest clinical decision-support systems using an artificial intelligence approach to help physicians manage patients with rheumatic diseases.

In 1984, Lindberg became the Director of the National Library of Medicine (NLM), where he established the National Center for Biotechnology Information. From 1992 to 1995, he also served as the first Director of the National Coordination Office for High Performance Computing and Communications. At NLM, Lindberg initiated the Integrated Advanced Information Management System (IAIMS) program to transform health care institutions, and the Unified Medical Language System (UMLS) Project to facilitate access to machine-readable information located in various sources, including the scientific literature, factual data banks, and knowledge-based expert systems. Under his direction, NLM instituted MEDLINEplus and PubMed, databases widely used by health care professionals and the general public; and supported a host of innovative projects including the Human Genome Project and the Visible Human Project. In my estimation, Lindberg is equal in stature to John Shaw Billings, who was Director of the Army Surgeon General's Library that was the forerunner of NLM.

I was surprised and honored when Lindberg suggested I write a history of medical informatics, "before all of you old fogies in the field have died." I began working on the book, "History of Medical Informatics in the United States" [9] in 1986, when I was a Fellow at the Center for the Studies of the Behavioral Sciences (CASBS) located on the Stanford University campus. I had the help of librarians there to find a large number of early publications, including one on a bottom shelf in the Stanford Engineering Library, printed in the purple ink of an old ditto machine, but still readable. Also of help were the many copies of their publications sent to me by fellows in the American College of Medical Informatics. My book was published by the American Medical Informatics Association (AMIA), thanks in large part to the efforts of Clement McDonald, then chair of AMIA's publications committee. While at the Stanford University, I had the opportunity to visit the University libraries and browse through the files of Joshua Lederberg's work with Ed Feigenbaum in developing DENDRAL. I was also impressed by the work done in the 1970s by Edward (Ted) Shortliffe who developed MYCIN; by Casimir Kulikowski who developed CASNET; by Jack Myers and Randolph Miller who developed INTERNIST; by Octo Barnett who developed DXplain; and by Gwilym Lodwick who developed computer-aided diagnosis of bone tumors and the Missouri Automated Radiology System (MARS) as early as the 1960s.

In 1974, I was invited by Maurice Sedouilh, Director of the European Region of the World Health Organization (WHO), to go with him to Moscow, Kiev, and Tbilisi to study and report to WHO on medical uses of computers in Russia. Although I was informed that their Minsk computers were merely copies of IBM computers, I was very impressed by M. L. Bykovskiy's presentation of an enhanced application of the Bayesian approach to computer-aided diagnosis. Sedouilh invited John Anderson from London, Peter Reichertz

from Germany, Paul Hall from Stockholm, Ezio Mase from Italy, Sudarikov from Russia, and me to assemble periodically to advise him about computer developments that might be useful for the WHO.

Paul Hall had implemented, as early as 1967, an information system on the hospital wards of the Karolinska Institute in Stockholm, and had instituted a multiphasic health testing system in Sweden. I well remember one of his lectures in which he eloquently described how *data* is collected to form *information* which can be further aggregated to become *knowledge*, from which one can develop an *expertise*, and finally acquire the *wisdom* to make good judgments between available alternatives. Paul Hall was a charmer. One evening, when we were at his home in Stockholm, he played the piano and then danced with my wife, Bobbie. I realized it was time for us to leave Sweden.

In our zeal, this harmonious group formed an international organization, Salutas Unitas (Unity for Health), with Ezio Mase, as president. William Spencer and Carlos Valbonna from Baylor University, Donald Lindberg, and Sidney Garfield also became members. Since Mase was the medical officer responsible for supervising health spas in Italy, each year he arranged for us to have a meeting at a different spa. We gave talks and published papers from these delightful meetings that continued until, regrettably, Ezio Mase died. I can recall the national excitement created by the Russian launching of Sputnik in 1957. That remarkable event stimulated the United States to create in the Department of Defense (DoD) an Applied Research Project Agency (ARPA), that developed ARPANET in 1969 to link computers of different types located in various institutions. This achievement led to the development of the Internet; and one of its developers, Vinton Cerf, gave a memorable keynote talk at a SCAMC conference, describing his landmark contributions to developing the Internet.

I soon became convinced that professional meetings on medical informatics are the best way to learn about innovations, and maintain relationships with colleagues who have similar interests. In the United States the annual Symposium on Computer Applications in Medical Care (SCAMC) were clearly the best conferences on medical informatics. It was at one of my earliest meetings that I met the remarkable Marion Ball. Marion is one of the most charming and smartest people I know. She meets her friends with warm and effusive greetings, yet I have seen her chair international meetings where she very efficiently carried on with the agenda by gently but firmly adjudicating strong international differences. Marion is a natural leader and organizer. She was instrumental in merging the Society for Computer Medicine (SCM) with the Society for Advanced Medical Systems (SAMS) to form the American Association for Medical Systems and Informatics (AAMSI). This merger was so successful, that Thomas Piemme, who had very successfully managed the SCAMC conference for many years, agreed to merge SCAMC with AAMSI. The American College of Medical Informatics (ACMI), that had been formed with Marsden Scott Blois as its first president, also agreed to join in while I was the second president of ACMI. Thus the American Medical Informatics Association (AMIA) was born, with Donald Lindberg as its first president. In my opinion, the birth of AMIA was the most significant medical informatics organizational development in the Americas. Marion Ball became the AMIA delegate to the International Medical Informatics Association (IMIA); and in a few years she became the first American and the first woman to lead IMIA, where she efficiently implemented organizational changes needed to move into the new millennium.

The MEDINFO conferences IMIA held every three years, offered me a place to renew friendships with people from other nations who were also working in medical informatics. The first MEDINFO was held in Stockholm in 1974; and it was a pleasant surprise for me to be invited by Werner Schneider, a member of the Program Committee chaired by Francois Gremy, to moderate one of the sessions. It was at the first MEDINFO that Joe Terdiman described our pilot medical information system and Sidney Garfield presented his vision of a new medical delivery system. It was there that I first learned the new term, *informatics,* and its derivation from the Russian and German *informatik* and the French *informatique*. Another pleasant surprise occurred when I was invited by the Organizing Committee for MEDINFO ‘80 in Tokyo, to chair the Program Committee. I enjoyed the planning trips in Japan, where I became friends with M. Oshima, chair of the Organizing Committee; with S. Kaihara who co-edited the Proceedings with Donald Lindberg; and with Gustav Wagner from Heidelberg, one of the early developers of disease registries. It was at MEDINFO ’80 that their medical information systems were described by Peter Reichertz in Hannover, Germany; by John Anderson in London; by Jan van Bemmel in Amsterdam; and by William Spencer and Carlos Vallbona at the Texas Institute for Rehabilitation and Research. There I met A. M. Cormack, Professor of Physics at Tufts University, who presented a keynote paper describing his

early work with a computer-aided tomography (CAT) scanner, that led to his sharing of a Nobel Prize in 1979 for the development of one of the first imaging machines. The advances in imaging that followed were among the most important technologies developed in the first five decades of medical informatics.

Some of the other MEDINFOs and some of the presented papers I found memorable included MEDINFO '83, graciously hosted in Amsterdam by Jan van Bemmel. Here, Hans Peterson described his Stockholm County Health Information System; and Jean-Raoul Scherrer, from the University Hospital in Geneva, described his approach to developing a medical information system. MEDINFO '86 was held in Washington, D.C., and Donald Lindberg very efficiently chaired the Organizing Committee.

MEDINFO '89 had been scheduled to be held in Beijing. However, after the Tianamen Square disaster, many physicians declined to go to China. The chair of the Program Committee, Phil Manning from the University of Southern California, rose to meet this quandary and developed a complete program for a second conference in Singapore. Since I personally feel that physicians should provide their services regardless of political strife, I gave a keynote paper at Beijing and learned more than I ever would need to know about traditional Chinese medicine.

MEDINFO '92 was held in Geneva, and the opening ceremony was a great surprise when Scherrer, chair of the organizing committee, entered riding on an elephant. Bruce Blum, from Johns Hopkins University, described the evolution of their oncology clinical information system. Susan Grobe, from the University of Texas, presented a paper on nursing informatics. Vimla Patel, from McGill University, gave an illuminating paper on the relationship between medical informatics and cognitive psychology. MEDINFO '95 was held in Vancouver, British Columbia. Jochen Moehr, from the University of Victoria, with Vimla Patel, gave an insightful paper describing some problems associated with the newly developing patient information systems. Moehr graciously hosted some of us at his home.

In writing my reminiscences, I make this disclaimer: I have mentioned those who most affected my personal career. I am not claiming that the persons or events mentioned were the best of the best, but they contributed to, and had attributes that greatly influenced my life; so I consider them to be memorable for me. Furthermore, I confess that when one is trying to recall events that happened 40 or 50 years ago, it is sometimes difficult to separate fact from fantasy; so others who may have shared some of my memories may differ with my reminiscences.

Yes, indeed, my life has brought me many surprises, mostly good ones. At my age of 92 years, I now appreciate how one's plans must adjust to unplanned surprises that often bring new problems, which can, however, create opportunities that may be exploited. I have learned the importance of having enthusiasm for one's work, preferably within a supportive organization; and of having respected colleagues, warm friends, and loving family; and the need for boundless optimism and good humor; and the remarkable stimulation from greeting each morning with „It's going to be a great day today!", followed by having a good cup of coffee.

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Correspondence to:
Morris F. Collen, MD., Director Emeritus
Division of Research
Kaiser Permanente
2000 Broadway
Oakland, CA 94612
USA
E-mail: Mfcollen@aol.com