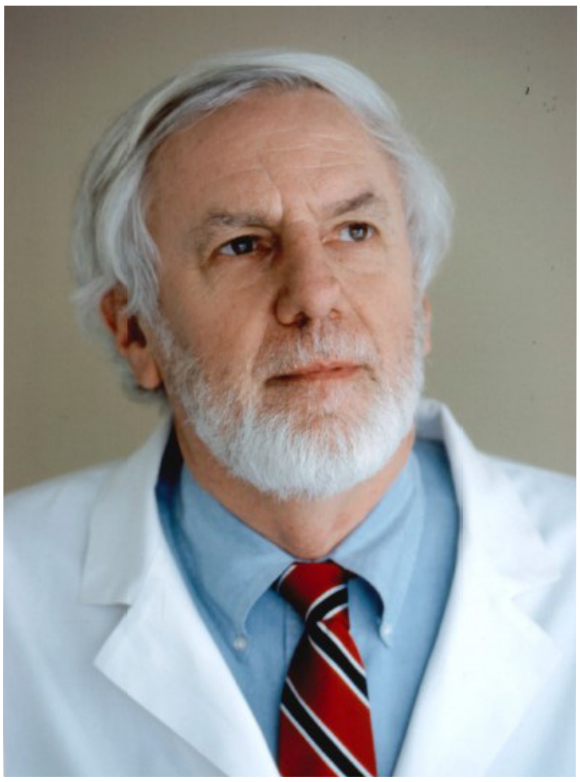
THE FACULTY OF MEDICINE
Harvard University

Warner Vincent Slack



Photograph courtesy of the Slack Family

Warner Vincent Slack, MD, a pioneer of medical informatics, was a Professor of Medicine at Harvard Medical School in the Division of Clinical Informatics, Department of Medicine, and Department of Psychiatry at Beth Israel Deaconess Medical Center. For over 50 years, Dr. Slack conducted pioneering research on the use of computers in the medical world and was one of the founders of medical informatics. His goal was to empower both doctors and patients by improving the communication between them.

Patient-Computer Dialogue

Warner Vincent Slack, MD, was born in East Orange, New Jersey, in 1933 and was the son of Evelyn Francis Slack and Charles Morse Slack, a prominent physicist who helped develop the reactor engine for the Nautilus, the first atomic-powered submarine. He received his bachelor's degree from Princeton University in l955, and the results from his senior thesis in biology were published in Science (1). He graduated from Columbia University's College of Physicians and Surgeons in 1959. During residency training in neurology at the University of Wisconsin in 1960-61, Dr. Slack came to foresee the great potential of computers in medicine.

After completing military service with the United States Air Force in the Philippines, Dr. Slack was awarded a research fellowship at the University of Wisconsin. Dr. Slack became intrigued with the possibility that computers could directly "interview" patients, gaining detailed information and valuable insight that could help physicians better treat them. In l965, with Dr. G. Philip Hicks and other members of the Department of Medicine at Wisconsin, Dr. Slack developed and evaluated the first compute -based medical history system. A LINC computer was programmed to engage in an interactive dialogue with a patient. The computer communicated with the patient utilizing questions, explanations, requests, and comments displayed on the screen, using the computer keyboard for responses. Dr. Slack programmed the computer to store the patient's responses and use them to determine which statements or questions would be presented next and collect summary statements and print them after the interview. Data from the

histories were then available for analysis and research.

A preliminary study of this program, which indicated that the computer was potentially more reliable and more accurate than the physician historian, was published in the New England Journal of Medicine in l966 (2). This widely quoted article was the first on computers in medicine to be published in the New England Journal of Medicine and the first study of patient-computer dialogue to appear in the scientifi literature: “In a pioneering effort at the University of Wisconsin, Slack and his co-workers developed the first online compute -based medical history system,” wrote Dr. JF Rockhart of MIT and the Lahey Clinic (3). Publication of this research led to further studies of automated medical interviewing at the Mayo Clinic (4), the Massachusetts General Hospital (5), the University of Utah (6), Duke University (7), and other medical centers in the United States (8-10) and abroad (11-1) based on the principles first enumerated in Dr. Slack’s original articles continue today (13-21).

In 1970, Dr. Howard Hiatt, then Chairman of the Department of Medicine at the Beth Israel Hospital, recruited him to Harvard Medical School. Dr. Hiatt recalled hiring Dr. Slack as among his most significant achievements as chairman. “Residents and medical students learned from him and the very impressive colleagues that he recruited, nurtured, and developed in his division.” Dr. Hiatt said. With longtime partner Dr. Howard Bleich, Dr. Slack served as co-chief of the Division of Clinical Computing at the Harvard-affiliated Beth Israel Deaconess Medical Cent . Among their many projects, Drs. Slack and Bleich oversaw some of the earliest and most effective hospital-wide clinical computing systems and continued his lifelong work on patient computer dialog.

Dr. Slack’s research with patient-computer dialogue has also increased understanding of the process of medical and psychiatric interviewing and led the way to new avenues of research. His findings dispelled concerns that patients would not respond favorably to computer interviews. He demonstrated that computer interviews, when well-written and considerate of the patient’s perspective, are well received. In some instances, patients preferred the computer to the traditional medical interview, particularly when communicating about personal or private matters or sharing emotionally painful information. Other investigators (20-23) confirmed these observations have led to several related studies about the quality of information communicated in a clinical interview and patients’ attitudes about their clinical experiences (24-26). Applying this principle in a subsequent study, Dr. Slack and his colleagues demonstrated that a computer-based screening interview could elicit more HIV-related factors in potential blood donors’ health histories than the standard questionnaire and interviewing methods currently used at the Red Cross (20).

Early computer-based histories were insensitive to nonverbal information, such as posture, facial expression, and body movement, which the physician uses to assess the patient’s emotional status and reliability as a respondent. However, it is difficult to monitor and study nonverbal behavior in traditional medical interview. Furthermore, nonverbal cues that emanate from the interviewer can introduce bias. As a result, little is known about the actual helpfulness of nonverbal information in the

clinical process (31).

Recognizing that the computer has unique advantages in studying some types of nonverbal communication, Dr. Slack developed a program that monitored the patient's heart rate and response latency during a computer interview and branches to different questions contingent on this nonverbal information and the keyboard responses. Dr. Slack's program, which eliminated interviewer bias as an independent experimental variable, was the first to monitor nonverbal information in a way that could be studied as part of the interviewing process (31). This research has led to an investigation by others (32), and most recently, to Dr. Slack and his colleagues' discovery of a positive correlation between age and response latency in computer interviews (33).

In the early l970's, Dr. Slack began to study patient-computer dialogue as an approach to psychotherapy. Until that time, in studies of computers in psychiatry by Dr. Slack and others, patients had only the keyboard as a means of communication (23,34,35). Dr. Slack's new hypothesis was that speaking aloud would be a more effective psychotherapy approach with a compute 's assistance. With his brother, Dr. Charles W. Slack, he wrote a computer interview that encouraged people to speak aloud about their emotional problems. The computer, though noncomprehending as a listener, was informed as an interviewer. It used information from keyboard responses to a psychiatric history to promote conversation appropriate to the individual subject. Analysis of the patient's spoken words and the participants' subjective reaction (36,37) suggested that the program had therapeutic value. Dr. Slack extended his study of "computer-assisted soliloquy" to the treatment of anxiety. In a controlled study, he demonstrated that talking aloud can be more effective at lowering state anxiety scores and heart rate than thinking quietly (38).

Patient Counseling

Interested in computer-based instruction as an adjunct to the medical interview, Dr. Slack began to explore his idea that an interactive computer could model the medical professional and provide direct consultation to patients regarding managing medical problems. He and his colleagues developed a dietary counseling program that asks about general dietary behavior, elicits food intake details on an average day, and helps the patient plan a 1200 to 1700 calorie weight-reducing diet. Computer-generated printed summaries include estimates of the caloric content of food portions and the proposed diet's details (39). Volunteers have reacted favorably to this program and gained valuable insight into their eating behavior from the computer sessions (40). Whether such a program can result in long-term weight reduction, however, awaits further study.

Dr. Slack and his colleagues also developed a "computer-based patient's assistant" for women with urinary tract infections. The program takes a history of the present illness, performs a review of systems, provides instruction for the collection of a clean voided urine specimen (41), interprets laboratory data, decides whether a patient needs referral to a physician, tests the reliability of the patient's responses by re-asking selected questions, addresses the patient's uncertainties, explains the diagnostic and

therapeutic options, offers opportunities to review information, incorporates the patient s decisions into therapeutic choices, writes a prescription for antimicrobial therapy, writes a progress note for the chart, schedules a follow-up visit, writes a summary (with reminders) for the patient, conducts a follow-up interview, and guides the progress of therapy.

Dr. Slack and his colleagues developed a computer-administered health screening interview for hospital personnel. This program, which protects each respondent's confidentiality while offering health-relate advice and consultation, is routinely used in Beth Israel Hospital (21).

The Programming Language Converse

The growing interest in computer-based interviewing led to developing programming languages to facilitate conversation. The programming language Converse, generated in Dr. Slack's laboratory, provides a means to construct, edit, test, and operate computer-based interviews in English, French, Spanish, and Portuguese and to generate printed summaries in English. Converse can be used to teach, test, and counsel. Converse has also proven helpful in survey research, in which the anonymity of the respondent must be protected.

Converse offers sophisticated capabilities for use in complex interviews. Multiple contingencies can determine the course of the interview. The wording presented on the screen can be modified or created according to the patient's information and was nearly an ideal model for developing clinical and experimental interviews. At Beth Israel Hospital, Converse was used to survey users' opinions of the hospital's clinical computing system. The program was also used at Brigham and Women's hospitals, St. Luke's Hospital in Denver, Westmoreland Hospital in Pittsburgh, the Federal University in Rio de Janeiro, and the University of Wisconsin Hospitals in Madison.

Computer-Based Physical Examination

While other workers incorporated variations of the computer-based medical history into multiphasic screening installations, hospitals, and offices, . Slack and his colleagues extended their ideas to an interactive branching program for use by the physician (58). This program directs a dialogue with the physician, who responds by entering the patient's physical findings. It was the first interactive progra to obtain clinical information directly from physicians for use in inpatient care. Experience with the program indicated that physicians could quickly enter physical findings. The typescript generated by the computer was more legible and generally more complete than the handwritten description. By reminding the physician of essential details of the examination, the program offered educational value. This study paved the way for the study of similar systems in other institutions (5960).

As hospital-wide clinical computing systems increase, it seems likely that physical findings will be obtained routinely from physicians through dialogue with a computer and then made available on terminals throughout the hospital and in printed summaries for placement in the patient's chart.

Computer-Based Clinical Laboratory System

At the University of Wisconsin, Drs. Slack and Hicks developed a computer-based clinical laboratory system (62). They used a LINC computer to collect laboratory results from Autoanalyzers and laboratory technologists, interpret these results, and generate reports for inclusion in the patient's chart. The study led to a collaborative effort with Digital Equipment Corporation and the development of one of the first commercially available clinical laboratory programs (LABCOM), which was then widely deployed.

Internship and Residency

Dr. Slack and Dr. John Greist extended the principles of computer-based interviewing to an internship interview, the first compute -based employment interview to be reported in the literature (63). The computer interviewed applicants about their experience and interests and then provided them with information and answered their questions about the internship program at the University of Wisconsin Hospitals. As the medical residency selection committee director, Dr. Slack and his colleagues developed a plan to improve the internship matching program's flexibility (64)

Computers in Medical Diagnosis

In collaboration with Dr. David Gustafson, Dr. Slack studied the use of subjective probabilities in conjunction with Bayes' theorem as an approach to medical diagnosis (65). This was one of the first studies to employ subjective probabilities in the diagnostic process.

Empowering Patients

In conjunction with his studies of patient-computer dialogue, Dr. Slack developed the conviction that patients should be offered the opportunity to make their own medical decisions, particularly when the value judgments that go hand in hand with medical expertise are involved (66). His studies with computer-based counseling indicate that many patients appreciate acknowledging their right to decide. Clinically informed patients are more likely to comply with their own decisions than with decisions dictated to them. His article "The Patient's Right to Decide," published in The Lancet (67), has been widely quoted. Over the past decades, his ideas, once considered radical and controversial, have achieved ever-increasing acceptance.

Aptitude tests

In collaboration with his colleague, Dr. Douglas Porter, Dr. Slack has demonstrated that, contrary to widespread belief (including literature published by Educational Testing Service and the College Board), students can raise their scores on the Scholastic Aptitude Test (SAT) considerably when they study for the examination (68). To the extent that the results can be raised by training, the test measures achievement, not aptitude for predicting first-year college grades, Drs. Slack and Porter found that the SAT ranked below the widely used achievement tests. It ranked even further below high-school grades, which are generally recognized to be uneven and unstandardized. The study's results, commonly quoted in scientific, educational, and political forums, have been influential in reformative efforts for admiss

considerations at colleges and universities that have decided to eliminate their applicants' SAT requirements. In the wake of these and other criticisms, the College Board, which administers the test, dropped the term "aptitude" and in 1997 announced that "SAT" was merely an acronym that "does not stand for anything."

Clinical Computing Systems

In the 1960s, medical computing's principal challenge was building and deploying a "total hospital information system." By 1970, the U.S. Public Health Service had spent more than $7 million on a single project with this goal in mind. Success was not forthcoming; by 1975, most investigators had abandoned the idea of a central computing system and concentrated instead on individual hospital departments. Although helpful in the respective departments, the programs were electronically separate and unable to share information. Computer manufacturers sold what they called hospital information systems, but the hospital that purchased one spent a great deal of money and received little in return. In the mid-1970s, digital computers in hospitals were still used primarily for fiscal purposes, just as they had been 15 years earlier.

In 1976, Drs. Slack and Bleich began to develop their own integrated, hospital-wide clinical computing system. Their goals, now widely accepted (50, 69), including the capture of information at computer terminals located at the point of transaction, immediate availability of that information at any other terminal, rapid response time, minimal "down" time, preservation of accuracy and reliability of the information, protection of patient confidentialit , user-friendliness to the point where no user manuals would be needed, and a common registry for all patients. The primary criteria for success would be the intensity with which the programs were used, the users' assessment (by computer-based survey) of the programs' helpfulness, and the extent to which the programs could influence the process and outcome of medical care (70).

Five years later, in l982, the clinical computing system at Beth Israel Hospital -- the first to employ the computer architecture, software design, clinical logic, and human factors they had envisioned -- appeared to be the most comprehensive and most heavily used in the United States and the most well-received by its users (50). At any time of the day or night, a physician could turn to a computer terminal, type a confidential password, and access the clinical computing system. Clinicians could retrieve the patient's history of admissions and outpatient visits, lookup results from the laboratories, read diagnostic reports from radiology and other clinical departments, look up prescriptions filled in the pharmacy, request delivery of a patient's chart, send electronic mail messages to anyone in the hospital, use PaperChase to search the National Library of Medicine's MEDLINE database of references to the medical literature, and receive advice on the management of electrolyte and acid-base disorders, the use of antibiotics, and the pharmacology of new medications in the hospital's formulary. Available at any terminal as soon as they were generated, laboratory results and clinical reports for all inpatients and outpatients were kept online for at least 12 months.

Since l982, as new clinical programs have been added to the system, use has increased dramatically (51). During one week in 1988, a total of 1737 clinicians at Beth Israel Hospital used one or more of the options in the clinical information system 58,757 times (over twice the use in 1984). They performed 40,958 lookups of clinical and laboratory data, performed 906 searches of the MEDLINE database, made 366 requests for advice and consultation, and sent 13,538 electronic mail pieces. (This electronic mail system was one of the first to be developed for use in a clinical setting.) During one week in 1992, clinicians performed 56,000 lookups of clinical and laboratory data and conducted 1445 searches of the medical literature. And during one week in 1995, they sent 35,000 messages by electronic mail, many of which were directly related to patient care (71). There are now over 3000 computer terminals located in the hospital's inpatient and outpatient facilities.

To produce such a computing system required major technologic innovations. To coordinate programmers' efforts to work on diverse but integrated systems, a technique was developed to collect patient information using multiple computers. Since the computers and disc drives available then were not fast enough to handle all the transactions of a large teaching hospital, a technique was developed that connects computers to let them function as a single, more powerful unit (69).

This networking technique permits computing throughout the hospital from a single, integrated database. It enables information entered at any terminal to be immediately available on any other terminal. In contrast, with additional networking techniques, messages are passed from one computer to another. Still, all the computers in the network cannot function together as a single, more powerful unit (69).

Physicians at all levels, including students and trainees, have become increasingly enthusiastic about these systems (47), which have played an essential role in the teaching programs at Beth Israel Hospital. When house officers are asked what made them choose Beth Israel Hospital, many replied that it was th computing system. When Arthur D. Little proposed a clinical computing system to support 167 hospitals operated by the U.S. Department of Defense, Beth Israel Hospital's computing system was the prototype. The firm reported that no other system meets physicians clinical needs better, and no other has seen such a steady increase in use among physicians (72). The cost of this computing is well below the cost of other systems that accomplish less.

Drs. Bleich and Slack realized the data that was routinely collected by their systems could help discover new knowledge. Along with Dr. Charles Safran, they designed the user-friendly ClinQuery program to help clinicians search the clinical computing system database (the most comprehensive in the country) by clinical and demographic descriptors (73). With this program, any physician, nurse, or medical student can identify all admissions in which diabetic ketoacidosis was diagnosed, the serum bicarbonate level was under 12 mMol/L, and the length of stay exceeded seven days. Once particular admissions are identified, all data stored in the computerized record can be displayed. Authorized persons can also request the patient's complete medical record for further study. Over 30 months, 530 doctors, nurses, medical students, and administrators used the ClinQuery program to search the hospital's clinical

database 1786 times. They displayed detailed information on 30,851 patients and requested a complete medical record 5319 times. In 1389 of the 1786 searches completed, the searcher responded to a computer-based questionnaire about the reason for the search. Responses indicated that 32% of the inquiries were for clinical research, 17% for patient care, 17% for teaching and education, 11% for hospital administration, and 12% for general exploration. In 58% of the searches, respondents indicated definite or probable success in finding the desired information due to these data, Drs. Bleic and Slack concluded that physicians and allied personnel would repeatedly obtain, view, and analyze aggregate clinical information if provided with appropriate tools (67). Access to ClinQuery became an increasingly important resource for patient care, teaching, and clinical research at the Beth Israel Hospital.

To evaluate the effect of their hospital-wide clinical computing system on medical care, Drs. Bleich, Slack, and their colleagues performed a time-series study of computerized alerts to physicians. They looked at whether alerts about rising creatinine levels in hospitalized patients receiving nephrotoxic or renally excreted medications led to more rapid adjustment or discontinuation of those medications and whether such alerts protected renal function. They concluded that the alerts affected physician behavior and helped preserve renal function. The alerts were well accepted by physicians (74).

Clinical Computing at Brigham and Women's Hospital

In 1980, when Harvard's Departments of Medicine at Beth Israel and Brigham and Women's hospitals were consolidated, Dr. Eugene Braunwald invited Drs. Bleich and Slack to expand their academic Division to include Brigham and Women's Hospital. In 1982, the administration at Brigham and Women's Hospital asked Drs. Slack and Bleich developed a clinical computing system as they had done with such success at Beth Israel Hospital. Drs. Bleich and Slack formed the Center for Clinical Computing, a not-for-profit corporation chartered with the support of Harvard Medical School, Beth Israel Hospital, and Brigham and Women's Hospital, to engage in teaching and research and provide clinical computing to Harvard teaching hospitals. By 1987 all registrations, clinic visits, laboratories, and clinical departments were computerized, as they had been at Beth Israel Hospital. In 1988, after the computing system was complete, administrative responsibility was transferred back to the hospital. Drs. Bleich and Slack demonstrated their systems to physicians and hospital administrators visiting from all over the world. His 1997 book, *Cybermedicine: How Computing Empowers Doctors and Patients for Better Health Car*e, was one of the first books discussing how clinical computing could empower patients.

Dr. Slack was a Tutor in Medicine and course developer and director of "Introduction to Interviewing." He served for four years on one of Harvard Medical School's admissions subcommittees, for three years on Harvard's human subjects committee. For eight years as chairman of the internship and residency selection committee for the Department of Medicine at Beth Israel Hospital. He served Harvard's new pathway steering committee for program evaluation and Harvard's Committee on minority affairs. He served on three review committees for the U.S. Public Health Service and the extramural research

review committee for the Veterans Administration, the National Library of Medicine, of the National Institutes of Health. He served on the Editorial Boards of the Journal of Medical Systems, Computers in Human Behavior, Computers in Psychiatry/Psychology, and Methods in Psychiatric Research. From 1989-1998 he served as Editor-in-Chief of M.D. Computing.

Civil Rights and Social Justice

A lifelong advocate of civil rights, Dr. Slack and a colleague, Dr. Maxie Maultsby, Jr., a distinguished African-American psychiatrist, worked for a season with the University of Wisconsin football team during the 1960s to help ease tensions related to integration. In 1965 Dr. Slack traveled to Alabama for the Selma to Montgomery Freedom March, led by Dr. Martin Luther King, Jr., to help treat any marchers who might be injured. More recently, as a member of the medical organization Cape Cares, Dr. Slack, then in his 70s, traveled twice to Honduras, offering medical treatment to residents of remote villages.

Lifetime Recognition

The importance of Dr. Slack's work has been widely recognized in the scientific literature, in commercial developments, and the national press during his career spanning six decades. Dr. Slack, who celebrated his 85th birthday on June 10, 2018, continued working until early this year when pulmonary fibrosis forced him to stop. Beyond his professional accomplishments, family and friends recall his extraordinary personal warmth, optimism, humor, gentleness, and generosity. On June 23, 2018, he died peacefully in the arms of his beloved wife, Carolyn Slack, on the morning of their 62nd wedding anniversary. A memorial website (https://www.warnerslack.org) has been created with his lifework with tributes from colleagues and friends. The Warner Slack Scholarship for Clinical Informatics at Beth Israel Deaconess Medical Center supports medical informatics students. He will long be remembered as an outstanding researcher, innovator, educator, mentor, and friend.

Respectfully submitted,

Charles Safran, MD, *Chairperson*
Howard L. Bleich, MD
Yuri Quintana, PhD
Charles W. Slack

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