New connections between medical knowledge and patient care

Lawrence L Weed

Upon this gifted age, in its dark hour,
Rains from the sky a meteoric shower
Of facts ... they lie unquestioned, uncombined.
Wisdom enough to leech us of our ill
Is daily spun, but there exists no loom
To weave it into fabric

Edna St Vincent Millay¹

The meteoric shower of medicine's scientific achievements can overwhelm a doctor's mind. A patient has no assurance that his or her doctor is able to take into account all relevant scientific knowledge and integrate it with detailed data about the patient's own condition. Yet few doctors, patients, or policy makers recognise that modern information tools can become the loom for weaving these two bodies of knowledge into a fabric. In fact, few recognise the dimensions of the problem.

This state of affairs has one underlying cause: misplaced faith in the unaided human mind. Medical practice requires tools to extend the mind's limited capacity to recall and process large numbers of relevant variables, just as medical science requires the microscope to extend our capacity to see at the microscopic level. We must abandon the arrogance of professional "expertise" that shuns such tools. Instead, we must use the new tools routinely as they are developed for more and more diagnostic and management problems.

Limits of the human mind

Until now, we have believed that the best way to transmit knowledge from its source to its use in patient care is to first load the knowledge into human minds (the long and expensive education of professionals) and then expect those minds, at great expense, to apply the knowledge to those who need it. However, there are enormous "voltage drops" along this transmission line for medical knowledge (see box).

In short, medicine lacks a modern information infrastructure that rigorously and efficiently connects all those who produce and archive medical knowledge to all those who need the proper application of that knowledge. The medical education and delivery systems operate on the wrong premises and with inadequate tools. The medical and economic harm that results is incalculable. One observer, for example, estimates that, in hospitals in the United States, "180 000 people die each year partly as a result of iatrogenic

Summary points

Medicine lacks an information infrastructure to efficiently connect those who produce and archive medical knowledge to those who must apply that knowledge

There are serious "voltage drops" along the transmission line for medical knowledge in the present healthcare system

Good medical practice requires tools to extend the human mind's limited capacity to recall and process large numbers of relevant variables

Knowledge should be held in tools that are kept up to date and used routinely—not in heads, which are expensive to load and faulty in the retention and processing of knowledge

Such information tools would allow fundamental changes in our approach to medical education

The tools would also allow a defined and consistent approach for controlling and keeping track of inputs to the healthcare system, which in turn would enable outputs to be properly interpreted and corrective feedback loops to be used routinely

injury, the equivalent of three jumbo jet crashes every three days. When the causes are investigated, it is found that most iatrogenic injuries are due to errors and are, therefore, potentially preventable."³

Reasons for relying on the human mind

Why has misguided reliance on the human mind been allowed to continue in medicine? It has not been for lack of evidence of the problem. For decades, the medical profession itself has documented high levels of error, far higher than other industries tolerate. Governmental and private payers have focused on unnecessary care and unmanageable costs. New tools and practices to address these problems have been developed. Indeed, I, among others, have written extensively for many years about the flawed information structure in medicine and about potential

PKC Corporation,
1 Mill Street, Box
A-8, Burlington,
VT 05401-3078,
USA
Lawrence L Weed,
president

BMJ 1997;315:231-5

“Voltage drops” along transmission line for medical knowledge

- Only a portion of medical knowledge is ever loaded into the minds of professionals
- Not all of the knowledge loaded in the minds of professionals is retained
- Much of the knowledge that professionals retain becomes obsolete, and there is no assurance that they will learn new knowledge relevant to their patients' problems
- Even with the limited knowledge that it retains, a doctor's unaided mind cannot reliably integrate that knowledge with the infinite variety of data about patients in order to identify and systematically assess all diagnostic or treatment options based on each patient's unique characteristics and needs
- Faced with information overload, doctors fall back on “clinical judgment,” that is, global, intuitive assessment of findings rather than organised investigation and explicit linkage of each finding in the patient to the relevant diagnostic or management options in the medical literature. Yet cognitive psychology shows that experts' global judgments are inferior to judgments based on thorough analysis of specific data²
- Doctors not only rely improperly on their global judgments but also habitually fail to gather or consider information relevant to their judgments. This happens because graduate medical “education” instills doctors with a faith that they can safely rely on the limited information their minds can process; because such faith is a necessary defence mechanism for the unaided mind; because medical education and medical practice reward specialisation (which, by definition, excludes relevant information); because the unaided mind's normal functioning uses techniques for discarding information (such as premature formation of hypotheses, selective perception of data, focus on statistical analysis of limited variables, and disregard of individual variation from statistical patterns); and because such cognitive pitfalls and textbook classifications of diseases cause doctors to focus on the few characteristics that a patient shares with others who have the “same diagnosis” while discounting the hundreds of characteristics that make the patient different from those others and that may have more to do with his or her therapeutic needs than the diagnostic label
- For financial and demographic reasons, many people who need medical care have little or no access to the medical knowledge residing in expensively educated, highly paid, geographically limited doctors. Nor do they have sufficient access to the skills that doctors possess, because the rules of accreditation mean that the same professional group monopolises both skills and knowledge

solutions.⁴⁻¹³ And, outside the medical profession, extensive research in cognitive psychology has documented the folly of uncritical reliance on the mind's limited capacities.¹⁴

Despite ample evidence of the problem, barriers to acknowledging and acting on this evidence are embedded in the healthcare system. Legal rules, for example, mandate reliance on educational accreditation. That reliance persists, despite the harm it causes, because it serves psychological, social, and financial interests of providers, patients, and payers. As Robyn Dawes explains: “The greatest obstacle to using [external cognitive aids] may be the difficulty of convincing ourselves that we should take precaution against ourselves.... The idea that a self-imposed external constraint on action can actually enhance our freedom by releasing us from predictable and undesirable internal constraints is not a popular one.... States license psychologists, physicians and psychiatrists to make (lucrative) global judgments of the form, ‘It is my opinion that....’ People have great misplaced confidence in their global judgments, a confidence that is strong enough to dismiss an impressive body of research findings and find its way into the legal system.... Reverence [for experts] may serve a purely social function. People and organisations have to make decisions, often

between alternatives that appear equally good or bad. What better way to justify such decisions than to consult any intuitive expert, and the more money he or she charges, the better. ‘We paid for the best medical advice’ can be a palliative for a fatal operation.”¹⁵

Consequences of relying on the human mind

We should never have placed so much power in the hands of those who memorise knowledge, regurgitate it in examinations, forget much of it, specialise in a small piece of it, and never fully integrate what they do with the details of patients' needs. In particular, we should never have permitted specialisation to distort the basis of medical decision making. Medical problems often cross the artificial boundaries among body systems that define medical specialties, and patients commonly present with multiple, interacting problems. Yet specialists often fail to account for relevant information outside their specialised knowledge and, as a result, commit serious errors.

Such failings will continue so long as medical education and accreditation are based on the premise that practitioners' minds should be loaded with scientific knowledge. Now that knowledge can be built into the tools that practitioners use in their daily work, we can no longer justify requiring students to spend years “learning” some of the facts of basic science, without ever providing them with the conditions under which a true scientist functions. They will never be able to practise in the sheltered conditions provided to scientists—that is, one or two problems at a time with ample resources and enough time to devote to them. Without those conditions, the unaided mind is bound to fail.

Moreover, dependence on the mind's limited capacity affects not only individual patients and providers but the medical care system as a whole. Corrective feedback loops are impossible when flawed information tools are the basis of all medical care, clinical research, and medical education. Outcome studies, for example, often defy useful interpretation, because the outcomes under study reflect undefined, uncontrolled inputs—the global judgments of doctors that emerge from the ill defined, idiosyncratic recall and processing capabilities of the human mind.

New premises and new tools

The time has come to abandon the wrong premises and inadequate tools that underlie the current systems of medical education and care. If we are willing to adopt radical change, we may find that productivity can improve by an order of magnitude. When the travel system changed from trains to aeroplanes, it became possible to travel from New York to Seattle in five hours instead of five days; tinkering with the railways would never have accomplished that change. In medicine a comparable change is to transmit medical knowledge through modern information tools rather than through the fallible minds of doctors.

When evaluating tools to improve medical decision making, it is important to distinguish between two stages of decision making: firstly, retrieving and organising information in a usable form to improve capacities for making decisions, and, secondly, exercising judgment based on that information to arrive at a decision. There has been considerable interest in

second stage tools, that is, artificial intelligence software that tries to replicate the actual decision making of an expert physician. This approach fails to recognise, however, that an expert's decision making is only as good as the information that the expert takes into account, which the mind's limited capacities for recall and processing severely restrict. "Studies of expertise have repeatedly demonstrated that the expert is distinguished, not by possession of any general skills, but by the ready availability from memory of appropriate knowledge to resolve the problem."¹⁶

The real need, therefore, is for tools that support the first stage of decision making—and thereby empower human judgment in the second stage, where no computer or expert can substitute for a patient's values and self knowledge. Such tools include knowledge coupling software that retrieves medical knowledge and links it with patients' data (see box) and medical records that record patients' data and reveal the actions and thought processes of providers. These tools would permit corrective feedback loops and quality control. As a foundation for the second stage of decision making, the information tools would reveal when current medical knowledge yields a clear answer to, or no certain answer to, a diagnostic or management problem. They would also show where no single option is clearly preferable to alternatives. But in all cases the tools would give the evidence for and against each diagnostic or management option based on the details elicited from the patient. Human judgment then comes into play, as trade offs and ambiguities are assessed, and choices made. Informed patients would be able to assert their own values and goals. No longer would it be possible to maintain what some have called "collusion by all involved in health care, including doctors, to avoid or deny uncertainty."¹⁷ In this way information tools would prevent the paternalism of providers that flourishes when uninformed patients become passive objects in the medical care process.

Empowering patients

Patients rather than doctors should become the primary decision makers in medicine. A simple analogy may clarify this. In travel systems the consumer is the decision maker. People use the travel system successfully because the system has a highly developed infrastructure with all the linkages of the parts known to every traveller and with experts (such as pilots, mechanics, and travel agents) to handle specialised functions. The information that consumers need is

Knowledge coupling software in medical decision making

This is an information tool that, given a problem in diagnosis or management, helps assure that:

- All relevant diagnoses or management options known to medical science are readily available for consideration
- Unique features of the problem situation that bear on the discrimination among these options are appropriately checked and assessed
- Appropriate associations are made between the unique features of the situation and the many diagnostic or management options

built into the infrastructure in a usable way—maps at petrol stations, signs on roads and in airports, and the like. No one ever suggested to consumers that, because the total transportation system is sophisticated and complex, they would need to pay high fees for guidance from someone with four years of postgraduate training in geography. All that the public wants from the system's experts is that they be competent and routinely evaluated, not in general, but for the particular function they perform.

Similarly, in a demystified healthcare system modern information tools should be used routinely by all patients, in conjunction with providers who are trained to help at various steps in the system where patients cannot function on their own (such as feeling their own spleen or replacing their own hip). In order to assure high quality in the process of eliciting the information that people need to keep well or to discover, solve, or manage problems, knowledge coupling software would present to patients and providers questions about symptoms, physical findings, and inexpensive laboratory findings. At the end of each encounter, the software would, on the basis of the best current medical information, present the patient and provider with a list of exactly which causes or management options each positive response suggests, and the evidence for and against each option. That information would become part of the patient's medical record, facilitating coordination and scrutiny by other parties.

This is in contrast to the present system, which depends on each provider's idiosyncratic judgment and communication.

- Different providers, even when confronted with the same problem in the same patient, ask widely varying sets of questions when taking a medical history, perform different manoeuvres during physical examination, and order different laboratory tests
- A patient may never know what thoughts each positive finding triggers in a provider's mind—doctors vary enormously in how much and how well they educate their patients and how well they document the information they seek and conclusions they draw in medical records
- Providers vary widely in the number and nature of the follow up investigations and treatments that they order, and patients are often uninformed, passive objects in the process
- Patients are never given their medical record, showing the details of providers' actions or of their own medical condition

- Patients have no way of knowing the size, accuracy, and currency of the reservoir of knowledge that providers have, and on which they base their investigations and their diagnostic or management conclusions, nor do patients have any assurance that up to date practice guidelines are available for their problem or, if so, whether a provider's unaided mind can integrate all the details in a 100 page guideline with the mass of detailed data reflecting each patient's uniqueness
- The cost of doctors' time is exceedingly high in spite of all of these deficiencies.

These deficiencies would all be corrected in the new information structure. Since each patient is unique, no two individuals would have the same inputs into the new information system, and the outputs would be tailored to their unique needs. In a travel system we all may use the same maps, but each can fashion a trip unique to his or her needs. We do not ask questions like "What is the best trip across the country?" Instead, we define a high quality trip as one in which each step along the way suited the needs of the person making the trip. In the same way, high quality medicine should be a calculus of many well defined choices as patients work their way through a medical landscape that has become intellectually and economically accessible to them through modern information tools. A traveller may not understand or appreciate the underlying complexity and sophistication of a map and its construction, but that does not compromise the power and simplicity of routine use of that map.

Using information tools that facilitate each patient's navigating his or her journey through the medical landscape would be the opposite of the "cook book medicine" that so many critics fear. Cook book medicine often occurs when medical generalists and specialists alike rely on their memory and resort to "one size fits all" routines in busy clinics, in which details about each unique individual are often never taken into account and the same global judgments and procedures are set into motion over and over again.

Keeping medical practice up to date

A central system of software development could keep all users of the system up to date at all times. The inputs to the healthcare system would be consistently derived from defined sets of questions and observations by all providers as they work with patients in a highly organised information system. And those inputs would be intelligibly recorded in medical records that would permit the connections between specific provider inputs and patient outcomes to be traced. As this would occur with large populations, there would be a basis for corrective feedback loops on the medical knowledge that was built into the system.

In contrast, the present system lacks a defined and consistent approach for controlling and recording provider inputs. This precludes quality control and deprives medical science of the enormous knowledge that we might otherwise harvest from everyday patient care. The total cost of this chaotic system is high, and the lack of control over inputs means that outcomes defy any rational evaluation or improvement.

Implications for medical training

A vast network of expensive educational facilities and years of lengthy training could be bypassed as up to date

knowledge was channelled directly to the patients in need through modern tools of communication. Thousands of patients and providers could use a single developed information system. Each provider would be responsible for helping patients at one or more steps in the system where technical skill was necessary. Since much of the knowledge and the medical logic could be available in the new information tools themselves, anyone with high proficiency in a specific medical procedure and willingness to operate under the scrutiny and control of a total system of care could be accredited to perform those specific procedures. Providers' training and accreditation for a given skill would be inexpensive and far more focused and rigorous than at present, which in itself should do much to reduce the high level of errors that practitioners now commit. No one should be accredited on the basis of formal education, which demonstrates merely memorised knowledge or a capacity to generate logic pathways extemporaneously as new patients come by in a busy practice.

No single provider would need to maintain the illusion of being a "total physician," nor would the educational system need to support that illusion by requiring students to sweep superficially through and memorise an enormous amount of material at the expense of developing a sense of responsibility and excellence in the activities that they actually perform for patients. Instead, a sense of the whole would emerge from the providers' functioning within a system that permitted patients to achieve total care for themselves. However, this would require educating and empowering patients to play a role in decision making. Patients would have their own medical records, they would use knowledge coupling tools in conjunction with providers to support medical decision making, and they would be taught from childhood on how to interact with the system, just as they now learn how to interact with transport systems. As patients assume decision making power, their demands will reshape the healthcare marketplace in these directions.

Conclusion

Alfred North Whitehead wrote: "Civilisation advances by extending the number of important operations which we can perform without thinking about them."¹⁷ Retrieving and processing information in medicine are operations that we have tried to perform by thinking about them at the time of action under extraordinary time constraints. Enormous damage results from this misguided effort.

New information tools enable us to leave behind a world of medical practice in which providers and patients alike are victims of the "predictable and undesirable internal constraints" of the unaided human mind. Providers have been granted unjustified power to function in the face of avoidable ignorance of crucial details about medical science and about patients themselves. New tools can release patients and providers from this ignorance as they weave scientific knowledge into the fabric of patient care.

I acknowledge the invaluable help of Lincoln Weed in the preparation and editing of this manuscript.

Funding: None.

Conflict of interest: PKC Corporation develops and markets knowledge coupling software for medical decision making.

- 1 Millay ES. *Collected sonnets*. New York: Harper and Row, 1988: 140.
- 2 Dawes R. *Rational choice in an uncertain world*. New York: Harcourt Brace Jovanovich, 1988: 202-22.
- 3 Leape L. Error in medicine. *JAMA* 1994;272:1851.
- 4 Weed LL. Medical records, patient care and medical education. *Ir J Med* 1964;6:271-82.
- 5 Weed LL. Medical records that guide and teach. *N Engl J Med* 1968;278:593-600, 652-7.
- 6 Weed LL. *Medical records, medical education and patient care*. Cleveland: Case Western Reserve University Press, 1969.
- 7 Logan RL, Scott PJ. Uncertainty in clinical practice: implications for quality and costs of health care. *Lancet* 1996;347:595-8.
- 8 Weed LL. A new paradigm for medical education. In: *Recent trends in medical education, Macy Foundation Conference, Aspen, Colorado, September, 1975*. New York: Josiah Macy Jr Foundation, 1975.
- 9 Weed LL. Physicians of the future. *N Engl J Med* 1981;304:903-6.
- 10 Weed LL. The computer as a new basis for analytical clinical practice: coupling individual problem with medical knowledge. *Mt Sinai J Med* 1985;52(2):94-8.
- 11 Weed LL. *Knowledge coupling: new premises and new tools for medical care and education*. New York: Springer-Verlag, 1991.
- 12 Weed LL, Weed L. Reengineering medicine. *Fed Bull* 1994;81(3):149-83.
- 13 Weed LL. Reengineering medicine: questions and answers. *Fed Bull* 1995;82(1):24-36.
- 14 Weed LL. *Knowledge coupling: new premises and new tools for medical care and education*. New York: Springer-Verlag, 1991: 8, 37-42, 212, 226-7.
- 15 Dawes R. *Rational choice in an uncertain world*. New York: Harcourt Brace Jovanovich, 1988: 143, 208, 216.
- 16 Norman GR. Problem-solving skills, solving problems and problem-based learning. *Med Educ* 1988;22:279-86.
- 17 Whitehead AN. *An introduction to mathematics*. London: Williams and Norgate, 1911:61.

Netlines

QuackWatch

- Visit QuackWatch (<http://www.quackwatch.com/index.html>) to sample retired psychiatrist Steve Barrett's single handed attempt to debunk all so called alternative therapies and other quackery.

JournalsOnline

- Can't be bothered to traipse over to the library and wait until the photocopier is free? Try the new JournalsOnline service from the Bath Information and Data Services (BIDS) on <http://www.journalsonline.bids.ac.uk/JournalsOnline>. The service is free to British academics in institutions that subscribe to BIDS and to the appropriate journals. You will need to visit your library to get a password, which will also allow you to search the Science Citation Index on the BIDS site (<http://www.bids.ac.uk/websearch.html>). At present, only journals from Blackwell Science and Blackwell Publishers are available, but other publishers will be joining the scheme in time. Articles are available in Adobe Acrobat format and, when printed on a laser printer, seem far crisper than the equivalent photocopy.

Laboratory Syllabus in Molecular Cell Biology

- If you are about to start a MD or PhD in molecular biology, or are supervising a new student, you might like to consult the excellent online introduction to laboratory work (<http://plaid.hawk.plattsburgh.edu/acadvp/artsci/biology/bio401/LabSyllabus.html>) produced by Donald Sligh of the Biological Sciences Department at the State University of New York, Plattsburgh.

New Trauma Moulage

- The people at the excellent Trauma Moulage web site (<http://www.trauma.org/resus/moulage/moulage.html>) have just added a second online interactive tutorial. This time you get to ride in a helicopter, and you not only have the opportunity to kill your patient several times over but also to kill yourself if you get it wrong.

Urology site

- The Department of Urology at Princess Margaret Hospital, Swindon, have put together a web site (<http://ourworld.compuserve.com:80/homepages/SwindonUrol/>) linking to all sorts of urological resources on the web.

Surgical training

- The Association of Surgeons in Training now has a web site (<http://www.asit.rcseng.ac.uk>) featuring all sorts of information for surgeons in training, including the association's newsletter. There is an associated moderated email discussion list on surgical training—for details, send an email to asit@rodingdemon.co.uk.

MedNet 97

- The Second World Congress on the Internet in Medicine will take place on 3-6 November in Brighton—for details, see <http://www.mednet.org.uk/mednet/mednet.htm>. The congress is organised by the recently formed Society for the Internet in Medicine (<http://www.mednet.org.uk/mednet/>).

Orthopaedic and trauma surgery on the web

- Chris Oliver, consultant in trauma and orthopaedic surgery at Edinburgh Royal Infirmary, has kindly supplied Netlines with information on orthopaedic and trauma surgery on the web. For general orthopaedic sites with lists of links, see WorldOrtho (<http://www.worldortho.com>), the Orthopaedic Links page (<http://www.virtuallkamloops.com/cloughs/orthlink.html>), LinkOrthopaedics (<http://www.dundee.ac.uk/orthopaedics/link/welcome.htm>), and the Edinburgh Trauma and Orthopaedic Surgery home pages (<http://www.geocities.com/CapeCanaveral/8971>).
- The *Wheelless Textbook of Orthopaedics* (<http://www.medmedia.com/med.htm>) must rate as one of the best medical or surgical hypertext books on the web—it is well indexed, with links to core references, and fully searchable. A must for every medical student, surgical trainee, or consultant.
- Online orthopaedics journals include the *Electronic Journal of Orthopaedics* (<http://www.ejo.org/>) and the *Journal of Bone and Joint Surgery* (<http://www.jbjs.co.uk>). For orthopaedics images, see the EMBS Radiology Library (<http://www.njnet.com/~embbs/xray/xr.html>). The Tele Orthopaedics service of Institute of Orthopaedics, Oswestry (<http://www.keele.ac.uk/depts/rjah/rjah.htm>), invites you to submit problem x rays for departmental scrutiny.

Compiled by Mark Pallen
email m.pallen@qmw.ac.uk
web page <http://www.qmw.ac.uk/~rhubm001/mpallen.html>