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The Power of Knowledge in Radiologic Education and Decision Making

SUN TZU, the legendary Chinese general from the 4th Century BC, said that knowledge is power.[1] For him, knowledge of an enemy's strength, disposition, will to fight, supply lines, etc, was the most powerful weapon he had and often enabled him to defeat numerically superior foes. The great power of specific, relevant, and timely knowledge has repeatedly been proven in almost every aspect of life including finance, business, and politics.

Medicine is a particularly information intensive discipline and is becoming more so all the time. In fact medical knowledge is accumulating much faster than we can use it. It has been estimated that the entire body of medical knowledge doubles every 5 years—a staggering rate. There is a huge body of new facts (information) and strategies for applying those facts (knowledge) that would enable us to give better care, if only we could remember it all. In radiology, we have tried to cope with this knowledge boom by extending the length of residency and fellowship training, and by becoming increasingly subspecialized. This strategy has been fairly effective in large academic centers, but out on the front lines of radiologic practice, radiologists are fighting a losing battle in their attempt to practice state-of-the-art radiology. This is happening in the face of ever increasing pressure to command broad expertise because of the internecine turf wars that we must wage with our clinical colleagues over ownership of "our" chunk of medical knowledge. The result of all this is that we face sobering challenges to effectively educate our residents and fellows, and to keep ourselves as close to the cutting edge of radiologic knowledge as possible.

For a long time, humankind's ability to use and share knowledge was limited by what one could carry around in one's own head, or what one could learn from one's neighbors. This changed dramatically in 1454 AD when Johannes Gutenberg began printing books using moveable type. Up to that time, there were only 50,000 books in all of Europe. A mere 50 years later, there were some 10 million books available.[2] This brought about a stunning revolution in access to world knowledge and inaugurated the beginning of incremental science, or the ability to aggregate and add to knowledge. The mushrooming information burden that we face today is a tribute to the success of the "Gutenberg revolution."

We are in the midst of another equally cataclysmic revolution—brought about this time by computers. We have heard so much about this in the past, that we are not very impressed anymore. But most of the computer revolution that we have experienced has focused on some rather mundane information processing tasks. In medicine this has changed the way that we keep records, send out bills, and run our departments. We have certainly reaped great benefits from the number crunching prowess that has enabled computers to produce elegant digitally-based images, but we have not exploited this powerful technology at all to help us with our primary job as radiologists—knowledge processing. Our intellectual horsepower is still chugging along in time honored ways—little changed since the post-Gutenberg days. The main reason for this is that computer scientists are only now beginning to understand how to use computers to help us process knowledge. But there is real evidence that a variety of techniques ranging from programs that draw conclusions using statistical methods, through things like neural networks and artificial intelligence will turbo-charge the knowledge work that we do.[3] These tools have been likened to power tools for the mind that can amplify our cognitive powers in the same way that conventional power tools can greatly increase what we can do with our muscles.[2] This is the important part of the computer revolution for us in medicine.

There are many different ways that we will use computers for decision making in radiology. First of all, it will be a partnership. We are in no danger of being eclipsed or replaced by these tools. They will empower us. We can use them for what they do best (remembering large amounts of detailed information) and still keep doing what we do best (perceiving abnormalities and putting it all together). Sometimes computers will serve us best by giving us the right piece of information at the right time; a differential diagnosis, a discussion of a key diagnosis, an image or group of images from an electronic teaching file. This kind of selective, context-sensitive information can be available almost automatically.[4] To be really useful, this should be done selectively so that we do not have to wade through a lot of not quite relevant information. In this role, the computer is a knowledge filter, acting as a go-between that reaches out to large data and knowledgebases and finds information for us that addresses the specific clinical issues that puzzle us. Sometimes the computer will play a more direct role in decision making using a variety of inferencing techniques. Whereas a great deal of radiologic decision making is very subjective, some diagnoses can be made in a more quantitative, algebraic fashion. Many congenital syndromes, for example, are hard to remember and the diagnosis depends on the presence or absence of many skeletal or other abnormalities. These kinds of problems are easy for computers and it makes no sense for us to clutter up our limited memories with such unnecessary details. A difficult diagnostic problem can often be solved by consulting an expert, and this paradigm has served as a model for a class of computer systems known as expert systems. We will begin to see tools like this incorporated into our reporting systems, radiology information systems, and into image display and management systems.

Beyond the many ways that this sort of knowledge processing can help us, there is also now some real potential for computers to help with the perceptive phase of image analysis. Systems are being developed in mammography, for example, that can flag suspicious masses, can look for certain signs of malignancy, and can point out suspicious calcifications.[5,6] Programs that do this are exhibiting "computer vision." There are only a few areas so far in radiology where vision programs show promise. At this point, their function is not to "read the film," but to call our attention to potentially significant abnormalities. This may be particularly useful in special clinical circumstances such as high-volume screening mammography centers where we must rapidly interpret large numbers of cases, or when dealing with a population having a high prevalence of the target disease.

Despite the fact that we have extended the length of radiology training, it is no longer possible for finishing residents and fellows to know all that they need to know if they are going to enter the general practice of radiology. There are some computer-based radiologic education tools that may provide a useful supplement to conventional teaching methods. These systems can be dynamic, interactive, and flexible.[7] These programs will adapt to the student's needs providing extra instruction in areas of weakness, and glossing over areas that have already been mastered. When decision support tools become integrated into clinical practice, they will make radiologic education available at the moment of truth—when we are struggling with a difficult diagnosis.[4] That is not only when we need the information most, but it is also when we are most likely to remember it. This interaction can be documented by the program itself, which may well provide a solution to the coming need for physician recertification.

In this issue of the *Journal of Digital Imaging,* we have collected five papers that deal with these important issues. Several focus on radiologic education. Hayt et al[8] have developed a system for medical student education based on the PathMAC system at Cornell. This system is widely accessible via Macintosh computers on a network and features display of images and questions based on student observations. Kahn[9] at the University of Chicago has implemented a hypertext system as part of the department's radiology information system. This tool is used for primary education as well as decision support by medical students, residents, and attending radiologists. Greenes[10] describes key issues that the builders of education and decision support systems face and argues for a modular "building block" approach to system construction. His group has designed a tool set that can be used to build and integrate the key elements of such a system. Artifical neural networks are a nonalgorithmic programming method that in some ways mimic the structure, function, and decision-making capabilities of the human brain. These programs are appealing because they learn directly by being exposed to example cases. Piraino et al[11] describe their experience using an artificial neural network for the radiologic diagnosis of bone tumors. A critical issue for the acceptance of decision support systems is that they be smoothly integrated into the real clinical environment. Mutalik et al[4] discuss systems that have been developed at Yale that bring decision support to the image acquisition process in ultrasound, as well as expert systems that screen the cognitive content of dictated reports.

The challenges that today's complex and sophisticated practice of radiology pose are immense. We are moving forward to meet these challenges on many fronts. Computer-based decision making and education is but one of them. The accomplishments to date represent only the beginning of the beginning. Yet our partnership with knowledge-based computers is inevitable. The few research groups working in this field today will be joined by many others in the coming decades as the great potential of these tools begins to emerge.

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