X-Rays and the Number Crunchers

Digital processing of X-ray images improves diagnostic information

By DIETRICK E. THOMSEN

To arrive at an informed diagnosis a physician needs an accurate picture of what is wrong with the patient. Such a picture is often no metaphor. For something like 60 years the picture has been in many cases an actual radiogram made with X-rays. The X-ray machine has long been a standard feature of doctors' examining rooms.

In the last couple of years the faithful old X-ray machine has become the center of something of a technological revolution called digital radiography. Digital computers are now coupled to X-ray sensors to enhance the quality of X-ray images, to bring out information in the images that would not otherwise be available to the eye and to store the images and transmit them to video monitors in various places. One of the people prominent in the field, Ben A. Arnold, chief of research in medical imaging at South Bay Hospital in Redondo Beach, Calif., expresses the opinion that "the concept of an all-electronic radiology department is becoming increasingly viable both technically and economically."

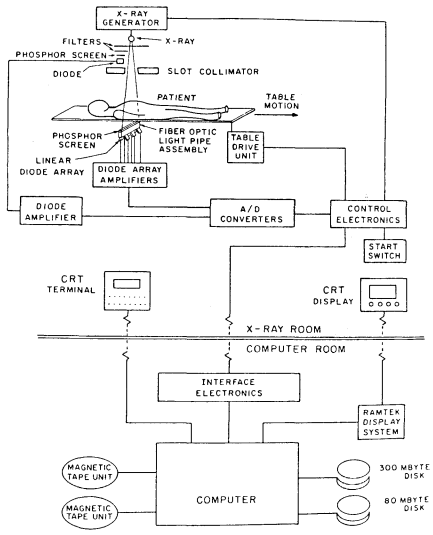
Arnold is a physicist. X-rays are a technique taken from physics, and their introduction into medicine brought in physicists too. During the First World War two prominent physicists, Marie Curie and Lise Meitner, took a hand in the beginnings of medical radiology. Both operated front-line X-ray screening stations for military personnel, Curie with the French army, Meitner with the Austrian.

Today, with the all-electronic radiology department perhaps a short way down the corridor, the presence of physicists, computer scientists and electronics engineers is even more pronounced. Digital radiography was one of the topics discussed at two meetings held simultaneously in New Orleans, the gatherings of the American Roentgen Ray Society and the Society of Photo-optical Instrumentation Engineers (SPIE) meeting on Application of Optical Instrumentation in Medicine X. One observer commented, "There are more physicists than physicians here." It did seem that there were as many if not more people talking in mathematical equations or the jargon of information theory as in the jargon of anatomy and physiology. The talk, especially at the SPIE meeting, was heavily oriented to the equipment, its present state and capabilities and the possibilities for its development in the future.

The X-ray tube itself, although the necessary starting point, got very little attention. The interest lies in what happens after the X-rays leave the tube and pass through the patient. In the usual system in use now, the X-rays are imaged on a phosphor screen. The screen image is scanned by a video image intensifier camera. The video scan puts out an analog electric signal — that is, a signal that traces the variations in brightness across the screen image. This signal goes into an analog-to-digital converter. There the picture is divided into a checkerboard of pixels (picture elements). To each element is assigned a number representing its relative contrast value. Now the computation programs of the digital computer can work on the information, enhancing contrast to distinguish different anatomical structures more sharply from one another and bringing out information latent in the data that would not appear to the unaided eye.

When the digital computation has been completed, the result is put through a digital-to-analog converter, generating an analog signal that will appear as the enhanced image on a TV monitor. Not necessarily a single monitor. It could be displayed in real time on monitors in distant parts of the hospital, in a physician's home or office, even to a consultant in a distant city, if the proper telemetric connections are available.

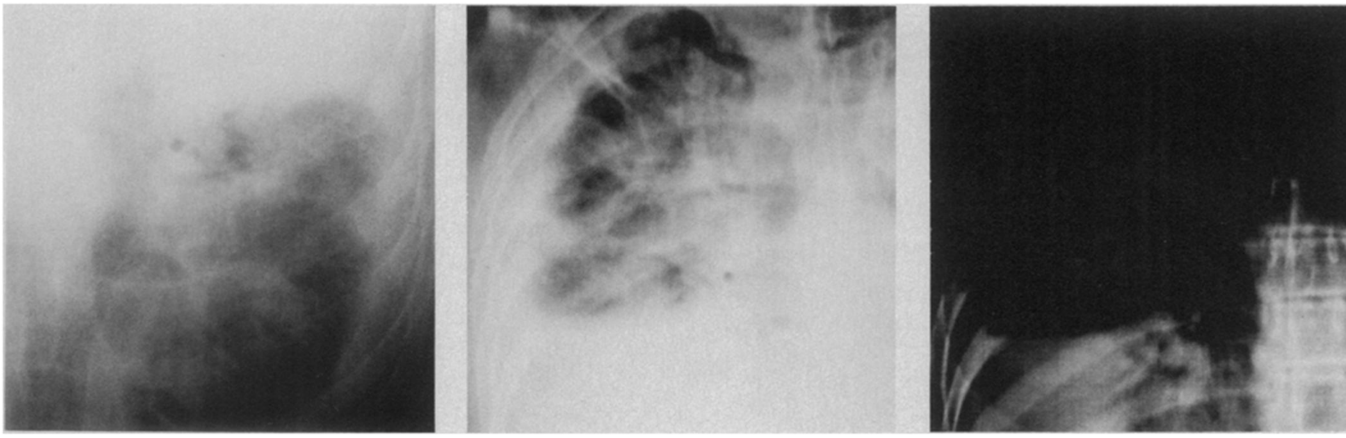
What this can mean in an emergency was pointed out by M.F. Stieghorst, a physician at the University of Wisconsin Clinical Science Center. Suppose, he says, an accident victim arrives in the emergency room with what the examining physicians suspect is a laceration of the aorta. This condition demands instant surgery. Suppose further that the relevant surgeon is operating on another patient at the time. Instead of waiting, the new patient's angiogram can be displayed on a monitor in the operating room where the surgeon is working. The surgeon can then either order the new patient to be brought to the next-door operating room immediately or inform the emergency room crew that there is no need for aortic surgery.



Digital radiography method developed by University of Pittsburgh group uses diode array to read X-ray brightness. Other digital methods use video amplifier cameras in place of the diodes.

These radiograms can be stored in digital form in a computer memory. André J. Duerinckx of Philips Ultrasound Inc. in Santa Ana, Calif., discussed possible ways of doing this. One might be magnetically coded floppy discs such as computer memories often use. Another possibility is "credit cards," plastic cards with magnetically coded strips, one per patient. In most hospitals now, radiograms are stored as hard copies on film kept in paper jackets, one jacket per patient. Archiving and retrieval are often cumbersome procedures. Duerinckx showed some pictures of current methods that drew giggles from the audience.

A single computer can handle image processing, and a single memory image storage, for several X-ray installations as well as nuclear magnetic resonance apparatus, nuclear medicine apparatus, ultrasound imagers, etc. In at least one institution, the University of Arizona Health Sciences Center, messages between these locations are sent along optical fiber cables, the latest thing in telecommunication techniques. D. Ouimette, who described the Arizona installation, says the fibers provide more traffic capacity and replace "a mess of cables."



Illustrations: Univ. of Pittsburgh

Digital X-ray imaging enhances contrast. A film X-ray of the upper right chest of a woman with cancer of the right lung (left) compared to a digital image of the same patient programmed to show the lung with high contrast (middle) and another programmed to show the spine with good contrast (right).

One of the newest things reported at the meetings was a system devised by a group at the University of Pittsburgh led by Donald Sashin, a physicist who is director of the radiological imaging division of the department of radiology there. This new arrangement takes out the video image intensifier. It uses an array of light-sensitive diodes to scan the patient's body line for line and convert the received X-rays to an analog electronic signal for the analog-to-digital converter. Its inventors feel that this device will eventually replace the video techniques because it is faster, cheaper, uses lower X-ray doses and is capable of distinguishing many subtle shades of gray. Others hearing the presentation were not so sure.

However the images may be made in the future, one of the long-range hopes for the processing is to be able to get quantitative information out as well as a picture. So far this is still in the experimental stage—one of the questions being how much can really be learned this way—but the ultimate intention is to present the radiologist with a table of numbers or graphs representing the information in the picture to help with the diagnostic interpretation.

Proponents of digital radiography aver that it has potential application any time X-rays are made. Its most extensive use so far is in angiography. Here it has the advantage of speed and of a need to inject less of the contrast material (usually something containing a lot of iodine) that is needed to make blood vessels show up on the X-ray picture. Injection of the contrast material causes discomfort to the patient, so lessening the amount is important. Says one physician, "You don't hear that yelp," when you inject the amount necessary for digital subtraction angiography (DSA), as the technique is called. X-ray dosage is also somewhat lower with DSA, but that's not the big plus. Speed and lower contrast dosage are.

The subtraction art of DSA refers to the processing technique, which subtracts from each other a number of different pictures of the same location to get an image of what's going on there. The different pictures may be taken at different times, beginning before the contrast material arrives at the site and continuing as it passes through. This is temporal subtraction. Energy subtraction uses pictures made with different X-ray energies. Hybrid subtraction is a newly developed way of combining the two. In the view of several people who discussed it, hybrid subtraction holds great promise for the future.

The contrast material may be injected intravenously either into a vein in the arm or into one at the site to be examined. Intra-arterial injection is also beginning to be tried. Intra-arterial injection calls for quick picture taking, but the technique is producing some pictures that interest people, particularly those obtained after injection at the root of the aorta to visualize the arteries supplying the heart muscle.

Indeed the heart, the coronary arteries and adjacent parts of the vascular system are one of the prime DSA subjects now. According to Edward Buonocore, a physician with the Cleveland Clinic in Cleveland, Ohio, one can study the chambers of the heart, their shapes, sizes and how they move during the heartbeat. DSA can bring up contrast between two blood vessels when they lie on top of each other or on a blood engorged organ. The ultimate hope is to be able to study the motions of blood flowing in the vessels, especially around damaged or constricted spots. Another physician, M.P. Capp of the University of Arizona Health Sciences Center, says that in the future one should be able to study flow dynamics all over the body in asymptomatic people with a simple injection into a vein.

Going away from the heart, DSA is being used to chart the branchings of the carotid arteries in the neck and head. Patrick A. Turski, a physician with the University of Wisconsin Clinical Sciences Center, reported a method for using DSA to make a "road map" of the carotid system so as to guide the insertion of a catheter that might be necessary, for instance, to dilate a constricted spot. With the road map, the therapist can see where the catheter is going before it gets there and so eliminate a certain amount of trial and error in getting it into the right place.

And finally the extremes. David M. Paushter, another physician with the Cleveland Clinic, reported on work done there on the use of DSA in studying musculoskeletal tumors of the extremities. In part this can help delineate the extent of a tumor by outlining the blood vessels that feed it, but the technique's main contribution is to show whether growth of the tumor has pushed major blood vessels out of place. This information is important to a surgeon in deciding whether an amputation is necessary or whether a less radical resection of the tumor will suffice.

Capp estimates that there are 200 to 300 digital radiology installations in the United States now. He says the industry is catching up with the new technology, and he expects digital techniques to replace X-ray filming within several years. One of his remarks is "Blue sky!"

There are, however, warnings against a premature bandwagon effect. One of them comes from Mark B. Gray, a physician who heads the department of radiology at the David Grant Medical Center at Travis Air Force Base in California. Gray and another Travis AFB physician, Paul Levesque, did a study of what is called analog subtraction angiography. This method, which involves piling up films and subtracting the images optically by shooting light through the pile, can be done without expensive special equipment. For now, Gray and Levesque conclude, it makes pictures as good as those from DSA. Gray does not expect that equality to last. In the future, especially when hybrid subtraction techniques are perfected, he expects that DSA will be far superior. For the moment, however, Gray has advised the Air Force against buying digital equipment — it can cost up to $250,000 per installation — that would have to be replaced in two or three years, when the technology should be really improved. □