The Case for Ultrasound

For thousands of years physicians have attempted to “see” disease states in order to better understand and treat them. Initially, only five physical senses were available to guide the treatment process. Available energy sources included visible light and mechanical forces for inspection and palpation.

More recently, new energy sources have been developed to better “see” disease. These energy sources include:

- X-ray
- MRI
- Nuclear Scan
- Ultrasound

**X-ray:**

X-rays were discovered in 1895 by Wilhelm Konrad Roentgen (1845-1923), and are high energy radiation of short wave length (0.01 to 10 nm). These rays are commonly produced by passing a high voltage current through a special X-ray (vacuum) tube. The X-ray tube (Coolidge tube) consists of a tungsten wire filament cathode that produces a stream of electrons when excited by high voltage electrical current. The electron stream is directed at an anode of solid tungsten within the tube, generating high energy X-rays that are capable of penetrating most human tissue.

X-rays also affect photographic film, blackening it upon exposure. This property is used to generate an image of tissue exposed to X-rays. Photographic film is blackened in inverse proportion to the energy lost in passage of X-rays through that tissue. X-ray, one of the earliest alternative energy sources to “see” disease, is very useful for evaluating structures and process within the body.

X-rays, however, are powerful sources of potentially dangerous radiation and are not readily utilized by the practicing surgeon-interventionist. High energy X-rays can ionize neutral atoms and cause genetic defects, carcinogenesis, and developmental defects in exposed fetuses.

Because they produce ionizing radiation, X-ray machines require special shielding and rooms for their safe use. X-ray devices are relatively bulky, expensive and non-mobile. Special knowledge and training are required to fully exploit their potential. Typically physicians who have specialized in radiology are relied upon to perform the examinations and interpret the images.

For these reasons X-ray energy is not readily used by the surgeon-interventionist.

**MRI:**

Magnetic resonance imaging utilizes signals emitted by a patient’s hydrogen atoms when that patient is placed in a strong magnetic field and the magnetic moment of the patient’s hydrogen atoms are perturbed by radiofrequency energy. Perturbation of the magnetized hydrogen atoms causes the emission of a radiofrequency signal that is sampled and processed by computers into images. MRI images are produced without the use of ionizing radiation.

To perform an MRI examination, the patient is placed into a structure housing a powerful magnet. The tube is open at both ends however, the environment is claustrophobic with little room for an operative team or instruments. Non-ferrous instruments must be used and care must be taken with those patients dependent upon pacemakers and life support systems during an MRI examination.

MRI units are very expensive, bulky, and non-mobile. The surgeon-interventionist must work around the equipment. MRI soft-tissue images can demonstrate startling detail, but these images are not available in real-time and are not convenient to use in a surgical setting.

**Nuclear Scan:**

Nuclear scans depend upon gamma radiation emitted from a patient’s body to produce an image. The gamma radiation originates from radiopharmaceuticals delivered to the patient via an oral or parenteral route.

A gamma scintillation device (“gamma camera”) is utilized to acquire the data necessary to produce a nuclear scan image. The camera functions by detecting gamma rays emitted by radiopharmaceuticals within the patient’s body and displays the distribution and intensity of that radiation as a photograph. Computers assist in the quantification of data and generation of images.

Nuclear scans make use of organ or system specific pharmaceuticals and are particularly effective in determining functional assessment of that organ or system. Nuclear imaging employs emissive energy as opposed to radiography, which uses transmissive energy (X-rays) to produce an image of the part studied.

Nuclear scan images are not sharply detailed and require, in most instances, reference to standard radiographic, CT, MRI or ultrasound studies. The structure and anatomic information provided by nuclear scans call for interpretation by physicians expert in their analysis.

Traditional nuclear scan equipment is expensive, bulky and non-mobile. The technology is not suitable for use by the surgeon-interventionist.
An exception to this generalization is the hand-held gamma probe used to localize a sentinel node in the surgical treatment of early malignant melanoma or breast cancer. In these cases, a lymphoscintogram of the lymphatic drainage system is first obtained by nuclear medicine. The lymphoscintogram is then used as a road map to guide intraoperative gamma probe localization of the sentinel node and its surgical removal.

**Ultrasound:**

Ultrasound technology utilizes high frequency sound waves above the range of normal hearing (15 cycles - 20 thousand cycles per second (Hertz)), to define body structures. Hand-held transducers contain arrays of piezoelectric crystals that produce and receive high frequency sound waves which range from 1-30 million cycles per second (Hertz).

A piezoelectric quartz crystal has the unique property of deforming when an electric charge is applied to it. With application of electrical energy, a sound wave is produced in much the same way sound is produced when a drumhead or cymbal is deformed. Conversely, when the crystal is deformed by a returning sound wave, it will produce a small electric charge. It is this electrical signal, generated by the returning sound wave, that is amplified and computer-manipulated to produce near real-time images on an ultrasound monitor.

In addition to being relatively inexpensive, ultrasound has other unique features that recommend it to the practicing surgeon. Ultrasound:

- Uses non-ionizing radiation to “see.”
- Doesn’t risk the development of genetic defects, carcinogenesis, or fetal defects.
- Doesn’t require a special room or shielding.
- Doesn’t require contrast material.
- Is safe in pregnant patients and females of childbearing age.
- Is mobile and portable.
- Doesn’t require extensive knowledge of radiation physics.
- Provides images in near real-time.
- Is capable of Doppler imaging.
- Is safe to use with patients who require a pacemaker, life support equipment, monitoring devices, or who have had a metal clip applied to a cerebroaneurysm.
- Is readily interpreted by the well-trained surgeon.

Real-time images of important anatomic detail are available to elucidate disease processes. Color Doppler ultrasound can be used to evaluate vascular structures and differentiate these from other tubular structures. Organ perfusion can also be assessed by color Doppler. For example, perfusion data can help differentiate between an ischemic testicular torsion from inflammatory epididymitis.

Important strides are also being made in three-dimensional ultrasound representation. Using the power of computers, two dimensional data slices of current ultrasound displays can be “stacked” and approximated into three-dimensional figures that can be rotated and viewed from different angles. Organs and disease processes can be viewed and analyzed in ways not now possible.

The portability of present-day ultrasound machines makes office, bedside and operating room examinations possible. Examination in real-time can hasten diagnosis, decision-making and treatment intervention.

As surgery inexorably becomes less invasive, there arises a need for technologies to assist the surgeon-interventionist to better “see” disease processes. Technologies that enabled modern surgeons to “see” provided the impetus for the minimally-invasive laparoscopic revolution. Today, technologies that image disease in wavelengths other than that of visible light, are available to guide the surgeon-interventionist. Of these technologies, ultrasound has the greatest potential to be of immediate benefit to surgeons of all disciplines who practice minimally invasive surgery.

Michael S. Kavic, MD

Editor-in-Chief

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