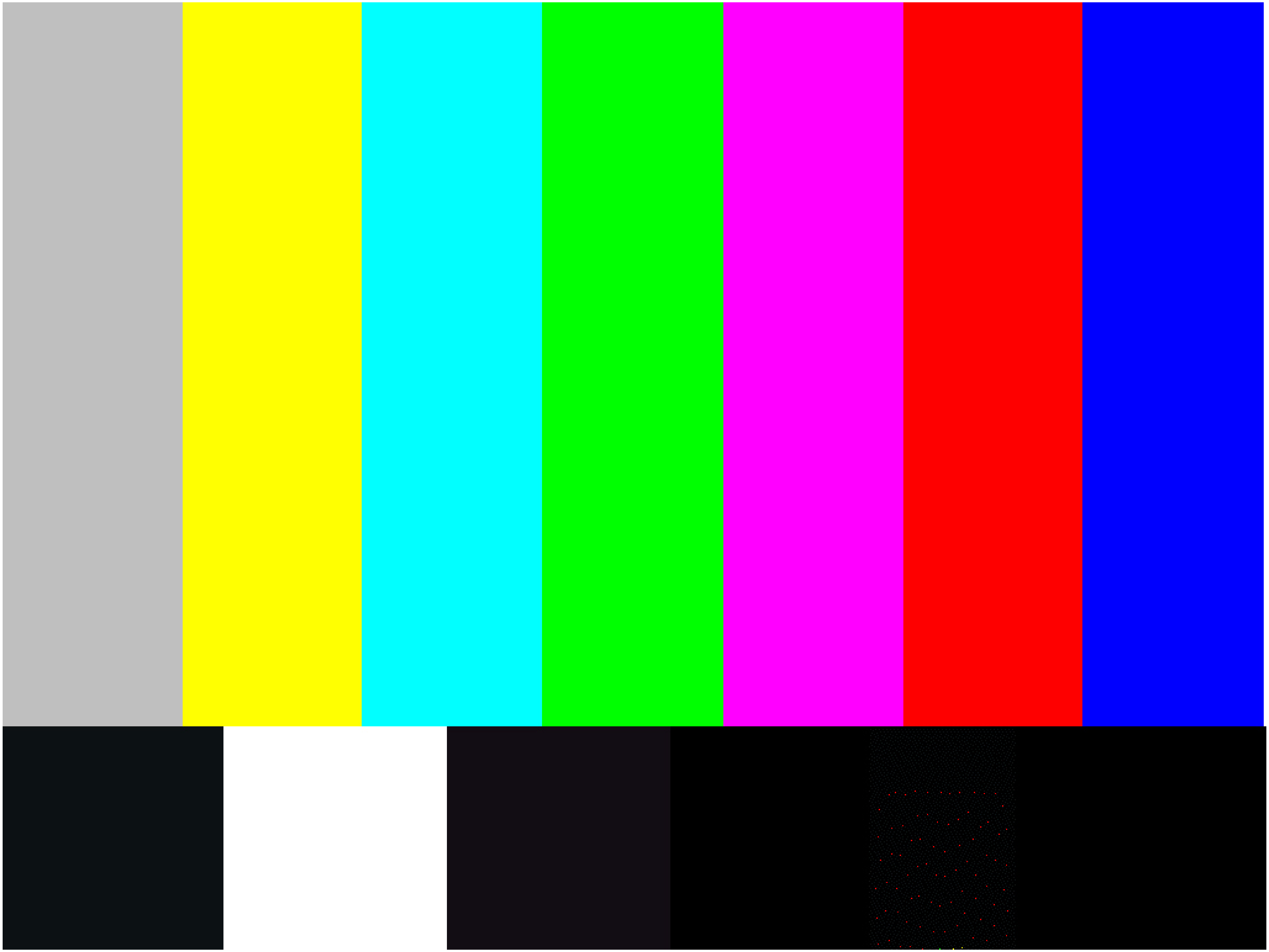


Medical Imaging

By:
Engr. Joseph Ronald Canedo

Medical Sonography (Ultrasound)

- is an ultrasound-based diagnostic imaging technique used to visualize muscles and internal organs, their size, structures and possible pathologies or lesions. Obstetric sonography is commonly used during pregnancy and is widely recognized by the public.

Medical Sonography (Physics)

- “Ultrasound" applies to all acoustic energy with a frequency above human hearing (20,000 hertz or 20 kilohertz).
- Typical diagnostic sonographic scanners operate in the frequency range of 2 to 18 megahertz, hundreds of times greater than the limit of human hearing.
- The choice of frequency is a trade-off between spatial resolution of the image and imaging depth: lower frequencies produce less resolution but image deeper into the body.

Medical Sonography

- Diagnostic applications
  - Sonography (ultrasonography) is widely used in medicine. It is possible to perform diagnosis or therapeutic procedures with the guidance of sonography (for instance biopsies or drainage of fluid collections).
    - Sonographers are medical professionals who perform scans for diagnostic purposes.
    - Sonographers typically use a hand-held probe (called a transducer) that is placed directly on and moved over the patient. A water-based gel is used to couple the ultrasound between the transducer and patient.

Medical Sonography

- Diagnostic applications
  - Sonography is effective for imaging soft tissues of the body.
    - Superficial structures such as muscles, tendons, testes, breast and the neonatal brain are imaged at a higher frequency (7-18 MHz), which provides better axial and lateral resolution.
    - Deeper structures such as liver and kidney are imaged at a lower frequency 1-6 MHz with lower axial and lateral resolution but greater penetration.

Medical Sonography

- Medical sonography applications
  - Cardiology
  - Endocrinology
  - Gastroenterology
  - Gynecology
  - Obstetrics
  - Ophthalmology
  - Urology - to determine, for example, the amount of fluid retained in a patient's bladder.
  - Musculoskeletal, tendons, muscles, and nerves
  - Vascular - arteries and veins
  - Intravascular ultrasound (e.g. ultrasound guided fluid aspiration, fine needle aspiration, guided injections)
  - Intervenional – biopsy, emptying fluids, intrauterine transfusion (Hemolytic disease of the newborn)
  - Contrast-enhanced ultrasound

Medical Sonography

- Therapeutic applications
  - Ultrasound may be used to clean teeth in dental hygiene.
  - Ultrasound sources may be used to generate regional heating in biological tissue, e.g. in occupational therapy, physical therapy and cancer treatment.
  - Focused ultrasound may be used to generate highly localized heating to treat cysts and tumors (benign or malignant), This is known as Focused Ultrasound Surgery (FUS) or High Intensity Focused Ultrasound (HIFU). These procedures generally use lower frequencies than medical diagnostic ultrasound (from 250 kHz to 2000 kHz), but significantly higher energies. HIFU treatment is often guided by MRI.

Medical Sonography

- Therapeutic applications
  - Focused ultrasound may be used to break up kidney stones by lithotripsy.
  - Ultrasound may be used for cataract treatment by phacoemulsification.
  - Additional physiological effects of low-intensity ultrasound have recently been discovered, e.g. its ability to stimulate bone-growth and its potential to disrupt the blood-brain barrier for drug delivery.

Medical Sonography

- Producing a sound wave
  - A sound wave is typically produced by a piezoelectric transducer encased in a probe. Strong, short electrical pulses from the ultrasound machine make the transducer ring at the desired frequency.
  - The frequencies can be anywhere between 2 and 15 MHz.
  - The sound is focused either by the shape of the transducer, a lens in front of the transducer, or a complex set of control pulses from the ultrasound scanner machine. This focusing produces an arc-shaped sound wave from the face of the transducer. The wave travels into the body and comes into focus at a desired depth.

Medical Sonography

Medical Sonography

- Receiving the echoes
  – The return of the sound wave to the transducer results in the same process that it took to send the sound wave, except in reverse.
  – The return sound wave vibrates the transducer, the transducer turns the vibrations into electrical pulses that travel to the ultrasonic scanner where they are processed and transformed into a digital image.

Medical Sonography

- Forming the image
  - The sonographic scanner must determine three things from each received echo:
    1. How long it took the echo to be received from when the sound was transmitted.
    2. From this the focal length for the phased array is deduced, enabling a sharp image of that echo at that depth (this is not possible while producing a sound wave).
    3. How strong the echo was. It could be noted that sound wave is no click, but a pulse with a specific carrier frequency. Moving objects change this frequency on reflection, so that it is only a matter of electronics to have simultaneous Doppler sonography.
  - Once the ultrasonic scanner determines these three things, it can locate which pixel in the image to light up and to what intensity and at what hue if frequency is processed

Medical Sonography

- Sound in the body
  - Ultrasonography (sonography) uses a probe containing one or more acoustic transducers to send pulses of sound into a material.
  - The frequencies used for medical imaging are generally in the range of 1 to 18 MHz. Higher frequencies have a correspondingly smaller wavelength, and can be used to make sonograms with smaller details.
  - However, the attenuation of the sound wave is increased at higher frequencies, so in order to have better penetration of deeper tissues, a lower frequency (3-5 MHz) is used.

Medical Sonography

- Modes of sonography
  - A-mode: A-mode is the simplest type of ultrasound. A single transducer scans a line through the body with the echoes plotted on screen as a function of depth. Therapeutic ultrasound aimed at a specific tumor or calculus is also A-mode, to allow for pinpoint accurate focus of the destructive wave energy.
  - B-mode: In B-mode ultrasound, a linear array of transducers simultaneously scans a plane through the body that can be viewed as a two-dimensional image on screen.
  - M-mode: M stands for motion. In m-mode a rapid sequence of B-mode scans whose images follow each other in sequence on screen enables doctors to see and measure range of motion, as the organ boundaries that produce reflections move relative to the probe.
  - Doppler mode: This mode makes use of the Doppler effect.

Medical Sonography

- Doppler sonography
  - Sonography can be enhanced with Doppler measurements, which employ the Doppler effect to assess whether structures (usually blood) are moving towards or away from the probe, and its relative velocity.
    - By calculating the frequency shift of a particular sample volume, for example a jet of blood flow over a heart valve, its speed and direction can be determined and visualized.

Medical Sonography

- Strengths of sonography
  - It images muscle and soft tissue very well and is particularly useful for delineating the interfaces between solid and fluid-filled spaces.
  - It renders "live" images, where the operator can dynamically select the most useful section for diagnosing and documenting changes, often enabling rapid diagnoses.
  - It shows the structure of organs.
  - It has no known long-term side effects and rarely causes any discomfort to the patient.
  - Equipment is widely available and comparatively flexible.
  - Small, easily carried scanners are available; examinations can be performed at the bedside.
  - Relatively inexpensive compared to other modes of investigation

Medical Sonography

- Weaknesses of ultrasonic imaging
  - Sonographic devices have trouble penetrating bone. For example, sonography of the adult brain is very limited.
  - Sonography performs very poorly when there is a gas between the transducer and the organ of interest, due to the extreme differences in acoustic impedance. For example, overlying gas in the gastrointestinal tract often makes ultrasound scanning of the pancreas difficult, and lung imaging is not possible (apart from demarcating pleural effusions).
  - Even in the absence of bone or air, the depth penetration of ultrasound is limited, making it difficult to image structures deep in the body, especially in obese patients.
  - The method is operator-dependent. A high level of skill and experience is needed to acquire good-quality images and make accurate diagnoses.
  - There is no scout image as there is with CT and MR. Once an image has been acquired there is no exact way to tell which part of the body was imaged.

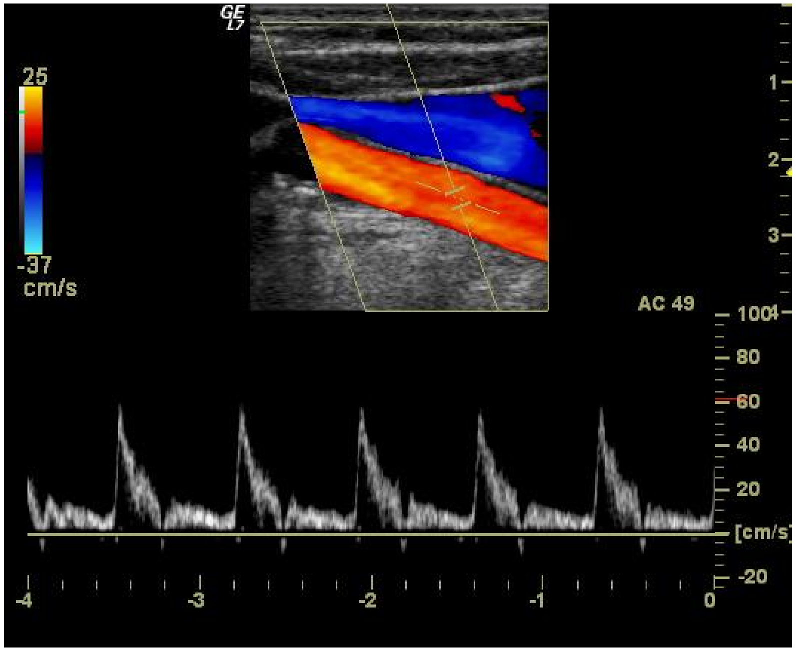
Medical Sonography

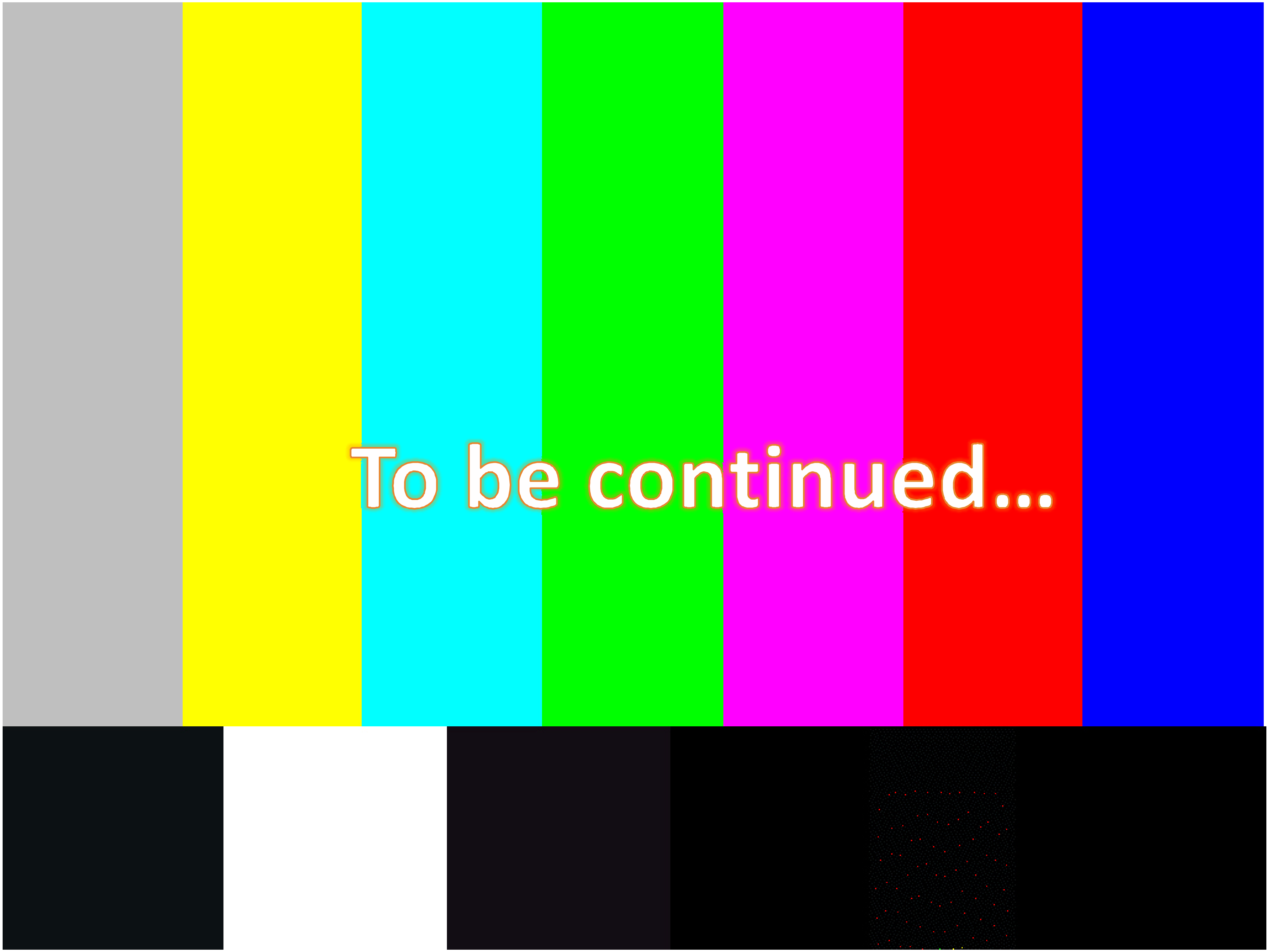
- Risks and side-effects
  - Ultrasonography is generally considered a "safe" imaging modality. However slight detrimental effects have been occasionally observed (see below). Diagnostic ultrasound studies of the fetus are generally considered to be safe during pregnancy. This diagnostic procedure should be performed only when there is a valid medical indication, and the lowest possible ultrasonic exposure setting should be used to gain the necessary diagnostic information under the "as low as reasonably achievable" or ALARA principle.

Medical Sonography

2D Echo Machine

Medical Sonography




To be continued...