Laboratory exercise: Diagnostic ultrasound

Introduction

The aim of the laboratory exercise is to:

- Understand the construction of a diagnostic ultrasound scanner.
- Understand the most fundamental functions of an ultrasound machine and be able to handle the machine.
- Understand how some artefacts arise in the ultrasound image.
- Get an insight on how you make a quality check of a diagnostic ultrasound scanner.

Gain a better understanding in the following expressions:

- Phased array
- Linear array
- Dynamic Focusing
- TGC
- Dynamic aperture
- Apodization
- Scan converter
- Cineloop
- Doppler
- Continuous Doppler (CW)
- Pulsed Doppler (PW)
- Color flow (CD)
- Power Doppler (PD)
- Pulse length
- Persistence
- Ultrasound artefacts
- Harmonic imaging
- Sono-CT/compound imaging
- Lateral resolution
- Axial resolution
- Elevation resolution
- What affects the resolution in an ultrasound scanner
- What affects the framerate

Preparations

- Read chapter 4, 5, 7 and 11 in Diagnostic Ultrasound: Physics and Equipment.
- Be prepared to discuss the key blocks of an ultrasound scanner

Important concepts and functions

2D grayscale image presents tissue anatomical structure and motion in two dimensions.
M Mode, Grayscale image of the tissue anatomical structure and motion along a line.
Pulsed Wave Doppler (PW). Flow measurement in one point. The flow is presented in a flow diagram where the y-axis represents the speed, x-axis represents the time and the intensity of the blood cells with a certain speed
Continuous wave Doppler (CW). Continuous Doppler. Flow measurement along one line
Color Flow (CD) Flow measurement in which direction and flow are presented in a color scale. The average flow both in space and time is measured and presented.
Power Doppler (PD) Flow measurement where the intensity of the returned Doppler signal amplitude is presented instead of direction. Especially useful at low flows.
Harmonic imaging Grayscale or flow measurement where one listens to harmonics instead of broadcast frequency spectra.

Function of the main controls

Scanhead Here you set the transducer/scanhead to be used.

B-mode / M-mode
Gain Amplification of the signal strength. Available for 2D, Doppler and color signal.
Time gain compensation (TGC) Amplification of the signal strength. Correction signal strength depending on the distance from the transducer.
Zones number of transmit focus in 2D image.
Focus The location of the transmit focus.
Depth The maximum depth to be shown.
Compress Changes the transfer function between signal strength and the gray scale image.
Zoom Enlarges the displayed image.
HD Zoom Enlarges and optimizes settings for a selected area.

Doppler/ Color flow
Baseline Represent speed or frequency zero during flow measurements. Can be moved by pressing this button.
Scale Adjusts the scales for flow measurement.
Filter Setting the filter for flow measurement.
Ang Corr Angle Correction PW Doppler.
SV Size Adjust the size of the sample volume of pulsed Doppler.
Steer Adjust the angle of the box during color flow flow measurement.

Other important concepts
Cineloop A digital image memory where the latest pictures are stored.
Persistence Averaging ultrasound images over time

Equipment

- HDI 5000, Diagnostic ultrasound scanner
- Philips Medical EPIQ 7, Diagnostic ultrasound scanner
- ULA-OP, research ultrasound scanner
- Tissue phantoms
- Artefact phantoms

Observe!

Take great care of the equipment which is being used during the laboratory exercise. A new transducer costs 100 000 SEK+ so don’t throw them in the floor and take great care of the cable.

Instructions

The laboratory exercise is divided into six parts:

1) Discussion of how a diagnostic ultrasound scanner is constructed

2) Investigate an ultrasound scanner's performance:

Quality control of the ultrasound image using two different transducers. The most important parameters to examine are:

- Axial resolution
- Lateral resolution
- Dead zone
- Penetration depth

More information how a quality control is performed practically is given during the lab.

Resolution before focus

	Linear array	**Phased array**
Axial resolution		
Lateral resolution		

Resolution in focus

	Linear array	**Phased array**
Axial resolution		
Lateral resolution		

Resolution after focus

	Linear array	**Phased array**
Axial resolution		
Lateral resolution		

	Linear array	**Phased array**
Dead zone		
Penetration depth		

Investigate also

- What happens if you change the number of focus/enlarge focus zone and its location
- What happens when turning on SonoCT/Compound imaging
- What happens when turning Harmonic imaging

3) Explore the function and operation of the ultrasound scanner by scanning yourselves.

Organs/places to scan:

- Measure blood flow in vessels, preferable one of the neck arteries (carotid artery). Use Pulsed Wave Doppler and Color Doppler, see if you can find both an artery and a vein.
- Abdominal and liver (the liver has different speckle pattern compared to other tissues)
- Kidney (Turn on Power Doppler when you have found it)
- Heart (try to run M-mode Doppler of the heart valves, try also Color Doppler)

4) Investigate a fetus phantom.

- Try to find the different cross sections shown in the printed images given.
- Estimate the gestational age the of the fetus in the fetus phantom.
  The following equations can be used:
  Gestational age = $58.65 + 1.07*BPD + 0.0138*BPD^2$
  Gestational age = $30.7 + 6.95*FL - 0.202*FL^2 + 0.00337*FL^3 - 0.0000181*FL^4$
  Where BDP is the biparietal diameter and FL the Femur length.
  Gestational age will be given in days and the distances in mm with on decimal and a mean value of at least three measurements should be used.

5) Investigate a phantom containing different artefacts.

- Describe how and why the artefacts arises.

6) Blind test – Pair the parameters changed in the ultrasound images (given in the table below) with the changed settings on the ULA-OP ultrasound scanner

Setting	**Mode (1,2,3,4 and 5)**	**Explanation**
Dynamic range		
Persistence		
Pulse length		
Frequency		
Switched off transducer elements		