Chapter 1: Getting Acquainted with Ultrasound

Knobology

Knobology is an accepted term in clinical ultrasound for the knowledge required for informed setting of all the dials and options on a modern ultrasound system. Tongue imaging using ultrasound has its own knobology. Even though you will always get an image with the default settings on your ultrasound system, there are some important guidelines that will make a big difference to the quality of the image sequence that you end up with once the data is stored on your computer.

Imaging controls can be described as pre or post processing. All functions requiring you to rescan to adjust them are pre processing whilst those that can be applied to a frozen image are post processing. Post processing is not relevant to tongue imaging as we export the data from the video port or internal image buffer before…..

Depth Setting

For most adults the depth from the chin to the roof of the mouth is less than 8cm. Furthermore the strength of signal diminishes with depth and the signal is often too weak to be visible beyond 8cm (see *Probe Frequency* for more on this). So a depth in the range 7-8cm is a good default. A shorter depth setting will often result in a faster frame rate. This is because depth is directly related to the amount of time the ultrasound machine waits after each pulse in order to record echoes from reflecting tissue boundaries.

If your speaker has a small mouth, there may therefore be a time resolution advantage to reducing the depth but there is a counter-argument to maintain the same depth for all speakers so that conditions such as spatial resolution and frame rate are constant.

Probe frequency

Probes often offer 2 or 3 possible operating frequencies that can be selected from the ultrasound control panel. These are usually in the range 2-12MHz. Lower frequencies can penetrate

to a deeper depth but the associated longer wavelength means that the axial (radial) resolution is poorer. Generally, it is desirable to forego some resolution and go for low frequency in order to get the best penetration and therefore the brightest tongue contours for high tongue positions. Again, as with depth, if you have a speaker with a small mouth, the extra penetration may not be required and a higher frequency and therefore better axial resolution can be achieved. As a guide, 5MHz corresponds to an axial resolution of 0.9mm and a penetration depth of approximately 60-70mm. [The exact depth at which no further reflections will be visible depends on the proportion of fat and muscle tissue and on the number and index of reflective tissue boundaries within the tissue].
General rule: Use the highest frequency probe that will penetrate to the depth of the palate.

Probe radius
The probe radius describes the curve of the tip of the probe [Note: Applies only to convex probes not linear ones]. Endocavity probes often have the smallest radius of about 10mm. Small radius probes often have a wider field of view (see *Field of View* for more on this). Their small tip size also means that they can be more easily positioned farther from the chin to avoid mandible shadow obscuring the tongue tip. Since endocavity probes have long rigid handles, it can sometimes be difficult to get the best angle because the probe handle is stopped against the speaker's chest. Getting the speaker to lean forward will help. Incidentally, leaning forward also extends the chin, making it easier to place the probe farther from the mandible. The longer probe handle is also more liable to get knocked if the speakers are restless (e.g. children) which can lead to undesirable movement of the probe relative to the head during a recording……….

Scanline density (frame rate)
This is not often something that the user is given direct control over. Scanline density refers to the number of radial echo pulses recorded in the process of creating a full sweep of the display. Along with *depth* and field of view, line density is inversely related to the rate at which complete sweeps can be completed. On the Mindray DP6600 for example there is a simple choice of toggling between 'high density' and 'high frame rate' which essentially halves the number of echo pulses used and therefore doubles the current frame rate (as determined by field of view and depth). With the Ultrasonix SonixRP machine, the scan line density is completely configurable. By reducing the number of scanlines, very high frame rates are achievable (>300Hz). This is at a cost of losing angular resolution [Wrench, Scobbie, 2011]. Quite often the user has no control over scan line density.
General rule: For DP6600 always set to high frame rate to avoid discontinuities in the output video images. For other systems try to maintain a high frame rate

Field of View
For tongue imaging in the midsagittal plane it is optimal to keep the entire tongue surface from tip to the epiglottis within the image. A field of view of around 120-150 degrees is usually required to achieve this. For some studies a 90 degree angle can be considered adequate, which is enough to view from the tip to the pharynx. Indeed, if the speaker has a high hyoid position, the shadow created by the hyoid may obscure the tongue root making a wider angle redundant. A reduction of the field of view from the maximum setting is often achieved by maintaining the same scan density but omitting some scanlines at the outer limits of the maximum field of view. So reducing the field of view often results in a higher frame rate with no loss of angular resolution. An angle of less than 90 degrees will show only a fraction of the tongue surface and is therefore not recommended for midsagittal tongue imaging.
General Rule: Use the smallest field of view that that encompasses the tongue surface for all participants in a given study.

Persistence (Frame averaging)
Persistence is the usual term given to the practice of averaging the data from two or more complete sweeps. It is also sometimes referred to as time smoothing, temporal smoothing, frame correlation or frame averaging. When looking at static structures this serves to reduce speckle and so make the image clearer. If the tissue structures under observation are moving (as the tongue often is during speech), persistence has the undesirable effect of producing double (or triple images). Persistence may sometimes be designated a different name (e.g. frame averaging). Most ultrasound systems have this option so look out for it under a different guise if you can't find reference to persistence.
General rule: Always SWITCH OFF PERSISTENCE if possible.

Edge Enhancement
Edge enhancement is used to enhance the definition of the echoes in the display. Increasing

edge enhancement will make an image appear 'crisper'. Implementation varies between manufacturers and seems to be a form of adaptive contrast or texture enhancement. It is not entirely clear how this operates but may do so at pre and/or post processing stages.

Greyscale and dynamic range

The strength of echo returns at different depths are visually interpreted as brightness varying from black for no reflection at a given depth to white for a very strong reflection at a given depth. Control of how the mapping between echo return strength and greyscale brightness levels is often provided to the user. In tongue imaging we are interested in the brightest tissue to air boundary reflection and not in differentiating between different weaker reflections between different tissue types. For this reason, there is no significant advantage in choosing one greyscale mapping over another.

Dynamic range defines the echo strength below which everything is black and the echo strength above which everything is white. This is very like the settings used to control the greyscale on acoustic speech spectrograms. Lowering the dynamic range will increase the contrast (which is good) but weak reflections may be lost.

General rule: If these settings are implemented in a pre-processing stage then you may be able to improve visibility of weaker reflections from the tongue root with adjustments but when in doubt revert to the default settings.

Acoustic power

Most systems will allow control of the amplitude of the transducer array output. The power, particularly low power, will affect the amount of penetration. However, as you increase above the base setting (often 0dB) you get little extra penetration and the whole image gets brighter so that you lose contrast. Acoustic power also affects how much heat is generated by the transducer.

General rule: Use the lowest power that gives the penetration you need. If in doubt then use the default setting.

Gain

Gain is the term given to the amplification of the received signal (as compared to Acoustic power which controls the transmitted signal strength). There can be three ways to control gain.

1. Overall gain is the amount of gain applied to the entire image.
2. TGC (time gain compensation) or DGC (depth gain compensation) is gain applied according to the depth of the image.
3. AGC (automatic gain control)

Focal points

The issue of lateral (angular) in-plane resolution must be considered on two separate levels. One is the scan line density, which we have already looked at. The other is the sharpness each of the individual echo pulses. You could think of each echo pulse as a beam of torch light, where the lens can be moved to concentrate (focus) the light to make it bright and narrow at a particular distance. With ultrasound there is often the option to set this focal distance and it is best to set it somewhere in the range 4-7cm where the tongue surface is likely to be.

There is also the option to set more than one focal point. This should be avoided as, for example, two focal points will require two pulses to be fired for each scanline, each having a different focal distance.

General rule: Ensure that ONLY ONE FOCAL POINT is selected and that it is set at a distance at which the tongue surface will often be.

Cine Loop

NTSC/PAL video output

When trying to get image sequences out of an ultrasound machine and stored onto a PC, it is generally not possible to

Older ultrasound systems provide North American NTSC or European PAL standard video output. Newer systems may only provide VGA, HDMI or other digital image standards.

Less common features

Harmonic imaging

Compound imaging

An internet search will reveal many names and varying techniques. Compound Resolution Imaging, SieClear™, SonoCT and Aplipure are but a few names you'll find described. The aim is to interrogate an interface with beams from varying directions which have been electronically steered. This increases the ideal scenario of the beam being 90 degrees to the reflector resulting in the reduction of artifacts and evening out of otherwise bright reflectors from interfaces that are parallel to the transducer face. Contiguous borders are also enhanced, especially those of curved or anisotropic structures. Varying levels of compounding are available and when artifacts are a helpful diagnostic tool, as in micro calcifications in breast scanning, the level of compounding should be considered and prudence used. Figs 28 and 29 show the same image with and without the application of 'compounding'.

User safety

- DO NOT drop or mishandle the transducers. Transducers are very expensive to replace and cracked housings are a safety hazard to users. I.e. Gel seeping through a crack into the piezo array is not a good thing.
- Freeze the image when you are not actively scanning. The probe will heat up if the probe is left transmitting into air. It will dry out any gel on the transducer and sometimes even uncomfortably hot when next placed under the chin.
- Use power settings that are "as low as reasonably achievable" (ALARA) yet still provide a clear tongue surface.
- Clean transducers with alcohol wipes before and after each examination.
- Do not allow transducer to soak in Cidex for more than one hour (Cidex or bleach will eventually destroy the acoustic membrane on the transducer face)

Chapter 2: Tongue image artefacts

How the ultrasound image is formed

The interpretation of an ultrasound image must be approached with the same caution you would extend to working out in what direction and how far away someone is actually standing in a hall of mirrors. Strictly speaking it is more closely analogous to standing in a pitch black room with semi-silvered mirrors and a torch and trying to work out how far away the mirrors are located based only on the reflection you can see of the torch.

The tongue body is often flat and perpendicular to the direction of the ultrasound beams with an air boundary beyond it. This is analogous to facing a fully silvered mirror and seeing a simple reflection. However, the tongue tip and root are often not at right-angles to the ultrasound beam. In such cases the reflection is weak and in some cases, reflects off secondary boundaries away from the direction of the ultrasound beam creating artefacts.

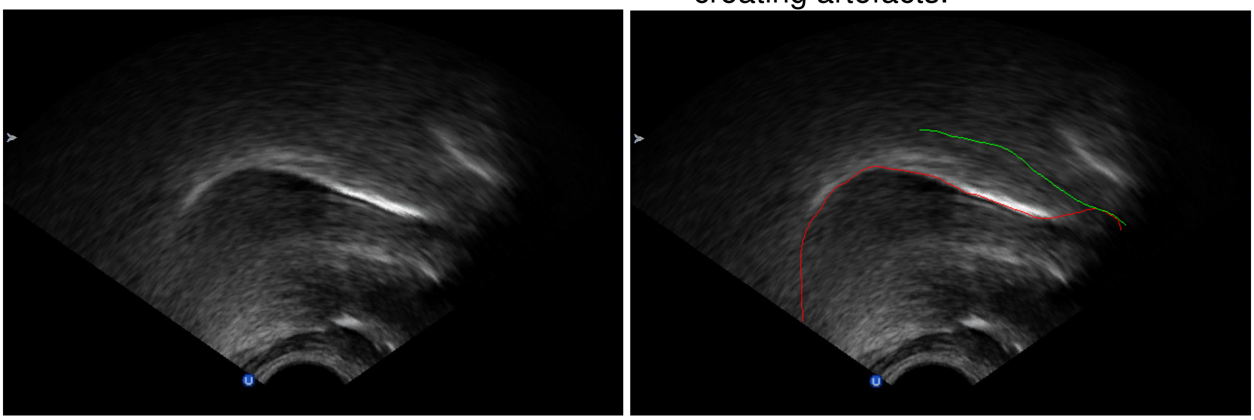
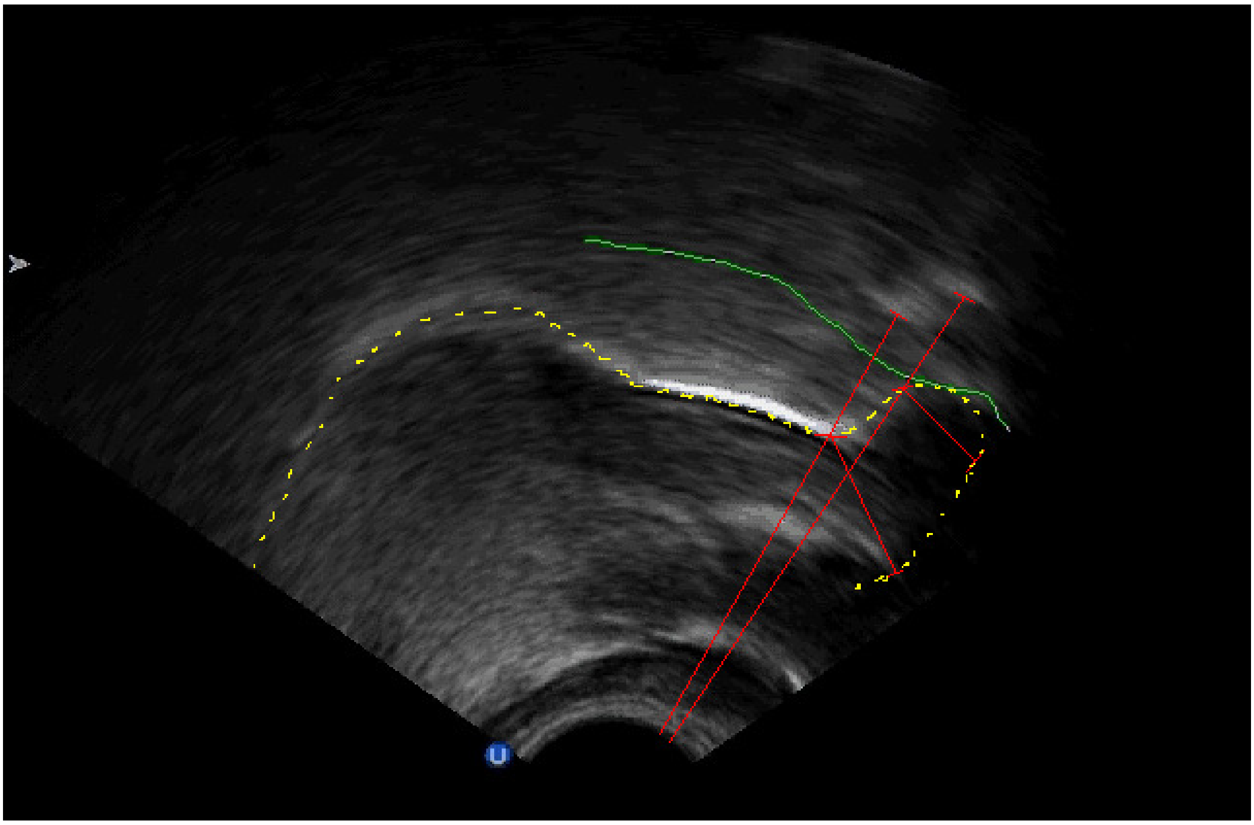


Image artefacts are problematic when they form a subjectively plausible continuation of the tongue surface contour. **For example**: In the above image, it is tempting to draw the tongue tip on the right so that it meets the bright line. However, with knowledge of where the palate lies it becomes apparent that the bright line is an artefact. There is also a bright reflection above the tongue body. This is also an artefact but the presence of an obvious tongue contour below it makes it easy to disregard when drawing the contour.



Chapter 2: Getting numbers from images

Chapter 3: Are these tongue contours different?

Chapter 5:

Chapter 6:

Chapter 7:

Chapter 8:

Chapter 9:

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