

The Return of the Words

This time, let's cover the reality of image acquisition using real-time volume imaging. There are pros and cons to this technology. See if you can spot the differences. Pro: it is real-time, quick, and tracks beat to beat as the patient breathes and coughs. Cons: it quickly tracks beat to beat as the patient breathes and coughs in real-time. For anyone that has ever tried to photograph animals or children, you understand what this can mean. The subject matter may shift or change suddenly so you had better be prepared to take the picture! If you have more time following the initial picture, optimize and shoot again. Still more time? Add layers, a filter, a different angle, anything that continues to capture the essence of the scene you see.

Every volume clip has the chance to tell a greater story than any 2D clip. There is so much more data available beyond just the front-facing cut plane. It is because of these universal principles that I use and promote a technique I will describe to unaccustomed users *and* volume familiar users alike. By using this workflow, you should feel comfortable that each exam will not only have all of the volume data available for processing, but also the *best quality* of that data by the time live scanning has ended. The language I use here is quite informal. I find that if I make things too focused, users will use the skills – but only to that one target. The beautiful thing about this, is that it is a *universal technique*. Try it for tricuspid valves, LAAs, RAAs, RVOTs, and of course, the mitral and aortic valves. Let's get scanning!

What you are about to do is take a high quality, full volume "scouting" image. If the study were to end following this image, you would have the basic volume data of the targeted *thing*. It might not have the highest frame rates (aka *volume rate*).. It might not have the highest spatial resolution.. yet the point is, you *will have it* to work with. Start with a good 2D image of the *thing* it is you would like to image. Try to have it in the center of the image. Try to have it onscreen. (Neither of these are required – just helpful.) Once visualized, press the (4D) button to initiate volume imaging. (You may see the image optimize if TEQ is enabled at rev 5.0 or later.) Capture the image.

From this point, you should begin a flow-chart sequence of self-questions about your image. Ask yourself one or more of these questions at each step.

Is this image the best I believe it can be? / Does it answer the question? / Does it illustrate the image's point?

- a. **No?** What don't you like about it? / What needs to improve? Is it.
 - i. Need higher VPS (aka temporal resolution)?
 - ii. Spatial resolution?
 - iii. Needs more definition?
 - iv. More or less gain?
 - v. *Is the POV impactful?*
- b. For each "**yes**" answer, the action is to continue on progressing through your study.

Capture the image/clip after each step and ask the question again. Repeat! The entire process should take a *maximum* of 60 seconds total. A few seconds to position and optimize the 2D image.. a few seconds to acquire a 2-3 second/beat volume image while you assess its quality.. a few more seconds to tweak one or two direct parameters.. a few seconds to assess and acquire... a few seconds to change one or two settings.. a few seconds to acquire... and so on. At each step, you are fine tuning each "layer" and saving your progress step in-case the image is lost, the exam ends, or the changes made were not beneficial. There is even a logic to the order of the questions. Let's break down these questions and answers further.

As the initial "scouting" full volume is being acquired, note the playback speed of the volume. Not just the *numerical value* of the VPS, but also the playing *visual quality* of the image. *Real-time* playback is accepted at ~14 to 15 frames per second [fps] or volumes per second [vps]. Lesser vps may be acceptable depending on your end goal for this image – especially if your ultimate goal is a static frame measurement *from* the stored clip. **How do you increase the temporal resolution?**

- ✓ Decrease your line density. The SC2000 offers users direct manipulation of their scan line density through the use of its SpaceTime controls. As covered before, "*T settings*" (T1, T2) decrease the number of scan lines in favor of a higher temporal resolution. This achieves the highest vps by maintaining the largest (90°x90°) volume size. It is useful to visualize valve motion (e.g. SAM), high heart rates, and hemodynamic *flow*. The SpaceTime (S/T) knob is located in the left most LCD knob position.
- ✓ Decrease your volume size. The SC2000 allows users to change the Azimuthal and Elevation planes on the fly. The user has the option to make changes as a defined aspect ratio by using the volume size LCD

knob (left of the center DVD slot). This will in-/decreases the volume size by X by Y as read out on the screen. Alternatively, by depressing the knob, users will cycle through Azimuthal and Elevational specific augments to in-/decrease in that orientation specifically. Either of these controls work to decrease the scanning area thus increasing temporal resolution. (Once a volume aspect is $<90^\circ$, the *volume tilt* function becomes available. See below.)

- ✓ Decrease your depth. The same rules that work for 2D work for Volume imaging. Decreasing the depth reduces the pulse repetition period (more pulses per second = faster data refresh rate).
- ✓ Quick trick! Use the 2D + RES + 4D trick covered in Volume 1 to quickly “mini volume zoom”!

Once you have high enough volume rates, you may actually find yourself with an *overabundance* of volume rates! This is a great problem to have! Now it's time to trade those temporal units back into spatial definition.

- ✓ Take your “*T-setting*” back up to an “*S-setting*” (*S1, S2, S3*). The *Spatial* settings on the SC2000 add scan lines to the field of view to increase the image resolution. These settings are useful when assessing anatomic structures. The higher you go up to *S3*, the more gain may appear in the FOV due to the increased sensitivity. Use the (4D) knob to adjust.

Things should be looking very appealing right about now. You have great temporal resolution and great spatial resolution. There are only a few more tips I can offer to fine tune from here. You're in it to become a pro, aren't you?

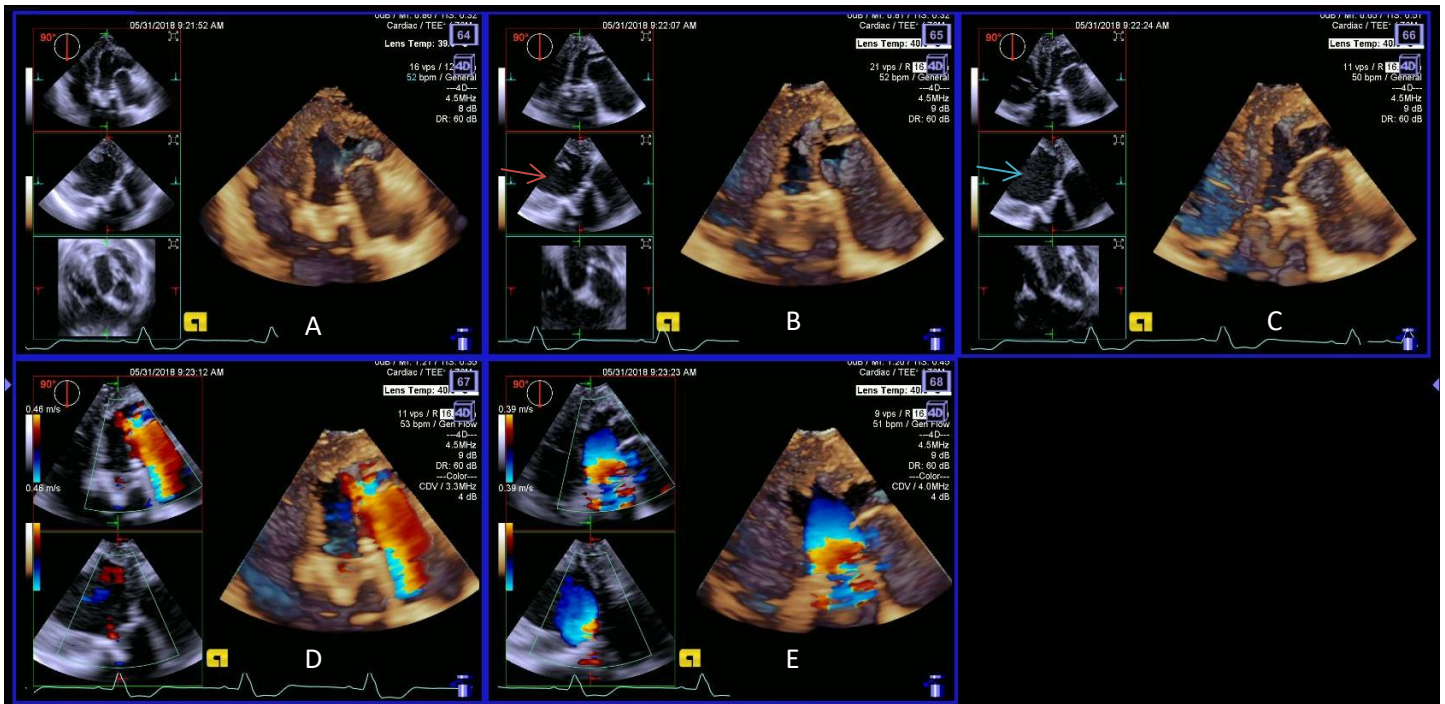
- ✓ Make sure the *Volume Enhancement* feature is turned to 0. This is found on the left hand side of the screen graphic user interface (aka GUI). This is a preset-able feature and can be stored as *off*. This feature applies a smoothing curve to the edges of the volume data for users that prefer a softer look.
- ✓ Play with the *dynamic range* control. Whereas gain controls the abundance of the stronger signal representation - the “black and white pixels” dynamic range controls the low level fill-in signals. In 2D imaging, we increase dynamic range to fill in tissue details where gain alone only affects larger targets. Try decreasing dynamic range (DR) to clear out atrial speckle while maintaining a strong mitral valve image. Try increasing dynamic range to slowly fill in structures without severely impacting the overall gain of an image.

4D Gain.

- ✓ This one is basically self-explanatory, yet it deserves this final mention to double check your gain settings once more before moving on. Try increasing and decreasing the overall gain or TCGs and watch if your targeted anatomy pops out further. Too much overall gain will render a fuzzy/snowy image. Decrease gains to show the depth and contour of the anatomy.

****Point of View**** Imaging is only data collection until it communicates a message. *The hole is located here. The sub-valve stenosis looks like this. Only this leaflet is affected. Puncture here. Yes, you have the leaflet.* This section is the second most important reason volume imaging exists, imo, just behind automated volume analysis. We'll get deep into volume orientation in a future installment, but for now, I would like to cover the *volume tilt* feature. The volume tilt feature is easy and quick to use, but can be somewhat tricky to pull off the first few times.

- ✓ In 4D imaging and once your *full volume* image is less than $90^\circ \times 90^\circ$, the volume tilt function appears on-screen in the heads up display area as coded to a soft key ~10 o'clock from the trackball. Press the button and use the trackball to beam steer the volume to different coordinates with the scanning pyramid. Use the side reference images to track your beam steering in virtual space.
 - Note 1: Do you recall beam steering in 2D imaging? When you shrunk down the sector width and swung the pie over to just focus on one object? It benefited from higher spatial and temporal resolution, right? That's exactly what we are doing with volume tilt – only now we have more dimensions under our control.
 - Note 2: Notice I wrote “*full volume is less than $90^\circ \times 90^\circ$* ”? Volume tilt does not work in conjunction with the RES+4D zoom technique. The system accepts the designated area established with the RES box translated into 4D. It will not pan that area around within the volume once scanning. Frankly, if you master the (BiPlane+)+(RES)+(4D) combo, volume tilt will be redundant.
- ✓ The Color, PW and CW knobs double as X, Y, and Z axis rotation tools in volume imaging. Remember which axes are which and around which are what directions? Exactly. Here's the easy way to remember the tools' function. The question just posed had three possible answers: Yes, No, or I don't know. The X rotation around the horizontal axis looks like a head nodding “yes”. Same with No or the Y rotation. It rotates around the vertical Y-axis. The Z-axis “shrug” may take a bit more imagination, but if you remember two out of three, I hear that ain't bad. (Of the three, I use the Z-axis rotation tool the most to anatomically align the volume image again after syncing to a plane.)



This is an example of the process in sequence. The images were acquired from deep transgastric to interrogate and possibly visualize the AVR. Image A is a full volume acquisition. The data is ok. Volume rates are adequate at 16 vps. We pressed for higher VPS by backing out to 2D, then RES+4D to achieve 21 VPS. Now, with volume rates in excess, we changed to a higher S-setting to delineate anatomy. The highest line density setting set it back to 11 vps. Was the trade-off worth it? Maybe – I know I have examples in data sets A and B with higher temporal resolution should a question arise from this data. Data sets D and E added color to assess the AI (D) and increased flow convergence (E). Time stamps are also noted on the images. 9:21:52 am to 9:32:23 am is 91 seconds.