3D matrix array TEE probes provide options for both 2D and 3D imaging. Indeed, their utility in obtaining multiple 2D images simultaneously is reason alone to purchase them. 3D volume visualization of mitral valve, aortic valve and cardiac sections provide insight into function. 3D post processing of 3D volumes allows analysis of ventricular function, mitral and aortic valves.

**2D Matrix Probe Analysis**

GE Matrix Biplane Imaging (X-plane)

GE Matrix Triplane Imaging
TEE matrix array probes allow for simultaneous Biplane visualization of 2D images. Usually this starts as orthogonal planes, with second image plane adjustable. Provide high frame rate resolution.

All vendors have this on their echo machines. Some also provide a tri-plane imaging capability.

Biplane (X-Plane) imaging is useful in examining the mitral valve. Starting this exam in the 2D mid-commissural views allows you to obtain orthogonal images from anterior lateral commissure to posterior lateral commissure with and without color. Useful for defining mitral valve leaflet coaptation (normal, billowing, prolapsed), measuring leaflet coaptation length.

Biplane (X-Plane) imaging is very useful in examining aortic valve (root), helping to define region of pathology with high frame rate resolution.

Biplane (X-Plane) imaging is very useful in looking at LV wall motion. Use of 2D Tri-plane imaging can be set up to see ME4ch, ME2ch, ME LAX, visualizing all LV wall segment function simultaneously.

3D Matrix Array Volume Sets

The acquisition of 3D Volume sets by 3D TTE or TEE probes provides a huge database to be mined into multiple 3D or 2D images. To investigate these 3D volumes, echo vendors have enhanced classic 2D measurement tools. In the newer platforms we can now easily measure distance, curvilinear distance, area, angles and volumes. Recent advances make it easier to acquire color imaging and obtain 3D volumes with color flow information.

Vendors have developed programs to facilitate analysis of 3D Volumes: 1) multi-planar reconstruction programs 2) multi-slice imaging capabilities 2) LV analytical packages 3) MV analytical packages. Other analytical “packages” are being developed including color flow analysis.

Current 3D TEE echo machine vendors are GE, Philips and Siemens. Tom Tec is a German company that has pioneered 3D echo post processing analysis of 3D volumes. Tom Tec has licensed some of their analysis programs to all three vendors. You will recognize their D’art, slice, Multiplane Analysis, and mitral valve analysis package in GE and Siemens applications. It is also licensed to some Cardiology PAC systems. Philips certainly has modified their new Epiq platform to allow 2D measurements only previously available through Tom Tec (angle measurement, circumference).
Uses of all these packages are best done when the user has an understanding of cardiac anatomy, physiology and dynamics. Obviously we learn more about anatomy and physiology as we view 3D images. Relying solely on automated programs may lead to incorrect measurements when needed adjustments are not made.

The reader is referred to the “Cardiac Anatomy for the Echocardiographer” in your syllabus. PowerPoint presentations illustrating use of multi-planar reconstruction, and multi-slice reconstruction are attached in your syllabus.

**3D Matrix analysis programs**

Three things are needed to utilize these programs;

1) Knowing what measurement you want. What anatomical structure do you want to visualize. How do you want it visualized? How do you want to visualize it playing in the cardiac cycle? How and when do you want to take your measurement?

2) What are the limitations of my image: frame rate, resolution? Where is the pathology in the cardiac cycle and am I able to visualize it accurately with my frame rate/ resolution: color ERO, torn chordae, prolapse etc.?

3) How to utilize the 3D programs to dissect and obtain the above.

The good news is that the most difficult thing about using the 3D machines/packages is “getting the chance to do it”. This means having the machine and off site analytical station!
Multi-Planar Reconstruction

3D volumes obtained can be dissected to “investigate” what is inside. Multi-planar reconstruction (MPR) provided by vendors most commonly allow users to dissect a 3D Volume and visualize four 2D echo sectors on a screen: 3 orthogonal planes X-Y-Z and a fourth of your volume. You can thus slice your 3D volume in 3 different ways and visualize them all. Programs allow you to make the X-Y-Z planes non-orthogonal if you wish. Vendors allow you to move in and out of this 4 screen display to focus on specific views or expand to more views when a multi-spice mode is applied.
MPR applications also have multi slice applications. MPR and multislice are useful for examining mitral and aortic valves and LV function. More recent programs from vendors also allow you to make angle measurements. This can be useful if you and your surgeon look at mitral leaflet angles to help determine possible of success of ring annuloplasty in treating Type II (Functional) MR.

A Power point using Philips MPR is provided to orientate you. Concepts in that Power Point can be easily applied to GE, Siemens, and Tom Tec multiplane reconstruction programs.

**Specialized 3D Matrix Analysis Programs**

3D TEE echo vendors have developed and continue to develop their 3D post processing software. The array of programs available is truly a goldmine for the interested cardiac echocardiographers. Depending on your surgical/interventional practice (AV repair, MV repair, Valve replacement, CABG, TAVR, E-clip, dual chamber pacemaker synchronization etc.) specific programs may have more or less interest for you.

Programs available include:
- LV analysis; wall motion, volumes, EF, wall segment motion/timing in cardiac cycle
- MV analysis
- AV analysis
- RV analysis

When using automated MV or AV analysis packets the user is cautioned to understand them, their assumptions, and point of measurements. They can be modified by the user post automatic analysis and this may be prudent at times. However they do give useful information.

**Left Ventricle**

In general, the things we want to know are LV global function, segmental function, volume and segmental synchrony/dysynchrony.

Acquisition of a Full LV Volume, optimizing borders resolution makes this possible. Vendors have programs to address this. Most use the AHA Myocardial 17 segment model. Validations of these models show them to be reasonably accurate.

Useful in valve disease for defining LV wall motion and volume. Useful in examining LV wall motion and volume in CAD, heart failure. Saved on hospitals Echo PAC can be compared to future echoes.

Very useful in examining LV wall segment timing of motion in the cardiac cycle.
Mitral Valve

3D echo of the mitral valve is superb for obtaining basic views or defining advanced images in understanding MV anatomy and function.

Acquiring the MV volume in a mid-commissural (anterolateral-posteromedial) or long axis (anterior/posterior) views will set up the MPR images in the orthogonal views of: AL-PM, A-P, and base-apex for easier on screen cropping.

Playing of En Fosse view of the mitral valve gives global overall perspective of leaflet function. This perspective allows the viewer to specifically define region of commissural scallops, posterior leaflet scallops, and their relationship to the anterior leaflet. The classic symmetry in the ASE/SCA Mitral valve nomenclature is found often not to be present.

This En Fosse view is also helpful to assess the orientation of the mitral valve anterior leaflet to the aortic root. Classically we are told that the aortic root sits at the center of the anterior leaflet of the mitral valve. This is not always the case in pathology and has bearing on LVOT/aortic root relationships and flow dynamics.

Mitral Valve Multi Planar Reconstruction (MPR)

All vendors provide a way to “dissect” the acquired 3D volume into multiple 2D cross sections. They allow 4, 5 and 6 plane visualizations. Most commonly a 4 plane visualization is used.

This allows spatial examination of 3D volume in 2D segments. A very important concept to grasp, and skill to develop. A PowerPoint using Philips MPR is provided to orientate you. Concepts in that PowerPoint can be easily applied to GE, Siemens, and Tom Tec multiplane reconstruction programs.

MPR can be used to define region of billowing, prolapse, leaflet height, scallop height, MV annulus diameters, shape and circumference, annular dynamics, define pathology, and area of regurgitation ERO. MPR can be used post repair to define adequacy of repair, leaflet coaptation length commissure to commissure, and if SAM present the mechanism of SAM. MPR images can be sued to assess coaptation heights from commissure to commissure and mitral leaflet coaptation tenting height and area. All vendors provide the necessary programs to so this. Application of MPR to mitral valve color flow 3D volumes allows measurement of the mitral regurgitant ERO.
MPR imaging facilitates understanding of normal apical movement of mitral annulus in systole and abnormal basal movement in Barlow’s type prolapse. Multi-planar analysis allows the imager to dissect and measure the MV apparatus, aortic root and any other cardiac structures however you wish. Your understanding of what you need, what your surgeon wants and how to assess the MV post repair is your limitation.

Phillips Multi Planar Reconstruction of Mitral Valve
Mitral Valve MPR Multi-slice

All vendors provide the ability to multi-slice the 3D volumes from a 2D MPR image. This is very helpful in examining the mitral valve. Allows you to slice the MV from commissure to commissure to look at coaptation length, specific region of billowing or prolapse, define ERO, leaflet/leaflet heights, region of SAM.

Phillips Mitral Valve i-Slice
GE Multi Slice of the mitral valve
Mitral Valve Analysis Packages

All vendors provide mitral valve analysis packages. These have been developed to define mitral annular geometry (annular diameter, circumference, height, NPA angles etc.). Again it is best to understand the anatomy that you are trying to measure and the limitations of each program.

Phillips Mitral Valve Analysis

TomTEC Mitral Valve Analysis
Aortic Valve

3D acquisition of the AV leaflets is affected by their movement between being parallel and perpendicular to the echo transducer beam as they open and close in the cardiac cycle. When parallel to the echo beam leaflet resolution is poor. Pathology progressing from sclerosis of leaflet to calcification tends to improve imaging of the aortic valve leaflets. The downs side is that aortic root calcification causes 3D shadowing.

I prefer to obtain the aortic root 3D image in the long axis view so that I obtain the LVOT/Aortic Root/Ascending Aorta for analysis. Short axis imaging of the aortic root can help define leaflet structure, orientation and help understanding of the LVOT geometry.

Aortic Valve Multiplane Reconstruction and Multi Slice

Can be used to define aortic root dimensions (diameters, circumference) of annulus, Sinuses of Valsalva, STJ and leaflet prolapse/angles.

Multi-slice applied to MPR of the aortic root can provide exceptional analysis.

Multiplane imaging with color can be useful in defining paravalvular leaks and measuring their ERO.

3D imaging is especially useful for the surgeon planning repair of the aortic root and assessing the adequacy of repair.

Aortic Root
Phillips Aortic Root Matrix MPR and Multi-slice

Phillips Aortic Root MPR dimensional measurements
Right Ventricle and Tricuspid Valve

In general, the RV and TV do not image as well with 3D because of where they lay. With pathology they dilate and are imaged better.

Vendors are developing RV analytical packages.
**Learning to Use 3D MPR, Multislice and Other Analysis Programs.**

To become facile and quickly use these 3D programs in the operating requires: 1) knowing what you wish to find and measure and 2) being facile with the programs.

In my experience, to become facile with the programs requires some practice best done outside the operating room. Ideally, to practice outside the operating room you will need either 1) on off echo machine PAC system storing your echoes and using the software platform on your echo machine, or 2) an off echo machine Q-station, echo pack to work on outside the lab, or 3) purchase3D program to place on shared laptop.

When purchasing an echo machine, coordinate how its 3D images are stored on your hospital’s PAC storage system and what post processing 3D software you may use. Having a 3D echo machine vendor different from your PAC storage vendor may require upgrades to utilize 3D store volumes.

**References**
