4D Auto RVQ
(Right Ventricle Quantification)

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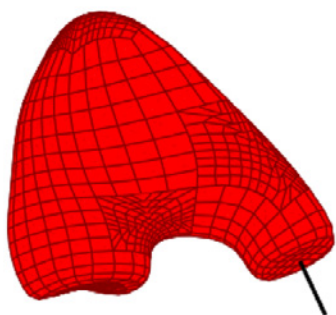GE Healthcare

Introduction

Right ventricle quantification has become increasingly important especially in patients with pulmonary hypertension or left ventricular dysfunction where the functional and anatomical performance of this chamber is key.

In current clinical practice, manual measurements in Magnetic Resonance Imaging (MRI) are considered the gold standard for quantitative assessment of RV volumes and ejection fraction. However, MRI may not always be available and is also time consuming to perform.

Echo based 4D quantification tools for the right ventricle have existed for some time, and are available from several vendors. These tools provide more objective and accurate measurements as compared to those derived from 2D, where access to desired views may be more difficult.

The 4D Right Ventricle Quantification tools are usually (semi-) automated to achieve quick access to the measurements of interest.

GE Healthcare has over the years introduced a series of quantification tools for 2D (e.g. 2D Strain, AFI and 2D Auto EF) as well as for 4D (4D Auto LVQ, 4D LV Mass, 4D Strain, 4D Auto AVQ). GE Healthcare has also licensed tools from TomTec.™ These tools, RV Function and Mitral Valve Assessment, were plug-ins into our Vivid™ E95 4D ultrasound system and the EchoPAC™ work station. We have now implemented GE Healthcare's 4D Auto RVQ tool as a replacement for TomTec's RV Function.* This tool is seamlessly integrated into the Vivid system's workflow providing quick access to 4D raw data analysis.

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Method

To measure the RV cavity volume during the cardiac cycle, a semi-automated segmentation algorithm is used. The algorithm is initialized with user-defined landmarks which locate and scale an initial 3D deformable model that represents the RV endocardium, the tricuspid valve plane and includes the RV outflow tract. The algorithm computes the deformation of the 3D model by solving a state estimation problem using an extended Kalman filter which combines RV geometry, a motion model, tissue tracking and edge detection algorithms.

4D Auto RVQ workflow description

The fully integrated tool requires a 4D data set containing the right ventricle acquired with a TTE or a TEE probe, either in a full volume or zoomed acquisition. Care must be taken during acquisition to ensure that the complete right ventricle and tricuspid valve are included, and that the volume rate exceeds 12 volumes per second for adequate temporal assessment and volume/EF calculation.

Speed of access to stored 4D images (from pressing the 4D Auto RVQ button on the touch panel until the 4D data is available for analysis) is twice as fast compared to its predecessor.

The workflow is divided into stages accessible both through the touch panel as well as on the main screen. When entering the tool, the first step is to adjust 2D gain and zoom if needed. These controls are available throughout the remaining stages to always ensure optimal image quality. Then at the **Alignment** stage (see Figure 1) one can quickly adjust the vertical axis so that it crosses through the Tricuspid Valve (TV) center point and the RV apex. The lower horizontal plane is parallel to the tricuspid valve at the base, while the upper horizontal plane is at the center of the RV. The alignment is done in 4 chamber and orthogonal 4 chamber views.
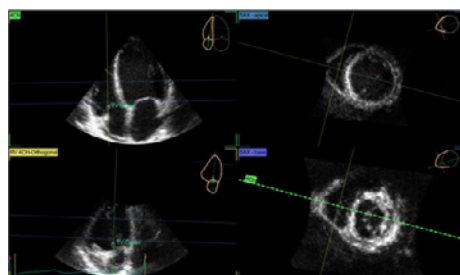
Six **Landmark** points (see Figure 2) are then placed (two tricuspid annulus points and the RV apex point in the 4 chamber view, and the RV/LV posterior and anterior points plus the RV free wall point in the short axis mid view). Placing of the Landmarks is required to aid the previously described algorithm in generating the RV model displayed in the **Review** stage. The contours can easily be edited by the operator through an intuitive and flexible user interface, either in an ED/ES 3 by 3 layout (see Figure 3), or in a Dynamic layout where the dynamic RV model is also shown. The editing offers undo/redo capabilities, and one can at any time go back and forth between the various stages as one observes the results and potential need for editing and adjustment. In the Review stage, the 3D model must be checked in all slices. To visualize the model in different slices, the user rotates and translates the reference slices in 2D view (dotted lines) to observe the segmentation in the other interactive views. The 3D model is adjusted by clicking and dragging contours in the 2D views as needed.
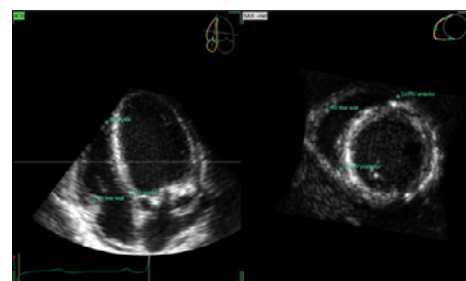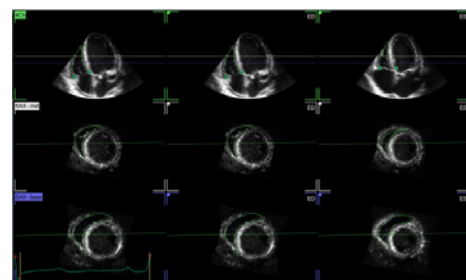

Figure 2. Landmarks

Figure 3. Review (ED+ES)

Figure 1. Alignment

RVOT editing is added to this tool and provides a useful additional editing capability. A full cycle dynamic loop can be played.

The same two layouts as mentioned above are also offered at the **Results** stage (Dynamic, ES+ ED) (see Figure 4). Both layouts provide the measurements and a time–volume curve.
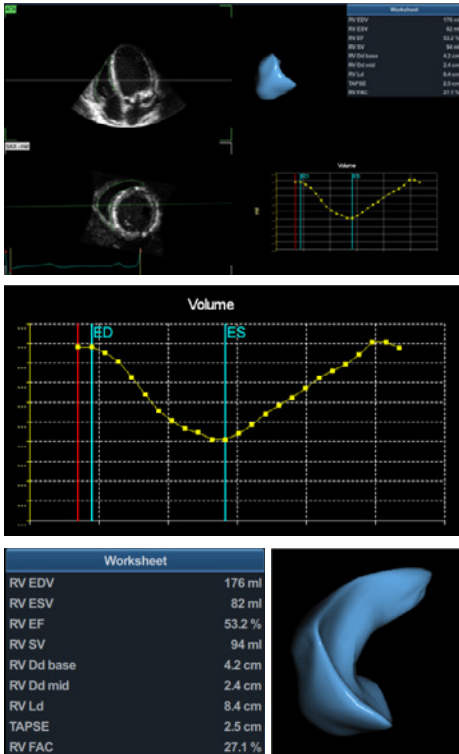

Figure 4. Results (Dynamic)

All measurements are transferred into the Worksheet for reporting when selecting the **Approve & Exit** stage. At this point, the tool also stores the complete setup and the results together with the exact screen view. When later recalling this particular image/loop and entering the 4D Auto RVQ tool, all prior alignments, landmarks, models and results are recalled for ease of continued analysis and review. This also serves as quality control.

Additionally, for documentation purposes at any time during use of the tool, image screen shots can be stored to the clipboard to be part of the study.

Validation

The 4D Auto RVQ tool has also been compared to the 4D RV Function tool by TomTec on a set of 15 right ventricle datasets, both normal and abnormal. Each data was automatically analyzed and then manually edited by an expert operator using both software. Results of the comparison are reported in table 1 as average ± standard deviation.

Table 1. Comparison between main 4D Auto RVQ and 4D RV Function tool by TomTec measurements.

	Measurement unit	Values 4D Auto RVQ	Values TomTec	Difference
EDV	ml	122 ± 32	122 ± 32	-0.1 ± 12.0[*]
ESV	ml	68 ± 22	66 ± 20	-2.1 ± 6.5[*]
EF	%	45 ± 7	46 ± 6	0.3 ± 4.5[*]
SV	ml	55 ± 15	55 ± 16	-0.1 ± 7.7[*]
Dd mid	cm	3.1 ± 0.7	3.2 ± 0.7	0.1 ± 0.6[*]
Ld	cm	7.9 ± 0.9	8.1 ± 1.0	0.2 ± 0.4[*]
TAPSE	cm	2.2 ± 0.5	1.8 ± 0.5	-0.4 ± 0.4[†]
RV FAC	%	40.4 ± 7.2	39.8 ± 7.8	-0.6 ± 6.3[*]

[*]Not significantly different (Two-tails paired Student's t-test with P>0.05)

[†]In 4D Auto RVQ, TAPSE is measured as the difference in distances between RV apex at ED and TV free wall annulus at ED and ES, meaning that the position of RV Apex for this measurement is fixed during cardiac cycle. This allows to mimic the TAPSE measurement that is usually performed in m-mode. Differently, in TomTec 4D RV-Function, this measurement is the difference in distances between Tricuspid free wall annulus and Apex positions at ED and ES.

Notes: The comparison of the RV basal diameter was omitted due to different computation/definition between the two tools. The measurement definition of TAPSE is also different in the two tools.

For further information regarding the validation, contact your local representative.

Limitations:

The measurements obtained from the two tools compared in the validation span a clinically significant range. However, the number of subjects analyzed is limited and further studies on specific populations are needed to identify the clinical benefit of using advanced 3D tools to characterize the RV.

4D Auto RVQ (and RV Function – TomTec) use an automated segmentation algorithm to initiate a 3D model from where the measurements are calculated. There is an inherent risk that these automated segmentation algorithms may give inaccurate 3D models. That means that the tool results should not be approved without review and, if necessary, editing of the 3D model. If the tools are used without review and editing, the expected accuracy will be negatively affected.

Imagination at work