Quantifizierung der Mitralregurgitation mittels geschwindigkeitskodierter 4D-MRT

Quantification of mitral regurgitation using velocity-encoded 4D-MRI

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Purpose

Various methods have been attempted to quantify mitral regurgitation using different imaging modalities, mainly ultrasound and magnetic resonance imaging. However, accuracy is still not satisfactory. One principal reason is that the acquisition of blood velocity is usually limited to one dimension. Our approach to overcome this limitation is four-dimensional (i.e. time-resolved three-dimensional) velocity-encoded MRI that provides a complete field of three-dimensional velocity vectors.
In this article we present our own software tool developed to quantify flow from 4D MRI and discuss the first results we obtained from it.

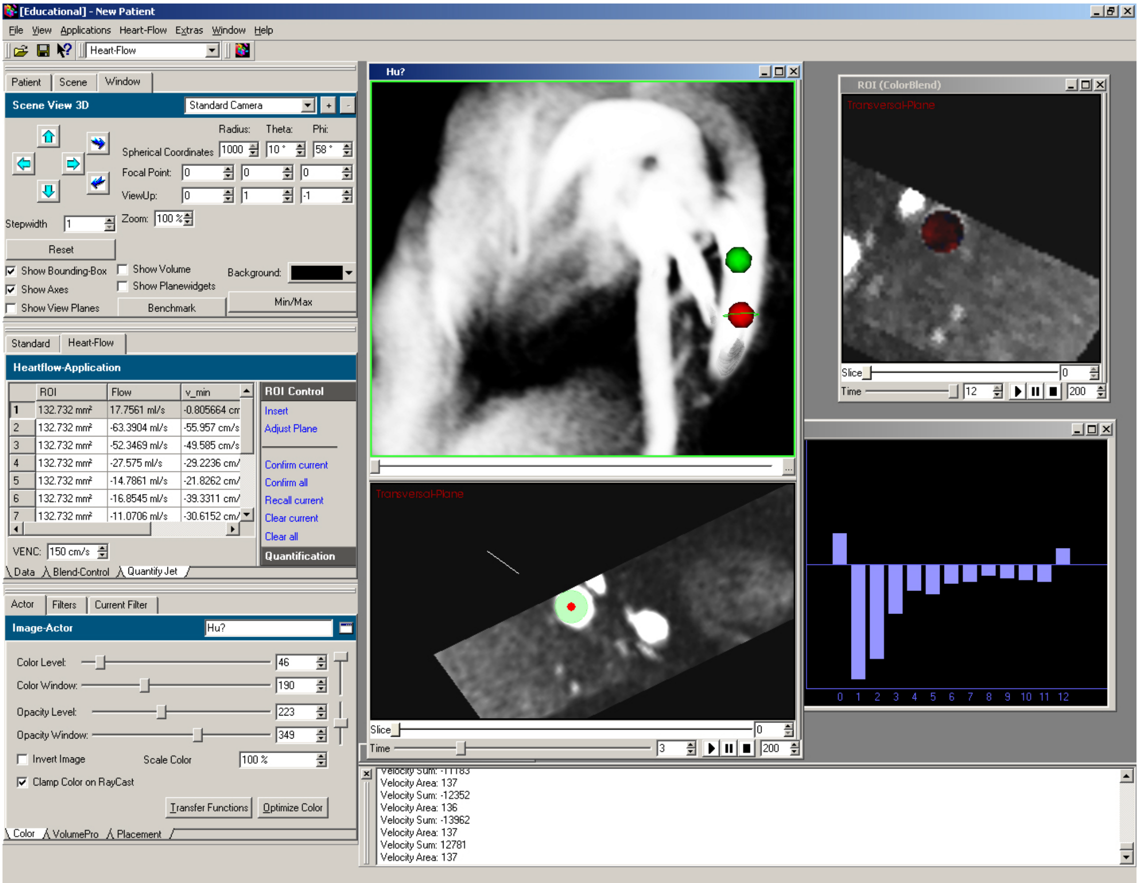
Material and Methods

In an animal experiment data was acquired from 6 pigs with surgically induced mitral insufficiency on a Siemens Magnetom 1.5 Tesla MR-Scanner. We used a specially adapted phase-contrast cardiac-MRI sequence that allows taking four images per slice and time step: one morphological (magnitude) image and three velocity-encoded (phase) images, one for each direction (a-p, f-h and r-l). Venc was at 150 cm/s, the image matrix size was 160 x 256 with a spatial resolution of 1.4 x 1.4 mm. The temporal resolution depending on the actual heart frequency usually was 13 frames per cycle. Hence one set of 13 magnitude and 3 x 13 phase images was acquired with ECG-triggering during one breath-hold. Repeating the sequence step by step covering the whole left heart finally resulted in one 4D dataset of the morphology and one 4D dataset of 3D velocity vectors.
To quantify the mitral regurgitation, a new component for our own software framework MEDIFRAME was developed. It allows the user to view the beating heart in 3D and to place an elliptical plane into the mitral valve area.

In a 2D window the corresponding reformatted image of this valve area can be viewed. Additionally the velocity component normal to the plane is calculated from the vector field and visualized using a red/blue color-coding technique. Finally, when the ellipse has been correctly placed, the discrete velocities are summed up in order to calculate the total flows for each time step (See screenshot).
For comparison purposes a standard time-resolved 2D sequence was used to image cross-sections of aorta and pulmonary artery which were quantified using the commercial Argus software-package from Siemens. In general the difference between aortic and pulmonary flow equals the mitral regurgitation.

Results and Conclusion

The form of the flow curve corresponded well to our expectations taking into account normal physiology as well as pathological effects due to the mitral insufficiency. The absolute values however sometimes differed significantly from the Argus-quantified values. The results were particularly sensitive to incorrect placement of the ellipse. If, for example, part of the ellipse jutted into the outflow tract, its strong flow during systole influenced the quantification result significantly. But after a certain training period, the results could be reproduced in a relatively reliable way by the same user (intra-observer reproducibility). Inter-observer reproducibility has not been examined yet.
In summary this work has shown that 4D velocity-encoded MRI is basically appropriate for the quantification of mitral regurgitation. Further work has to be done to make the method more reliable and accurate in order to exploit the advantages inherent in the full velocity field.


[Educational] - New Patient
File View Applications Heart-Flow Extras Window Help
Heart-Flow
Patient Scene Window
Scene View 3D
Standard Camera
Radius: Theta: Phi:
Spherical Coordinates 1000 10° 58°
Focal Point: 0 0 0
ViewUp: 0 1 -1
Stepwidth 1
Zoom: 100 %
Reset
Show Bounding-Box
Show Axes
Show View Planes
Show Volume
Show Planewidgets
Background:
Benchmark
Min/Max
Standard Heart-Flow
Heartflow-Application
ROI Flow v_min
1 132.732 mm² 17.7561 ml/s -0.805664 cm
2 132.732 mm² -63.3904 ml/s -55.957 cm/s
3 132.732 mm² -52.3469 ml/s -49.585 cm/s
4 132.732 mm² -27.575 ml/s -29.2236 cm/
5 132.732 mm² -14.7861 ml/s -21.8262 cm/
6 132.732 mm² -16.8545 ml/s -39.3311 cm/
7 132.732 mm² -11.0706 ml/s -30.6152 cm/
ROI Control
Insert
Adjust Plane
Confirm current
Confirm all
Recall current
Clear current
Clear all
Quantification
VENC: 150 cm/s
Data Blend-Control Quantify Jet
Actor Filters Current Filter
Image-Actor
Hu?
Color Level: 46
Color Window: 190
Opacity Level: 223
Opacity Window: 349
Invert Image
Scale Color 100 %
Clamp Color on RayCast
Transfer Functions
Optimize Color
Color VolumePro Placement
Hu?
Transversal-Plane
Slice 0
Time 3 200
ROI (ColorBlend)
Transversal-Plane
Slice 0
Time 12 200
0 1 2 3 4 5 6 7 8 9 10 11 12
Velocity Area: 137
Velocity Sum: -12352
Velocity Area: 136
Velocity Sum: -13962
Velocity Area: 137
Velocity Sum: 12781
Velocity Area: 137