Left Ventricular Asynchrony Quantification by Means of Myocardial Displacement Derived from Velocity Encoded MRI

Jan Paul[1], Anja Lutz[1], Peter Bernhardt[1], Patrick Etyngier[2], Wolfgang Rottbauer[1], and Volker Rasche[1]
[1]*Department of Internal Medicine II, University Hospital of Ulm, Ulm, Baden-Württemberg, Germany,* [2]*Medisys Research Lab, Philips Healthcare, Sureness, France*

Introduction: Many motion parameters obtained from tagged MRI data have been applied previously to quantify motion abnormalities, for decreasing the non-responder rate of about 30 % in Cardiac Resynchronization Therapy (CRT).
The aim of this study is to track segment-wise wall motion from velocity encoded MRI and then analyze parameters based on displacement for the distinction between healthy volunteers and patients with abnormal motion patterns.

Methods:
Data acquisition: 14 healthy volunteers (33±15 years, 9 female), 4 patients (46±29 years, 2 female) with Hypertrophic Cardiomyopathy (HCM), 6 patients (58±12 years, 3 female) suffering from Dilated Cardiomyopathy (DCM) including 2 patients with additional asynchrony, and 2 patients (29 and 76 years, both male) having asynchrony without DCM were investigated at a 1.5 T whole body MR scanner (Achieva, Philips) with a 32-channel cardiac coil. A velocity encoded (Tissue Phase Mapping, TPM) navigated segmented gradient echo sequence was applied in the apical, equatorial and basal short axis slice. The acquisition parameters were: FOV = 360² mm², in-plane resolution = 2.5² mm², slice thickness = 8 mm, acquisition matrix = 144², TR = 6.2 ms, TE = 4.6 ms, α = 15 °, 3 k-lines per segment, VENC = 30 cm/s, nominal scan duration = 5:03 minutes, black blood imaging with alternating presaturation pulses [1] and a SENSE acceleration factor of 2. For a heart rate of 60 bpm, 35 cardiac phases were measured with a phase interval of 25.3 ms.
Tracking: In-plane displacement ***x*** was computed from the averaged velocities ***v*** by the formula $\mathbf{x}(i;t)=\mathbf{x}(i;t-1)+\mathbf{v}(i;t)\cdot\Delta t$ for each segment *i* and cardiac phase *t*, using model assumptions based on a shape model, the segmentation of the left ventricle [2-3], additional background phase error correction and smoothing of the velocity vector field.
Parameters: The following parameters were derived from the displacement data: temporal uniformity of circumferential and radial strain (TUS_c and TUS_r) [4-6], maximal regional variance of strain (RVS_{max}) and the maximal regional variance vector of principle strain ($RVVPS_{max}$) [5], standard deviations SD(T_{onset}) and SD(T_{peak}) of onset and peak time [7], coefficient of variation (CV) [7], difference between septal and lateral peak circumferential strain (DiffSLpeakCS) [7], the base apex rotation correlation (BARC) [8], and the magnitude (||·||) of the onset (OS) and peak (PS) of strain delay vectors ***d*** = (*d*(septal→lateral), *d*(inferior→anterior), *d*(apex→basis))^T [9].

Results: Figure 1 shows 24 tracked segments (blue) with motion direction and amplitude (red arrows) exemplarily in a volunteer at four cardiac phases.
The parameter results are presented in Table 1 as mean ± standard deviation. TUS_c is reduced in DCM and/or asynchrony patients compared to volunteers, whereas TUS_r shows more overlap between the different groups. RVS_{max} and $RVVPS_{max}$ are increased in asynchronous patients compared to volunteers. While there is no large increase of SD(T_{onset}) for patients, SD(T_{peak}) is smaller in volunteers compared to the other groups. CV is increased in patients with DCM and/or asynchrony. The values of DiffSLpeakCS show no relevant differences between the groups. While the mean values of BARC indicate more twisting motion in volunteers and HCM patients compared to DCM and/or asynchrony patients, the standard deviations are too large to distinguish the groups. A large increase of ||OS delay vector|| can be seen in the DCM group compared to the volunteers and HCM patients. For DCM and/or asynchrony patients, ||PS delay vector|| is increased compared to volunteers.

Parameter	Volunteers Mean ± SD		HCM Mean ± SD		DCM Mean ± SD		Asynchrony Mean ± SD	
$TUS_c \in [0, 1]$	0.89	0.03	0.85	0.04	0.78	0.06	0.74	0.08
$TUS_r \in [0, 1]$	0.87	0.05	0.84	0.03	0.80	0.08	0.70	0.11
RVS_{max} [%²]	58.32	24.15	180.27	148.93	82.08	40.42	131.01	43.10
$RVVPS_{max}$ [%]	76.06	23.26	95.95	21.77	99.86	26.69	145.77	5.63
SD(T_{onset}) [ms]	12.55	5.84	12.59	5.24	28.46	8.87	21.30	10.83
SD(T_{peak}) [ms]	47.49	24.37	97.93	43.04	103.32	49.16	133.80	80.76
CV [%]	27.94	18.28	38.24	9.96	66.61	33.53	61.73	11.18
DiffSLpeakCS [%]	-1.16	1.97	0.24	2.08	2.63	2.14	0.30	1.80
BARC ∈ [-1, 1]	-0.10	0.52	-0.22	0.56	0.40	0.37	0.09	0.61
||OS delay vector|| [ms]	10.43	11.17	10.01	8.30	80.75	57.43	258.59	275.82
||PS delay vector|| [ms]	94.54	54.24	251.49	234.21	278.11	110.27	635.46	189.05

Table 1 Parameter values for asynchrony quantification obtained from displacement derived from velocity encoded MRI, shown as mean ± standard deviation for all groups.

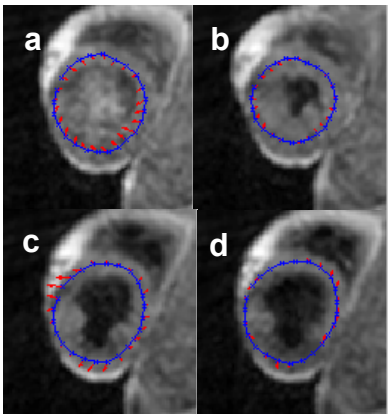

Figure 1 Example of tracking at 113 ms, 293 ms, 526 ms and 629 ms (from a-d).

Conclusion: Displacement can be obtained from TPM data. With the data analyzed here, only TUS_c, ||PS delay vector|| and SD(T_{peak}) show a reasonable large difference between patients with DCM and/or asynchrony compared to volunteers, but a larger data base is needed to compute significances between the parameter values for the different groups. A study with CRT patients is needed to analyze the value of these parameters regarding the prediction of CRT outcome.

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