

Appendix A: Head movement correction

A rigid-body registration was performed on the 4D CTA scans to correct for head movement during acquisition. This rigid registration was performed using the *RigidRegistration module* in MevisLab (Version 3.2a, MeVis Medical Solutions AG Bremen, Germany). The normalized gradient field (NGF) distance measure was used for the rigid multi-level registration. This method uses a Gauss-Newton optimization scheme to solve the optimization problem.

Parameter optimization

Subtractions of the 50% and 0% time phase in one cardiac cycle were done and the mean of the absolute difference between these time phases was calculated for 10 different HU thresholds and without a threshold. If a pixel value was above the threshold it was assumed to be part of the bony structures. A smaller absolute difference means that registration worked. Results are shown in [Table A1](#).

Table A1 Absolute difference between time phase 50% and 0% for every patient and 10 mask thresholds. The smallest absolute difference for each patient was indicated with green cells (best registration). The column on the right adds up the amount of patients where the registration worked best.

Patient	1	2	3	4	7	8	9	10	11	13	14	15	16	17	18	Best
Absolute difference (no registration)	8.9	14.3	12.4	15.2	8.5	9.6	11.0	12.7	11.2	11.1	9.8	10.3	10.2	10.9	9.1	
Mask: 0 HU	9.3	11.1	10.2	16.2	8.4	9.3	11.4	10.1	11.0	11.2	9.6	10.3	9.1	10.9	9.1	9
Mask: 100 HU	8.9	11.2	10.2	15.1	8.5	9.4	10.8	10.1	11.0	11.0	9.6	10.0	9.0	10.9	9.1	11
Mask: 200 HU	8.9	11.2	10.2	14.8	8.6	9.4	10.8	10.1	11.0	11.0	9.6	10.0	9.0	10.9	9.1	12
Mask: 300 HU	8.9	11.2	10.2	14.8	8.6	9.5	10.8	10.1	11.0	11.0	9.6	10.0	9.0	10.9	9.1	12
Mask: 400 HU	8.9	11.2	10.2	14.8	8.6	9.4	10.8	10.1	11.0	11.0	9.6	10.0	9.0	10.9	9.1	12
Mask:500 HU	8.9	11.2	10.2	14.9	8.6	9.4	10.8	10.1	11.0	11.0	9.6	10.0	9.0	10.9	9.1	11
Mask:600 HU	8.9	11.2	10.2	14.9	8.6	9.5	10.8	10.1	11.0	11.0	9.6	10.0	9.0	10.9	9.1	11
Mask:700 HU	8.9	11.2	10.2	14.9	8.6	9.5	10.8	10.2	11.0	11.0	9.6	10.0	9.0	10.9	9.1	10
Mask:800 HU	8.9	11.2	10.2	14.9	8.6	9.5	10.8	10.2	11.0	11.0	9.6	10.0	9.0	10.9	9.1	10
Mask:900 HU	8.9	11.2	11.5	14.9	8.6	9.5	10.8	10.1	11.0	11.0	9.6	10.0	9.0	10.9	9.1	9
Without mask	9.1	12.2	11.7	15.2	8.5	9.6	11.0	12.7	11.2	11.1	9.5	10.3	9.1	10.9	9.2	1

A mask with a threshold of 200 HU was chosen to perform the rigid-body registration for all patients. In this process, every time phase was registered to the first time phase of the corresponding cardiac cycle.