Prospective respiratory motion gating using a flexible external tracking device

Robin Simpson[1], Benjamin Knowles[1], Marius Menza[1], Michael Herbst[1,2], Cris Lovell-Smith[1], Maxim Zaitsev[1], and Bernd Jung[3]
[1]*Medical Physics, University Medical Centre, Freiburg, Germany,* [2]*John A. Burns School of Medicine, Hawaii, United States,* [3]*University Hospital of Bern, Switzerland*

Introduction: Reducing image artefacts due to respiratory motion is an important challenge for cardiac MR imaging. MR navigators can be used to monitor the position of the diaphragm, however they lead to imaging 'dead time' when information about the heart itself cannot be obtained, and for this reason they provide motion information at a maximum rate of once or twice per cardiac cycle. For cine imaging this means the information used to decide whether data are accepted or not can be up to one second out of date. MR navigators also need to be adapted for different field strengths, are affected by contrast agents and can affect the images themselves, for example causing inflow artefacts in late gadolinium enhancement[1]. External devices such as respiratory bellows have been shown to be useful for respiratory monitoring[1,2], but provide limited motion information. ShapeTape (Measurand Inc., NB, Canada) is a flexible motion tracking system consisting of bend-sensitive optical fibres, which has previously been used to monitor motion for foot[3] and brain[4] imaging (Figure 1). Several tapes, each with several sensors, can be attached to any part of the subject to gain a large amount of relative motion information with 6 degrees of freedom. This abstract presents initial experience applying ShapeTape to monitor respiratory motion in cardiac imaging.

Methods: The optical fibres of the ShapeTape are laminated to a non-ferromagnetic substrate made from beryllium copper. A 10 m fibre optic cable is attached to the active part of the system, enabling data transfer out of the scanner room via a waveguide. ShapeTape motion data is acquired at a rate up to 100 Hz; however, data communication with the scanner is currently restricted to about 25 Hz. A bSSFP (TruFISP) cine sequence (1.6x1.6x8mm spatial resolution, TE/TR 2.1/4.2ms, temporal resolution 33.6ms, flip angle 31°) was modified to allow prospective respiratory gating using ShapeTape, which was attached to the abdomen of the subject (see Figure 1). Two healthy volunteers were scanned and short axis cine images were acquired during free-breathing, breath-holding, conventional navigator gating and prospective respiratory gating using ShapeTape. All scans were performed on a 1.5T Siemens Symphony MRI scanner. Before image acquisition a 10 second calibration period was used to define the limits of respiratory motion. This range defined the initial data acceptance window of the minimum position +/-10% of the limits of motion. The limits of respiratory motion were constantly updated using motion over the previous 10 cardiac cycles to take respiratory drift into account. Gating was performed once per cardiac cycle, as is conventional, but also separately for each cardiac phase.

Figure 1: ShapeTape consists of four flexible tapes. For this abstract the end of a single tape was attached to the abdomen of the subject.

Results: Example ShapeTape data can be seen in Figure 2, together with the calculated acceptance window for a 10 percent acceptance. The respiratory motion is clearly visible, and the acceptance window takes into account drift in breathing position. Example peak systolic and diastolic images acquired without respiratory compensation, with conventional navigator gating, with ShapeTape gating once per cardiac phase and during a breath-hold can be seen in Figure 3. In both subjects ShapeTape gating once per cardiac frame provides similar quality data to conventional navigator gating in systole, and improved quality towards the end of the cardiac cycle when gating once per frame (eg sharper definition of LV trabeculae in Frame 19).

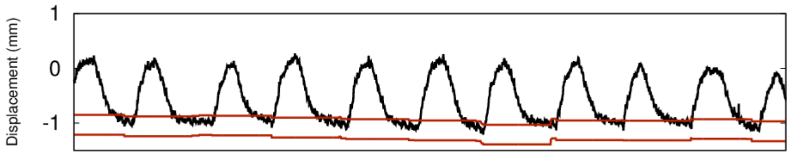

Figure 2: Example ShapeTape trace (black) with acceptance limits (red) when gating separately for each cardiac phase.

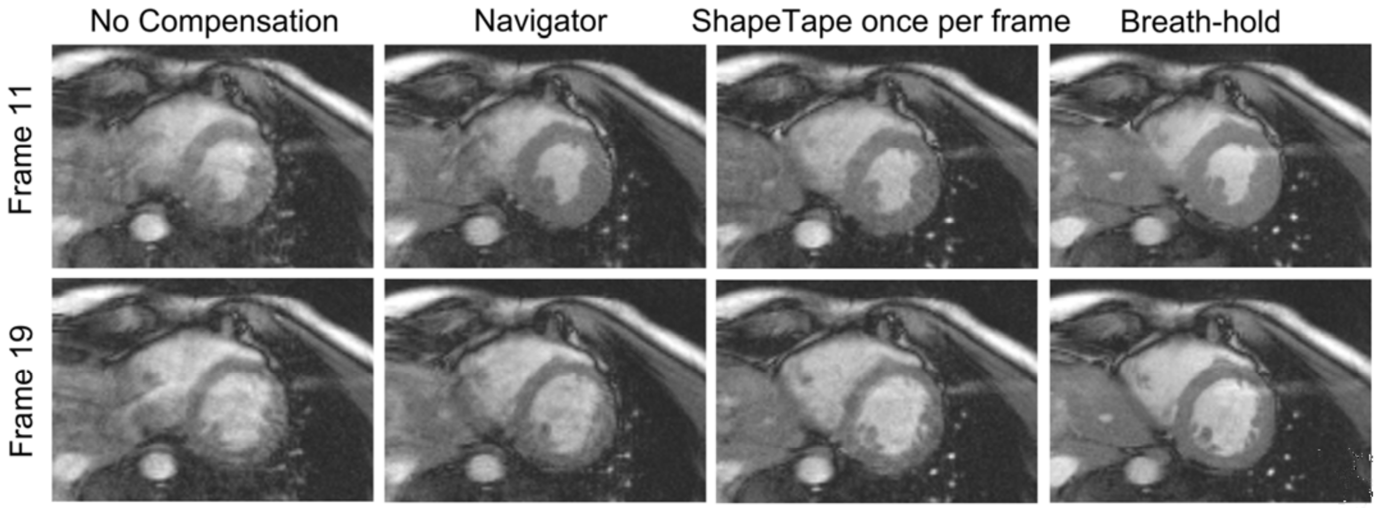

Figure 3: ShapeTape data compared with other methods. In this case 19 cardiac phases were acquired in total.

Discussion: ShapeTape has been successfully used to provide respiratory information that can be used for prospective gating. It can be quickly positioned and attached to the subject and gathers up-to-date information about respiratory motion without interrupting image acquisition. The high rate at which motion information is gathered allows gating to be separately performed for each cardiac phase. This improves image quality towards the end of the cardiac cycle and could provide good respiratory motion suppression even in the presence of fast or irregular breathing. This abstract presents initial experience using only one direction of motion from a single ShapeTape sensor: the ShapeTape therefore performs in a similar manner to respiratory bellows in this implementation. In future work, information in multiple directions from multiple ShapeTape sensors could be combined to provide more sophisticated respiratory gating.

Conclusion: ShapeTape provides a feasible alternative to conventional MR navigators which does not necessitate interruption of imaging and can be used flexibly to provide up-to-date and comprehensive information about respiratory motion.

References: 1: Peters et al JMRI 2013 Nov;38(5):1210-4; 2: Santelli et al MRM 2011 Apr;65(4):1097-102; 3. Lovell-Smith et al Proc. ISMRM 2012, #3313; 4: Herbst et al, Proc. ISMRM 2011, #2683
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