PTAGs: Partial k-space tagging combined with SSFP

V. M. Pai[1]

[1]Radiology, New York University, New York, NY, United States

Introduction: Myocardial tagging is an established approach for evaluating cardiac wall function. However, several hurdles still exist in developing tools for analyzing the tagged datasets. These include difficult in segmenting epicardial and endocardial contours and analysis of early systolic phases when SSFP-based sequences are considered, due to the transition from tagging to steady-state readout. Note that conventional tagging-based imaging studies usually generate the tagging echoes in the frequency-encoding direction; this is primarily done to enable minimization of scan duration by reducing the number of phase-encode lines acquired.

A partial tagging approach is presented here to help minimize some of the problems indicated above. In this approach, a multi-echo SSFP tagged dataset is acquired such that the central region of k-space is acquired in a non-tagged manner, and the outer regions of k-space are acquired with tagging on. Such a partial tagging approach can automatically provide tagged and untagged datasets from the same acquisition; the untagged dataset may then be used by conventional automated / semi-automated segmentation tools to generate the epicardial and endocardial contours for the tagged dataset. Since the center of k-space is acquired in a steady-state approach, without any need to account for the interruptions due to the tagging pulse, this minimizes the transition artifact arising through such interruptions, thus making it possible to analyze the early systolic phases. Also, by varying the flip angle when acquiring the central region of k-space, the contrast-to-noise ratio can be varied.

Methods: Due to the non-isotropic in-plane resolution, conventional tagging techniques acquire tagging echoes along the readout direction in k-space to minimize scan duration. However, use of an isotropic resolution imaging technique such as multiecho SSFP (MESSFP) implemented with the phased array approach to ghost elimination (PAGE) (MESSFP-PAGE) permits acquisition of tagging echoes along the phase-encode direction in short breathhold scan durations. In the partial tagging approach, the segments of the image data in the center of k-space are acquired in a stead-state fashion, with no tagging pulses applied, as shown in figure 1. On the other hand, the data segments farther away from the center of k-space are acquired with the tagging pulses applied. For the duration of the scan when the tagging pulses are applied, the interruption to steady-state is minimized by using a ramped RF flip angle approach to reach steady-state subsequent to the tagging pulses. For reconstructing the tagged image, the data from the entire k-space is used; while the untagged image is reconstructed from the segments of the data acquired with no tagging pulse applied. Phantom and human studies were performed on Siemens Avanto and TIM Trio systems (Siemens Medical Solutions, Malvern, PA).

Results: The first frame of a cine dataset acquired in the phantom (fig 2) and human (fig 3) cine acquisition with MESSFP-PAGE (fig 2a, 3a) and PTAG (fig 2b, 3b) approaches are shown in Figures 2 and 3 respectively. Since the center of k-space is acquired in steady-state in PTAGS, the image quality is considerably enhanced as compared to the conventional MESSFP-PAGE acquisition (which is affected by the ramped RF approach). Figure 4 compares the tagged data from MESSFP-PAGE and the PTAG approaches, along with the reconstructed untagged image from the PTAG data. Since the central k-space data and the tagged data are acquired in independent cardiac cycles, a higher flip angle can be used to acquire the central k-space data (60 in Figure 4(b,c)), and a lower flip angle can be used to acquire the tagged portion of the k-space (45 in Figure 4 (b,c)), thus providing better myocardium – to - blood contrast. Figure 5 shows the contrast (=Mean Signal (tagged) – Mean Signal (untagged)) for the water phantom. Due to the band-pass filtering effect of the PTAGs approach, the tag contrast is reduced compared to the conventional MESSFP-PAGE technique.

Conclusions: Partial tagging when combined with SSFP readout approaches can be used to obtain tagged and untagged images simultaneously; the untagged image may be used to segment the epi- and endocardium in the tagged image; use of partial tagging minimizes / eliminates the transition artifacts seen in early systolic phases when SSFP tagging is used. This may make it useful to study myocardial wall function in early systolic phases.

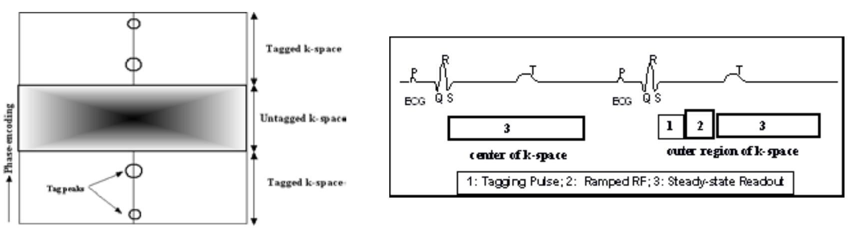

Figure 1. (a). Splitting k-space, (b). Acquisition of untagged and tagged portions of k-space.

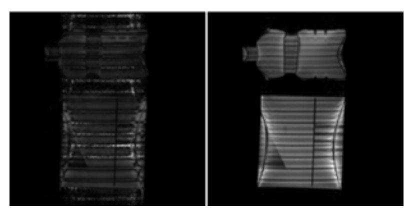

Figure 2. First frame of cine data from phantom. a). conventional SSFP-tagging, b). SSFP with partial tagging.

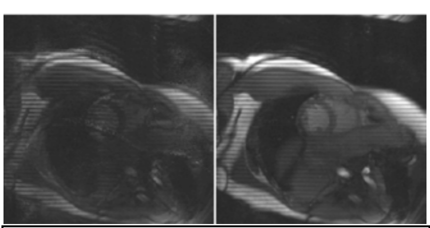

Figure 3. First frame of cine data from human scan a). conventional SSFP-tagging, b). SSFP with partial tagging.

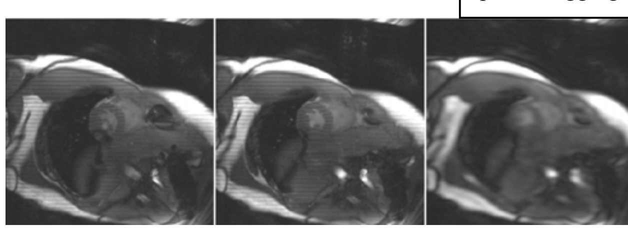

Figure 4. Tagged and Untagged Image reconstruction a). conventional SSFP-tagging, b). SSFP with partial tagging, c). reconstruction of central region of k-space.

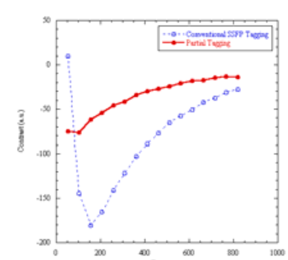

Figure 5. Tag fading with conventional SSFP and partial tagging.