Common Artifacts of Pulmonary Artery MRA and Potential Solutions

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Introduction

The importance of identifying pulmonary artery embolism (PE) is well established; however, the current gold-standard imaging study is multi-detector CT, which can lead to relatively high radiation exposure in a relatively young and radiation sensitive population. Contrast enhanced magnetic resonance angiography (CE-MRA) offers the possibility of assessing for the presence of PE without radiation exposure, but historically its performance has been limited by long scan times, poor spatial resolution, and incomplete chest coverage. Recent advances in 2D parallel imaging methods have facilitated resurgence in the use of CE-MRA for diagnosis of PE by providing high spatial resolution imaging over the whole chest in a short scan time [1,2]. The purpose of this work is to describe 2 common artifacts seen in pulmonary artery MRA and offer strategies for minimizing their impact on image quality and potential misdiagnosis of PE.

Materials and Methods

Since May 2008, our institution has performed approximately 200 clinical PE MRA studies on patients acutely presenting with dyspnea, the majority referred from the emergency department. Imaging was performed on 1.5T clinical scanners (Signa HDx, v14.0, GE Healthcare, Waukesha, WI) using a contrast-enhanced full-chest, near isotropic true spatial resolution of 1.3 x 1.8 x 2.0-2.4 mm^3 (interpolated to 0.7 x 0.7 x 1.0-1.2 mm^3), 14-19 sec breath-hold protocol with elliptical centric phase-encode ordering and a total table-time of 5-6 min, comparable with CTA [2]. Based on our clinical experience in interpreting these studies, two principal sources of image degradation that interfere with interpretation have been identified: 1) slight central signal dropout in medium-sized pulmonary arteries (principally the bilateral lower lobe lobar vessels) and 2) blurring of the pulmonary arteries relative to the pulmonary veins in smaller patients.

Central Signal Dropout

Figure 1 shows an example of this artifact (left panel), compared with a CTA-proven embolism (right panel). While our first hypothesis was that this artifact arose from the changing amount of contrast within the pulmonary arteries during the acquisition [3], it became clear that this was an incorrect explanation because this artifact persists on delayed equilibrium-phase images. We believe that this artifact is a result of Gibb's ringing made more apparent through zero-filling.

To test this hypothesis, a 1D numerical phantom consisting of a boxcar function vessel profile was reconstructed at a series of different resolutions by zero-filling in Fourier-space followed by inverse Fourier transform. These profiles were compared with the actual measured profiles of both artifacts and true emboli, matching both vessel width and reconstruction resolution.

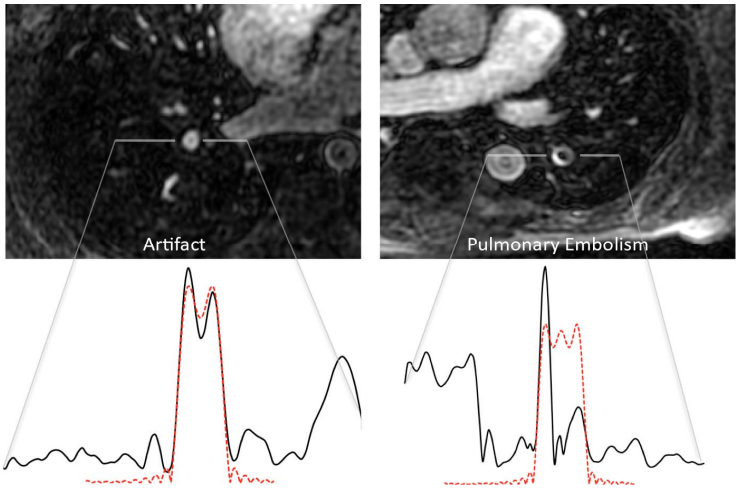

Figure 1. *Artifact (left) due to Gibb's ringing vs. true embolism (right). When vessel is 3-5 true pixels wide, Gibb's ringing results in a single, central signal drop-out of up to 18%. True embolism is gives >80% signal dropout.*

Pulmonary Artery Blurring

As has been described [3], time-varying contrast concentration within vascular structures during MRA acquisition can cause artifacts such as ringing or blurring, based upon the relative timing of *k*-space acquisition and the bolus profile. For example, with elliptical-centric ordering, even when the acquisition is well timed to the bolus arrival, if the bolus dissipates prior to the completion of *k*-space sampling, the pulmonary arteries will be blurred due to the decreased gadolinium concentration during the acquisition of the periphery of *k*-space, while the pulmonary veins will remain sharp if contrast persists within them (Figure 2, left panel).

Using the standard injection protocol of single-dose (0.1 mmol/kg) gadolinium contrast administered at 1.5 mL/sec, the bolus length can be as short as 7 sec in a small (*e.g.* 45 kg) patient – roughly half the acquisition time. In order to mitigate the related artifacts, our injection protocol was changed such that the single-dose of gadolinium was diluted to a total volume of 30 mL so that the bolus lasted throughout the duration of *k*-space sampling.

Results and Discussion

Central Signal Dropout

Figure 1 demonstrates the close correlation of the Gibb's ringing artifact (red dashed line) and the measured profile of the central signal dropout artifact (left panel) and the lack of correlation between the Gibb's ringing artifact and the profile of a true embolism (right panel). The maximum peak-to-trough signal drop-off due to Gibb's ringing is 18%. True emboli typically demonstrate drop-off close to background (>80%). Gibb's ringing only results in a single centrally-located signal drop-off in vessels that are 3-5 true pixels in size (4-9 mm at the resolutions acquired using our protocol), explaining the association of this artifact with the bilateral lower lobe lobar arteries, which are typically of this size.

Pulmonary Artery Blurring

The right panel of Figure 2 shows the markedly improved visualization of the smaller vessels resulting from prolonging the contrast bolus to last throughout the acquisition.

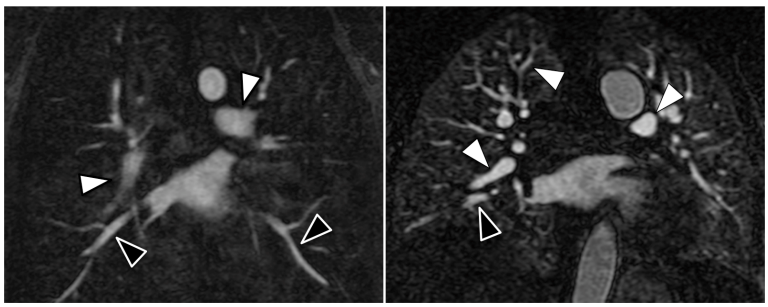

Figure 2. *A 7s bolus for a 15s scan results in blurring of pulmonary arteries as contrast dissipates before the periphery of k-space is acquired (left panel). A 20s bolus obtained by diluting single-dose Gd into a 30 mL volume results in significantly improved sharpness of the pulmonary arteries (white arrowheads). Pulmonary veins = black arrowheads.*

Conclusion

PE MRA has been clinically accepted at our institution as a useful alternative to CTA particularly in young patients where radiation dose reduction is a high priority. Based upon our experience interpreting approximately 200 clinical cases, we have identified and provided solutions to two common artifacts that are unique to MRA, namely central signal dropout in medium size vessels and blurring of the pulmonary arteries with short bolus duration.

References

1. Nael, et al, Invest Radiol 2007; 42:392-398. 2. Schiebler, et al, Proc. ISMRM 2009; p.3928. 3. Maki, et al, Magn Reson Imaging 1996; 6:642-651.