Comparison of Test Bolus Timing and Fluoroscopic Triggering for Carotid MRA

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Synopsis
Elliptical centric CEMRA has become an accepted method for the clinical assessment of the carotid and vertebral arteries. Test bolus timing (TBT) and fluoroscopic triggering (FT) are both well-accepted methods to synchronize the start of a 3D acquisition to the peak of the contrast agent bolus. We compared TBT and FT in 10 patients. Both methods produced excellent results. FT required a faster frame rate (e.g., 2.0 fps versus 0.84 fps for TBT) because the observer cannot retrospectively interpolate between adjacent frames. For maximal speed, FT used a thick-slab coronal acquisition with a twister (i.e., projection dephaser) gradient.

Methods
Ten consecutive patients requiring evaluation of the cervical arteries received the standard TBT [1] that we use in our clinical practice at 1.5T. The TBT uses a 2mL test bolus injected at 3mL/s followed by 30mL saline flush injected at 2mL/s, a single 6mm-thick axial slice, 32x16cm FoV with a 256x128 matrix, S/I spatial saturation to suppress flow and TR/TE/flip = 17.8ms/3.0ms/30° to achieve 0.84 frames per second (fps). The circulation time was estimated and recorded. The 3D acquisition was launched from an FT [2] sequence. At the time that the 25mL bolus was injected at 3mL/s (followed by a 30mL saline flush injected at 2mL/s), a timer was started so the fluoroscopic images were time-stamped for comparison with the TBT series. The 3D coronal acquisition was 22x15cm FoV, 256x224 matrix, 64 1.2mm thick slices, TR/TE/flip = 5.3ms/1.4ms/45° for a 52s scan time and a 1.0 mm³ voxel size before zero-filling. The FT sequence used the same 3D scan parameters, but with no phase encoding on the slice axis, a reduced number of views (94) on the phase encoding axis, and a twister (projection dephaser gradient) with a spatial period of 15mm to suppress stationary tissue from the 77mm-thick slab.

Results
All 10 elliptical centric CEMRA examinations were graded as very high quality. The measured circulation time ranged from 13 to 24s (mean = 17.35 ± 3.35s). The first appearance of contrast on the fluoroscopic sequence was 0.7 to 4.3s (mean = 2.51 ± 0.94) before the circulation time estimated with TBT. Figure 1 shows three frames of the TBT: 10.4s (before arrival of the bolus), 14.0s (early arrival), and 16.4s. Figure 2 shows the FT frames at corresponding times (in inverse video). Figure 3 shows the resulting coronal MIP from the 3D set, where 17s was selected for the circulation time.

Discussion
Both TBT and FT have their own distinct advantages. Since the TBT images are retrospectively reviewed, we find 0.84 fps to be sufficient, since the observer has the luxury of interpolating between adjacent frames to estimate the optimal circulation time. At 0.84 fps we were able to acquire in the axial plane, with S/I spatial saturation, which suppressed both venous and arterial flow until the arrival of contrast agent in the vessel. TBT does not require real-time decision-making, and allows measurement and consideration of the venous return time (which can typically vary from 5-9 seconds) when determining the optimal circulation time. Our experience is FT requires a faster frame rate than 0.84 fps. This led us to use a thick slab coronal acquisition without SAT to achieve 2.0 fps. A twister gradient suppressed stationary tissue from the thick slab. One advantage of FT is the 2mL-test bolus can be added to the main bolus to improve SNR and to reduce background contamination. Perhaps most importantly, the FT procedure is simpler, saving 5-10 minutes of setup, acquisition, and interpretation time per exam. With FT, however, it is important not to trigger the 3D acquisition at the initial appearance of the contrast agent. In our experience, good results are obtained when we wait approximately 2.5 seconds to let the arterial intensity build almost to its maximum. In summary, both TBT and FT are effective methods, and both work well in clinical practice. The technical requirements of FT are more stringent. The choice between the two methods for any given practice is a matter of training, equipment and software availability, and preference.
