MRI case study: Imaging of the carotid arteries using the t-slip technique

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By J Sparkes
Superintendent Radiographer, Neath Port Talbot Hospital
and A Noyes
Clinical Applications Specialist, Toshiba Medical Systems UK

Introduction
A patient presented to hospital with facial and arm numbness. It was necessary to exclude stroke and carotid dissection. Several imaging modalities were used including CT, ultrasound and MRI. This case study outlines the patient pathway and presents the benefits of t-slip MRI for imaging of the carotid arteries.

History
A 29-year-old male presented to the medical admissions unit at Neath Port Talbot Hospital with an acute history of left-sided facial pain, with pain and numbness on his right arm and leg. Initial assessment gave differential diagnosis of query stroke, query carotid dissection.

Imaging methods
Primary imaging
It was necessary to exclude, urgently, a stroke or carotid dissection as the cause of his symptoms. Primary diagnostic tests were CT head and Doppler ultrasound of carotid arteries.

Radiology reports for the primary imaging were as follows:
- CT head report: No focal intracranial lesion. Ventricular system and basal cisterns are within normal limits. Brainstem and posterior fossa structures are within normal limits within the scope of CT examination. No evidence of extra-cerebral haemorrhage. No evidence of any territorial infarct.
- Carotid Doppler report:
  - Right side: Widely patent common artery with a PSV of 80.1cm/s. The carotid bifurcation appears clear. The internal carotid artery is patent with no significant stenoses or flow turbulence observed. PSV is 90.2cm/s; the external carotid artery is patent with no significant stenoses or flow turbulence noted. The vertebral artery is patent with antegrade flow.
  - Left side: Again widely patent common carotid artery with a PSV of 76.8cm/s; again, the carotid bifurcation appears clear. The internal carotid artery is patent with no significant stenoses or flow turbulence noted. The vertebral artery is patent with antegrade flow.

Due to the normal findings, the patient was sent home with a neurology referral for further assessment.

Secondary imaging
The patient was referred back to radiology two weeks later for further secondary imaging as part of the routine diagnostic pathway for imaging of the carotid arteries, requesting MRI of the internal auditory meatus and carotid vessels. The scans were performed with head base, anterior neck and spine coils using a Vantage ZVG MRI scanner.

Sequences
- Head/IAM sequences:
  - Sagittal T1 weighted fast spin echo
  - Axial T2 weighted fast spin echo
  - Axial FLAIR (fluid attenuated inversion recovery)
  - Axial diffusion weighted
  - Coronal T2 weighted fast spin echo
  - Axial 3D SSFP (steady-state free precession) weighted

- Carotid sequences:
  - Coronal SSFP weighted
  - Axial SSFP weighted
  - Coronal t-slip (time spatial labelling inversion pulse)

Current imaging techniques for carotid arteries
There is a variety of methods of imaging the carotid arteries using MRI. Below are some suggestions as to limitations of such techniques, for example Time of Flight (TOF) 2D or 3D, Contrast enhanced MRA (CEMRA) and Phase contrast (PC).

- TOF: Turbulent flow at stenotic areas may cause flow voids and thus over-stage stenoses.
- Size of scan region is limited, as the greater the scan region, the more rephrasing occurs, reducing the visualisation of the vessel.
- Needs to be scanned perpendicular to vessel, so can be difficult to visualise branches coming off major vessels accurately, as they may not be perpendicular to slice direction.
- 2D is good for slow flow areas, but lower resolution than 3D.
- 3D is good for fast flow areas.

- CEMRA: Can demonstrate venous and arterial flow.
- Cost of contrast.
- Contrast side affects NSF (nephrogenic systemic fibrosis).
- PC: Long scan times.
- Better for slow flow areas
- Turbulent flow causes over-staging.

The t-slip technique
The t-slip technique was developed in Japan by Miyazaki et al (Toshiba Medical Systems) and introduced clinically in 2001. This technique could originally be used only together with the FASE (fast advanced spin echo) sequence. The use of t-slip together with SSFP sequences was introduced in 2005, allowing faster imaging with greater signal to noise.

This technique is an advanced application based on arterial spin labelling. It provides bright blood anatomical images of selected vessels (arteries or veins). The sequence makes use of a selective tagging pulse, that applies an inversion pulse within the tagging area, resulting in selective saturation of the signal in this region. The timing of this pulse is known as the BBTI (black blood inversion time) and is variable depending on the vessel to be demonstrated and its velocity. This is used to selectively visualise the target blood vessels and both the t-slip region and imaging area can be orientated in any direction. The tagging pulse is applied in conjunction with a pre-saturation pulse to null signal from opposing vessels, for example jugular vein, when looking at the carotid artery.

Imaging using t-slip is a gated technique, using one or a combination of respiratory, ECG and peripheral gating. When using this technique for imaging of the carotid arteries, ECG gating is the preferred method as this provides a good regular trace, allowing faster imaging than respiratory gating. If you are visualising vessels in an area with potential motion, for example in renal arteries, respiratory motion...
is overcome by the use of respiratory gating. When imaging the aorta, a combination of ECG and respiratory gating is applied. Cardiac motion is minimised by using ECG gating, and respiratory motion by the use of respiratory gating. Figure 1 (S1) illustrates the main elements of the scan set-up. The carotid arteries are imaged in the coronal plane, with the t-slip box positioned axially over the carotid arteries (S2). Finally, the pre-sat band is placed axially to cover the sagittal sinus as shown in (S3), to stop inflow of the jugular vein.

The BBTI used in this case was 1400. The sequence took 3 mins 48 sec.

• MRI report:
No significant focal intra-parenchymal or extra-axial abnormality has been demonstrated. There is no evidence of any focal infarct or haemorrhage. The MR angiogram of the carotid and vertebral arteries is normal, with no evidence of dissection.

Conclusion
The results of the t-slip study of the carotid arteries confirmed the results found with the Doppler study. This method was advantageous for this patient as he was not exposed to ionising radiation or the use of contrast media, often used in both CT and MRI vascular examinations. This technique adequately demonstrates the carotid vessels, even with fast flow, making it ideal for younger patients. This is advantageous when compared with other MRI techniques, such as the use of TOF and PC, which often over-stage stenoses in turbulent and fast flow vessels. Although this method copes well with fast blood flow, it can also be utilised for very slow flow and is therefore ideal for the elderly as well. In this case, cardiac gating was used, however peripheral pulse or respiratory gating can also be utilised. This overcomes complications caused when patients have poor or irregular cardiac output.

MRI using t-slip technology to provide information on vessels has several advantages when compared with other imaging modalities. It is able to provide 3D MIPs clearly identifying the anatomy of the carotid arteries, without the use of ionising radiation, intravenous contrast or invasive techniques.

References
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