Novel uses of time resolved imaging contrast kinetics 3D magnetic resonance angiovenography (TRICKS MRA/V)

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Learning objectives

To describe the physical principles and practical employment of the Time Resolved Imaging Contrast Kinetics 3D (TRICKS) MRA/V.

To highlight use of TRICKS beyond the already-established above knee MRA, including pelvic venography and imaging of arteriovenous malformations (AVM).
Background

Magnetic resonance angiography (MRA) and venography has recently been increasingly used to provide non-invasive imaging and assessment of vasculature. When compared to conventional diagnostic angiography, typically digital subtraction angiography (DSA), the non-invasive nature and lack of ionising radiation are appealing to both clinicians and patients.

Conventional MRA

Dynamic MRA can be obtained with 3-dimensional time-of-flight (TOF) and contrast enhanced MRA (CEMRA). TOF MRA has good spatial resolution but relies on the velocity of flowing blood protons for signal with turbulent flow often resulting in artefacts. It is also limited in the assessment of smaller blood vessels and cannot yield any flow data. CEMRA can offer additional functional information on flow direction and velocity but requires very accurate timing of data acquisition to coincide with contrast media bolus arrival in the target vessels. Many bolus tracking techniques exist but all suffer the penalty of potential timing errors, additional scan time and complexity of setup.

Principles of TRICKS - Abbreviated Version

MRA/V has high spatial and temporal resolution. An undersampled Cartesian based technique of K space segmentation ensures central K space sampling at peak arterial and venous enhancement, hence no need to precisely co-ordinate bolus arrival & image acquisition.

Rapid temporal sampling can depict short lived vascular shunts without the trade off of lower spatial resolution which remains around 1mm². The entire volume is repeatedly sampled every 2-6 seconds yielding 25 phases of isotropic raw images for volume rendering or to produce rotational Maximum Intensity Projection images.

Principles of TRICKS - In-Depth Explanation

Time-Resolved Imaging of Contrast KineticS (TRICKS) is a technique which acquires multiple 3D volumes during the passage of contrast bolus through the target vasculature with subsequent repeated central K-space sampling combined with temporal interpolation to generate a series of time-resolved 3D images [Korosec et al 1996].
TRICKS removes the planning constraints of CEMRA whilst maintaining spatial and temporal resolution and additional offering dynamic functional flow data.

TRICKS combines Elliptical Centric (EC) view order with undersampled Cartesian based acquisition techniques to generate high spatial and high temporal resolution MRV [Du & Bydder 2007]. EC view ordering ensures high temporal resolution with an effective frame rate of one volume every 2-6 seconds ensuring good arterial-venous discrimination [Du & Bydder 2007, Salanitri 2005, Madhuranthakam et al 2005, Korosec et al 1996]. The undersampled Cartesian based technique of K space segmentation samples the entire K space for each time point. K space is divided along the phase encoding direction with each region (A, B and C) sampling the entire set of section encoding values. The central region A, responsible for contrast resolution, is sampled more frequently than regions B & C (peripheral K space, responsible for higher spatial frequencies). This ensures central K space segment is acquired during peak arterial or venous enhancement [Carroll et al 2001]

While for conventional contrast enhanced MRA it is critical to coordinate the acquisition of central K space with contrast arrival, TRICKS is less dependent to bolus arrival and therefore there is no need to co-ordinate bolus arrival with image acquisition [Carroll et al 2001]. Like ultrafast/subsecond contrast enhanced MRA, TRICKS MRA/V can achieve temporal sampling rapid enough to depict short lived vascular processes such as shunts but unlike ultrafast contrast enhanced MRA, in TRICKS MRA/V there is no trade-off of low spatial for good temporal resolution[Salanitri 2005]: In TRICKS spatial resolution remains comparable with conventional MRA. Since TRICKS is a 3D imaging technique, image acquisition is near isotropic and therefore rotational MIP images can be produced in addition to volume rendered images. Spatial resolution is around 1mm$^2$ in-plane and 1-2mm$^2$ through-plane.
The advantages of 3D volumetric, dynamic, temporally-resolved images formed by TRICKS allows for robust, reliable and accurate data acquisition without resolution sacrifice to allow for better diagnostic assessment of vascular disease and malformations.

**TRICKS Below Knee MRA**

Due to timing errors and variability of distal lower limb flow, CEMRA imaging of the below knee arterial tree is often compromised by either delayed contrast arrival, such as asymmetric filling or occlusive vascular disease, or early venous return. The temporal resolution of TRICKS circumvents such difficulties without the need to consider bolus injection timings and consistently yields pure arterial phase images with high sensitivity and specificity [Shannon Swan et al 2002].

Figures 1 and 2 demonstrate the clear demonstration of both normal and diseased below knee arterial vasculature.
**Fig.**: TRICKS video sequence showing clear demonstration of normal below knee arterial vasculature.

**References**: Department of Radiology, Imperial College NHS trust - London/UK

Fig.1.
Fig.: TRICKS video sequence showing diseased below knee arterial vasculature with multiple bilateral stenoses.

**References:** Department of Radiology, Imperial College NHS trust - London/UK

Fig. 2.

**Pelvic Congestion Syndrome**

Pelvic Congestion Syndrome (PCS) is the presence of long-standing pelvic pain due to a variety of causes including ovarian vein incompetence[1]. The most important etiological factor is parity, which is associated with ovarian vein dilation and valvular
incompetence in 50-73% of women; although it is important to note that not all women with ovarian vein incompetence are symptomatic [Pui 2006, Tarazov et al 1997, Kim et al 2009]. In women whose Pelvic Congestion Syndrome is caused by ovarian vein incompetence, successful treatment can be achieved with surgical ligation or transcatheter ovarian vein embolization [Capasso et al 1997, Gandini et al 2008]. To select patients suitable for surgical or interventional therapy, we have found that TRICKS MRA/V to be a non-invasive technique with high spatial and temporal resolution which can delineate ovarian vein and parauterine venous dilation with greater conspicuity than that achieved with conventional T2/T2*W imaging and that the temporal resolution allows for assessment of dynamic filling and grade of reflux beyond the capabilities of single phase CT or three phase MRA thus enabling the diagnostic separation of different grades of reflux (Dick et al, in Press).

The following patient with suspected PCS was shown to have marked ovarian vein incompetence (fig. 3).
Fig.: TRICKS video sequence showing early filling of bilateral incompetent ovarian veins with subsequent filling of ovarian varices within the pelvis.

References: Department of Radiology, Imperial College NHS trust - London/UK
Fig. 3.

Arteriovenous Malformations

Vascular anomalies can be venous, arteriovenous or haemangiomatous malformations and have correspondingly varied functional characteristics. The therapeutic management of such vascular malformations requires characterisation of the structural extent of the
lesion and involvement of local structures but also the evaluation of afferent feeding and efferent draining vessels and their relative contribution to the anomaly.

Traditionally assessed by DSA and/or duplex ultrasonography for superficial lesions, the temporal resolution of TRICKS MRA/V allows for an accurate assessment of velocity of in- and out-flow from such lesions, which can be combined with other MRI sequences for morphological/structural assessment of the lesion for comprehensive one-stop imaging of vascular malformations. 3D CEMRA has been found to be comparable to the spatial and temporal resolution of DSE for the evaluation of such lesions but TRICKS dynamic imaging adds clinically important data regarding feeding and draining vessels crucial for therapy planning with the benefit of multiplanar reformation [Herborn et al 2003].

The following are examples of AVM evaluated by TRICKS at our institution:

Patient 1

Massive forearm AVM demonstrated on TRICKS with conventional angiogram correlation (figures 4 - 8).
Fig: TRICKS Video sequence showing massive forearm AVM

References: Department of Radiology, Imperial College NHS trust - London/UK

Fig. 4
Fig.: Corresponding MRI MIP image of massive forearm AVM.

References: Department of Radiology, Imperial College NHS trust - London/UK

Fig. 5
**Fig.**: Selected diagnostic conventional angiogram image showing close correlation of AVM morphology to TRICKS imaging.

**References:** Department of Radiology, Imperial College NHS trust - London/UK

Fig. 6
Fig.: Selected diagnostic conventional angiogram image showing close correlation of AVM morphology to TRICKS imaging.

References: Department of Radiology, Imperial College NHS trust - London/UK

Fig. 7
**Fig.**: Selected diagnostic conventional angiogram image showing close correlation of AVM morphology to TRICKS imaging.

**References:** Department of Radiology, Imperial College NHS trust - London/UK

Fig. 8.

*Patient 2*

Large slow flow AVM of the anterior aspect of the ankle and calf with visible arterial supply and large dilated draining vein (fig. 9).
Fig.: TRICKS Video sequence showing a large slow flow AVM on the anterior aspect of the ankle and lower calf with visible arterial supply and large dilated draining vein.  

References: Department of Radiology, Imperial College NHS trust - London/UK  
Fig. 9

Assessment of Venous Vascular Patency

By using TRICKS venography we have been able to assess for central venous vascular patency without the need for ionising radiation imaging techniques.
Figures 10 and 11 were both performed using synchronous bilateral venous injection in the wrist veins for assessment of central thoracic venous patency. Figure 10 demonstrates normal patent central venous vasculature. Figure 11 demonstrates complete occlusion of the right subclavian vein, proximal to the insertion of the cephalic vein. Multiple collaterals are visible at the occlusion site, some of which extend into the right para-vertebral veins and then descend filling the right internal jugular vein which drains normally into the right brachiocephalic vein.

Fig.: TRICKS video sequence showing normal and patent central venous vasculature following bilateral upper limb intravenous contrast injection.

References: Department of Radiology, Imperial College NHS trust - London/UK
Fig. 10. TRICKS video sequence showing occluded right subclavian vein and collateral vessels following bilateral upper limb intravenous contrast injection.

References: Department of Radiology, Imperial College NHS trust - London/UK
Fig. 11
Fig. 7: TRICKS video sequence showing clear demonstration of normal below knee arterial vasculature.

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Fig. 6: TRICKS video sequence showing diseased below knee arterial vasculature with multiple bilateral stenoses.

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**Fig. 5:** TRICKS video sequence showing early filling of bilateral incompetent ovarian veins with subsequent filling of ovarian varices within the pelvis.

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Fig. 3: TRICKS Video sequence showing massive forearm AVM

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**Fig. 0:** Corresponding MRI MIP image of massive forearm AVM.

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**Fig. 0:** Selected diagnostic conventional angiogram image showing close correlation of AVM morphology to TRICKS imaging.

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Fig. 0: Selected diagnostic conventional angiogram image showing close correlation of AVM morphology to TRICKS imaging.

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Fig. 0: Selected diagnostic conventional angiogram image showing close correlation of AVM morphology to TRICKS imaging.

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Fig. 4: TRICKS Video sequence showing a large slow flow AVM on the anterior aspect of the ankle and lower calf with visible arterial supply and large dilated draining vein.

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Fig. 2: TRICKS video sequence showing normal and patent central venous vasculature following bilateral upper limb intravenous contrast injection.

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Fig. 1: TRICKS video sequence showing occluded right subclavian vein and collateral vessels following bilateral upper limb intravenous contrast injection.

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Conclusion

TRICKS MRA/V has excellent spatial and temporal resolution and allows for non-invasive and non-ionising radiation-dependent production of 3D volume images dynamically over multiple phases. The superior temporal resolution gives almost "real time" flow imaging that illustrates bolus transit, differential filling rates and direction of flow enabling its use in several new anatomical and system areas in addition to its known angiographic applications.

Novel useful applications include pelvic venography in pelvic congestion syndrome, AVM delineation, assessment of central venous patency and below knee MRA.
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References


