Journal of Neuroradiology 44 (2017) 210–216

Available online at ScienceDirect www.sciencedirect.com

Elsevier Masson France EM|consulte www.em-consulte.com

Original Article

Comparison between enhanced susceptibility-weighted angiography and time of flight sequences in the detection of arterial occlusion in acute ischemic stroke

O. Vanaerde[a,*], J.-F. Budzik[a], A. Mackowiak[b], L. Norberciak[c], M. Uettwiller[d], X. Leclerc[e], S. Verclytte[a]

[a] Department of radiology, Catholic university hospitals, 115, rue du Grand-But-Lomme, 59160 Lille, France
[b] Department of neurology, Stroke unit, Catholic university hospitals, 59160 Lille, France
[c] Clinical research department, Catholic university hospitals, 59160 Lille, France
[d] GE Healthcare, 59000 Lille, France
[e] Neuroimaging department, CHU de Lille, 59000 Lille, France

ARTICLE INFO

Article history:
Available online 1 March 2017

Keywords:
Acute stroke
Susceptibility-weighted imaging
Arterial occlusion
Time of flight

ABSTRACT

Purpose. – Optimizing the MRI protocol in acute ischemic stroke remains a challenging issue. In this field, susceptibility-weighted sequences have proved their superiority over T2*. Besides the strengthened susceptibility effect, enhanced susceptibility-weighted angiography (eSWAN) sequence provides also a time-of-flight (TOF) effect, allowing the exploration of the intracranial arterial circulation. The objective of our study was to compare eSWAN and 3D TOF, considered as the reference, in the detection of arterial occlusion in acute stroke.
Methods. – Patients who underwent MRI between March and July 2014 for suspected acute stroke with an acute ischemic lesion on diffusion-weighted imaging (DWI) were prospectively included in this study. eSWAN and TOF images were analyzed under double-blind conditions by a junior radiologist and a senior neuroradiologist for the detection of arterial occlusion. eSWAN images were assessed in order to estimate the inter-observer agreement. After a consensus, eSWAN and TOF data were compared to calculate inter-modality agreement.
Results. – Thirty-four patients were included. Inter-observer agreement was excellent (kappa: 0.96) for eSWAN detection of occlusion. After consensus, comparison between TOF and eSWAN showed substantial agreement (kappa: 0.71). eSWAN provided better detection of distal occlusions, but poorer performance for detection of siphon occlusions.
Conclusions. – Shortest echoes eSWAN images enabled detection of arterial occlusion with substantial agreement with TOF images. The susceptibility vessel sign associated with the TOF effect improved the identification of distal occlusions. In acute stroke protocol, eSWAN may represent a valuable alternative to T2* and TOF sequences.

Introduction

Optimization of the magnetic resonance imaging (MRI) protocol in acute ischemic stroke remains a challenging issue, requiring a compromise between the duration and the relevance of the sequences acquired [1].

The exact location of the occlusion is crucial, being a prognostic factor when an intravenous thrombolysis is considered [2–4] and allowing to select patients eligible for mechanical thrombectomy. MR angiography (MRA) with non-enhanced time-of-flight (TOF) techniques is a key sequence in routine MRI protocol in acute stroke. It has an excellent sensitivity (range 80 to 90%) [5] in the detection of arterial occlusion, while being a noninvasive imaging.

The T2* sequence performs a dual role by allowing the detection of intracranial hemorrhages and the localization of any potential thrombus, visible in the form of a signal loss along the course of the artery and called the susceptibility vessel sign (SVS) [6–10].

Abbreviations: TOF, Time-of-flight; ESWAN, Enhanced susceptibility-weighted angiography; DWI, Diffusion-weighted imaging; MIP, Maximal intensity projection; MPR, Multiplanar reconstruction; FOV, Field of view; NIHSS, National institute of health stroke score.

* Corresponding author. Department of radiology, Catholic university hospitals, 115, rue du Grand-But-Lomme, 59160 Lille, France. Tel.: +33643070117.
E-mail address: ovanaerde@gmail.com (O. Vanaerde).

http://dx.doi.org/10.1016/j.neurad.2017.01.125
0150-9861/

Susceptibility-weighted MR sequences are more recent sequences and have proved many potential benefits, especially in acute stroke [11–14]. They are 3D sequences with a higher spatial resolution that have proved their superiority over T2* both in the thrombus [15,16] and hemorrhage detection [17–19]. Brush sign can be detected. As it is related to signal loss of cortical and deep veins subject to local hypoxia, it would reflect cerebral hypoperfusion and thus be correlated with penumbra volume [20–23].

One of these sequences, called susceptibility-weighted angiography (SWAN) (General Electrics Healthcare, Milwaukee, USA) is based on a multi-TE readout using a 3D acquisition. The longest TE are associated with a strengthened susceptibility effect, leading to an improved detection of arterial thrombus in comparison with the T2* sequence. The shortest TE leads to a TOF effect, allowing a 3D exploration of the intracranial arterial circulation, analyzable with MIP or MPR just as well as MRA with TOF technique.

In the classical SWAN sequence, the different echoes read are combined together as a weighted average by a reconstruction algorithm. More recently, an upgraded version of the SWAN sequence, called enhanced SWAN (eSWAN), allowed generating independent series of images for each TE value. The radiologist can analyze separately eSWAN images obtained with the shortest and the longest TE read, and thus give priority to TOF or susceptibility effect.

eSWAN sequence therefore offers several benefits by theoretically combining the contribution of the susceptibility-weighted imaging, whose superiority over the standard T2* in stroke is now well established, and of a 3D TOF-like sequence, which has, however, never been evaluated in acute stroke conditions. In case of good efficiency, eSWAN sequence may substitute for T2* and TOF sequences in acute stroke protocol.

The objective of our study was to compare the TOF effect of the eSWAN sequence, obtained with the shortest TE read, with a standard 3D TOF sequence in the detection of the arterial occlusion in acute ischemic stroke.

Material and methods

Patients

This study was approved by our local ethic committee and written informed consent was obtained from all subjects.

Between March and July 2014, all the patients included in this prospective study in our institution (Saint-Philibert Hospital - Lomme) were recruited consecutively with the following inclusion criteria:

- clinical symptoms compatible with acute stroke;
- time range between symptoms and MR imaging less than 4 h 30 [24];
- presence of at least one acute ischemic lesion on the diffusion-weighted images (DWI).

Exclusion criteria were:

- MR contraindications;
- negative DWI;
- differential diagnosis;
- incomplete acquisition of the full MRI protocol or technical issues leading to uninterpretable eSWAN and/or TOF sequences (e.g. motion artifacts).

Image acquisition

MRI examinations were performed on a 3 T GE MR750 W scanner (General Electrics Healthcare, Milwaukee, USA). eSWAN is performed routinely in our institution, replacing T2*. This sequence was acquired with the readout of four different TE (13, 19, 25 and 32 ms) for a duration of 4 minutes 18 seconds, with the following parameters: FOV = 24×19.2 cm^2, slice thickness = 2 mm, matrix = 384×384, spatial resolution = $0.625 \times 0.5 \times 2$ mm^3.

3D TOF sequence included 36 slices acquired with two contiguous overlapping slabs for a duration of 1′57 with the following parameters: FOV = 22×16.5 cm^2, slice thickness = 1.4 mm, matrix = 320×224, spatial resolution $0.687 \times 0.73 \times 1.4$ mm^3. Our MRI protocol also included 2D Flair and DWI sequences. The total MRI examination duration was 10 minutes 25 seconds.

Image analysis

Two readers, an experienced neuroradiologist (SV, 8 years of experience in neuroradiology) and a junior radiologist (OV, 3 years of experience in general radiology) independently analyzed eSWAN and TOF images in random order, looking for arterial occlusions. Analysis was based on a 2-point-scale: arterial occlusion, based on a local signal loss, or acceptable permeability.

For each sequence, analysis was based on the number and location of the arterial occlusions, involving basilar arteries, carotid siphons, middle cerebral arteries (M1 and M2 segments), posterior cerebral arteries (P1 and P2 segments), anterior cerebral arteries (A1 and A2 segments), and superior cerebellar arteries.

3D eSWAN images, using only the shortest echo images (13 ms), were analyzed in 5 mm MIP (maximum intensity projection) reconstructions (axial, coronal and sagittal) and in MPR (multi planar reconstruction). The same reconstructions were used to read the TOF images (Fig. 1).

During SWAN and TOF analysis, readers had access to Flair and DWI images.

Each reader used the same PACS Workstation (Carestream Health, Rochester, USA). The two independent blinded analyses (for TOF and eSWAN images) took place 2 weeks apart to avoid recall bias. In case of disagreement between the two readers, a consensus reading was performed: the senior and junior radiologists re-analyzed eSWAN and TOF images together, until an agreement was found concerning the occlusion site.

Statistical analysis

The statistical analysis was made with the R software (version 3.0.1).

It was performed in two steps. The first one was to evaluate the inter-observer agreement between the two readers for the detection of the arterial occlusion using eSWAN images. The second one consisted in evaluating agreement between eSWAN and TOF images, considered in our study as a routine reference for the detection of the arterial occlusion, after a consensus between the two readers for each sequence.

Percentage of observed agreement as well as Cohen's kappa coefficient and its 95% confidence interval (CI) were used. When multiple occlusions occurred, in order to be considered as concordant, the observers had to give, in addition, the same location for each occlusion. Cohen's kappa coefficient was interpreted as follows: less than 0.00, poor agreement; 0.00–0.40: slight agreement; 0.41–0.60: moderate agreement; 0.61–0.80: substantial agreement; > 0.81: excellent agreement.