Evaluation of the supraaortic arteries using non-contrast-enhanced Velocity MR Angiography "Inhance"

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Abstract

Introduction The aim of this study was to compare the recently developed phase contrast-based Inhance 3D Velocity magnetic resonance angiography technique (Inhance) to the contrast-enhanced standard method (CE-MRA) in the evaluation of the supraaortic arteries.

Methods Inhance and CE-MRA were performed in ten consecutive patients with a suspected pathology of the supraaortic arteries on a 3-T MR scanner. Two neuroradiologists evaluated in consensus both sequences regarding the visualisation of the supraaortic arteries and their segments on a five-point score. Diagnostic certainty regarding the overall presence of a vascular pathology was rated on the same five-point score.

Results On CE-MRA as well as on Inhance, a vascular pathology of the supraaortic arteries was detected in seven patients. There was no statistically significant difference in the overall diagnostic certainty regarding the presence or absence of pathologic findings for CE-MRA compared to Inhance. Furthermore, no statistically significant difference was found with regard to visualisation of the distal cervical and intracranial arterial segments, while CE-MRA was superior to Inhance in the visualisation of the origins of the cervical vessels from the aortic arch.

Conclusion Non-contrast Inhance proved useful in the evaluation of the supraaortic arteries with limited assessment of the proximal supraaortic branches. Hence, this technique features a valuable alternative to CE-MRA in the visualisation of the supraaortic arteries, particularly in patients with renal insufficiency.

Purpose

To date, contrast-enhanced magnetic resonance angiography (CE-MRA) represents the standard magnetic resonance angiography (MRA) technique for the evaluation of supraaortic arteries. Compared to the noninvasive and invasive reference standards computed tomography angiography (CTA) and digital subtraction angiography (DSA) for the evaluation of supraaortic vessels, CE-MRA proved to have a very high diagnostic accuracy [1–3]. In patients with impaired renal function, CE-MRA has for years been used in preference to CTA. However, recent reports linking the use of gadolinium-based MR contrast agents with nephrogenic systemic fibrosis (NSF) [4–6] have limited their widespread application in patients with renal insufficiency. Time-of-flight (TOF) MRA, as a widely used non-contrast technique for the evaluation of cranial arteries, is limited with respect to the extracranial supraaortic arteries by the restricted field of view. Another method to visualise vessels without contrast is using phase contrast (PC) techniques. Here we tested whether a recently developed PC-based Inhance 3D

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Velocity MRA technique might be beneficial in the assessment of the supraaortic vessels, compared to CE-MRA.

Methods

The study was approved by our institutional review board, and all participants gave their written informed consent prior to study onset.

MR imaging

Ten consecutive patients (eight male; age range 33–74 years, mean 53.2 years) with suspected pathology of the supraaortal arteries underwent MRI on a 3-T scanner (Signa HDxt; GE Healthcare, Milwaukee, USA) using a standard head and neck coil (neurovascular array). For patient characteristics see Table 1. Exclusion criteria included all standard contraindications to MRI (pace maker, claustrophobia, implanted metallic devices, history of renal disease, contrast reaction, etc). Within the diagnostic workup, the following two MR sequences were performed: (1) CE-MRA and (2) Inhance 3D Velocity MRA (Inhance). Inhance is a non-contrast 3D PC-MRA pulse sequence, which is optimised in respect to data acquisition time as well as stationary tissue suppression. In order to speed up data acquisition, a partial k-space filling technique is used, and corners of k-space are not acquired in slice and phase direction. Missing data are zero filled prior to Fourier transform. Additionally, Inhance is used in combination with parallel imaging techniques in order to further speed up data acquisition. To enhance contrast-to-noise ratio transverse magnetisation is spoiled using phase cycling of excitation radiofrequency pulses prior to each excitation mostly removing signal from the tissue with long T2. Sequence parameters are given in Table 2.

Data postprocessing and analysis

Data postprocessing was performed interactively using the multiplanar reconstruction function of a standard workstation (AW workstation; GE Healthcare). Maximum intensity projection (MIP) reconstructions of the CE-MRA and the Inhance were generated with a slab thickness of 10 mm. Two experienced neuroradiologists analysed the source images and the MIPs of both sequences in consensus. They evaluated the visualisation of the supraaortic arteries and their segments (as detailed in Table 3) on the following five-point score: excellent (5), good (4), adequate (3), questionable (2), and poor (1). Diagnostic certainty regarding the overall presence of a vascular pathology was rated on the same five-point score. Furthermore, readers assessed the presence, nature and localisation of a potential vascular pathology in the respective vessel segments. Final diagnosis

regarding the presence or absence of vascular pathologies was based on clinical records and—if available—on CTA or DSA as reference standard.

Wilcoxon rank sum tests were performed to test for significant differences between the potential of Inhance versus CE-MRA in the depiction of the different vessel segments as well as the diagnostic certainty regarding a potential vascular pathology. Alpha level was set to 0.05. Furthermore, interobserver agreement regarding the visualisation of the different vessel segments was evaluated using Cohen's kappa coefficient. For this purpose the five-point score was dichotomised into diagnostic (5, 4 and 3) and non-diagnostic (2 and 1).

Results

All examinations were completed successfully, and all contrast injections were performed safely and without side effects. All studies were determined to be of diagnostic image quality by both observers. Patients' characteristics and vascular findings are summarised in Table 1. CTA and/or DSA were available in eight of the ten patients, including all of those patients in whom a vessel pathology was found on MRA. In all patients where a vascular pathology was detected on CE-MRA, this diagnosis could be approved by CTA and/or DSA.

There was no statistically significant difference in the overall diagnostic certainty regarding the presence or absence of pathologic findings for CE-MRA compared to Inhance ($p=0.52$, Figs. 1 and 2). Furthermore, no statistically significant difference was found with regard to visualisation of the distal cervical and intracranial arterial segments, while CE-MRA was superior to Inhance in the visualisation of the origins of the cervical vessels from the aortic arch. Mean and median scores as well as p values are detailed in Table 3. Interrater agreement concerning the visualisation of the different vessel segments with respect to dichotomized groups was kappa=0.64, indicating good agreement.

Discussion

The present study was conducted to test the potential of Inhance in the delineation of the supraaortic arteries and their pathologies compared to CE-MRA. Three-tesla CE-MRA proved to have a very high diagnostic accuracy for the evaluation of the supraaortic vessels compared to CTA and DSA. This technique has the following advantages, which make it very useful for imaging of cervical arteries: (1) it relies on the shortening of T1 relaxation time of blood after venous contrast injection, and thus is not directly dependent

Table 1 Patient characteristics, final diagnoses and Inhance MRA findings

N	Sex	Age (years)	CTA/DSA	Clinical symptoms/suspected diagnosis	Final diagnosis	Diagnosis approved on Inhance
1	m	44	y/n	Hemiparesis r	No vascular pathology	y
2	m	62	n/y	Dizziness, suspected re-stenosis post-stenting V2 l	No in-stent stenosis	y
3	m	33	n/n	Dizziness, trauma	No vascular pathology	y
4	m	74	y/y	US-suspected re-stenosis post-TEA + Patch ICA r	Stenosis proximal ICA r	y
5	m	33	y/n	Thymus—carcinoma Horner's syndrome	Stenosis CCA l	y
6	m	74	y/y	Hemiparesis l	Tandem stenosis ICA r	y
				Stent proximal ICA l	In-stent stenosis ICA l	y
				Stent proximal VA l	In-stent stenosis VA l	y
					MCA occlusion r	y
7	m	68	y/n	MCA ischemia l ICA and CCA stent l	No in-stent stenosis	y
8	m	50	y/n	Visual deficit/occlusion of VA l	Dissection VA r	y
9	f	57	y/n	Wallenberg syndrome	Stenosis BA	y
10	f	37	n/n	Dizziness Dissection VA?	No vascular pathology	y

N patient number, *CTA* computed tomography angiography, *DSA* digital subtraction angiography, *m* male, *f* female, *y* yes, *n* no, *r* right, *l* left, *BA* basilar artery, *CCA* common carotid artery, *ICA* internal carotid artery, *MCA* middle cerebral artery, *VA* vertebral artery, *TEA* thromboendarterectomy, *US* ultrasound

on flow to produce a signal; (2) it is acquired in coronal plane, and thus depicts the supraaortic vessels in their whole extent from the aortic arch up to the circle of Willis, and (3) it shows only limited vulnerability to artefacts from motion and swallowing due to its very short acquisition time. If performed on MR systems with fast gradients, the image quality and diagnostic value of CE-MRA can rival those of CTA and DSA for the evaluation of cerebrovascular diseases [7, 8].

Besides MRA, recent advances in multislice CT technology have led to a great increase in the value of CTA for the evaluation of cerebrovascular diseases, especially due to its superior spatial resolution. Yet, ionising radiation and risks

Table 2 Imaging parameter

	Inhance	CE-MRA
FOV (mm)	320×256	300
Matrix size (mm)	384×384	300
TR (ms)	ca. 3.4	3.9
TE (ms)	ca. 8.4	1.4
Slice thickness (mm)	1.2	1.2
Orientation of acquisition	Coronal	Coronal
Duration (min:s)	8:40	0:36

FOV field of view, *TE* echo time, *TR* repetition time

associated with iodine-based contrast agents, meaning nephrotoxicity and allergic reactions, are drawbacks of CTA. For years, CE-MRA was considered a harmless alternative, especially in patients with impaired renal function. However, in the recent years, the potential risk of NSF following the administration of gadolinium-based contrast material in patients with renal insufficiency has to be thoroughly considered in these patients, which resulted in a significant proportion of patients with contraindications for both CTA and CE-MRA. This has a considerable impact for the diagnostic workup of patients with cerebrovascular diseases, as especially older patients with arteriosclerotic changes of the supraaortic vessels frequently also suffer from renal insufficiency. That is why non-enhanced MRA techniques become ever more important. TOF-MRA is the most established non-contrast MRA technique to assess supraaortic arteries, particularly intracranially but also extracranially [9, 10]. It has to be acquired perpendicular to the vessel, meaning the axial plane for the supraaortic arteries. Consequently, covering the supraaortic vessels in their whole extent demands extensive measurement time, frequently not acceptable for routine clinical conditions. Furthermore, TOF-MRA is dependent on blood flow and is thus vulnerable to saturation effects. This may have relevant limitations, if vascular lesions disturb normal blood flow, namely signal loss in stenotic areas with stenosis overestimation due to intravoxel dephasing and complex flow.

Table 3 Visualisation of the different vessels segments and diagnostic certainty regarding the overall presence of vessel pathologies

	Median		Mean		p value
	CE-MRA	Inhance	CE-MRA	Inhance	
Origin CCA r + l	5	3.5	3.8	2.9	0.02*
Origin ICA r + l	5	3	4.6	3.3	0.000*
C1 r + l	5	4.5	4.7	4.4	0.31
C2/3 r + l	5	5	4.5	4.3	0.51
C4/5 r + l	3	3	3.1	3.5	0.26
C6/7 r + l	3.5	4	3.4	3.9	0.06
Origin VA r + l	4	2	3.7	2.6	0.001*
V2 r + l	4.5	4	4.4	3.9	0.14
V3 r + l	4	3.5	3.7	3.3	0.29
V4 r + l	4	4	4.2	4.2	0.74
BA	4	4.5	3.7	4.2	0.22
DC regarding overall presence of a pathology	5	4.5	4.5	4.5	0.52

Mean/median value of visualisation and diagnostic certainty as rated on a five-point score: excellent (5), good (4), adequate (3), questionable (2) and non-diagnostic (1)

r right, *l* left, *CCA* common carotid artery, *ICA* internal carotid artery (*C1* cervical, *C2/3* petrous, *C4/5* cavernous, *C6/7* cerebral segment), *VA* vertebral artery (*V2* intraforaminal, *V3* C2–dura, *V4* intradural segment), *BA* basilar artery, *DC* diagnostic certainty

*$p < 0.05$, difference statistically significant

Another non-contrast, flow-based MRA is the PC technique. It is based on the application of a bipolar gradient pulse pair producing a phase shift depending on the velocity component along the gradient. The method holds the common disadvantages of non-contrast MRAs mentioned above, is technically demanding and requires a relatively long acquisition time. Thus, this technique has not really found its way in the routine assessment of the supraaortic
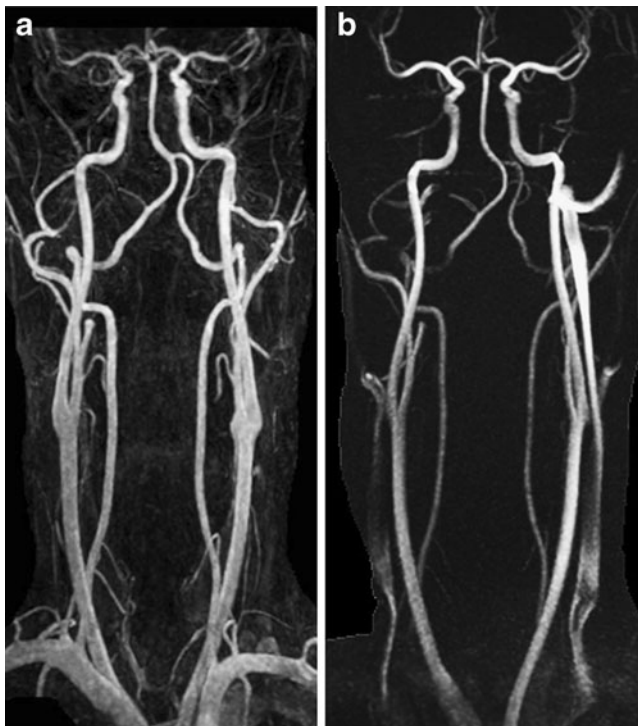

Fig. 1 MIPs of CE-MRA (**a**) and Inhance (**b**) of a 44-year-old patient with acute left-sided lenticulostriate infarction. MRA was performed to exclude an ICA dissection, which was not detected on both sequences
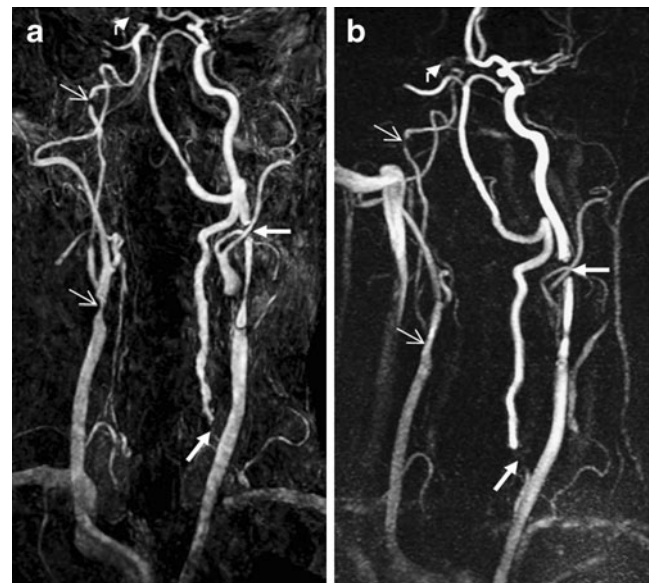

Fig. 2 MIPs of CE-MRA (**a**) and Inhance (**b**) of a 74-year-old patient. Both sequences show a tandem stenosis of the right ICA (*thin arrows*) as well as an occlusion of the right MCA (*angled arrows*). After stenting of the left-sided proximal ICA and VA, hemodynamic relevant in-stent stenosis must be suspected based on the signal loss within the stent on CE-MRA as well as on Inhance (*thick arrows*)

vessels. Recently, an optimised version of this PC-MRA-technique, the so-called Inhance, has been developed. This new application is supposed to be robust, fast and easy to use and ought to deliver consistent, reproducible images even in difficult-to-scan anatomies with an acceptable scan time. Compared to TOF, Inhance offers the advantage that additional to the intracranial arteries the extracranial arteries can as well be assessed in the same acquisition without an enormous extension of the acquisition time. However, our results indicate that Inhance is of limited use in the assessment of the origins of the cervical vessels (common carotid artery, internal carotid artery, vertebral artery). This fact ought to be considered in the clinical application of this sequence.

Preliminary data have been published showing an effectiveness of Inhance in the evaluation of the intracranial arteries [11]. In addition, authors assume that Inhance might help to minimise image distortion associated with magnetic susceptibility variations (e.g. caused by orthodontic devices) compared with TOF.

Conclusion

In this feasibility study, we found that, apart from their ultimate origins from the aortic arch, Inhance allows good visualisation of the supraaortic vessels, and depicts cervical vascular pathologies comparably to CE-MRA. This suggests that Inhance might be a reasonable alternative to CE-MRA, especially in patients with renal insufficiency.

Conflict of interest We declare that we have no conflict of interest.

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