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Diagnostic Performance of Combined Contrast-Enhanced Magnetic Resonance Angiography and Phase-Contrast Magnetic Resonance Imaging in Suspected Subclavian Steal Syndrome

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Abstract

Purpose: The study sought to evaluate the efficacy of magnetic resonance imaging (MRI) in patients with suspected subclavian steal syndrome (SSS) using both contrast-enhanced (CE) MR angiography and phase-contrast (PC) MRI.
Methods: Fifteen suspected SSSs from 13 patients were evaluated using CE-MR angiography and PC-MRI. Ten patients also received dynamic CE-MR angiography.
Results: All MRI examinations were technically successful. By combining CE-MR angiography with PC-MRI, 10 SSSs were diagnosed in 9 patients. The delay enhancement dynamic technique predicted SSS with a sensitivity, specificity, and accuracy of 57.1%, 100%, and 72.7%, respectively. Without the dynamic technique, affected delay-enhanced arteries were poorly visualized and could be mistaken for occluded vessels. Retrograde vertebral flow by PC-MRI was used to predict ipsilateral SSS with a sensitivity, specificity, and accuracy of 100%, 60%, and 86.7%, respectively. There were 2 false positives including 1 patient with a proximal total occlusion of the affected vertebral artery and another with brachiocephalic steal syndrome rather than SSS. This suggested that retrograde vertebral flow does not always indicate SSS.
Conclusions: CE-MR angiography combined with PC-MRI is efficacious when evaluating SSS in clinical practice.

Résumé

Objet : L'étude avait pour objectif d'évaluer l'efficacité des techniques d'imagerie par résonance magnétique (IRM), notamment l'angiographie par résonance magnétique (ARM) avec injection de produit de contraste et l'IRM par contraste de phase, chez les patients qui semblent présenter un syndrome de vol sous-clavier.
Méthodes : Une ARM avec injection de produit de contraste et un examen d'IRM par contraste de phase ont servi à évaluer 15 cas présumés de syndrome de vol sous-clavier chez 13 patients. Dix patients ont également subi une ARM dynamique avec injection de produit de contraste.
Résultats : Tous les examens d'IRM ont été réussis sur le plan technique. Le recours concomitant à l'ARM avec injection de produit de contraste et à l'IRM par contraste de phase a permis d'établir 10 diagnostics de syndrome de vol sous-clavier chez 9 patients. Comme méthode de prédiction du syndrome de vol sous-clavier, la technique dynamique d'acquisition tardive après injection d'un produit de contraste a affiché une sensibilité de 57,1 %, une spécificité de 100 % et une précision de 72,7 %. Sans la technique dynamique, les artères étaient difficiles à discerner et ressemblaient à s'y méprendre à des vaisseaux occlus. Comme méthode de prédiction d'un syndrome de vol sous-clavier ipsilatéral, l'observation d'un débit rétrograde dans l'artère vertébrale lors de l'IRM par contraste de phase a affiché une

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sensibilité de 100 %, une spécificité de 60 % et une précision de 86,7 %. Deux résultats faussement positifs ont été observés. Dans le premier cas, il s'agissait d'une occlusion totale de la partie proximale de l'artère vertébrale touchée, et dans le second, d'un vol brachiocéphalique plutôt que d'un vol sous-clavier. Ces constatations révèlent que la présence d'un débit rétrograde dans l'artère vertébrale n'évoque pas toujours un syndrome de vol sous-clavier.

Conclusion : Le recours concomitant à l'ARM avec injection de produit de contraste et à l'IRM par contraste de phase permet d'évaluer efficacement le syndrome de vol sous-clavier dans un contexte clinique.

Key Words: Brachiocephalic steal syndrome; Magnetic resonance angiography; Phase-contrast imaging; Subclavian steal syndrome

Subclavian steal syndrome (SSS) involves changes in hemodynamics secondary to proximal subclavian artery (SA) stenosis or occlusion where the SA ''drains'' the blood from the ipsilateral vertebral artery (VA) [1]. Symptoms from compromised vertebrobasilar and brachial blood flow include paroxysmal vertigo, drop attacks, or arm claudication [2].

Catheter-based angiography is still the gold standard for imaging of SSS due to its ability to depict narrowing of the SA and retrograde flow within the ipsilateral VA. Because angiography involves ionizing radiation exposure and is costly and invasive, Doppler ultrasonography (US) is currently the first-line choice for imaging SSS. Documenting retrograde flow in an intertransverse segment of the VA is the most commonly used method for indicating the presence of ipsilateral SSS on Doppler US [3–6]. However, this modality is operator dependent and limited in patients with short necks, large scars, deep thoracic vessel locations, and tortuous vessels with unusual configurations.

In cases with inconclusive results on Doppler US, noninvasive magnetic resonance imaging (MRI) is favored, although it is more expensive and takes longer to perform than US. There are various MRI techniques available to evaluate patients with suspected SSS [7–11]. Among them, contrast-enhanced (CE) MR angiography and phase-contrast (PC) MRI are preferred [7,8], although the literature concerning the diagnostic performance of the combined protocol is still limited. This retrospective study was designed, therefore, to address the technical feasibility and efficacy of the combination of CE-MR angiography and PC MRI in diagnosing SSS, as well the potential pitfalls encountered when using this combined technique.

Materials and Methods

Patients

Our institutional review board approved this single-institution, retrospective study and waived informed consent. From 2007-2013, a total of 13 patients (10 men and 3 women; mean age, 61.7 years, range, 9-86 years) with suspected SSS and inconclusive results on Doppler US were referred to our department for further evaluation. Ten patients were suspected of having left-sided SSS, 1 patient was suspected of having right-sided SSS, and 2 patients were thought to have bilateral SSS involvement.

Among the 13 patients, 2 received graft surgery including 1 patient (case #9) who received a left common carotid artery to left SA graft operation for left SA total occlusion at another hospital. The other patient (case #13) with congenital right aortic arch (RAA) with a hypoplastic aberrant retroesophageal left SA and a Kommerell's diverticulum received aortopexy, excision of the Kommerell diverticulum, division and reconstruction of the left SA with an aorta-left SA graft.

MRI Protocol

All MRI examinations were performed with a 1.5-T MRI (Magnetom Sonata, Siemens Medical Solutions, Erlangen, Germany) equipped with a high-performance 3-axis gradient system. Signal reception involved the use of a standard birdcage head coil and a 2-element phased-array neck coil. In addition to the triplane gradient echo localizer pulse sequence, the scan protocol, during the same imaging session, included (a) coronal 3-dimensional (3D) T1-weighted (T1W) fast low angle shot (FLASH) gradient echo sequence used for CE-MR angiography (with scan fields from the skull base to upper chests before and after intravenous gadolinium-based contrast agent injections), and (b) axial 2-dimensional (2D) through-plane velocity-encoded FLASH gradient echo sequence used for PC-MRI with the retrospective pulse-gated cine technique applied proximal ($n = 12$) or distal ($n = 1$) to the carotid bifurcation.

The gadolinium chelate was injected at 1.0-2.0 mL/s using a dual-head power injector (Missouri Ulrich; Ulm, Germany), followed by a saline chaser of 20 mL injected at the same rate through a 22- or 24-gauge peripheral IV line in the upper extremity. The dose of gadolinium given was 0.1 mmol/kg gadobenate dimeglumine (Gd-BOPTA, MultiHance; Bracco SpA, Milano, Italy), gadoteric acid (Gd-DOTA, Dotarem; Guerbet, Roissy CdG, France), or gadobutrol (Gd-BT-DO3A, Gadovist; Bayer Schering Pharma, Berlin, Germany).

To obtain the appropriate scan-delay after contrast injection for CE-MR angiography, the combined applications to reduce exposure bolus technique was used [12]. By using the parallel acquisition technique (generalized autocalibrating partially parallel acquisitions [GRAPPA) with an acceleration factor of 2, data acquisition times of approximately 8 seconds were used, with small variations among individuals [13].