Improved Detection of Parenchymal Cysticercal Lesions in Neurocysticercosis with T2*-weighted Angiography Magnetic Resonance Imaging

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Rationale and Objectives: Magnetic resonance imaging (MRI) is an important tool for the diagnosis and management of various central nervous system infections. In the present study, we investigated the role of T2*-weighted angiography (SWAN) imaging in the diagnosis of neurocysticercosis (NCC) viz-a-viz conventional MRI.

Methods: Symptomatic (n = 46) and asymptomatic (n = 88) cases from a pig-farming community were imaged using both conventional and SWAN MRI between July 2009 and May 2011. Two experienced neuroradiologists independently reviewed all the images to characterize the lesions as well as detection of the scolex.

Results: A total of 250 lesions were detected in 70 individuals. On conventional MRI, the lesion and scolex visibility was 82.4% (206/250) and 60% (150/250), respectively, which increased to 96.8% and 81%, respectively, using SWAN imaging. On combining SWAN with conventional MRI, the scolex visibility increased to 85% (213/250) of the total 250 lesions detected. Overall, adding SWAN to conventional MRI increased the lesion detection and scolex visibility up to 18% (206 vs. 250) and 30% (150 vs. 213), respectively.

Conclusion: SWAN imaging when added to the conventional MRI protocol for population screening for NCC in endemic regions improves both lesion detection and definitive diagnosis of neurocysticercosis.

Key Words: Neurocysticercosis; MRI; susceptibility weighted imaging.

INTRODUCTION

Neurocysticercosis (NCC) is a parasitic infection of the central nervous system (CNS) caused by the larvae of *Taenia solium*, commonly known as tapeworm. It is the most common cause of acquired epilepsy in the developing world including India (1,2). The diagnosis of NCC is masked by its polymorphic clinical presentation. A wide range of serological assays has been developed for the diagnosis of NCC such as detection of anticysticercal antibodies in serum or cerebrospinal fluid (CSF) by enzyme linked immunosorbent assay (ELISA) or immunoblot with varying sensitivity and specificity (3). However these assays have been less than satisfactory giving high false positive and false negative reactions. An enzyme linked immunoelectrotransfer blot (EITB) assay using specific glycoprotein (GP) antigens was developed by the Centers for Disease Control and Prevention, Atlanta, GA, with reported sensitivity of 98% and specificity of 100% (4). A study showed only 28% sensitivity in serum samples of patients with single cyst infection (5). Subsequent studies from other countries have shown variable results. In Ecuador, 86% of patients with active lesions, 67% with transitional lesions, and only 41% of patients with inactive lesions were positive by the EITB, thus having an overall sensitivity of only 53.6% (6). In a recently published report from South India, only 12 of 46 (26.1%) patients with computed tomography (CT) diagnosis of NCC were positive by EITB (7).

Neuroimaging modalities such as CT and magnetic resonance imaging (MRI) have greatly improved the accuracy

Acad Radiol 2012; 19:958–964

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doi:10.1016/j.acra.2012.03.019

of diagnosis of NCC. Although CT is considered a more sensitive tool for the detection of calcifications (8), MRI is better to resolve the differential diagnosis of NCC as it provides objective evidence on the number and topography of lesions, its stage of involution, and the degree of inflammatory reaction. It provides both morphological and functional information and is considered the best neuroimaging tool for the detection of degenerating and innocuous (viable) cysticercosis (9).

Susceptibility-weighted imaging (SWI) with and without phase filtration has been shown to spot calcification as well as demonstrate scolex in a CT hyperdense lesion (10,11). The filtered phase images obtained from a gradient echo sequence have been reported to be as good as CT for the detection of the calcified stage of the parasite (12) as well for the demonstration of the scolex. The loss of phase coherence measured after an radio frequency pulse because of fluctuations in local magnetic fields resulting from intrinsic molecular motion and diffusion (T2), and magnetic field inhomogeneities that occur at macroscopic level ($T2^{l}$) is referred to as T2⋆. It is inverse of relaxivity (R2⋆). T2⋆-weighted angiography (SWAN) is a type of SWI that helps in visualizing and clearly delineating small vessels and micro bleeds, large vascular structures, and iron and calcium deposits in the brain. It generates more than twice the signal-to-noise ratio compared to a conventional T2⋆-weighted imaging, thus allowing high spatial resolution (13,14). It exploits the susceptibility differences between tissues and uses the phase image to detect these differences. Recently, SWAN-derived phase imaging has been shown to correlate with CT Hounsfield units and R2⋆ values, and shown to be able to differentiate diamagnetic from paramagnetic substances (15).

In the present study, we used conventional MRI with and without SWAN imaging to investigate whether the inclusion of SWAN imaging will make any noticeable change in the detectability of NCC in the pig farming community.

MATERIALS AND METHODS

Study Subjects

The study was performed in subjects from the pig farming community (including pig breeders and their families) of Mohanlalganj block, Lucknow district in Uttar Pradesh, India. The community was selected on the basis of our previous studies that showed a high prevalence of *T. solium* taeniasis (18.6%) and NCC-related seizures (5.8%) in the cases belonging to this community (16,17). Apparently healthy asymptomatic individuals as well as individuals with seizures were enrolled randomly for the present study between July 2009 and May 2011. All treatment-naive symptomatic subjects had new onset seizures. Only subjects with seizure focus corresponding to the side of lesion were included. All symptomatic cases received antiepileptic drugs after MRI. None of them was given antihelminthic drugs before MRI. The seizures were classified as per international league against epilepsy classification of seizures (18). Asymptomatic cases were defined as individuals with no evidence/history of seizure, headache, sensory or motor neurofocal deficit, cranial nerve involvement, and psychiatric or behavioral abnormalities. The subjects who did not have demonstrable cysticercus lesion on MRI or had symptoms related to non-NCC pathology were excluded. The Institute's ethics committee approved the study and all individuals included in the study consented for enrollment.

Neuroimaging

Whole-brain conventional and SWAN MRI used a 3T MR scanner (Signa HDxt, General Electric, Milwaukee, WI) using a 12-channel head coil. MRI included T2-weighted (repetition time (TR)/echo time (TE)/number of averages (NEX)/ = 5.6 ms/9.5 ms/1/imaging matrix of 320 × 320 pixels), T1-weighted (TR/TE/inversion time = 2.4 ms/12 ms/0.92 ms/imaging matrix of 512 × 256 pixels) and T2-weighted fluid attenuated inversion recovery (FLAIR, TR/TE/inversion time = 8.8 ms/86 ms/2.2 ms/imaging matrix of 256 × 160 pixels). All these images were acquired with a field of view of 240 × 240 mm^2 and 3-mm slice thickness without any interslice gap. In addition, SWAN imaging with TR/TE/NEX = 40 ms/24.5 ms/0.7 imaging matrix of 320 × 224 pixels and with 2.4-mm slice thickness was also used. After administration of gadolinium contrast agent at a dose of 0.1 mmol/kg body weight T1-weighted MRI was repeated using the same precontrast acquisition conditions.

The final diagnosis in these cases was based on typical MRI characteristics and other major/minor criteria as described in the literature (3). Viable (vesicular) cysticerci appeared as cystic lesions having a thin wall demarcated from the parenchyma without perilesional edema or contrast enhancement (Fig 1). Degenerating cysts appeared as ill-defined lesions surrounded by perilesional edema that enhanced after contrast administration (Fig 2). The perilesional edema was best visualized on MRI with FLAIR technique, whereas calcified (dead) cysticerci appeared either as small hypodense nodules on T2-weighted/FLAIR and/or SWI, with/without perilesional edema with/without nodular/ring contrast enhancement. All the subjects who were positive for calcified lesion on phase imaging underwent CT to confirm the presence of calcification (Fig 3).

Imaging Analysis and Quantification

Complex data consisting of real and imaginary parts were collected using multi-echo SWAN imaging. The phase calculation with removal of susceptibility artifacts was performed by using in-house developed Java-based software as described (15).

Number of lesions (single or multiple), stage of cysticerci (vesicular, degenerating, and calcified), and topography of the cyst/cysts were analyzed from the images obtained by