

Detection of multiple intracranial hemorrhages in a child with acute lymphocytic leukemia (ALL) by susceptibility weighted imaging (SWI)

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Susceptibility weighted imaging (SWI) combines magnitude and phase information from a high-resolution, fully velocity compensated, three-dimensional (3D) gradient echo sequence. We report on the use of this MRI technique in a young patient with acute lymphocytic leukemia (ALL) and demonstrate a higher detection rate of hemorrhagic lesion in comparison with other T2*-weighted sequences.

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Abbreviations: SWI, susceptibility-weighted imaging; 3D, three-dimensional; MRI, magnetic resonance imaging; ALL, acute lymphocytic leukemia; T1W, T1-weighted; T2W, T2-weighted; GRE-EPI, gradient-echo single-shot echo-planar imaging; FoV, field of view; GRE, gradient-echo

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Introduction

Susceptibility weighted imaging (SWI) combines magnitude and phase information from a high-resolution, fully velocity compensated, three-dimensional (3D) gradient echo sequence [1,2]. Originally designed as MR-Venography, this sequence uses susceptibility differences between deoxygenated venous blood and the adjacent tissue for depiction of intracranial veins. However, SWI is able to display susceptibility differences between any tissues e.g. between normal brain parenchyma and blood products. The magnetic susceptibility (χ) is a physical property that describes the degree of magnetization of a material in response to an applied magnetic field. If χ is positive, the material is called paramagnetic and the local magnetic field is strengthened compared to the external magnetic field e.g. hemorrhage; alternatively, if χ is negative, the material is diamagnetic and the local magnetic field is weakened e.g. calcification.

We report on the use of this MRI technique in a young patient with acute lymphocytic leukemia (ALL) demonstrating multiple cerebral hemorrhages.

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Case Report

A 14-year-old boy presented with increasing fatigue, diminished appetite and generalized loss of power in the pediatric outpatient department. The physical examination showed multiple hematomas on the lower limbs, petechiae on the body as well as conjunctival and intraocular signs of bleeding. He did not present any focal neurological signs; the lab test indicated normal blood coagulation. A bone marrow biopsy revealed the diagnosis of dendritic cell leukemia, a subtype of T-cell leukemia.

A magnetic resonance imaging (MRI) scan (Siemens Magnetom Vision plus) of the brain showed multiple abnormal signal intensity foci, consistent with hemorrhages of varying ages on T1-weighted (T1W) and T2-weighted (T2W) images. Because of suspected hemorrhages a gradient-echo single-shot echo-planar imaging (GRE-EPI) and an SWI data set were also acquired.

The high-resolution SWI sequence is a fully flow

compensated 3D gradient echo sequence (TR/TE/ α = 60/40/25°, FoV = 240 x 150 x 72 mm³, matrix = 512 x 240 x 60, zero filling to 512x384x96). Acquisition time for the coverage of the whole brain was 9.5 minutes. Phase images do not need additional acquisition time. Images were reconstructed with an in-house developed interactive tool chain [3]. Phase images were unwrapped using a new algorithm (S Witoszynskyj et al., presented at the 2005 annual meeting of the International Society of Magnetic Resonance in Medicine, [freely available from the author](#)), high pass filtered and converted into a phase mask [4,5] to highlight phase changes associated with differences in magnetic susceptibility. The phase masks were then multiplied with the corresponding magnitude images to create susceptibility weighted images (SWI). Minimum intensity projections over 7 slices were computed from the SWI in sliding window mode.

T1-weighted images showed 13 lesions and T2-weighted images 15 lesions, all consistent with subacute to chron-



Figure 1A. A minimum intensity projection over 7 adjacent slices depicts two hypointense lesions in the right pedunculus cerebelli and the pons.

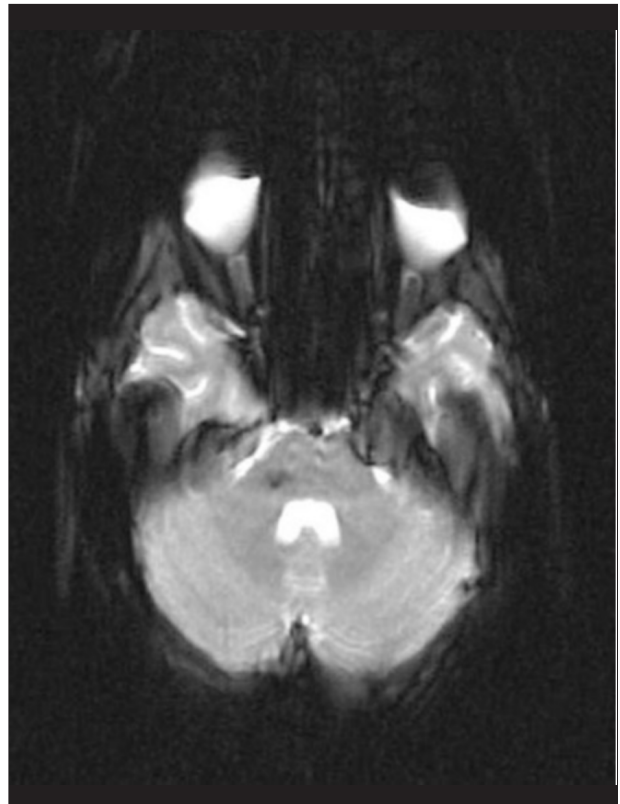


Figure 1B. Corresponding GRE-EPI image. Note the suboptimal demarcation of the cerebellar lesion and the geometric distortion due to magnetic field inhomogeneities at the interfaces between tissue and air.

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ic hemorrhages. The GRE-EPI depicted 20 hypointense lesions (Fig. 1b and 2b), while 31 were noted in SWI (Fig. 1a and 2a). Most hemorrhages were located in the cerebral hemispheres (26 in total, 9 of those in the parietal lobe, 10 in the frontal lobe, 3 in the temporal and 4 in the occipital lobe). Two of the hemorrhages were located in the putamen and the external capsule, and one each in the corpus callosum, pons and the cerebellum. All of the hemorrhages noted on the T1W, T2W and the GRE-EPI were seen on SWI. The lesion count difference between SWI and GRE-EPI was due to small hemorrhages (<10mm).

Discussion

Hemorrhagic complications are common in patients with acute leukemia and constitute its second most frequent cause of death. Intracranial hemorrhage influences the achievement of com-

plete remission and also shortens the probability of overall survival in acute leukemia patients [6]. It is therefore essential to document and follow-up all such hemorrhages. The following discussion provides a brief overview of the role played by conventional MR imaging in evaluation of intracranial hemorrhages and highlights the complementary role played by SWI in assessing such lesions in a more detailed manner. MR imaging characteristics of intracranial hemorrhages depend on multiple intrinsic parameters like the oxygenation state of hemoglobin and the integrity of red blood cells resulting in the typical signal variation in time and space on T1- and T2- weighted images.

The high magnetic susceptibility of most



Figure 2A. Minimum intensity projection over 7 adjacent slices showing multiple hemorrhages.

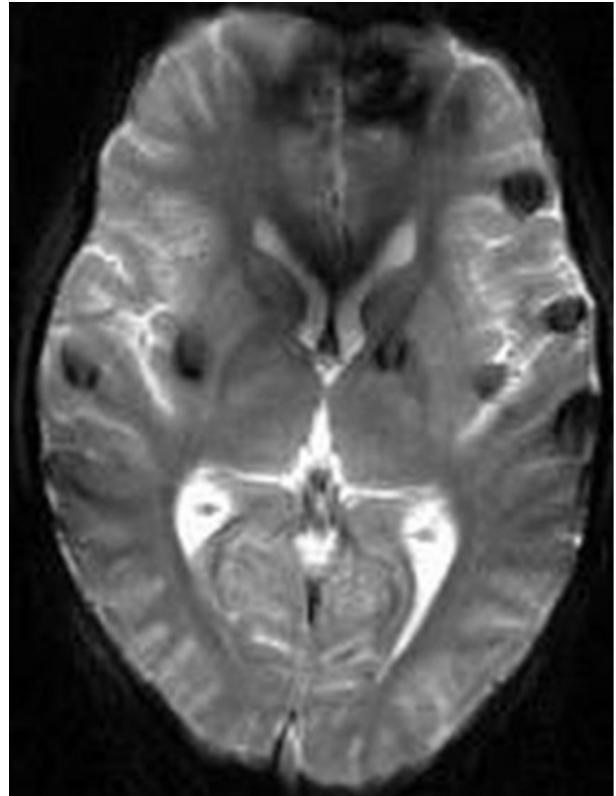


Figure 2B. Corresponding GRE-EPI. The small lesions in the corpus callosum and the occipital grey matter can not be depicted (see arrows in Figure 2A).

hemoglobin degradation products (deoxyhemoglobin, methemoglobin, ferritin and hemosiderin) leads to a local distortion of the magnetic field, which can be exploited with MRI. Local susceptibility differences within voxels cause spin dephasing and signal loss. GRE sequences feature a high sensitivity towards these susceptibility effects as a result of the missing 180° refocusing pulse. Independent of the age of the hemorrhage, GRE sequences show these areas as hypointensities [7].

In routine clinical imaging, GRE-EPI is widely used for detection of hemorrhages. GRE-EPI is characterized by low spatial resolution and long echo time. In comparison to a conventional GRE, this sequence type provides a comparable sensitivity for detection of hemorrhages in the supratentorial compartment with a forty to fifty fold increased time resolution [8]. A major disadvantage of GRE-EPI is that the signal loss occurs exactly in interesting regions and that the true spatial extent of lesions is therefore difficult to assess. Additionally it shows pronounced geometric distortion in the skull base and in areas close to the cranial bone due to susceptibility artefacts at the interfaces between air or bone and the parenchyma. However, high spatial resolution would lead to a decrease in spin dephasing and thus the visibility of lesions would be reduced. The highly resolved SWI overcomes this limitation by combining high spatial resolution with excellent sensitivity towards local magnetic field inhomogeneities by incorporating phase images.

In a study which compared the ability of SWI and GRE in detection of hemorrhagic shearing lesions in patients with posttraumatic diffuse axonal injury, SWI proved to be superior and could depict up to six times more lesions than GRE. Differences were greatest in the frontal white matter, the brainstem and the cerebellum and for microhemorrhages ($<10\text{mm}$) [9], which is con-

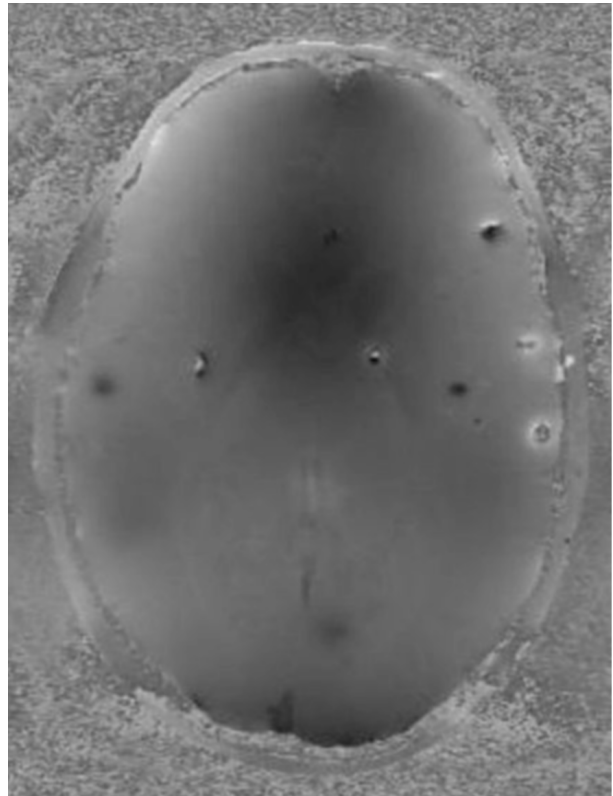


Figure 2C. Corresponding phase image with the typical topography of a paramagnetic dipole (dark areas below and above the lesion and a bright rim at the equator of the lesion).

sistent with our results. SWI also enables a better definition of lesion borders and localization.

Furthermore, analysis of the phase images provides a plethora of additional information that is not accessible by the magnitude or the SWI images alone. Both the magnitude and the SWI image only present signal loss due to local magnetic inhomogeneities but not whether it is caused by paramagnetic or diamagnetic substances. In contrast, the phase images map the different local resonance frequencies (Fig. 2c). As a result, lesions have a specific appearance in phase images depending on their magnetic susceptibility which allows discrimination of calcified and hemorrhagic tumors for example [10,11]. A dis-

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advantage of this method is its long acquisition time. However, acquisition time can be reduced without loss of sensitivity or spatial resolution by using high field strengths, which become increasingly available in routine clinical use.

In conclusion, SWI showed a higher sensitivity in detecting hemorrhagic lesions associated with acute leukemia compared to other T2*-weighted sequences. We speculate that such detailed evaluation may alter patient management in particular in patients with more inconspicuous findings.

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