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Original Research Article

DOES ADDING A SEQUENCE IN BRAIN MRI HELP IN THE EVALUATION OF SEIZURES?

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ABSTRACT

Objective

To evaluate the diagnostic utility of Susceptibility Weighted Angiogram (SWAN) in brain magnetic resonance imaging (MRI) by identifying venous angiomas causing epileptic seizures.

Methods

A retrospective observational study was performed in the Radiology department at King Fahad Military Medical Complex (KFMC) hospital in Dhahran from January 2016 to 2021. All consecutive adult patients who underwent brain MRIs for epilepsy with SWAN were included. Patients with brain tumors, traumatic brain injuries, and post-surgical cases were excluded. The presence of tuft of small deep parenchymal veins draining into a more prominent (transcortical or subependymal) collector vein as seen on SWAN image was considered a venous angioma and confirmed on either contrast-enhanced studies or cerebral angiograms. Two experienced neuroradiologists interpreted the studies with mutual consensus. The significance of such finding was considered if SWAN-detected venous malformation corresponded to an epileptiform focus on respective electroencephalogram (EEG). Findings were compared with incidentally detected venous angiomas in normal brain MRIs in patients without indications of seizures (control group, n=112). Proportion analysis (Z-test) was used to determine significance.

Results

Out of 112 patients, 64 were females (57%), and 48 were males (43%), with a mean age of 19.24 (range, 5-45 years). Twenty-three patients (epilepsy group) were found to have venous malformations while three (control group) had venous angiomas (Z-value= 3.93; p-value< 0.001). Out of 23 patients, 20.53% were SWAN-detected venous angiomas, 5 corresponded to epileptiform foci on respective EEGs compared to none of 3 incidentally detected venous angiomas in the control group (p-value<

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0.001).

Conclusion

Venous angiomas are usually asymptomatic when detected incidentally. However, adding a SWAN sequence in routine brain MRI for epilepsy patients may help to detect venous angiomas, which may cause focal seizure activity in these patients.

الملخص

الهدف

تقييم الفائدة التشخيصية لصورة الرنين المغناطيسي الموزنة بقابلية التمغنط (سوان SWAN) بالتصوير بالرنين المغناطيسي للدماغ في تحديد الأورام الوعائية الوريدية المسببة لنوبات الصرع .

المنهجية

تم إجراء دراسة مرجعية في قسم الأشعة بمستشفى مجمع الملك فهد الطبي العسكري بالظهران من يناير ٢٠١٦ إلى يناير ٢٠٢١. تم اختيار جميع المرضى البالغين الذين خضعوا لتصوير الدماغ بالرنين المغناطيسي لتشخيص الصرع باستخدام تقنية سوان. تم استبعاد المرضى الذين يعانون من أورام في المخ وإصابات في الدماغ وحالات ما بعد الجراحة. تم اعتبار وجود خصلة من الأوردة المتينة الصغيرة العميقة التي تصب في وريد جامع أكثر بروزا (عبر القشرة الدماغية أو تحت البطانة العصبية) في الصورة ورمًا وعائيًا وريديًا وتم تأكيده بناء على الفحوصات التي استخدمت الصبغة الوريدية أو فحوصات الأوعية الدموية. نتيجة تشخيص الأشعة تمت بالاتفاق من قبل أخصائيان أعصاب. تم النظر في أهمية كون التشوه الوريدي الذي تم اكتشافه بتقنية سوان يتوافق مع تركيز الصرع المشاهد على مخطط كهربية الدماغ. تمت مقارنة النتائج مع الأورام الوعائية الوريدية المكتشفة بالصدفة في التصوير بالرنين المغناطيسي للدماغ في المرضى الذين ليس لديهم أعراض الصرع (المجموعة المرجعية عدد=١١٢). تم استخدام تحليل النسب (Z-test) لتحديد الفروقات الإحصائية .

النتائج

من أصل ١١٢ مريضاً كان ٦٢ من الإناث (٥٧٪) بمتوسط عمر ١٩.٢٤ سنة (المدى ٥ - ٤٥ سنة). تم العثور على تشوهات وريدية في ثلاثة وعشرين مريضا في مجموعة الصرع. تم اكتشاف أورام وعائية وريدية لدى ثلاثة مرضى في المجموعة المرجعية .(Z-value=3.93;p-value<0.001) من بين ٢٣ مريضًا, كان ٢٠.٥ ٪ لديهم أورام وعائية وريدية تم اكتشافها بواسطة تقنية سوان, بينما خمسة مرضى وجد لديهم توافق في بؤر الصرع بين تخطيط كهربية الدماغ مقارنة مع ب ثلاثة أورام وعائية وريدية تم اكتشافها بالصدفة في المجموعة الضابطة (p-value<0.001).

الخلاصة

عادة ما تكون الأورام الوعائية الوريدية بدون أعراض عند اكتشافها بالمصادفة. إضافة تقنية سوان SWAN للتصوير بالرنين المغناطيسي الروتيني للدماغ لمرضى الصرع قد يساعد في الكشف عن أورام الأوعية الدموية الوريدية.

Keywords: seizures, MRI, brain, epilepsy, susceptibility weighted angiogram

1. INTRODUCTION

Epilepsy can occur both in children and adults [1, 2]. It happens due to abnormal excessive or synchronous neuronal activity in the brain, leading to periods of unusual behavior, sensation, and occasionally unconsciousness. Genetic factors, brain insult (hypoxic-ischemic,

birth trauma, accidents), high fever, excessive fatigue, poisoning, alcohol, brain tumors, vascular malformations, certain brain conditions (stroke, Alzheimer's disease), infectious and developmental disorders are amongst vast causes of such disorder. Once an epileptic seizure is witnessed or observed by the bystanders or family members, clinically assessment, laboratory, and non-laboratory testing are required to evaluate further to identify the cause of this problem [1–3]. Neuroimaging, including computed tomography (CT) and MRI, remain essential tools for a thorough diagnostic workup of this condition [4]. MRI is preferred and recommended because of its inherent contrast properties, multiplanar imaging and delivers extraordinary detail of grey and white matter of brain parenchyma [5].

Brain vascular malformations are frequently associated with intractable seizures, a common cause of lesional epilepsy [6]. It is thought that cavernous angiomas can trigger epilepsy by irritating surrounding brain tissue, probably because of repeated hemorrhages [7]. Susceptibility-weighted imaging (SWI) is a high spatial resolution MRI sequence that accentuates the paramagnetic properties of blood products [1, 3]. Using paramagnetic deoxy-hemoglobin (deoxy-Hb) in the cerebral veins as an intrinsic contrast agent, SWI can demonstrate the normal cerebral veins and cerebral venous abnormality without contrast administration [3, 4]. We started incorporating SWAN (susceptibility weighted angiogram) in routine brain MRI to detect calcification, blood products, or microbleed for a few years. We observed small venous angiomas on routine MRI imaging workup in patients with focal seizures. Therefore, we aimed to evaluate the significance of their detection in contributing to seizure activity.

2. METHODS

This retrospective cross-sectional study was performed in the Radiology department at King Fahad Military Medical Complex (KFMC) hospital in Dhahran from January 2016-2021. All patients (n=112) who underwent routine brain MRI in diagnostic or follow-up work-up for epilepsy with brain MRIs (with SWAN sequences) were included. Patients with structural brain lesions or tumors, traumatic brain injuries, and post-operative cases were excluded. The Hospital Research and Ethics Committee approved the research protocol. The study was conducted in accordance with the Helsinki Declaration. Clinical information was obtained from patients' medical records via Hospital Information System (HIS). At the same time, MR imaging findings were reviewed through the Radiology Information System (RIS) and the Picture Archiving and Communication System (PACS). All clinical and radiological data were kept confidential.

All MRI brain studies were performed on a 1.5 Tesla machine (General Electric/ GE, Optima 450 W GEM, 2013, Florence, South Carolina, USA). Routine brain imaging

included T1-Weighted axial and sagittal. Fast Spin Echo (FSE) sequences, T2-Weighted axial, FLAIR (Fluid Attenuation and Inversion Recovery), and DWI (Diffusion-Weighted Imaging). For SWAN, TE 50 milliseconds; TR minimum (74ms); flip angle of 15 degrees; matrix 320 x 192; FOV 24 cm; section thickness 2 mm; bandwidth 41.67 kHz, the number of slice 40; acquisition time 4 minutes. Axial, coronal, and sagittal T1W post-contrast images were acquired in needed cases.

Presence of blooming artifact (i.e., susceptivity artifact caused by the presence of a paramagnetic substance, seen as an area focal hypo-intensity/black area) when seen as a linear or curvilinear structure was taken as a vascular structure containing blood within. Either contrast-enhanced (axial, sagittal, and coronal) T1W imaging or cerebral angiographies were performed if the blooming artifact was seen opacified with contrast. Two experienced neuroradiologists interpreted the brain MRIs, blinded clinical information and final diagnoses and made consensus reporting. Any vascular malformation suspected on SWAN sequence was confirmed on subsequent contrast-enhanced study or cerebral angiography. Significance was considered if SWAN-detected venous malformation corresponds to an epileptiform EEGs focus. High-frequency discharges and sharp focal waves acquired on EEGs were deemed to be epileptiform foci.

Findings were compared with incidentally detected venous angiomas in normal brain MRIs that employed the same protocol (control group). In cases of detection of venous angioma in normal or asymptomatic consecutive patients (for whom MRI brain imaging was requested for non-specific causes other than seizures or epilepsy like headaches) at the same study period by the SWAN imaging, EEGs were acquired to document any abnormal findings for the study purposes. Z-test (proportion analysis) was used to determine significance.

3. RESULTS

Out of 112 patients, 64 were females (57%), and 48 were males (43%), with a mean age of 19.24 (range, 5-45 years). Twenty-three patients (epilepsy group) were found to have venous malformations while 3 (control group) had venous angiomas (Z-value, 3.93; P-value, 0.0008) [Table 1].

Table 1 Imaging (MRI) and EEG findings in the control and epilepsy group.

Groups	Total Number	Vascular Malformation	EEG Activity
Control Group	112	23	5
Epilepsy Group	112	3	0

EEG: electroencephalogram

Twelve out of 23 patients were seen to have venous malformations in their frontal lobes (either subcortical or at centrum semiovale), while 9 patients were in parietal lobes [Figure 1]. Most of the positive cases (17/23) had epileptic foci on EEGs. Out of 23 (20.53%) SWAN-detected venous angiomas, 5 corresponded to epileptiform foci on respective EEGs compared to none of 3 incidentally detected venous angiomas in the control group (P-value, 0.0005).

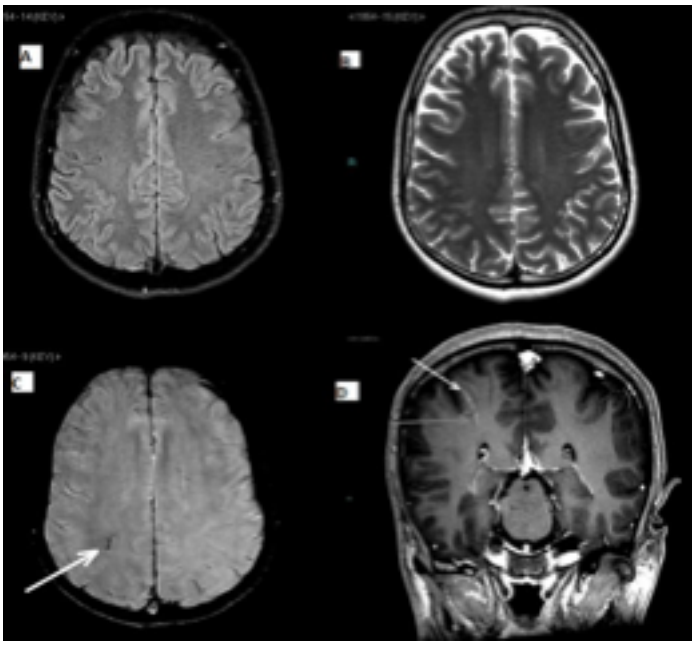

Figure 1 Selected MR brain images of a patient showing(a) axial FLAIR and (b) axial T2W images (upper row), (c) axial SWAN image, and(d) contrast-enhanced coronal T1W images (bottom row). Note that the vascularmalformation (in this case, a venous angioma) is seen as a linear enhancingstructure (d) reaching the subcortical parietal lobe that was a small branchingblack structure on SWAN image (c).

4. DISCUSSION

Susceptibility weighted imaging, also called blood-oxygen-level-dependent (BOLD) venographic imaging or T2* weighted angiography, is an MRI sequence that is extremely sensitive to venous blood, hemorrhage/blood products or microbleed, and iron/methemoglobin [8–10]. It is a high-resolution 3-dimensional-multi-echo gradient sequence generated by a combination of magnitude and filtered phase images. It uses tissue magnetic susceptibility differences to develop a unique contrast different from spin density, T1 W, T2W, and T2* W angiography [8].

Short TE provides a time-of-flight effect allowing high-resolution visualization of cerebral vessels [8, 9]. We exploited this capability of SWAN imaging in our routine practice

to detect small venous malformation (venous angioma) and found a reasonably high proportion of detection amongst the population with a statistically significant P-value. No prior local studies are available to document such observation. We initially started to use this sequence particularly for trauma settings (to look for microbleed or diffuse axonal injury) and in cases of stroke (to look for hemorrhagic component or transformation of an infarct). However, later we found that incorporating it as a regular sequence in routine epilepsy work-up could pick small venous malformations that remained undetected on initial non-SWAN MRI imaging.

Developmental venous anomalies (also known as venous angiomas) are usually incidental findings [10]. However, patients can present with intracranial bleeding (1-5%). An association has also been described with ischemic stroke and epilepsy. A venous angioma is an intertwined vascular formation that undergoes expansion, provoking the appearance and progression of the inflammatory process in brain tissue [11]. MRI shows a tangle of blood vessels (may look like spokes of a wheel) with a prominent cortical draining vein (giving a caput medusae sign) [8]. Digital subtraction angiography remains the gold standard in the evaluation of arteriovenous malformations. However, SWI/ SWAN imaging offers improved sensitivity in detecting low-flow vascular malformations invisible on routine gradient-recalled echo (GRE) sequences. In addition, SWI/ SWAN imaging helps differentiate nidus from hemorrhage and calcifications [12]. Developmental venous anomalies, when isolated, require no treatment, and the complication rate is extremely low (about 0.15% per annum), mainly from spontaneous thrombosis of the collecting vein, leading to venous infarction and hemorrhage [6]. If part of a mixed vascular malformation (i.e., associated with a cavernoma), treatment is predicated on the other component.

More recently, SWI/ SWAN imaging has been used in patients with trauma, stroke, vascular malformations, (hemorrhagic) brain metastases, multiple sclerosis, specific developmental disorders, dementias, and in functional MRIs [13–20]. In multiple sclerosis, it is observed that white matter lesions tend to develop around small veins (giving a so-called central vein sign) [14]. In cases of polymicrogyria (a developmental cortical abnormality), abnormalities of cortical veins have been demonstrated by SWI/SWAN imaging [20]. We strongly feel that SWI/ SWAN imaging needs to be incorporated as a regular sequence in routine brain MRI for the epilepsy work-up to detect small venous malformations that can sometimes cause focal seizures, particularly when an epileptic focus is suspected on EEGs.

Limitations to our study include its retrospective nature, small sample size and single-center study. We did not specify EEGs findings and correlated these with MRI findings. Not every patient who had venous angioma in the brain underwent routine angiography, possibly because of smaller size and relatively less severity of symptoms. Larger prospective studies are needed to incorporate subgroups of epilepsy in both pediatric and adult age

groups presented with seizures. Future studies should evaluate the role of high strength MRI (3T) machine and SWI/ SWAN imaging in detecting such vascular malformations and simultaneously correlating these findings with the clinical and EEGs patterns.

5. CONCLUSION

Venous angiomas are usually asymptomatic when detected incidentally. However, adding a SWAN sequence in routine brain MRI for epilepsy patients can help to detect venous angiomas that may cause focal seizure activity.

CONFLICT OF INTEREST

The authors declare that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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