Original Article

Detection of acute small amount of subarachnoid hemorrhage: Comparison between fluid-attenuated inversion recovery MR imaging and CT

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Subarachnoid hemorrhage; CT; FLAIR; Lumbar tap

Abstract Purpose: To evaluate the possibility of detecting small amount of acute subarachnoid hemorrhage (ASH) diluted by CSF not revealed by CT but identified on fluid-attenuated inversion recovery (FLAIR) MRI.
Patients and methods: 50 patients with acute neurological symptoms were referred from the neurosurgery department to the radiodiagnosis department for computed tomography CT and magnetic resonance imaging MRI examination.
Results: Lumbar puncture proved 41 positive cases, MRI (FLAIR) interpreted 43 positive cases (40 true positive and 3 false positive) and 7 negative cases (6 true negative and one false negative) while CT interpreted 39 positive cases (37 true positive and 2 false positive) and 11 negative cases (7 true negative and 4 false negative).
Conclusion: FLAIR MRI was more sensitive and more accurate in the diagnosis of acute SAH than CT scan, having a much higher negative predictive value to exclude acute SAH, however its positive predictive value was slightly lower than CT, but there was no statistically significant difference statistically between the two in diagnosis of SAH.

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1. Introduction

Headaches, an exceedingly common complaint, are mostly caused by migraine, tension-type, and other primary headache disorders. Two percent of all Emergency Department (ED) patients have a chief complaint of headache, and those 2% have a serious life-threatening condition diagnosed in the ED. One such disorder is subarachnoid hemorrhage (SAH) (1). Although trauma is the leading cause of SAH, ruptured intracranial aneurysms account for 80% of non-traumatic cases (2).

Intracranial aneurysm rupture is an acute neurosurgical emergency with a fatality rate of between 40% and 60%, whereas misdiagnosis is associated with a further increased morbidity and mortality, furthermore misdiagnosis of SAH
is an important cause of medico-legal actions against physicians (3).

Computed tomography (CT) is the preferred method for routine imaging of patients with suspected subarachnoid hemorrhage (SAH) due to its high sensitivity and wide availability (4,5).

Until recently, MRI was thought to be less sensitive for detection of SAH. However, recent studies have demonstrated that fluid attenuated inversion recovery (FLAIR) MRI is equal to or even more sensitive than CT for detection of acute or subacute SAH (3–5). Both methods have their limitations; CT has a lower sensitivity in the posterior fossa due to beam-hardening artifacts, whereas cerebrospinal fluid (CSF) pulsations, vascular pulsation or supplemental oxygen may cause FLAIR artifacts in the form of hyperintense signal of the sub-arachnoid spaces (6).

The French Society of Radiology’s guide to good use of medical imaging examinations recommends MRI as the frontline examination for exploring cerebrovascular events or disorders. It has been widely accepted by neuroradiologists that MR imaging is insensitive to acute SAH, and the reason why SAH cannot be seen with MR imaging consistently has been attributed to the complex hemorrhagic signal intensity seen in the MR image (7).

The aim of the current study is to compare the utility of FLAIR MRI with established diagnostic technique (CT) in their detecting capacity of a small amount of subarachnoid hemorrhage and evaluate whether MRI is more sensitive than CT.

2. Materials and methods

This prospective study was performed during the period from 1st of March 2012 to 31 May 2013. A total of 50 patients (27 females and 23 males) with an age range between 22 and 83 years (mean age 49.7 years) were examined.

2.1. Patients preparation

No preparation was done. The patients were sent immediately after referral from the unit of neurosurgery to the Radiodiagnosis Department in Ain Shams University Hospital.

2.2. Scan protocol

CT was performed using GE (Bright speed 8; GE medical systems, Milwaukee, USA). The CT data acquisition was performed according to the following protocol: spiral mode, 0.6-s sections, collimation; 16 × 1.25 mm, pitch; 1.75, section thickness; 1.25 mm, reconstruction interval; 1.00 mm, FOV; 220 mm, acquisition parameters; 120 kVp/200 mA.

MRI imaging was performed by Philips Intera Achieva 1.5 T super conducting MR unit (Philips Medical Systems, the Netherlands), with the use of head coil. FLAIR examination was performed at 6700/150 (TR/TE) with an inversion time (TI) of 2200 ms, a field view 230 mm, matrix 189 × 256, scan time of 3 min 50 s and section thickness 5 mm in axial plane. The time between two examinations was less than 3 h.

Then these patients submitted finally to lumbar tap examination after 8–12 h from the onset of event.

2.3. Image analysis

Regarding CT, positive findings for SAH were expressed characteristically as hyper dense appearance of the extravasated blood in the basal cisterns, with or without the appearance of intra ventricular hemorrhage (IVH). Some patients express other findings such as epidural, subdural, intracerebral hematoma, and fractures of bony parts of the skull. CT imaging was obtained between 1.5 and 4 h from the onset of the event.

Positive findings in FLAIR MRI are being expressed as high intensity from bloody CSF in the SAS or intraventricular system than the nearby cortical gray matter.

Yellow ting (xanthochromia) after centrifugation of lumbar spiral tap gives a definite indication to prove the diagnosis made primarily by CT or MRI or both of them.

3. Results

Out of these 50 patients 27 were females and 23 were males, grouped further according to traumatic and spontaneous events and according to lumbar puncture results. We found that among these 50 patients, 41 patients (21 females and 20 males) were proven to have acute SAH by lumbar puncture which is the gold standard for our study. The total number of patients that had traumatic SAH proved by lumbar puncture was 19 (46.3%). The total number of patients that had spontaneous SAH proved by lumbar puncture was twenty two (53.7%).

The site of bleeding is very important because it gives a clue to the cause of bleeding, the interpeduncular and quadrigeminal cisterns look to be the most common site of SAH, where we found 8 patients out of 41 (19.5%) for each, while 6 and 4 patients had SAH in the ambient and superior and interior cerebellar cisterns (14.6%) and (9.8%), respectively, and the remaining 15 patients (36.6%) had SAH in other areas of the brain (Table 1).

In our current study, among these 41 patients that proved to have acute SAH, intraventricular hemorrhage (IVH) was seen in 23 patients (56%), 14 patients being within traumatic group (60.9%) and 9 patients within spontaneous group (39.1%).

Regarding the distribution of bleeding patterns in different areas of ventricular system; 60.9% was in the lateral ventricle,

| Table 1 | No. of patients and distribution of SAH in different areas of the brain. |
|---------|-----------------|-----------------|
| Subarachnoid spaces | No. of patients | Incidence of distribution in areas (%) |
| Interpeduncular cistern | 8 | 19.5 |
| Ambient cistern | 6 | 14.6 |
| Quadrigeminal cistern | 8 | 19.5 |
| Superior and interior cerebellar cistern | 4 | 9.8 |
| Other areas | 15 | 36.6 |
| • Superficial cortical sulci |
| • Anterior IIF |
| • Sylvian fissure |
30.4% in the 3rd ventricle and 8.7% in the 4th ventricle as shown in table (Table 2).

25 out of 41 Patients (61%) had intracerebral hemorrhage, 10 of them (40%) had history of trauma, and the remaining 15 (60%) were of spontaneous SAH, 4 patients out of those 10 with traumatic SAH had hemorrhage in the frontal lobe, 3 in the temporal lobe and 3 in the occipital lobe. The remaining 15 patients had a history of spontaneous SAH, 10 of them in the frontal lobe and the remaining 5 in the parietal lobe with associated thalamic, brain stem and internal capsule hemorrhage (Table 3).

FLAIR MRI interpreted 43 positive cases while CT scan interpreted 39 positive cases.

FLAIR MRI was truly positive in 40 cases, falsely positive in three cases, truly negative in 6 cases and was falsely negative in one case.

While CT findings were truly positive in 37 cases, falsely positive in two patients, truly negative in 7 patients and was falsely negative in 4 patients (Fig. 1).

For the 41 lumbar puncture positive patients we also assessed in our study IVH was associated with SAH. Six patients had FLAIR positive IVH not seen in CT and 2 cases had CT positive IVH not seen on FLAIR MRI imaging. However IVH could not be fully excluded in the third and fourth ventricles because of CSF pulsation. The sensitivity of MRI exceeds its specificity, because the CSF pulsation in basal cistern area and around the ventricular foramen may make MRI less specific for characterization if it was not carefully assessed according to the focality and absence of the other sign of hemorrhage such as layering (Fig. 2).

FLAIR MRI appears to be more accurate than CT in the detection of acute SAH which had an accuracy of 92% in comparison to that of CT which was 88%.

Regarding the positive cases which were detected by both CT and FLAIR MRI, the latter showed to be more accurate with delineation and identification of the full extent of hemorrhage and any associated findings than CT scan (Fig. 3).

In this study, the sensitivity for the diagnosis of acute SAH by FLAIR MRI was 97.6% being higher than that of CT scan which was 90.2%. The negative predictive value of FLAIR MRI in exclusion of possibility of SAH was 85.7% being much higher than CT scan which was (63.6%) (Figs. 4 and 5).

MRI had lower specificity (66.7%) compared to the CT (77.8%) and a slightly lower positive predictive value (93%) compared to CT (94.9%) (Table 4).

After results had been collected statistical analysis was done using computer soft-ware statistical package of SPSS-p 21.o. That data were simple measures of percentage, sensitivity, specificity, accuracy, positive and negative predictive values. Statistically significant difference between various studies was analyzed by chi-square ($\chi^2$-test).

## 4. Discussion

The diagnosis and depiction of SAH with CT depend on the attenuation value of the blood in the CSF spaces whereas in MR imaging mainly depend on the difference of T1 and T2 relaxation times of SAH relative to those of the CSF and brain parenchyma. It is postulated that MR imaging may be superior to CT for detection of SAH based on their CSF-blood mixtures at lower CSF/blood ratios (8).

The CT value gradually increases with an increase in hematocrit value (HCT). CT value versus HCT has linear relation. The highest CT value was measured at HCT 45% (whole blood) (55 HU) and the lowest was at HCT 27% (34 HU). Regarding FLAIR MR imaging, the hyperintense appearance of SAH and acute IVH may relate to several factors, including the effects of both T1 and T2 relaxation. The FLAIR images produce strong T2W images, that are highly sensitive to T2 prolongation in tissue which probably results from high pro-

### Table 2  Association of IVH and SAH.

<table>
<thead>
<tr>
<th>Type of associated hemorrhage</th>
<th>No. of patients and %</th>
<th>Male</th>
<th>Female</th>
<th>Distribution of bleeding pattern in different areas of ventricular system</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVH</td>
<td></td>
<td></td>
<td></td>
<td>Lateral v.</td>
</tr>
<tr>
<td>Traumatic</td>
<td>14</td>
<td>8</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Spontaneous</td>
<td>9</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>13</td>
<td>10</td>
<td>14</td>
</tr>
</tbody>
</table>

### Table 3  Association of IVH and SAH between SAH and ICH among traumatic and spontaneous groups of patients.

<table>
<thead>
<tr>
<th>Intracerebral hemorrhage</th>
<th>No. of patient and %</th>
<th>Male</th>
<th>Female</th>
<th>Distribution of bleeding pattern in different areas of the brain</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Front. lobe</td>
</tr>
<tr>
<td>Traumatic</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Spontaneous</td>
<td>15</td>
<td>9</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>14</td>
<td>11</td>
<td>8</td>
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tein content in these compartments. The T1 and T2 relaxation times of the CSF, blood mixtures decrease with increasing blood HCT, i.e. increase in protein concentration, reaching the highest SAH/CSF ratio above HCT 40.5%, blood. SAH/CSF ratio of FLAIR images versus HCT has non-linear relation. T1 and T2 at selected times longer than effective TE of 120 and HCT of 22.4% blood were more hyper intense than was the normal cortical gray matter on FLAIR images and at selected times longer than effective of 160, HCT of 9% blood and above was more hyper intense than was the normal cortical gray matter (9).

CT sensitivity for SAH detection decreases with time with the reduction of hemoglobin concentration. In contrast, signal intensity on FLAIR imaging correlates with cellularity and protein levels, which increase in CSF over time in the case of SAH (10,11). Whereas the sensitivity of CT in the detection of SAH is very high within the first 24 h (over 95%), it falls sharply in the following days, FLAIR imaging is reported to be equivalent in the acute phase and even better than CT for subacute SAH (5,12).

In this study the number of female patients proved to have SAH (21), was slightly more than the number of male patients (20). This difference is statistically insignificant and these finding are compatible with the findings of Yuan et al. (8) in Taiwan.

FLAIR imaging detected 40 cases out of 41 cases proven by lumbar punctures. The cause beyond the negative result in one of them is postulated to be the very minor leak that was difficult to detect on FLAIR MRI because its sensitivity in detection with hematocrit ranges between 9% and 40.5% (13). Among the 43 positive FLAIR cases, 40 patients proved to be truly positive by lumbar puncture while the other 3 cases had high intensity signals in various cisterns in FLAIR MR

Fig. 1 25 year old female patient, axial brain CT scan shows bilateral frontoparietal sulcal SAH (arrowheads), FLAIR image confirms the SAH (arrowheads). Lumbar tap was positive.

Fig. 2 44 year old female patient, brain CT scan shows to be normal while FLAIR imaging shows high signal intensity in the left side of the suprasellar cistern (arrow) which was interpreted as subacute SAH. Lumbar puncture was negative, thus MRI was falsely positive which was due to the CSF pulsation in a certain area of basal cisterns which makes MRI less specific for detection and characterization of hemorrhage.
Regarding the results of the CT scan, it proved to be truly positive in 37 cases out of 41 proved positive cases by lumbar puncture and 2 cases were falsely positive which may be due to brain edema with congestion in the SAS which can mimic SAH. CT scan showed to be falsely negative in 4 cases which had positive lumbar puncture, the reason beyond this negative result was the attenuation value which must be higher than the nearby cortical gray matter (more than 34 HU). So the minor leak or very small amounts of hemorrhage which had a hematocrit value of 27% whole blood and below cannot be detected on CT. Intracranial blood in anemic patients (hematocrit < 30%) may appear isodense with the brain and thus be more difficult to see (14).

Verma et al. (15) in their study comparing combined FLAIR/SWI versus CT in detecting SAH found that SWI and FLAIR detected a higher number of SAH compared to CT. Comparing CT and FLAIR, they found that FLAIR imaging is more sensitive for detection of SAH, both in the subacute and acute phases.

As regards the site of acute SAH, we found that FLAIR was less specific in diagnosis of SAH in the basal cisterns showing three false positive cases that were not detected by CT which is more specific in this region, however in SAH involving the cortical sulci, sylvian fissures and anterior interhemispheric fissure, FLAIR was more sensitive than CT and highly specific with no false positive cases.

This is compatible with Verma et al. who found that CT was very accurate for perimesencephalic SAH followed by SWI and FLAIR, however FLAIR identified all SAH in the

![Fig. 3](image1.png) 63 year old male patient with acute IVH and intraparenchymal hemorrhage. Although the IVH is more easily seen on the CT scans than on the MRI, FLAIR images shows hypointensity, consistent with clot in the posterior aspect of the right lateral ventricle. In addition, heterogeneous signal is present in the medial part of the right parietooccipital lobe with surrounding hyperintensity, consistent with an AVM. Lumbar tap was positive.

![Fig. 4](image2.png) 33 year old female patient, the images show the supraventricular level, FLAIR image showing SAH as curvilinear high signal-intensity areas in the bilateral cortical sulci (arrowheads), while CT scan was negative. Lumbar tap was positive.
frontoparietal sulci and was more accurate than CT and SWI for temporoparietal and sylvian regions. Their study demonstrates that a combination of SWI and FLAIR yields a distinctly higher detection rate for SAH due to their complementary detection capabilities. The detection strength of SWI is high for centrally located hemorrhages. FLAIR, on the other hand, provides excellent detection of superficial SAH. The frequency of undetected SAH was the highest for CT. They suggested, that if MRI is planned for a suspected SAH, then a combination of FLAIR and SWI has to be included whenever possible.

All IVH appear hyper intense in the FLAIR MR images, during the 1st 48 h. IVH was commonly seen as layered fluid-fluid levels in the dependent portions of the ventricles and thus was easy to see against a dark CSF background. After 48 h, isointense, hypointense and mixed (16).

In our current study among these 41 patients that proved to have SAH, IVH was seen in 23 patients (56%), 14 patients being within traumatic group (60.9%) and 9 patients within spontaneous group (39.1%).

Regarding the distribution of bleeding patterns in different areas of ventricular system being 60.9% in the lateral ventricle 30.4% in the 3rd ventricle and 8.7% in the 4th ventricle as shown, our findings seem to be lower than what are found by Bakshia et al. (17) in USA. This disagreement may be explained by the differences in our modalities of diagnosis and experience of technicians and radiologists and those in USA.

The most important causes of intracerebral hemorrhage (ICH) are hypertension, aneurysm and vascular malformation accounting for 80% in addition to other causes such as trauma. Not surprisingly, the average outcome is worse than in patients with purely subarachnoid hemorrhage (18).

In our current study, we found an association between SAH and ICH among traumatic group in an incidence of 40% from the total, and among the spontaneous group in an incidence of 60% from the total. These results totally disagree with what are found in USA by Wu et al., (19) and Yuan et al., (8) in Taiwan, where they found that traumatic SAH, is less common than spontaneous one. This may be explained by the presence and widening of the circle of violence in Egypt during the last period.

FLAIR MRI is the most sensitive method for detecting SAH and the best one for delineation of the total extent of pathologic changes (20).

In this current study, after assessment of the true and false positive and negative CT and FLAIR MR imaging values of the cases, the prevalence of both studies was listed and compared according to lumbar puncture results which are considered as gold standard.

The sensitivity of MRI exceeds its specificity, because as we see, the CSF pulsation in a certain area of basal cisterns and around the ventricular foramen makes MRI less specific for characterization if it was not carefully assisted according to the focality and absence of other signs of hemorrhage such as layering.

In this study, the FLAIR MRI sensitivity in detection of SAH was 97.6%, while the specificity was 66.7% and by comparison with CT scan, we found that FLAIR MRI was more sensitive but less specific than CT which had a sensitivity of 90.2% and specificity of 77.8%.

FLAIR MRI appears to be more accurate than CT in the detection of SAH which had an accuracy of 92% in comparison to that of CT which was 88%.

For these cases of SAH which were detected by both CT and FLAIR MRI, the latter showed to be more accurate in

![Fig. 5](image) 24 year old male patient with negative CT and positive FLAIR MR imaging findings i.e. No SAH shown on CT scan, FLAIR MR image showing presence of high intensity in right occipital lobe sulci (arrows). Lumbar tap was positive.

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<thead>
<tr>
<th>Table 4</th>
<th>Comparison between CT and FLAIR MRI in relation to sensitivity and specificity.</th>
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<tbody>
<tr>
<td></td>
<td>Sensitivity (%)</td>
</tr>
<tr>
<td>CT</td>
<td>90.20</td>
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<tr>
<td>FLAIR MRI</td>
<td>97.60</td>
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Detection of acute small amount of subarachnoid hemorrhage

better delineation and identification of the full extent of hemorrhage in SAS than CT scan. In this study, the positive predictive value for the diagnosis of SAH by FLAIR MRI was 93% being slightly lower than that of CT scan which was 94.9%, while the negative predictive value of FLAIR MRI in the exclusion of possibility of SAH was 87.5% much higher than that for CT scan which was 63.6%.

Regarding the American College of Radiology (ACR) appropriateness criteria for SAH detection:
The recommended protocol for clinically suspected acute subarachnoid hemorrhage (SAH), not yet confirmed was in the following sequence: CT head without contrast (rating 9), CT head with contrast (rating 5) if CTA was done, MRI without contrast (rating 5).

The recommended protocol for proven SAH by lumbar puncture or imaging was in the following sequence: arteriography cervicocerebral (rating 8), arteriography neck (rating 8) for treatment planning as part of cerebral angiography, CT head without contrast (rating 8), CTA head with contrast (rating 8), MRA head without contrast (rating 7), MRA head without and with contrast (rating 7) (4,5,6 may be appropriate; 7,8,9 usually appropriate).

Thus the role of MRI in ACR protocol for MRI in acute subarachnoid hemorrhage is assigned as (may be appropriate) for both clinically suspected, not yet confirmed and confirmed. The recommended imaging modality in ACR guidelines is CT without contrast in the first situation, and CTA in the second.

However ACR guidelines also mentioned the relatively high radiation exposure for CT and CTA, both having an effective dose estimated range of (1–10 m Sv for adults and 0.3–3 m Sv for pediatric group) while MRI had a zero radiation exposure.

5. Conclusions

In summary, we found that the FLAIR MRI was more sensitive and more accurate in the diagnosis of acute SAH than CT scan, its positive predictive value to exclude acute SAH being also much higher than CT scan, but being less specific with a much higher than that for CT scan which was 63.6%.

Further larger studies and clinical trials are needed in order to include FLAIR MRI as an integral part of examination of the patient during an acute event of any suspected acute SAH.

Conflict of interest

The authors have no conflict of interest to declare.

References