Imaging of acute subarachnoid hemorrhage: A comparison between combined SWI and FLAIR versus CT.

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Purpose

SWI is a new and very sensitive MRI-technique for the detection of hemorrhage, and is well established in the diagnosis of intracranial hemorrhage. Aim of this study was to compare SWI with the first choice methods CT and FLAIR in acute subarachnoid hemorrhage (SAH). The comparison with FLAIR was in order to analyse detection characteristics and complementary information of SWI in different areas of the subarachnoid space. Further these data are compared with CT, to evaluate whether MRI with combined FLAIR and SWI is more accurate than CT only.
Methods and Materials

Twenty-five patients (17 male, 8 female; mean age 48.1 years) with acute SAH underwent CT and MRI within 7 days after symptom onset (mean 6h 18 min for CT and 54 h16 min for MRI). 9 of them suffered from traumatic brain injury, 6 patients had a ruptured aneurysm, 2 patients had a ruptured arterio-venous malformation. 8 patients suffered from spontaneous SAH after acute onset of severe headache. SWI, FLAIR, and CT data were analyzed independently by two experienced senior radiologists with at least 10 years of experience. After interpretation of all scans, findings were discussed and a consent was found in those cases, where findings dispersed. For data evaluation anatomical areas, where SAH occurred, were categorized in 8 subarachnoid spaces (1. frontal-parietal convexity, 2. temporal-occipital convexity, 3. interhemispheric cisterns, 4. Sylvian cisterns, 5. perimesencephalic cisterns, 6. posterior fossa cisterns, 7. tentorial cistern and 8. intraventricular space). The intraventricular space was further subdivided in 3 areas for evaluation (lateral ventricles, III. and IV. ventricle).
Results

1. In total 146 areas with SAH were found in defined subarachnoid regions (Table 1 on page 19). CT identified 110 (75.3%), FLAIR 127 (87.0%) and SWI 129 areas (88.4%). FLAIR and SWI combined found all 146 SAH (100%), which were significantly more findings than CT only (p<0.0062).

Combined CT with FLAIR found 137 areas (93.8%) and CT with SWI 135 areas (92.5%).

2. A consensus between all modalities was seen in 93 hemorrhage regions (63.7%) (Table 2 on page 20). Additional consensus between two modalities were found as follows: FLAIR and CT 6 (4.1%), CT and SWI 11 (7.5%), FLAIR and SWI 16 (11.0%). None of the hemorrhage areas was detected by CT only. 11 were found by FLAIR only (7.5%) and 9 (6.2%) by SWI only. Together 20 hemorrhage areas (13.7%) were found only in one modality.

3. SWI and FLAIR have complementary diagnostic detection effects: Overall, 11 areas with SAH were detected by FLAIR only, 8 of them in the temporoccipital convexity, where SWI had low detection rate with 12 of 21 (57.1%) (see patient in Fig. 1 on page 5, Fig. 2 on page 5 and Fig. 3 on page 6). By trend FLAIR showed more findings in the Sylvian cistern (100% compared to SWI 83.3% and CT 83.3%) (see patient in Fig. 4 on page 7, Fig. 5 on page 8 and Fig. 6 on page 9).

9 areas with hemorrhage were identified by SWI only, 4 of them inside the intraventricular spaces. Here, FLAIR had a low detection rate with 12 of 19 (63.2%) (see patient in Fig. 7 on page 10, Fig. 8 on page 11 and Fig. 9 on page 12). A further region, where SWI showed a higher detection rate by trend was interhemispheric (100% compared to FLAIR 72.2% and CT 55.6%) (see patient in Fig. 10 on page 13, Fig. 11 on page 14 and Fig. 12 on page 15). SWI had a lower detection rate by trend, when SAH was adjacent to bone and air structures (see patient in Fig. 13 on page 16 Fig. 14 on page 17 Fig. 15 on page 18).

4. Subdividing the internal ventricle system in lateral, III. and IV. ventricle a total of 37 SAH were found (Table 3 on page 21). Only SWI identified all 37 SAH (100%), of them CT found 28 (75.7%). SWI showed significantly more findings (p<0.019) compared to FLAIR only, where 22 (59.5%) hemorrhage areas were identified. By combining CT with FLAIR 30 areas with hemorrhage were found (81.1%).
Fig. 1: In FLAIR sequence the temporal-occipital SAH is clearly visible (see arrows).

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**Fig. 2:** In contrast to Fig.1 a temporal-occipital hemorrhage in the same patient cannot be surely diagnosed (see arrows).

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Fig. 3: SWI either does not allow the clear diagnosis of a temporo-occipital SAH (see arrows).

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Fig. 4: FLAIR shows SAH in the right Sylvian cistern (see arrows).

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Fig. 5: Correspondingly SAH in the right sylvian cistern can be seen in CT (see arrows).

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Fig. 6: SWI identifies SAH in the Sylvian cistern through nonuniform and irregular dark signal (see arrows).

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Fig. 7: In FLAIR sequence intraventricular hemorrhage cannot be identified in the posterior horns of the lateral ventricle (see arrows).

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Fig. 8: CT also does not allow the diagnosis of intraventricular hemorrhage in the posterior horns of the lateral ventricles (see arrows).

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**Fig. 9:** SWI clearly shows hemorrhage in both posterior horns of the lateral ventricle (see arrows).

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**Fig. 10:** The FLAIR image shows a fine SAH in the interhemispheric cisterns (see arrows)

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**Fig. 11:** Whereas in CT the interhemispheric SAH can not conclusively be diagnosed (see arrows).

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Fig. 12: SWI allows the diagnosis of interhemispheric SAH (see arrows).

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**Fig. 13:** Perimesencephalic SAH is clearly visible in FLAIR sequence (see arrows).

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**Fig. 14:** CT also detects perimesencephalic SAH unequivocally (see arrows).

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Fig. 15: SWI identifies SAH along the Aa. cerebri mediae through hypointense irregularities, nonuniform signal and rough vessel boundary (see small arrows). Above the sphenoidal sinus it is difficult to differentiate, whether the susceptibility artifacts (see large arrow) are due to adjacent air and bone structures or due to SAH, while FLAIR and CT easily show SAH in the same region (see Fig.10 an 11).

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Table 1: As seen in Tab.1 a total number of 146 SAH were identified. CT only found 110 of these areas (75.3%), only FLAIR 127 (87.0%) and only SWI 129 (88.4%). Combined SWI with FLAIR found all 146 hemorrhage areas (100%), CT with FLAIR 137 (93.8%) and CT with SWI 135 (92.5%). Abbreviations: FPC = frontal-parietal convexity, TOC = temporal-occipital convexity, IHF = interhemispheric cisterns/fissure, SVF = Sylvian cisterns/fissure, PMC = perimesencephalic cisterns, PFC = posterior fossa cisterns, TNC = tentorial cistern and IVH = intraventricular hemorrhage)

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Table 2: As Tab.2 shows, an agreement between all modalities was found in 93 of 146 areas (63.7%). Additional agreements between two modalities were found as follows: FLAIR and CT 6 (4.1%), CT and SWI 11 (7.5%), FLAIR and SWI 16 (11.0%). None of the hemorrhage areas was found by CT only. 11 were found by FLAIR only (7.5%) and 9 (6.2%) by SWI only. Together 20 hemorrhage areas (13.7%) were found only in one modality. Abbreviations: FPC = frontal-parietal convexity, TOC = temporal-occipital convexity, IHF = interhemispheric cisterns/fissure, SVF = Sylvian cisterns/fissure, PMC = perimesencephalic cisterns, PFC = posterior fossa cisterns, TNC = tentorial cistern and IVH = intraventricular hemorrhage).

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Table 3: Tab. 3 shows hemorrhage in different areas of the internal ventricle system, which was subdivided in lateral, III. and IV. Ventricle. A total of 37 SAH were found. Only SWI identified all 37 SAH (100%). An agreement between CT, MRI and SWI was find in 20 cases (54.1%). Additional agreements between two modalities were found as follows: CT and SWI 8 (21.6%), FLAIR and SWI 2 (5.4%). 7 hemorrhage areas were only seen by SWI (18.9%). CT found 28 (75.7% = 54.1% + 21.6%) and FLAIR 22 (59.5% = 54.1 + 5.4%) of them. By combining CT with FLAIR 30 hemorrhages were found (81.1% = 54.1% + 21.6% +5.4%).

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Conclusion

MRI is more sensitive than CT in detecting SAH. The combination of SWI and FLAIR provides a significantly higher detection rate for SAH compared to CT alone, mostly due to their complementary detection characteristics in different anatomical regions. SWI is more sensitive for intraventricular and interhemispheric hemorrhage, while FLAIR identifies more haemorrhages in the temporal-occipital regions and in the Sylvian cisterns. The frequency of undetected SAH was the highest for CT.


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