

# Post-Embolization Susceptibility Changes in Intracranial Giant Meningiomas: Multimodal Histogram Analysis Using Non-Contrast-Enhanced Susceptibility-Weighted PRESTO, Diffusion-Weighted, and Perfusion-Weighted Imaging

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## Purpose:

It is reported that susceptibility-weighted (SW) imaging can be used after neoadjuvant chemotherapy to identify tissue hypoxia in patients with breast tumors. This study aimed to investigate the imaging characteristics of susceptibility-weighted principles of echo shifting with a train of observations (SW-PRESTO), to assess the relationship with other MR parameters, and to determine the correlation with histopathological characteristics.

## Materials and Methods:

Institutional ethics committee approval and informed consent were obtained. Sixteen patients, each with confirmed meningioma, were studied before and after pre-operative embolization therapy: 8 patients were histopathologically determined to have ischemia and 8 patients were not. In each patient, a single ROI for the entire tumor was placed on each imaging plane. Histogram variables (mean, sd, min, max, histogram width, mode, peak height, skewness, and kurtosis) of the SW map at SW-PRESTO (TR/TE/FA= 20/28/10), of the ADC map used for DW imaging (4500/63/10), and of CBV, CBF, MTT, and TTP maps used for PW imaging (1181/40/75) were compared pixel-by-pixel between corresponding imaging planes before and after embolization therapy using the Wilcoxon rank-sum test. The rate of change ( $\Delta$ = postembolization – preembolization) in histogram variables was correlated with histopathological parameters, such as hemorrhage, calcifications, or intravascular thrombosis. The predictive value for ischemia was measured using receiver operating characteristic (ROC) curve analysis.

## Results:

After distal embolization therapy, SW map showed that mean ( $p<.001$ ), min ( $p<.001$ ), mode ( $p<.001$ ), peak height ( $p<.001$ ), and kurtosis ( $p<.001$ ) decreased and sd ( $p<.001$ ) and histogram width ( $p<.001$ ) increased in the ischemic group. The max value increase in the non-ischemic group was observed. PW imaging revealed a decrease in CBV mean and an increase in MTT max ( $p<.001$ ) in the ischemic group. An increase in CBV mean and a decrease in TTP min ( $p=.005$ ), representing reactive shunt formation, were observed in the non-ischemic group. DW imaging revealed decreases in mean ( $p=.008$ ), min ( $p<.001$ ), max ( $p<.001$ ), and mode ( $p<.001$ ). The sd ( $p<.001$ ) and histogram width ( $p<.001$ ) increased in the ischemic group, while min ( $p<.001$ ) and max ( $p=.003$ ) increased in the non-ischemic group. The histogram ( $\Delta$ ) of SW map did not correlate with histopathologic characteristics, such as hemorrhage and calcifications. The ROC curve analysis showed the largest area under the curve (Az) for mean and kurtosis values (Az=.766, CI .492-1.00) that were obtained at SW-PRESTO.

## Conclusion:

Significant post-therapeutic changes in intrinsic T2\*-weighted MR contrast, as seen on SW map, are probably associated with spatial T2\*-weighting, due to alterations in arterial blood-flow and deoxyhemoglobin levels. SW-PRESTO may represent a new imaging biomarker that can be used to distinguish variable degrees of ischemia in post-embolization meningioma.

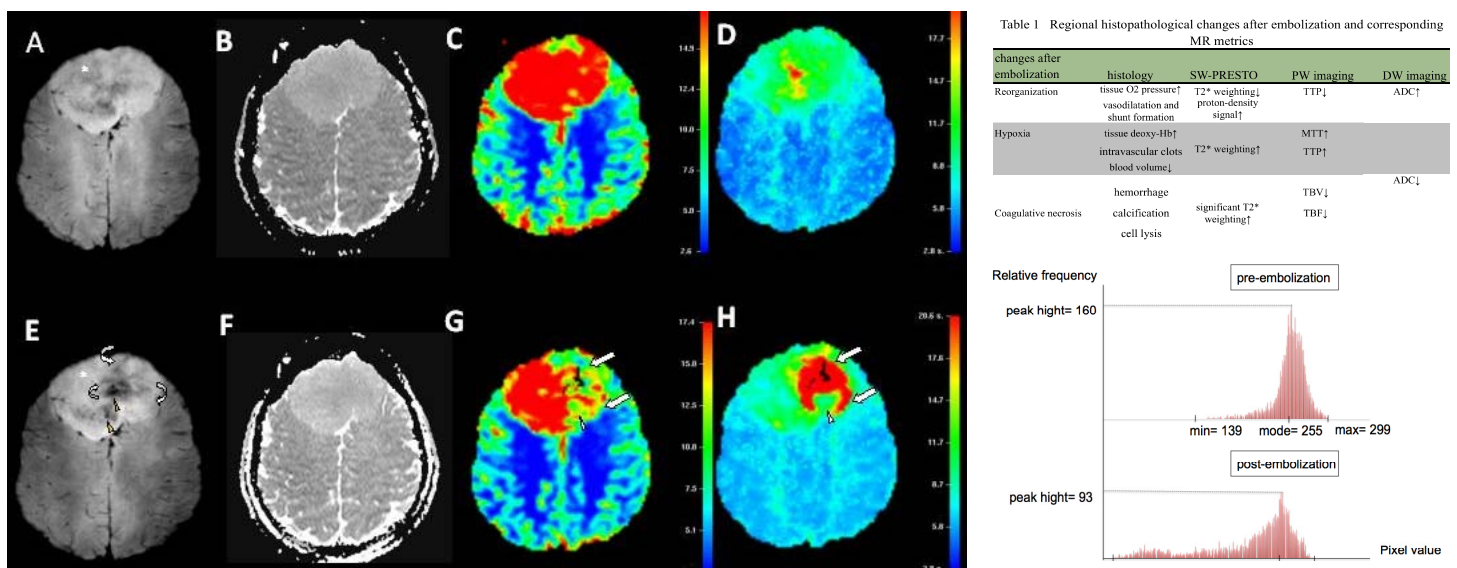
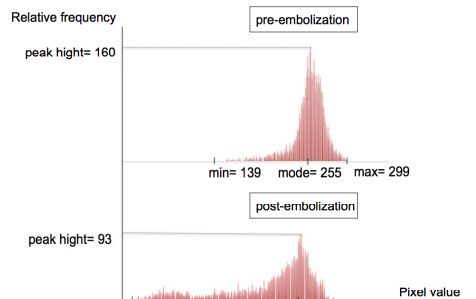


Table 1 Regional histopathological changes after embolization and corresponding MR metrics

changes after embolization	histology	SW-PRESTO	PW imaging	DW imaging
Reorganization	tissue O <sub>2</sub> pressure↑ vasodilatation and shunt formation	T2* weighting↓ proton-density signal↑	TTP↓	ADC↑
Hypoxia	tissue deoxy-Hb↑ intravascular clots blood volume↓	T2* weighting↑	MTT↑ TTP↑	ADC↓
Coagulative necrosis	hemorrhage calcification cell lysis	significant T2* weighting↑	TBV↓ TBF↓	



(A-D) Pre-embolization SW, ADC, CBV, and MTT maps. (E-H) Post-embolization SW, ADC, CBV, and MTT maps. (E) A significant decrease in signal intensity on SW map (curved arrows) with dot-like low signal intensity (yellow arrowheads) is noted to correspond to areas of CBV decrease and MTT increase (arrows). A paradoxical increase in signal intensity on SW map (asterisk), corresponding to negative CBV and MTT changes, is observed. In contrast, there was no change in signal intensity corresponding to a decrease in CBV without an associated MTT increase (white arrowhead). No significant change on the ADC map corresponding to SW map, CBV map, and MTT map is observed. The representative histogram pattern denotes decreases in the mean, min, max, mode, peak height, and kurtosis, as determined using SW map in another ischemic patient.