Table 9: Vascularity and Hemorrhage

Author (Year)	Title	Study Description	Number of Patients	Evidence Class	Conclusions
Di Ieva (2007)[120]	Fractal dimension as a quantitator of the microvasculature of normal and adenomatous pituitary tissue.	Clinical experience characterizing vascular surface fractal dimension in pituitary lesions	34	Diagnostic / III	There was a statistical significant difference between the mean vascular surface fractal dimension estimated in normal vs adenomatous tissues (*P* = .01), normal vs secreting adenomatous tissues (*P* = .0003), and normal versus non-secreting adenomatous tissues (*P* = .047), whereas the difference between the secreting and non-secreting adenomatous tissues was not statistically significant. This demonstrates that fractal dimension is an objective and valid quantitator of the two-dimensional geometrical complexity of the pituitary gland microvascular network in physiological and pathological states.
Finelli (1993)[121]	Varied microcirculation of pituitary adenomas at rapid, dynamic, contrast-enhanced MR imaging.	Patients with pituitary adenomas underwent dynamic contrast enhanced MR imaging. The early enhancement patterns of normal pituitary structures and tumor tissue was documented.	16	Diagnostic / III	Arterial-phase enhancement of 16 macroadenomas was observed, suggesting a primary arterial blood supply to these lesions. The technique reveals the microcirculatory dynamics associated with pituitary adenomas and suggests a dominant arterial blood supply for macroadenomas. Arterial phase enhancement can be used to characterize microcirculation for preoperative assessment and surgical planning.

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Yuh (1994)[123]	Sequential MR enhancement pattern in normal pituitary gland and in pituitary adenoma.	Patients with pituitary adenomas and non-tumor controls prospectively underwent dynamic MR imaging with either a 5 or 10 second temporal resolution during a bolus injection of gadolinium. Qualitative visual analysis of the enhancement patterns via the MR images were compared between the 2 groups of patients.	10	Diagnostic / II	Quantitative analysis revealed that posterior lobe enhancement occurred 9.8 +/- 1.5 sec (mean +/- SEM) before the anterior lobe in healthy subjects, whereas tumor enhancement occurred significantly before the anterior lobe but only slightly before the posterior lobe in patients with adenomas. The sequential enhancement pattern of the normal pituitary gland was found to be consistent with its vascular anatomy. In contrast to previous reports, pituitary adenomas were found to enhance earlier than the anterior lobe. These results suggest that pituitary adenomas have a different MR enhancement pattern from normal tissue and may be because of a direct arterial blood supply, similar to that of the posterior pituitary lobe.

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Sakai (2013)[62]	Arterial spin-labeled perfusion imaging reflects vascular density in nonfunctioning pituitary macroadenomas.	Patients underwent both conventional MR imaging and arterial spin-labeled perfusion imaging. Degree of enhancement was calculated by dividing the signal intensity on T1-weighted with contrast to the T1-weighted without contrast. Normalized tumor blood flow values were calculated by dividing the mean value of the tumor region of interest by mean region of interest values in the cerebellar hemispheres. Relative microvessel attenuation was calculated by dividing the total microvessel wall area by entire CD31 stained tissue area. These parameters were compared with each other as well as the presence of intra- or postoperative hemorrhage by surgeon visualization.	11	Diagnostic / III	A statistically significant difference in normalized tumor blood flow values was observed visually between the intraoperative hypovascular and hypervascular groups ($P < .05$). One of these hypervascular cases actually did have symptomatic postoperative hemorrhage. ASL perfusion imaging can reflect the vascular density of NFPAs and may be a viable test in predicting intra/postoperative tumor hemorrhage.

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Kurihara (1998)[124]	Hemorrhage in pituitary adenoma: correlation of MR imaging with operative findings.	Patients with conventional MR imaging were retrospectively reviewed. The intensity of intratumoral cystic cavities using T2-weighted images were correlated with hemorrhage found at surgery as the gold standard.	113	Diagnostic / III	Twenty-nine of 52 hemorrhagic cysts demonstrated high/low signal (H/L) fluid-fluid levels on T2-weighted image (T2WI). In 19 of them, 2 components could be separately seen at operation: the supernatant high-intensity area represented xanthochromic fluid, and the dependent low-intensity area represented liquefied hematoma. The H/L fluid-fluid level was observed predominantly in hematomas on MR images obtained after longer intervals. In patients with repeated MR examination, follow-up MR imaging revealed additional hemorrhage or new formation of fluid-fluid levels. The preoperative MR images are well correlated to the operative findings in hemorrhagic pituitary macroadenomas. It proved that 52 of 54 cystic cavities had hemorrhagic components.
Lazaro (1994)[125]	Haemorrhagic pituitary tumours.	Clinical experience using TR/TE to assess pituitary lesions	12	Diagnostic / III	Intratumoral hemorrhage on MRI was characterized by high signal intensity on short TR/TE sequences and not different in hormone secreting versus NFPAs.

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Tosaka (2007)[126]	Assessment of hemorrhage in pituitary macroadenoma by T2*-weighted gradient-echo MR imaging.	Patients underwent both conventional MR and T2*-weighted MR imaging. Histology of surgical specimens was evaluated for hemorrhage. T2*-weighted characteristics were correlated with histologic assessments.	25	Diagnostic / III	T2*-weighted GE MR imaging detected various types of dark lesions, such as "rim," "mass," "spot," and "diffuse" and combinations, indicating clinical and subclinical intratumoral hemorrhage in 12 of the 25 patients. The presence of intratumoral dark lesions on T2*-weighted GE MR imaging correlated significantly with the hemorrhagic findings on T1- and T2-weighted MR imaging ($P < .02$ and $< .01$, respectively), and the surgical and histologic hemorrhagic findings ($P < .001$ and $< .001$, respectively). T2*-weighted GE MR imaging could detect intratumoral hemorrhage in pituitary adenomas as various dark appearances. T2* weighted GE MRI might be useful for the assessment of recent and old intratumoral hemorrhagic events in patients with pituitary macroadenomas.
Stadlbauer (2008)[89]	Proton magnetic resonance spectroscopy in pituitary macroadenomas: preliminary results.	Patients underwent proton MR (1H-MR) spectroscopy. Metabolite concentration of choline containing compounds was correlated to histological and surgical findings of hemorrhage as well as MIB-1 as a proliferative index.	16	Diagnostic / III	The study found a strong positive linear correlation between metabolite concentrations of Cho and the MIB-1 proliferative cell index ($R = 0.819$, $P < .001$). Eleven patients had a hemorrhagic adenoma and showed no assignable metabolite concentration of Cho, and the FWHM water was 13.4-24.4 Hz. In 10 patients, the size of the lesion was too small (<20 mm in 2 directions) for the acquisition of MR spectroscopy data. Quantitative 1H-MR spectroscopy provided important information on the proliferative potential and hemorrhaging of pituitary macroadenomas. These data may be useful for noninvasive structural monitoring of pituitary macroadenomas.