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ORIGINAL ARTICLE

Diagnosing Neoplastic Hematoma: Role of MR Perfusion

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Abstract

Background The imaging appearance of neoplastic hematoma can be complicated by the presence of a large hematoma, even on magnetic resonance imaging (MRI). We describe the role of MR perfusion (MRP) in detecting neoplastic hematomas in patients with intraparenchymal hematoma (IPH).

Material and Methods A retrospective review was performed for consecutive patients with IPH, where MRP was performed. Routine, post-gadolinium MRI and MRP were analyzed. All patients were either operated on for evacuation of IPH or followed up on imaging. The MRP parameters of cerebral blood volume (CBV) and cerebral blood flow (CBF) and pattern of enhancement (peripheral linear vs. nodular) were recorded. Sensitivity, specificity, positive (PPV) and negative predictive values (NPV) were calculated for these parameters for diagnosing neoplastic hematoma.

Results Of 116 patients with MRP, 16 patients (male 8; mean age—65.5 years) had IPH on their initial MRI. For diagnosing neoplastic hematoma, the sensitivity, specificity, PPV and NPV for increased CBF and CBV were 100%, 88.9%, 87.5%, and 100%; for peripheral linear enhancement were 100%, 28.6%, 50%, 100% and for nodular enhancement were 85.7%, 77.8%, 75% and 12.5%, respectively. The combination of peripheral linear enhancement and increased CBF and CBV showed 100% sensitivity, specificity, PPV and NPV.

Conclusion In our small series, the combination of peripheral linear enhancement and increased CBF and CBV showed 100% sensitivity, specificity, PPV and NPV for diagnosing a neoplastic hematoma. These findings need to be validated in a larger study.

Keywords Neoplastic Hematoma · MRI · Neoplastic hematoma · Magnetic resonance perfusion · Idiopathic intraparenchymal hematoma

Introduction

Differentiation of a primary or idiopathic intraparenchymal hematoma (IPH) from a neoplastic hematoma is a common clinical dilemma. In most cases, the differential diagnosis is based on imaging and clinical history. Computed tomography (CT) scan features favoring neoplastic hematoma include atypical location, multiple hemorrhagic sites, disproportionate edema, or a nodule along the periphery of the hematoma; however, magnetic resonance imaging (MRI), with its overall superior tissue characterization and spatial resolution, is considered a better technique [1, 2]. On MRI, features suggestive of a neoplastic hematoma include mixed intensity appearance of the hematoma, identification of abnormal soft tissue in or adjacent to the IPH and enhancement of this soft tissue. The predictable sequence of T1 and T2 signal characteristics seen in IPH is often not observed in neoplastic hematoma. The evolution of T1 hyperintensity (subacute methemoglobin) from the periphery to the center is seen in idiopathic IPH, whereas subacute methemoglobin is known to remain at the periphery for a longer duration in a neoplastic hematoma. The presence of a discontinuous or irregular hemosiderin rim along with persistent or increasing edema in the late stage of development is more consistent with neoplastic hematoma [1, 2].

Although these features may serve as useful guidelines, they must be interpreted in the context of the overall clinical picture, because they are relatively nonspecific. In most cases, reliable differentiation of a primary IPH from

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a neoplastic hematoma requires repeated imaging over time. Most patients may also need a biopsy. The MRI appearance can be complicated by the presence of a large hematoma and this is particularly problematic in the subacute phase, where patchy enhancement of the hematoma itself makes the detection of neoplastic hematoma extremely difficult.

Perfusion studies have been used for the diagnosis and characterization of tumors [3–8]. Perfusion imaging has also been used in lobar hematomas [9]; however, perfusion has not been used (to our knowledge) in the detection of underlying malignancy in patients with IPH. The purpose of our study was to investigate the role of MR perfusion (MRP) in the detection of underlying malignancy in patients with IPH.

Materials and Method

A retrospective review was performed for consecutive patients who had an MRP done in a 6-month period. The study was approved by the institutional research ethics board.

Patient selection

All patients with IPH on initial head CT scan with follow-up MRI of head and MRP, were included in our study. Patients who underwent MRP for known malignancy were excluded from the study. All patients were either followed up on imaging or were operated on for evacuation of IPH. Patients who underwent surgery had pathological confirmation of the diagnosis. Patients who did not undergo surgery were followed up clinically as well as on imaging with contrast-enhanced MRI.

Image acquisition

The MRI was acquired using 1.5 T magnet (Signa, GE, Boston, MA). The brain tumor MRI protocol in our institution included axial T2-weighted imaging, fluid-attenuated inversion recovery imaging (FLAIR), isotropic diffusion-weighted imaging (DWI), T2*-weighted images pregadolinium and postgadolinium T1-weighted images and MRP, which was acquired using a published protocol [7].

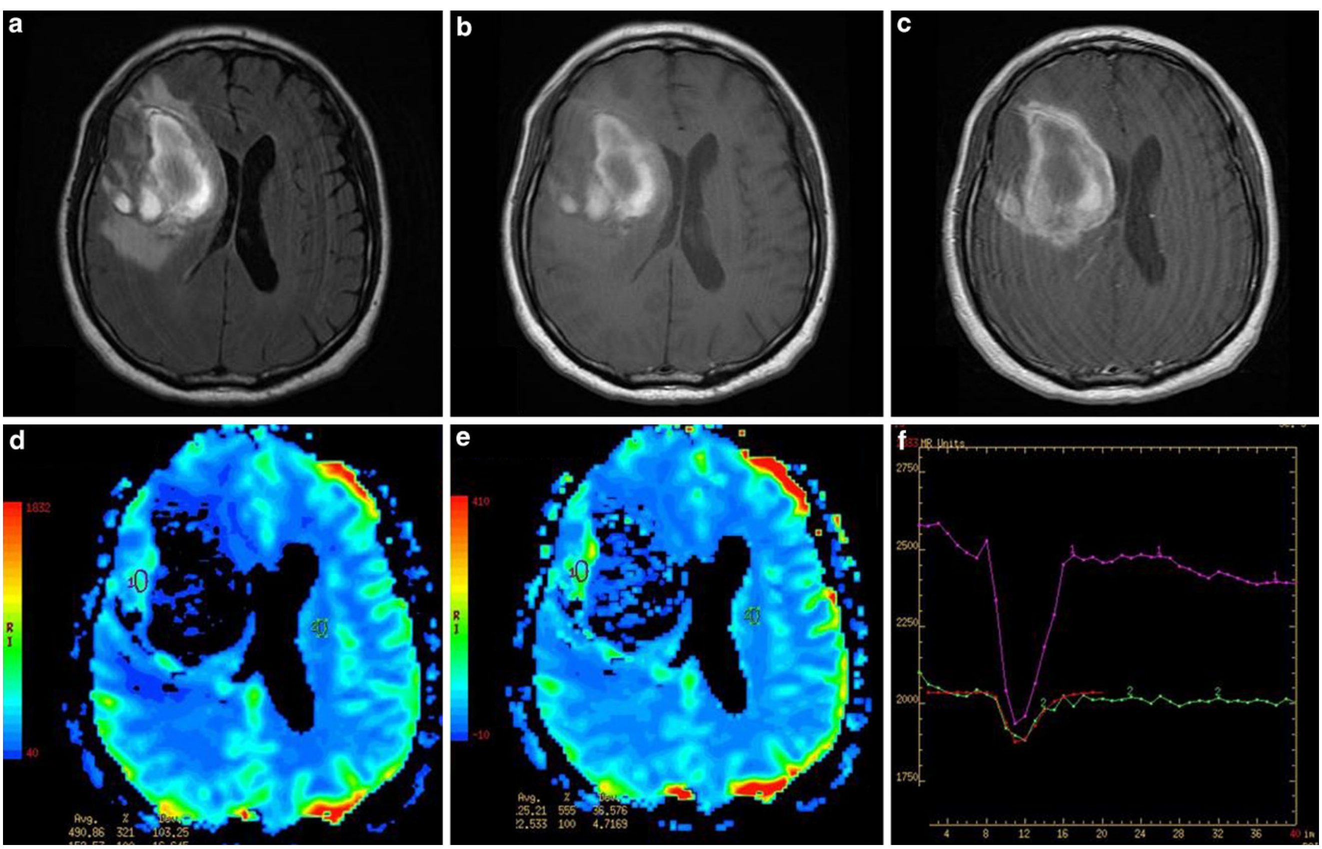

Fig. 1 Patient presented with large right frontal hematoma. Head MRI with FLAIR (**a**), pregadolinium T1 (**b**) and postgadolinium T1 (**c**) images done 3 weeks later showed heterogeneous peripheral and nodular enhancement on postgadolinium T1 image (**c**). MR perfusion done on the same day showed increased blood flow (**d**) and volume (**e**) at the periphery of the hematoma (arrow). Time-intensity curve (**f**) confirmed the increase in the blood volume (with higher area under the curve) compared to the contralateral normal appearance of white matter

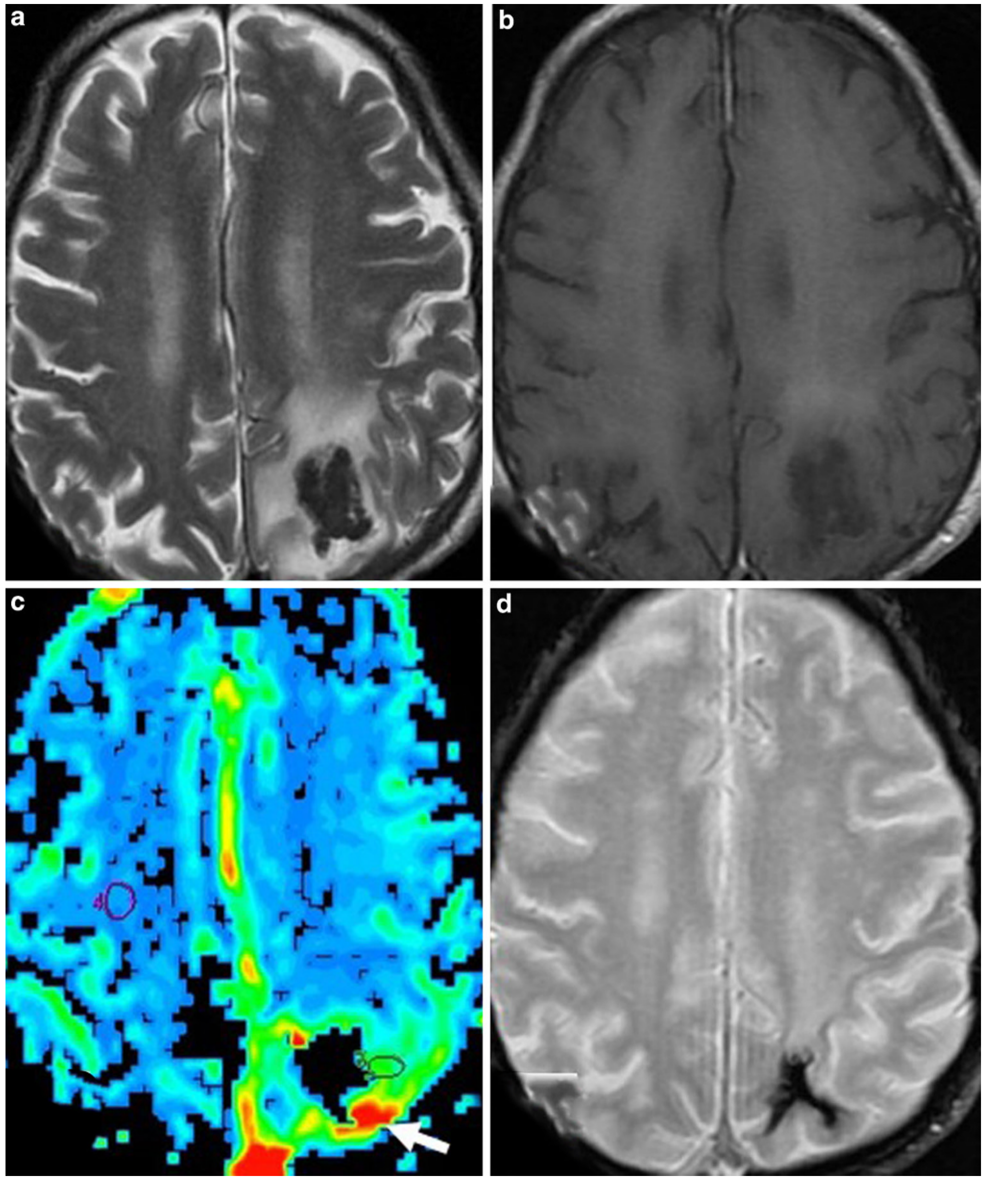

Fig. 2 Patient presented with left parietal hematoma. Head MRI (**a**, **b**) done on day 1 showed no enhancement on postgadolinium T1 image (**b**). The MR perfusion done on the same day showed increased blood volume (**c**) at the periphery of the hematoma (*arrow*). Gradient images (**d**) from MRI done 8 months later showed resolution of the hematoma. No enhancement was shown on any of the follow up-images

Image analysis

The MRI was analyzed by a fellowship trained neuroradiologist with more than 7 years of experience (JS). Routine pregadolinium and postgadolinium MRI were evaluated for evidence of peripheral linear or nodular pattern of enhancement. Relative cerebral blood flow (rCBF) and relative cerebral blood volume (rCBV) maps of MRP were qualitatively analyzed (Figs. 1 and 2). The volume of hematoma was calculated on the initial diagnostic CT scan using the a + b + c/3 formula on https://www.mdcalc.com/abc2-formula-intracerebral-hemorrhage-volume.

Statistical analysis

Contingency table analysis with sensitivity, specificity, positive and negative predictive of rCBF, rCBV, peripheral linear and nodular pattern of enhancement for diagnosis of underlying malignancy were performed and a receiver operating characteristic (ROC) curve was generated. Student's t test and the χ^2-test were done to compare continuous and categorical variables, respectively, and p value of less than 0.05 was considered significant.

Results

Out of 116 patients with MRP done in the 6-month study time period, 16 patients (male8; female 8; mean age—65.5

Table 1 Description of patients with cerebral hematoma

Patient	Age (years)	Sex	Location	CBF	CBV	Peripheral enhancement	Nodular enhancement	Follow-up diagnosis
1	65	M	Rt Frontal	↑	↑	Yes	Yes	Glioblastoma
2	69	M	Lt Temporal	N	N	Yes	Yes	No tumour
3	50	M	Rt Fronto-parietal	↑	↑	Yes	Yes	Glioblastoma
4	62	F	Lt Temporo-occipital	N	N	Yes	Yes	No tumour
5	62	F	Lt Temporo-occipital	N	N	Yes	No	No tumour
6	55	M	Rt Fronto-parietal	↑	↑	Yes	No	Glioblastoma
7	69	F	Lt Parietal	N	N	No	No	No tumour
8	55	M	Lt Fronto-parietal	N	N	Yes	No	No tumour
9	76	M	Lt Parietal	↑	↑	No	No	No tumour
10	54	M	Rt Parietal	↑	↑	Yes	Yes	Melanoma
11	66	F	Lt Occipital	↑	↑	Yes	Yes	Glioblastoma
12	82	F	Lt Parieto-temporal	↑	↑	Yes	Yes	Glioblastoma
13	54	F	Rt Thalamic	N	N	Yes	No	No Tumour
14	82	F	Lt Occipital	N	N	Yes	No	No Tumour
15	70	F	Rt Temporal	N	N	Yes	No	No Tumour
16	77	M	Rt Parietal	↑	↑	Yes	Yes	Metastasis

M male, *F* female, *CBF* cerebral blood flow, *CBV* cerebral blood volume, *N* normal, *Rt* right, *Lt* left

years, range 50–82 years) had IPH on initial head CT without known malignancy (Table 1). The mean interval between patient's hospital presentation and MR study was 5 days (range 1–21 days), seven patients underwent surgery and were proven to have neoplastic hematoma (5 glioblastoma, 1 melanoma, and 1 metastasis). The other 9 patients were followed up on imaging which did not demonstrate any underlying neoplasm. The two groups were similar in their age ($p=0.67$) and sex ($p=0.13$). The average volume of neoplastic hematoma (27.5 ml) was not significantly different ($p=0.14$) compared to that of non-neoplastic hematoma (12.3 ml).

Table 2 shows the sensitivity, specificity, positive (PPV) and negative predictive values (NPV) for peripheral linear or nodular enhancement, increased rCBF and rCBV as well as combination of rCBF and rCBV and peripheral linear enhancement for diagnosing neoplastic hematoma. The ROC curves are seen in Fig. 3.

Table 2 Sensitivity, specificity, positive (PPV) and negative predictive values (NPV) for peripheral enhancement, nodular enhancement and increased CBF and CBV on MR perfusion for diagnosing underlying malignancy in IPH

	Peripheral enhancement	Nodular enhancement	Increased CBV and CBF
Sensitivity	100	85.7	100
Specificity	28.6	77.8	88.9
PPV	50	75	87.5
NPV	100	12.5	100

CBF cerebral blood flow, *CBV* cerebral blood volume

Only one patient (patient number 9) had an increase in rCBF and rCBV in IPH with no underlying neoplasm (Fig. 2). Because there was suspicion of underlying neoplasm based on MRP findings, this patient had a close follow-up with MRI and MRP 1 month later. There was decrease in both rCBF and rCBV on follow-up and the IPH showed complete resolution with no underlying neoplasm.

Discussion

To our knowledge, this is the first study to report the role of MRP compared to routine MRI for diagnosing neoplastic hematoma. A neoplastic hematoma needs more urgent management and will have a different prognosis. Several features have been described on routine imaging for the diagnosis of a neoplastic hematoma [1, 2]. These imaging features are complicated by the enhancement of the IPH in the subacute phase. Increased rCBF and rCBV on MRP had the highest sensitivity, specificity, PPV and NPV for diagnosing a neoplastic hematoma. Peripheral linear enhancement by itself had lower specificity and PPV. The combination of peripheral linear enhancement and increased rCBF and rCBV had 100% sensitivity, specificity, PPV and NPV for diagnosing a neoplastic hematoma (Fig. 3).

Increased rCBF and rCBV was falsely positive in only one patient (Fig. 2) and we could not find any definitive reason for this. All other patients with neoplastic hematoma showed enhancement on the postcontrast study. Location of the IPH in this patient over the convexity of brain may have resulted in volume averaging with adjacent vessels resulting

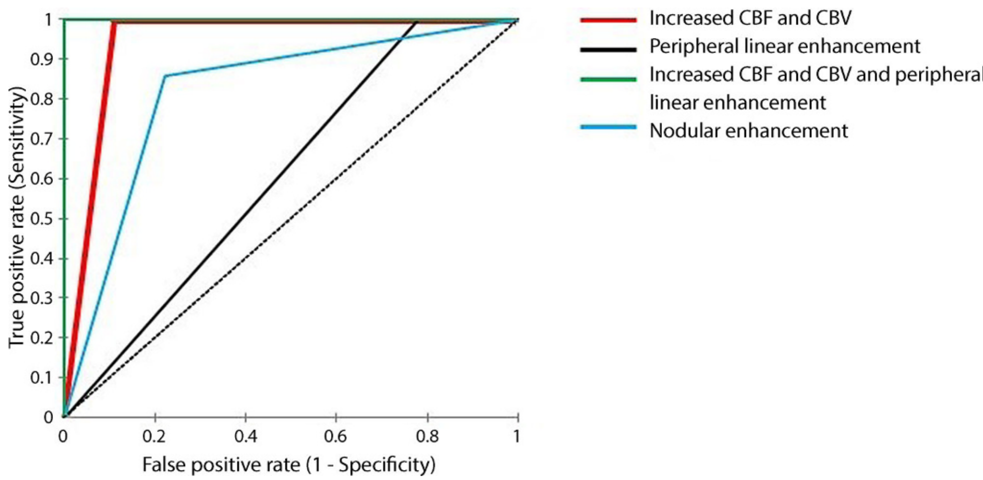

Fig. 3 ROC curve of peripheral linear enhancement, nodular enhancement, increased cerebral blood flow (CBF) and cerebral blood volume (CBV) and combination of increased CBF and CBV with peripheral enhancement for diagnosing neoplastic hematoma

in increased rCBF and rCBV. Another possibility could be an underlying vascular malformation that was obliterated after hemorrhage or a postictal phenomenon; however, we did not see any enhancement or vascular malformation on the initial or follow-up images.

The usual causes of neoplastic hematoma are high-grade gliomas and metastases, such as renal, thyroid and melanomas [2]. Perfusion imaging has been very useful in identifying the neoplastic lesions from other pathologies and has also been used to differentiate higher grade tumors from lower grade tumors [3–7]. Our study is the first to suggest that MRP may help in diagnosing neoplastic hematoma.

Most patients with IPH routinely undergo postcontrast MRI. We recommend that MRP can be performed by administering the same volume of gadolinium in these patients. Acquisition and postprocessing of MRP adds approximately 5 min of MR time. The MRP software is widely available in most of the academic and private settings. Incorporating MRP into the MRI protocol will increase the sensitivity and specificity as well as increase the PPV and NPV in diagnosing underlying malignancy in patients with IPH. If MRP is not available, similar information can be obtained from CT perfusion (CTP) [10]; however, minor drawbacks of CTP for this indication include an additional study, injection of iodinated contrast and a small dose of radiation.

Limitations

This is a retrospective study of a small number of patients with a single reader; however, this study generates an important hypothesis for the use of perfusion in diagnosing underlying malignant causes of IPH. An additional limitation is that our study did not include patients with underlying vascular malformations and MRP must also be tested for the identification of vascular causes of IPH. We also did not do any quantitative analyses. Since we wanted to make this a practical tool and qualitative analysis of MRP by itself showed very high diagnostic value. We plan a prospective larger study in patients with IPH, where we plan to perform quantitative as well as qualitative analysis with inter-rater reliability.

Conclusion

In our small series, MRP appears to be an important additional tool for diagnosing neoplastic hematoma as it showed very high sensitivity and specificity as well as PPV and NPV. This important finding needs to be tested in a larger study.

Compliance with ethical guidelines

Conflict of interest J.J.S. Shankar and N. Sinha declare that they have no competing interests.

Ethical standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

References

1. Destian S, Sze G, Krol G, Zimmerman RD, Deck MD. MR imaging of hemorrhagic intracranial neoplasms. AJR Am J Roentgenol. 1989;152:137–44.
2. Atlas SW, Grossman RI, Gomori JM, Hackney DB, Goldberg HI, Zimmerman RA, Bilaniuk LT. Hemorrhagic intracranial malignant neoplasms: spin-echo MR imaging. Radiology. 1987;164:71–7.
3. Law M, Yang S, Babb JS, Knopp EA, Golfinos JG, Zagzag D, Johnson G. Comparison of cerebral blood volume and vascular permeability from dynamic susceptibility contrast-enhanced per-

fusion MR imaging with glioma grade. AJNR Am J Neuroradiol. 2004;25:746–55.
4. Law M, Cha S, Knopp EA, Johnson G, Arnett J, Litt AW. High-grade gliomas and solitary metastases: differentiation by using perfusion and proton spectroscopic MR imaging. Radiology. 2002;222:715–21.
5. Ellika SK, Jain R, Patel SC, Scarpace L, Schultz LR, Rock JP, Mikkelsen T. Role of perfusion CT in glioma grading and comparison with conventional MR imaging features. AJNR Am J Neuroradiol. 2007;28:1981–7.
6. Jain R, Ellika SK, Scarpace L, Schultz LR, Rock JP, Gutierrez J, Patel SC, Ewing J, Mikkelsen T. Quantitative estimation of permeability surface-area product in astroglial brain tumors using perfusion CT and correlation with histopathologic grade. AJNR Am J Neuroradiol. 2008;29:694–700.
7. Parks NE, Bhan V, Shankar JJ. Perfusion imaging and contrast enhancement characteristics of tumefactive demyelinating lesions compared to high grade gliomas. Can J Neurol Sci. 2016;43:316–8.
8. Shankar JJ, Woulfe J, Silva VD, Nguyen TB. CT perfusion and permeability in the prognosis of high grade gliomas. AJR Am J Roentgenol. 2013;200:W504–9.
9. Olivot JM, Mlynash M, Kleinman JT, Straka M, Venkatasubramanian C, Bammer R, Moseley ME, Albers GW, Wijman CA; DASH investigators. MRI profile of the perihematomal region in acute intracerebral hemorrhage. Stroke. 2010;41:2681–3.
10. Greenlaw G, Shankar JJS. Correlation of CT and MR perfusion and permeability parameters for intracranial tumors. Electronic poster in ASNR; 26.–28.05.2016; Washington DC. 2016.