Evaluation of Glioblastomas and Lymphomas with Whole-Brain CT Perfusion: Comparison Between a Delay-Invariant Singular-Value Decomposition Algorithm and a Patlak Plot

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Aims and objectives

Glioblastoma is known to be the most common and malignant gliomas in adults (1-9). Maximal safe resection feasible with goal for image-verified complete resection is recommended to treat patients with glioblastomas followed by chemoradiation treatment (6). Primary central nervous system lymphoma is less common compared to glioblastoma (1, 5). Lymphoma is basically treated after biopsy with least invasive approach also followed by chemoradiation therapy (6). These two tumors typically show contrast enhancement, and it is sometimes difficult to differentiate these on conventional imaging studies alone. Therefore previous studies revealed the usefulness of diffusion (2) and perfusion (3, 4) magnetic resonance (MR) imaging as well as $^{18}$F-fluorodeoxyglucose positron emission tomography (5, PET) to separate these two entities. Compared to glioblastomas, lymphomas have been reported to show less diffusivity, less tumor blood volume and higher maximum standard uptake value (2-5).

Cranial CTP is commonly used for the evaluation of patients with acute stroke or tumors (7-14). There are several post processing techniques for CTP and these can be divided into those with or without evaluating the tissue permeability. A delay-invariant singular-value decomposition algorithm (SVD+; Toshiba Medical Systems, Otawara, Japan) is one of the major algorithms based on the lack of contrast leakage (15). On the other hand Patlak model is one of the algorithms taking into account the contrast leakage (16-18). Ideally, correction of contrast leakage is recommended in enhancing lesion during perfusion analysis.

Therefore the purpose of this study was to differentiate glioblastomas from lymphomas by CT perfusion with 320-row CT using with a delay-invariant singular-value decomposition algorithm (SVD+) and a Patlak plot.

Methods and materials

This retrospective study was approved by our institutional review boards, and written informed consent was waived.

Patients

This study included consecutive 17 adult patients (12 men and 5 women; age ranged from 38-89 year-old; median 69 years) from April 2012 to September 2013 at our institution. All patients were diagnosed pathologically after CTP without any treatment or biopsy before. There were 10 glioblastomas (6 men and 4 women; age ranged from 38-89 year-old; median 67 years) and 7 lymphomas (6 men and 1 woman; age ranged from 61-86 year-old; median 71 years).
Imaging Technique

All CTP were obtained with 320-slice CT (Aquilion ONE Vision Edition, Toshiba Medical Systems, Otawara, Japan). The contrast material (Iopamiron 370, Bayer, Osaka, Japan) was injected using a power injector through a 20-gauge intravenous line in the cubital vein with a start delay of 5 s. A total of 24.5mgI/kg was injected in 10s (3-5ml/s) followed by a saline flush. The parameters for the CTP were as follows; 80 kV, 80 mA, 1 s/rot, every 2 s, for the first 15 rot; 80 kV, 80 mA, 1s/rot, every 5 s for the next 5 rot, and 80 kV, 50 mA, 1 s/rot, every 30 sec for the last 5 rot; slice collimation = 320 × 0.5 mm; CTDI = 10.4mGy; DLP=2549.8mGycm; Eff dose=5.86 mSv (Head=0.0023, European Guideline).

Analysis

The data were analyzed by a neuroradiologist (A.H.; 17-year experience in neuroradiology) using a commercially available software (Aquilion ONE, Toshiba Medical Systems, Otawara, Japan). CTP data were analyzed using a delay-invariant singular-value decomposition algorithm (SVD+) and a Patlak plot. SVD+ was analyzed by arterial input and venous output functions placed within the contralateral internal carotid artery at the supraclinoid segment and within the superior sagittal sinus at the occipital pole, respectively. The Patlak model was applied to calculate the rate of contrast leakage out of the vascular compartment (8, 9, 11 16-18). Patlak plots were created from the arterial and parenchymal time enhancement curves obtained (11). The largest ellipsoid regions of interests (ROIs) were placed to cover the enhancing lesion as much as we could at the level of maximum diameter of each lesion. We placed ROIs, taking care not to include necrotic/cystic parts or calcified portions of the lesion and also avoiding any major cortical vessels (7). Another region of interest was also placed over the normal appearing gray matter cerebral hemisphere, which was contralateral basically. The relative tumor blood volume and flow compared to contralateral normal-appearing gray matter (rCBV and rCBF derived from SVD+, and rBV and rFlow derived from the Patlak plot) were calculated. Statistical analysis was performed by the same author using statistical software (JMP, version 9.0.2; SAS Institute, Cary, NC and MedCalc Software version 12.2.0.0; MedCalc, Mariakerke, Belgium). The Mann-Whitney U test and receiver operating characteristic (ROC) analysis were used for statistical analysis. A p value less than 0.05 was considered as significant.

Results

Glioblastomas showed significantly higher rFlow (3.05 ± 0.49, mean ± standard deviation) than lymphomas (1.56 ± 0.53; P < 0.05, Fig.1). rFlow ranged from 1.51 to 6.71 in glioblastomas and from 0.71 to 2.14 in lymphomas. There were no statistically significant differences between glioblastomas and lymphomas in rBV (2.52 ± 1.57 vs. 1.03 ± 0.51; P > 0.05, Fig. 2), rCBF (1.38 ± 0.41 vs. 1.29 ± 0.47; P > 0.05, Fig. 3), or rCBV (1.78 ± 0.47 vs. 1.87 ± 0.66; P > 0.05, Fig. 4). rBV ranged from 0.63 to 5.04 in glioblastomas
(Figs. 5-7) and from 0.66 to 2.09 in lymphomas (Figs. 8-10). rCBF ranged from 0.80 to 2.08 in glioblastomas and from 0.91 to 2.78 in lymphomas. rCBV ranged from 1.05 to 2.50 in glioblastomas and from 1.30 to 3.20 in lymphomas.

ROC analysis (Fig. 11) showed the best diagnostic performance with rFlow (Az = 0.87), followed by rBV (Az = 0.77), rCBF (Az = 0.61), and rCBV (Az = 0.53). There was a statistically significant difference between rFlow and rCBV (P < 0.05). There were no statistically significant differences in other comparisons (P > 0.05).

Images for this section:
**Fig. 1:** rFlow derived from Patlak plot. Glioblastomas show significantly higher rFlow (3.05 ± 0.49, mean ± standard deviation) than lymphomas (1.56 ± 0.53; P < 0.05). rFlow ranges from 1.51 to 6.71 in glioblastomas and from 0.71 to 2.14 in lymphomas.

**Fig. 2:** rBV derived from Patlak plot. There is no statistically significant difference between glioblastomas and lymphomas in rBV (2.52 ± 1.57 vs. 1.03 ± 0.51; P > 0.05). rBV ranges from 0.63 to 5.04 in glioblastomas and from 0.66 to 2.09 in lymphomas.
Fig. 3: rCBF derived from SVD+ There is no statistically significant difference between glioblastomas and lymphomas in rCBF (1.38 ± 0.41 vs. 1.29 ± 0.47; P > 0.05). rCBF ranges from 0.80 to 2.08 in glioblastomas and from 0.91 to 2.78 in lymphomas.
Fig. 4: rCBV derived from SVD+ There is no statistically significant difference between glioblastomas and lymphomas in rCBV (1.78 ± 0.47 vs. 1.87 ± 0.66; P > 0.05). rCBV ranges from 1.05 to 2.50 in glioblastomas and from 1.30 to 3.20 in lymphomas.
Fig. 5: A 63-year-old female with glioblastoma Postcontrast T1-weighted image shows an enhancing mass in the left occipital lobe (arrow).
Fig. 6: A 63-year-old female with glioblastoma rCBF derived from SVD+ shows increased tumor blood flow in an enhancing portion (rCBF = 2.07).
**Fig. 7:** A 63-year-old female with glioblastoma rFlow derived from Patlak plot also shows increased flow in the lesion (rFlow = 2.05).
Fig. 8: A 76-year-old male with lymphoma Postcontrast T1-weighted image shows an enhancing mass in the bilateral frontal lobes (arrow).
Fig. 9: A 76-year-old male with lymphoma rCBF derived from SVD+ shows increased tumor blood flow in an enhancing portion (rCBF = 5.52).
Fig. 10: A 76-year-old male with lymphoma rFlow derived from Patlak plot shows increased flow in the lesion which is less than in rCBF map (rFlow = 2.51).
**Fig. 11:** ROC analysis shows the best diagnostic performance with rFlow (Az = 0.87), followed by rBV (Az = 0.77), rCBF (Az = 0.61), and rCBV (Az = 0.53). There is a statistically significant difference in between rFlow and rCBV (P < 0.05). There are no statistically significant differences in other comparisons (P > 0.05).
Conclusion

CTP analysis with a Patlak plot was helpful in differentiating between glioblastomas and lymphomas, but CTP analysis with SVD+ was not.

Personal information

References


