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Comparison of two algorithms for analysis of perfusion computed tomography (PCT) data for evaluation of cerebral microcirculation in chronic subdural hematoma

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Abstract

The aim of this work was comparison of two algorithms for perfusion computed tomography (PCT) data analysis for evaluation of cerebral microcirculation in the perifocal zone of chronic subdural hematoma (CSDH). Twenty patients with CSDH after polytrauma were included in the study. The same PCT data were assessed quantitatively in cortical brain region beneath the CSDH (zone 1), and in the corresponding contralateral brain hemisphere (zone 2) without and with the use of perfusion calculation mode excluding vascular pixel 'Remote Vessels' (RV); 1st and 2nd analysis method, respectively. Comparison with normal values for perfusion indices in the zone 1 by the 1st analysis method showed a significant ($p < 0.01$) increase in CBV and CBF, and no significant increase in MTT and TTP. Use of the RV mode (2nd analysis method) showed no statistically reliable change of perfusion parameters in the microcirculatory blood flow of the 2nd zone. Maintenance of microcirculatory blood flow perfusion reflects the preservation of cerebral blood flow autoregulation in patients with CSDH.

1 Introduction

A chronic subdural hematoma (CSDH) is a multi-etiological disease, characterized by the formation of a capsule around a subdural hemorrhage causing local and general compression of the brain [1,2]. The most frequently occurring CSDH are formed after a craniocerebral trauma [3]. One of the key aspects determining the clinical course and outcome in patients with CSDH, is the reaction of the microvasculature in the adjacent cerebral cortex area, called a perifocal zone [4]. However, information on the status of the cerebral microcirculation and autoregulation in this zone remains contradictory. One explanation for this may be the imperfection of software algorithms for the calculation of cerebral perfusion in computer tomography [5,6]. Nevertheless, after the development of computer-tomographic algorithms for the calculation of perfusion parameters, excluding data on blood flow in large cortical vessels, it became possible to evaluate the character of pial blood flow in the 'region of interest' [7,8]. Thus, it seems possible to expand perceptions on the state of cerebral blood flow and to clarify the mechanisms that maintain microcirculation in the

perifocal zone of CSDH, based on the state of cerebral autoregulation in patients with CSDH.

The aim of this work was to compare two algorithms for perfusion computed tomography (PCT) data analysis for evaluation of cerebral microcirculation in the perifocal zone of CSDH.

2 Materials and Methods

A single-center prospective study protocol was approved by the local research ethics committee. Twenty patients with CSDH after polytrauma were included to the study for the period from January 2013 to March 2014. Inclusion criteria were CSDH on CT or magnetic resonance scans, indication for surgery, and signed informed consent to participate in the study. Exclusion criteria were age younger than 16 years, bilateral CSDH, serum blood creatinine level >120 mg/l, and acute deterioration necessitating decompressive craniotomy.

After PCT all patients were subjected to a single burr hole craniotomy under general anesthesia. The cavity of the hematoma was washed out with warm Ringer's solution. After sufficient drainage of the hematoma, the drainage catheter Pleurofix® (B.Braun Melsungen AG, Germany) was placed in the cavity for 2 days.

Perfusion computed tomography

All patients underwent PCT within the first day before surgery using a 64-slice Philips Ingenuity CT® (Philips Medical systems, Cleveland, USA). The perfusion examination report included an initial native CT of the brain followed by 4 extended scannings of the 'region of interest', 32 mm in thickness, within 55 seconds, with a contrast agent administered (the Brain Perfusion mode). The scanning parameters were: 120 kVp, 70 mA, 70 mAs and 1000 msec. The contrast agent (Ultravist 370, Shering AG, Germany) was administered with an automatic syringe-injector (Stellant, One Medrad, Indianola, PA, USA) into a peripheral vein through a standard catheter (20 G) at a rate of 4–5 ml/sec in a dose of 30–50 ml per examination.

Acquired data were transferred to a Philips Ingenuity Core workstation (Philips Healthcare Nederland B.V., the Netherlands, 2013, v.3.5.5.25007). Artery and vein marks were automatically recorded followed by manual control of indices in a time-concentration diagram.

Color-coded perfusion maps were produced to describe cerebral perfusion: cerebral blood volume (CBV), cerebral blood flow (CBF), mean transit time (MTT), and time to peak concentration of the contrast (TTP). The same PCT data were assessed quantitatively in cortical brain region beneath the CSDH (zone 1), and in the corresponding contralateral brain hemisphere (zone 2) without and with use of the perfusion calculation mode excluding vascular pixel 'Remote Vessels' (RV), 1st and 2nd analysis method, respectively. The «Remote Vessels®» (2nd analysis method) excluded voxels, reflecting the flow of blood in the large vessels, allowing to analyze changes of perfusion in capillaries.

Statistical Analysis

Data are shown as a mean ± standard deviation. A statistical analysis of all the results was performed using the paired Student's t-test. $P < 0.05$ was considered statistically significant.

3 Results

Sex distribution had a male predominance (8 women, 12 men). Mean age was 54.7±15.6 (range 17–87) years. CSDH was located in the left hemisphere in 11 patients and on the right side in 9 patients. The average volume of the CSDH was 84.2±12.4 (range 56–17) cm^3. The mean shift in the septum pellucidum was 7.1±1.4 (range 5–12) mm. The wakefulness level according to the Glasgow Coma Score was 13.1±0.5 (range 11–15). The severity level according to the Markwalder Grading Score was 1.8±0.5 (range 0–3).

The acquired and analyzed data are summarized in Table 1. Comparison with normal values for perfusion indices in the perifocal zone of CSDH in the calculation algorithm with flow in large cortical vessels (1st analysis method) showed a significant ($p < 0.01$) increase in CBV and CBF, and no significant increase in MTT and TTP ($p > 0.05$). However, when using the RV mode (2nd analysis method), comparison of perfusion parameters in the perifocal zone with normal values [9] showed the changes to be nonsignificant ($p > 0.05$).

In the zone of the intact hemisphere, comparison with normal values for perfusion indices revealed in the 1st analysis method a statistically reliable increase in CBV and CBF ($p < 0.01$), but no significant change in MTT and TTP. At the same time, use of the RV mode showed no statistically reliable change of perfusion parameters ($p > 0.05$) in the microcirculatory blood flow of the cortex on the zone 2 (side contralateral to the hematoma).

4 Discussion

One of the fundamental properties of the cerebral circulation is the ability to maintain constant microvascular perfusion under fluctuating arterial blood and intracranial pressure [10]; this property is called cerebral autoregulation [10]. It was noted that indicators of cerebral perfusion and the state of autoregulation are in close interdependence and microvasculature perfusion disorders result from damage of the autoregulation mechanism [11,12]. It has been proposed that CSDH disrupts the mechanisms of cerebral blood flow autoregulation, as evident through cerebral microcirculation disorders with the development of congestion and hyperperfusion syndromes. Thus, there was a fair increase in CBV as compared to the symmetrical zones of the opposite hemisphere, while time characteristics have not significantly changed corresponding to congestion and hyperperfusion patterns, indicating cerebral autoregulation disorder [4,13]. Nevertheless, these findings, as well as the fact that the studies were carried out without using algorithms, appeared to be the basis for critical comments on the work. In our study we used a CT analysis algorithm which excludes pixels from large vessels thus enabling to adequately assess perfusion in the pial bed of the perifocal zone of the CSDH.

It should be noted that CBF and CBV in the area opposite to the compression are significantly different from normal values when analyzed by1st algorithm. Using the

algorithm RV has shown that these changes are not reliable, which may explain the venous outflow in a presence of intracranial hematoma.

Our data prove the stability of microvasculature perfusion in the CSDH perifocal zone and, consequently, preserved cerebral blood flow autoregulation in patients with such pathology. Hyperemia and hyperperfusion in the perifocal zone of CSDH described in previous studies [4] do not affect the microcirculation, as no pial perfusion disorders were revealed. A possible reason for the development of such syndromes in the perifocal zone could be the formation of de novo blood vessels in the capsule, with the development of over-capillary shunting phenomena causing an increasing volume blood flow rate. In practice, our results show that the onset of foci of local cerebral hyperperfusion non-affecting the pial bed direction is probably an early marker of de novo angiogenesis in the capsule formation with the development of brain compression [14]. Clarification of this statement might be the basis for early diagnosis of compression formation based on the detection of the characteristic features of cerebral perfusion.

It should be noted that our study has some methodological limitations, the main one being the impossibility of dynamic non-invasive assessment of the state of perfusion in the perihematomal area without PCT rescanning. Moreover, taking into account the characteristics of our study design, we were unable to assess the perfusion characteristics of the perifocal zone in patients with a bilateral CSDH or in patients with a CSDH at a decompensated state. Both these issues require further study.

5 Conclusion

The detection of hyperemia and hyperperfusion in the perifocal zone of the CSDH in the 1st analysis method is apparently associated with the change in blood flow and blood supply at the level of resistive and capacitive vessels and does not affect the capillary bed.

The perfusion indices of blood flow in the perifocal zone of the CSDH show no significant differences from the symmetrical zone of the contralateral hemisphere.

The maintenance of microcirculatory blood flow perfusion reflects the preservation of cerebral blood flow autoregulation in patients with chronic subdural hematomas. Exclusion of large vessels from the analysis of microcirculation (2nd method) is more suitable for evaluation of cerebral blood flow status in patients with CSDH.

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Table 1

Data on comparison of the analyzed parameters.

		CBV (ml/100 g)	CBF (ml/100 g × min)	MTT (sec)	TTP (sec)
1	Group 1 (zone adjacent to the CSDH without RV)	11.07±2.82	149.15±33.18	4.48±0.66	27.57±0.83
2	Group 1 (zone opposite to the CSDH without RV)	9.31±2.33	122.84±29.52	4.63±0.76	27.78±1.13
3	Group 2 (zone adjacent to the CSDH with RV)	5.66±0.96	88.36±16.2	3.84±0.61	27.47±0.84
4	Group 2 (zone opposite to the CSDH with RV)	5.16±0.8	75±20.97	4.08±0.86	27.94±1.3
5	Normal value [9]	4.5±0.6	64.02±0.6	4.3±0.8	-
	P (1–2)	*	*	0.53	0.52
	P (1–3)	***	***	*	0.70
	P (2–4)	***	***	0.05	0.70
	P (3–4)	0.09	*	0.32	0.19

CBV, cerebral blood volume; CBF, cerebral blood flow; MTT, mean transit time; TTP, time to peak concentration of the contrast.

*** P <0.001,

* P<0.05