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## Perfusion computed tomography in the diagnosis of acute focal neurological symptoms – a report of four cases

## Badanie perfuzyjne tomografii komputerowej głowy w diagnostyce przyczyn ostrych ogniskowych objawów neurologicznych – opis czterech przypadków

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### Summary

Perfusion computed tomography (PCT) is used for acute stroke evaluation, single reports suggest, that it may also falsely identify patients with neurological deficits related to seizures. We report four cases of patients with acute focal neurological symptoms, without ischemic focus in routine computed tomography (CT), who underwent PCT and electroencephalography within 12 hours after symptom's onset. Patients have finally been diagnosed with ischemic stroke with secondary hemorrhage (case 1), postictal Todd's paresis (case 2), hemiparesis in course of seizure (case 3) and ischemic stroke with concomitant nonconvulsive status epilepticus (case 4). The results suggest, that PCT may be significant in the differential diagnosis of acute focal neurological symptoms.

Key words: stroke, Todd's paresis, PCT

### Streszczenie

Badanie perfuzyjne tomografii komputerowej (Perf-TK) głowy jest wykorzystywane w ocenie pacjentów z udarem niedokrwinnym mózgu, pojedyncze doniesienia wskazują jednak, że może ono błędnie identyfikować chorych z objawami ubytkowymi w przebiegu napadów padaczkowych. Przedstawiamy opis czterech przypadków chorych z ostrymi ogniskowymi objawami neurologicznymi, bez świeżych zmian niedokrwiniowych w rutynowej tomografii komputerowej (TK) głowy, którzy w ciągu 12 godzin od wystąpienia objawów mieli wykonane Perf-TK głowy i badanie elektroencefalograficzne. U pacjentów ostatecznie rozpoznano: udar mózgu niedokrwiniowy wtórnie ukrwotoczony (przypadek 1), niedowład ponapadowy Todda (przypadek 2), niedowład w przebiegu niedrgawkowego stanu padaczkowego (przypadek 3) oraz udar mózgu niedokrwiniowy z towarzyszącym niedrgawkowym stanem padaczkowym (przypadek 4). Uzyskane wyniki wskazują, że Perf-TK głowy może różnicować udar i napady padaczkowe jako przyczynę ostrych ogniskowych objawów neurologicznych.

Słowa kluczowe: udar, niedowład Todda, Perf-TK głowy

### INTRODUCTION

**Perfusion computed tomography (PCT) is a recognized tool in an early ischemic stroke imaging. It gives the possibility of visualizing the area of penumbra which, according to some authors, may allow introduction of thrombo-**

**lytic treatment, even in patients with excluding SITS-MOST criteria** (1). There have only few reports been published on the role of this imaging tool in the diagnostics of acute focal neurological symptoms related to seizures. Single reports suggest that it may falsely identify ischemic stroke in

these patients while others indicate its role in differentiating these two pathologies. Hand et al. (2) reported, that conditions mimicking stroke may concern up to 31% of patients, in 21% of which seizures are a final cause of symptoms. Since these symptoms may not be possible to differentiate clinically, an effective diagnostic tool would allow avoiding unnecessary, potentially dangerous, thrombolytic treatment. Simultaneously correct antiepileptic treatment could be introduced, which may be particularly significant in cases of undiagnosed status epilepticus. We present four patients with acute focal deficits, without new focal lesions in routine computed tomography (CT), who had PCT and electroencephalography (EEG) performed within 12 hours since the symptoms occurrence. On the third day since the clinical symptoms occurrence we performed a follow-up non-contrast CT in order to visualize presumptive ischemic focus. Patients' consent to additional procedures was gained according to rules accepted by The Bioethics Committee of Medical Centre of Postgraduate Education. Perfusion parameters in all patients were measured at the level of the basal ganglia, the thalamus and the third ventricle. We analyzed the following parameters: CBF (cerebral blood flow), CBV (cerebral blood volume), MTT (mean transit time). Perfusion parameters were set up as asymmetry indices from corresponding regions of brain hemispheres. We calculated the index of asymmetry (AI) from the formula:  $AI = (\text{symptomatic hemisphere} - \text{reference hemisphere}) / (\text{symptomatic hemisphere} + \text{reference hemisphere}) \times 100\%$  (3). On the basis of literature (3) as a hypoperfusion or hyperperfusion we assumed the asymmetry index above 10%.

## CASES REPORTS

The cases are presented together in a form of a table (tab. 1, fig. 1-4).

## DISCUSSION

**Even though a transient motor deficit following epileptic seizure (Todd's paresis) has been described in the literature since 1827, until now no one could interchangeably state its etiopathogenesis.** While analyzing the available data we can assume that there are at least two separate pathophysiological mechanisms. The first one concerns the actual paresis after seizure, which occurs after demission of bioelectric activity characteristic for the seizure and should be accompanied by focal slowing in the basic activity in EEG. It could be caused by "exhaustion" of neurons secondary to hypoxia, the increase in lactates and local disturbances in blood flow (4, 5), what could result in focal hypoper-

fusion of the brain tissue. This conception, although often undermined, finds confirmation in some of the newer reports that explain the reduction of cerebral blood flow after seizure, to be a reflexive reaction following decreased brain oxygen and glucose metabolism (6). Hypoperfusion after seizure was found in many single photon emission computed tomography studies (SPECT), however, some patient with temporal epilepsy had also hyperperfusion lasting up to 30 minutes in the hippocampal region (7). Moreover, another study using perfusion magnetic resonance showed hippocampal hypoperfusion after seizure, but hyperperfusion in the parahippocampal gyrus as a result of increased metabolism in order to preserve the appropriate threshold of neuron excitability (8).

**Until now there have been only a few publications with PCT results in patient with focal deficits after seizures. They indicate mainly the presence of hypoperfusion after seizures in the hemisphere with the source of epileptic discharges, but except for basal ganglia (9) or the white matter (10), exceeding traditional vascular territories.** Gelfand et al. (9) described 8 patients with focal hypoperfusion, 1 with hyperperfusion and 1 with isolated prolonged MTT, however, in some patients no EEG was performed. Hauf et al. (3) included 3 patients with paresis after seizure in their research, in all of which hypoperfusion was found. In both these research, in cases of hypoperfusion, perfusion parameters were similar to those in the ischemic stroke – CBF and CBV decreased with increased MTT. However, in one case there was hypoperfusion with decreased CBF and CBV with no changes in MTT (10). MTT is a sensitive index of hypoperfusion secondary to a large vessel stenosis, that is why it's relative symmetry would rather indicate a metabolic cause of symptoms (10) and may at the same time be a differentiating parameter. In our case of Todd's paresis [2] MTT did not change significantly, but we visualized hyperperfusion of left hemisphere (frontal and occipital lobe and the basal ganglia) with maximum AI 16% with decrease in record amplitude and predominance of slow waves over the left hemisphere in EEG. According to our knowledge such case hasn't been published yet. We cannot, however exclude that during neuroimaging there was a transient epileptic activity, but we did not observe any changes in patient's state condition at that time. Moreover, localization of hyperperfusion areas did not indicate the stroke in the phase of reperfusion. Less likely, but not impossible, would be the presence of multifocal vascular malformations that could be the reason for increased blood flow. Finally, retrospectively analyzed course of the disease did not raise any suspicion of encephalitis or migraine.

Table 1. Cumulative characteristics of presented cases.

Case	Patient's age and sex	Clinical symptoms	Case history	Non-contrast CT	EEG	PCT			Diagnosis
						CBV (AI)	CBF (AI)	MTT (AI)	
1	66-year-old female	Left-sided paresis NIHSS*: 1 day – 14 2 day – 7 3 day – 6	– Hypertension – Smoking	Features of periventricular leukoaraiosis, without new ischemic lesions	Non-paroxysmal – discharge: over right hemisphere lowering of record reactivity, predominance of slow waves and disturbance of basic alpha wave rhythm	↓**30% – basal nuclei ↓14% – frontal and occipital lobes	↓42% – basal ganglia ↓24% – lateral part of temporal lobe	↑24% – basal ganglia ↑28% – lateral part of temporal lobe	Ischemic stroke with secondary hemorrhage (CT on the 3 day – hemorrhagic transformation of ischemic stroke focus in the right temporal lobe including deep structures of right hemisphere)
2	83-year-old male	Right-sided paresis NIHSS: 1 day – 20 2 day – 6 3 day – 6	– Two right-sided seizures on admission to the clinic – Past ischemic stroke with remaining right-sided hemiparesis (NIHSS – 6) – Post-stroke epilepsy – Hypertension – Chronic atrial fibrillation	Hypodense scar lesions in the deep structures of both hemispheres, periventricular leukoaraiosis, intense cortico-subcortical atrophy of cerebrum and cerebellum without new ischemic lesions	Non-paroxysmal discharges bioelectrical activity pattern disturbance with numerous theta waves in temporal leads mainly over left hemisphere	↑16% – basal ganglia ↑15% – frontal lobe ↑15% – occipital lobe	↑16% – basal ganglia ↑15% – frontal lobe ↑12% – occipital lobe	↑2% – basal ganglia ↑6% – frontal lobe ↓0.5% – occipital lobe	Todd's paresis (CT on the 3 day – without new ischemic lesions)
3	74-year-old male	Right-sided paresis NIHSS: 1 day – 22 2 day – 2 3 day – 2	– Status epilepticus of secondary generalized tonic-clonic seizures on admission to the clinic, stopped by i.v. injection of 1 mg of clonazepam – History of 2 ischemic strokes with remaining dysarthria and central paresis of left VII nerve (NIHSS – 2) – Hypertension – Diabetes type 2 – Chronic atrial fibrillation – Moderate aortic and mitral stenosis – Ankylosing spondylitis	Without pathological focal lesions	Paroxysmal discharges: often rhythmic impulses of high-tension sharp wave with a slow wave with clear predominance over right hemisphere	↑14% – occipital lobe	↑14% – occipital lobe	↑9% – occipital lobe	Paresis in the course of non-convulsive status epilepticus (CT on the 3 day – without new ischemic lesions)
4	37-year-old female	Left-sided paresis NIHSS: 1 day – 17 2 day – 12 3 day – 10	– Paresis preceded most likely by seizure in the form of facial asymmetry, salivation, unintentional movements of left upper limb – In the last months a few short incidents of loss of consciousness with facial asymmetry – Smoking	Without pathological focal lesions	Escalating paroxysmal discharges in the form of sharp waves over the right hemisphere	↓19% – basal ganglia ↑2% – lateral part of temporal lobe	↓26% – basal ganglia ↓10% – lateral part of temporal lobe	↑21% – basal ganglia ↑14% – lateral part of temporal lobe	Ischemic stroke accompanied by non-convulsive epileptic state – joined assessment of EEG record and clinical picture (CT on the 3 day – new ischemic focus in the right temporal lobe including deep structures and small focus in the left parietal lobe)

\*NIHSS – National Health Institutes Stroke Scale.  
\*\*Arrows indicate changes in perfusion parameters in symptomatic hemisphere in comparison to the contralateral hemisphere.  
Other abbreviations are explained in the introduction.

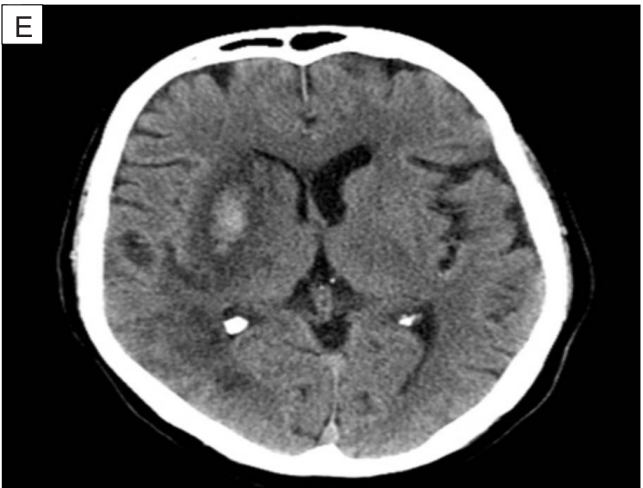
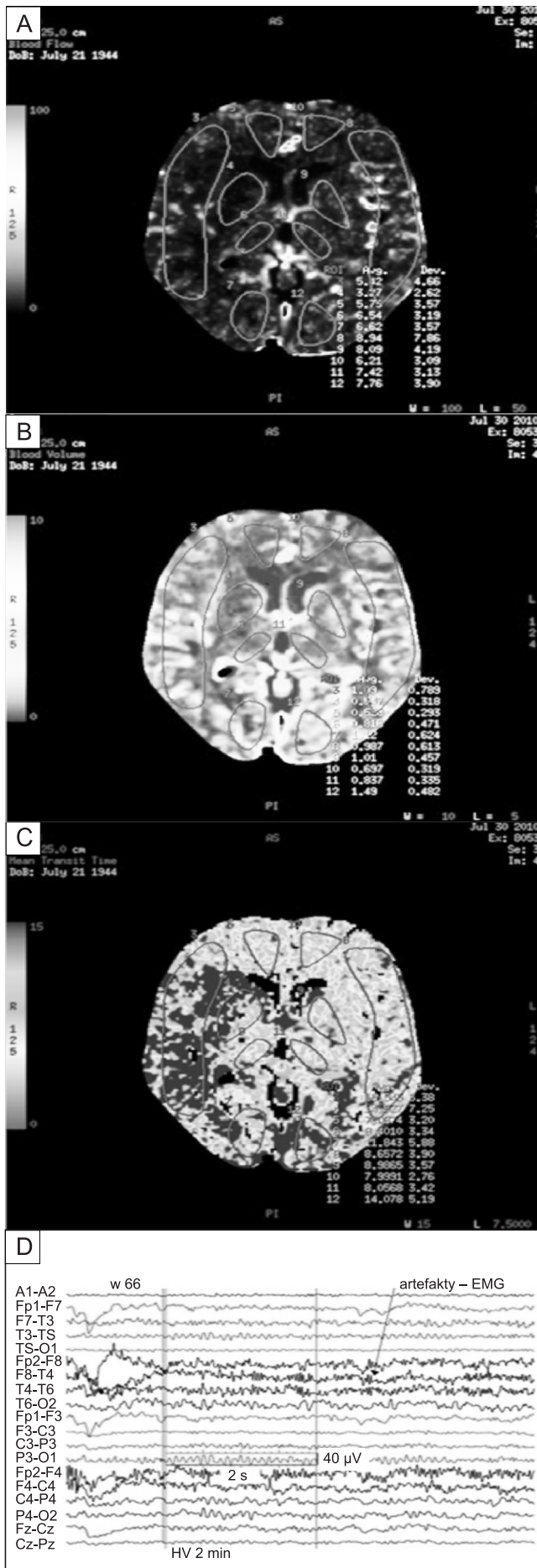


Fig. 1. PCT (A – CBF, B – CBV, C – MTT) and EEG (D) within 12 hours since the symptoms occur, as well as non-contrast CT on the third day symptoms onset (E) in a patient with ischemic stroke with secondary hemorrhagic transformation (case 1). Description in the text.  
Full color of the figures are available at website [www.pnmedycznych.pl](http://www.pnmedycznych.pl)

We used the conception of intra-seizure limb immobility (11), while making the diagnosis in the third case report. It comes from Gowers's considerations (12) who, not finding the dependence between the time of seizure and paralysis duration, postulated the mechanism of active retardation. Impulses from basal ganglia would have a modulating influence on retarding interneurons in the motor cortex (13). Luders et al. (14) proved that additional motor field of both hemispheres stimulation causes retardation of precise movements. However, there was a patient with paresis during seizure described who did not have epileptic discharges in the additional motor field registered, while they were present in the motor cortex (15).

Numerous SPECT and MR studies confirm the presence of focal hyperperfusion during focal seizure, which by many authors is explained by the increase in the brain metabolism. There is also an alternative conception of hyperperfusion mechanism concerning neuroprotective factors release as a reaction to epileptic discharges, such as vascular endothelial growth factor which, by nitric oxide, causes vessel dilating (16). However, there was also hypoperfusion during seizure described which occurrence was explained as "stealing phenomenon" from other brain regions to which epileptic discharges propagate (17).

The case we described [3] was diagnosed as the paresis during seizure, in spite of the fact that the bioelectrical features of status epilepticus in EEG were expressed mainly over the hemisphere ipsilateral to clinical symptoms. We found features of hyperperfusion in left occipi-



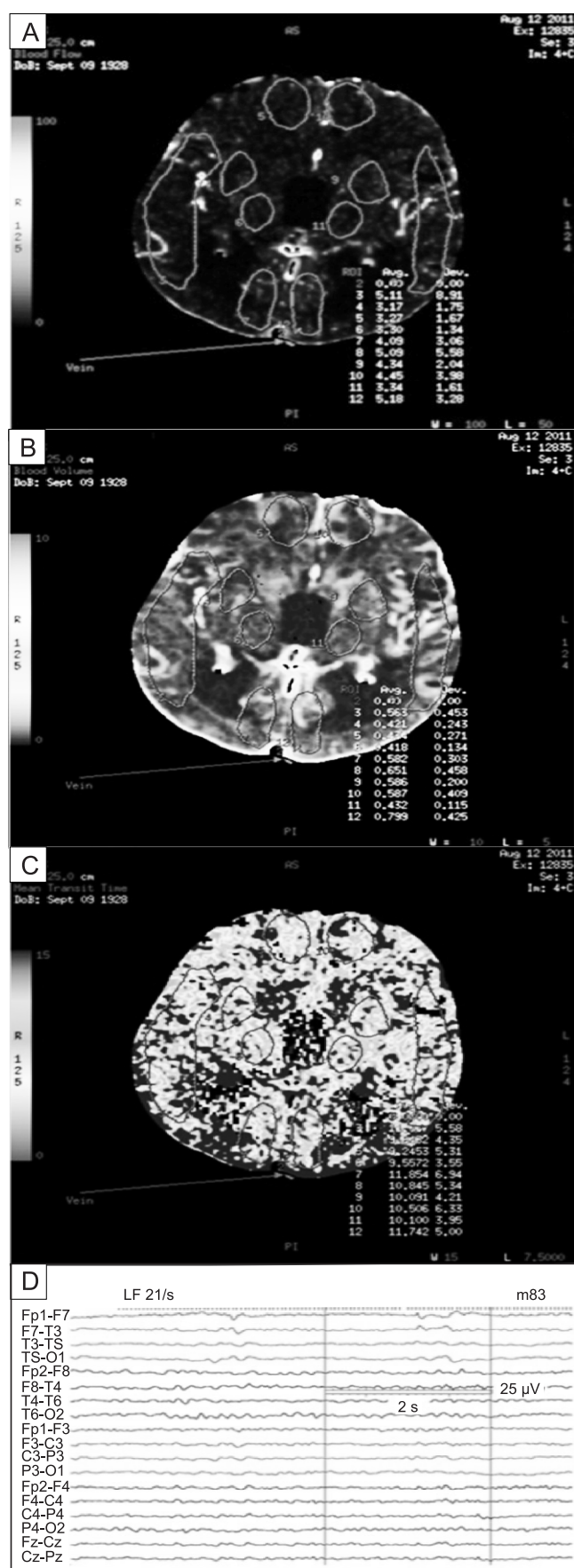


Fig. 2. PCT (A – CBF, B – CBV, C – MTT) and EEG (D) within 12 hours since the symptoms occur in a patient with Todd's paresis (case 2). Description in the text. Full color of the figures are available at website [www.pnmedyczynych.pl](http://www.pnmedyczynych.pl)

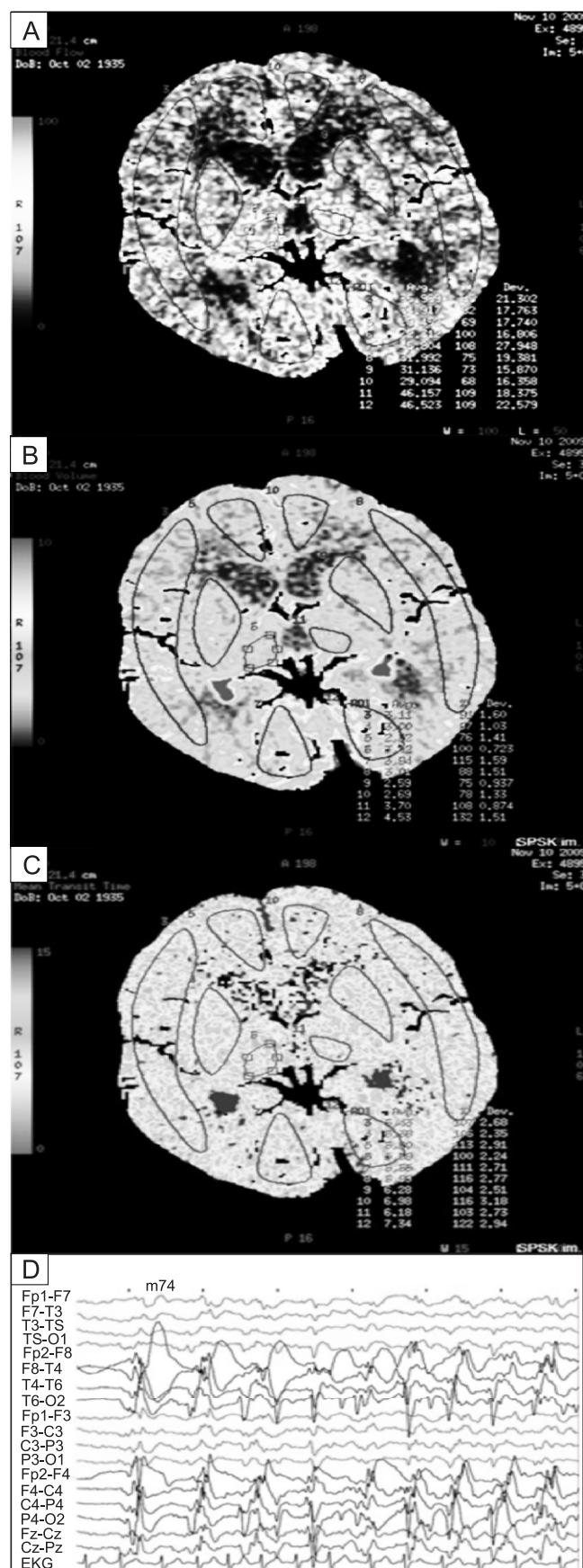


Fig. 3. PCT (A – CBF, B – CBV, C – MTT) and EEG (D) within 12 hours since the symptoms occurred in a patient in a nonconvulsive status epilepticus with coexisting paresis of right limbs (case 3). Description in the text.  
Full color of the figures are available at website [www.pnmedyczynych.pl](http://www.pnmedyczynych.pl)

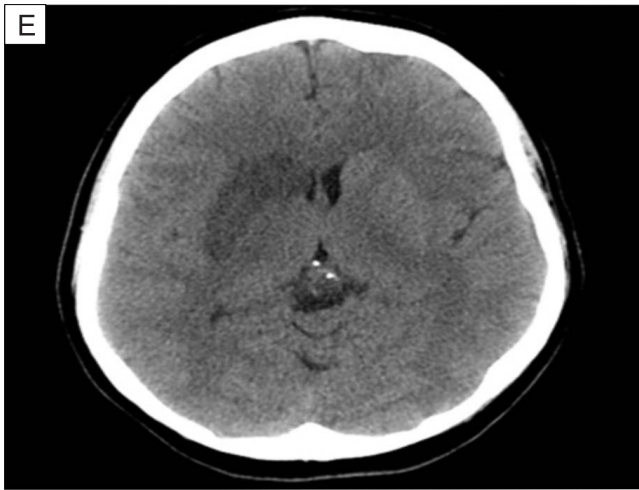
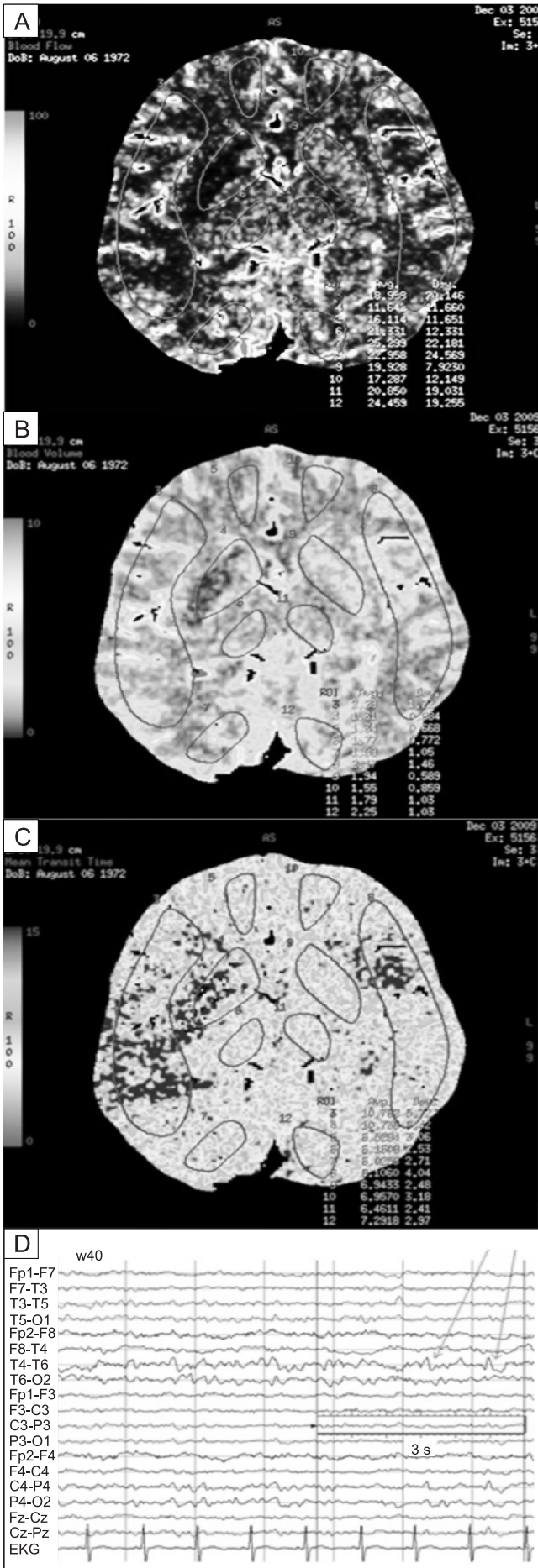


Fig. 4. PCT (A – CBF, B – CBV, C – MTT), EEG (D) within 12 hours since the symptoms occurred as well as non-contrast CT on the third day since symptoms onset (E) in a patient with ischemic stroke with nonconvulsive status epilepticus (case 4). Description in the text.

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tal lobe (AI: 13.6%), but only in CBV. Although yet known PCT studies in patients with paresis during seizures also indicate hyperperfusion, but it concerns only the region of the hemisphere with epileptic discharges. Analogically to hypoperfusion after seizure hyperperfusion during seizure described in the literature manifested in the increase in CBF and CBV and decrease in MTT (3, 18-20). Only one case report indicates lack of changes in MTT symmetry with accurate increase in CBF and CBV (21). Hyperperfusion was also found in the patient in whom the region of post-infarction scar was the source of epileptic discharges, despite the fact that theoretically in this region we would rather suppose to find hypoperfusion (19). In the group of 9 patients with nonconvulsive status epilepticus, hyperperfusion avoided the white matter, mean AI (CBV) was 21%, but the lack of hyperperfusion did not exclude nonconvulsive status epilepticus (3). It is difficult to explain hyperperfusion which we found in the occipital lobe contralateral to epileptic discharges in EEG. We cannot exclude that the change in a single perfusion parameter could be a result of unrecognized vascular malformation. Finally, small asymmetry index as well as unexpected prolonged MTT in this area suggest that these changes may be accidental and result from the technical limitations of the method.

Stroke hypoperfusion found in PCT is widely described in the literature. The case we presented [1] is typical with decreased CBV and CBF and increased MTT. AI values in regions, where in the third day since symptoms onset ischemic focus with secondary hemorrhage occurred, were between 24 and 42%.



It is noticeable, that in the lateral part of the right temporal lobe there is no decrease in CBV but there is lengthening of MTT and decrease in CBF – this area is mostly excluded from the ischemic area visible on the third day since symptoms onset and is very likely corresponding to penumbra.

Another diagnostic challenge are patients with ischemic stroke and concomitant seizures. Stroke begins with seizures in about 7% of patients (18). **The case [4] shows focal hypoperfusion corresponding to ischemia revealed in a follow-up CT, apart from paroxysmal activity found in these regions in EEG. Asymmetry indices (AI) were slightly lower than in case number 3 (14 – 26%), despite patient's more severe neurological state (NIHSS 17 vs. 14 points).** This type of changes in perfusion parameters, according to above mentioned literature data could also occur in paresis after seizure without a stroke, however,

the diagnosis of stroke could be suggested mainly by the localization of hypoperfusion typically in the medial cerebral artery vascularization territory and inclusion of the white matter. In such cases, the potential role of PCT in differentiation is particularly interesting, since, according to Polish Society of Neurology 2012 guidelines, stroke that begins with seizures is no longer an absolute contraindication to thrombolytic treatment (22).

**The gained results indicate that PCT may differentiate ischemic stroke and seizures as the cause of acute focal neurological symptoms.** On the basis of described cases it seems that the differentiating factor could be the presence or the lack of hypoperfusion in the symptomatic hemisphere. It is necessary to collect the appropriate group of patients in order to perform statistical analysis and get further conclusions.

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otrzymano/received: 17.07.2013  
zaakceptowano/accepted: 04.09.2013

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