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Case Report

Luxury perfusion: A paradoxical finding and pitfall of CT perfusion in subacute infarction of brain

Houman Sotoudeh, Assistant Professor[a,], Omid Shafaat, Research Fellow[b], Aparna Singhal, Assistant Professor[a], Asim Bag, Associated Professor[c]*

[a] *Department of Neuroradiology, University of Alabama at Birmingham (UAB), 619 19th St S, Birmingham, AL 35294, USA*

[b] *Department of Radiology and Interventional Neuroradiology, Isfahan University of Medical Sciences, 8174675731 Alzahra Teaching Hospital, Sofeh Blvd, Isfahan, Iran*

[c] *Department of Radiology, St. Jude Children's Research Hospital, 262 Danny Thomas Place, Memphis, TN 38105, USA*

ARTICLE INFO

Article history:
Received 6 August 2018
Accepted 27 August 2018
Available online 1 October 2018

Keywords:
Perfusion imaging
Stroke
Neurologic examination

ABSTRACT

In the context of recent guidelines for stroke management, application of computed tomographic perfusion (CTP) is anticipated to increase, especially within 6-24 hours after stroke onset. There are commercially available software packages to help to detect the infarct core and the penumbra, however, the results of these software are not always straightforward that might cause incorrect CTP interpretation. We present here a case of acute ischemic stroke in which the CTP software misinterpreted the results by labeling the normal hemisphere as infarction and ischemia due to luxury perfusion of the infarcted hemisphere. Awareness of laterality of the patient's symptoms and the understanding of functioning of perfusion analysis software is necessary to avoid this pitfall.

Introduction

Ischemic stroke, caused by occlusion of the intracranial arteries is the second leading cause of death and the third leading cause of disability in the world [1,2]. Computed tomographic perfusion (CTP) is physiological imaging of the hemodynamic status of the brain parenchymal tissue [3]. There are many different commercial CTP software packages from many different vendors to process the raw data of the CTP, and to date there is no standardization of all these software packages. As a result, the user interface and the algorithms used by these software are different. Awareness of the software functionalities is essential to avoid pitfalls in CTP interpretation.

Luxury hyper-perfusion is defined by the state of excessive brain blood flow in demand of the metabolic rate and oxygen demand of the brain tissue. It is nonnutritive flow to the infarcted tissue because of abnormal autoregulation system [4].

Grant support: None.

* Corresponding author.
E-mail addresses: hsotoudeh@uabmc.edu (H. Sotoudeh), omid.shafaat@yahoo.com (O. Shafaat), asinghal@uabmc.edu (A. Singhal), Asim.Bag@stjude.org (A. Bag).

https://doi.org/10.1016/j.radcr.2018.08.031

In this communication, we report a unique situation in which the CTP software misinterpreted the results of a 79-year-old man admitted to the hospital for stroke evaluation that was not compatible with the patient's clinical symptoms.

Case presentation

A 79-year-old man was brought to the emergency room with a complaint of decreased mental status for stroke evaluation. The patient was last seen healthy at 14:00 but was found unresponsive at 15:30 and was transported immediately to the emergency room. He had a history of hypertension and atrial fibrillation managed with oral antihypertensives and warfarin (Coumadin®).

At an outside facility, non-contrast computed tomography (CT) was performed, and no contraindications to tissue plasminogen activator (tPA) were found. The patient received tPA bolus at 17:30 and was transported to our hospital for further imaging and medical management.

The initial examination by the neurologist determined global aphasia, left gaze preference, trace withdrawal from noxious stimuli on the right side, brisk withdrawal on the left side and right-sided weakness with a National Institutes of Health Stroke Scale profile of 23.

Prior to repeat imaging, the patient was intubated for concern of airway protection. CTP was performed which showed asymmetry between the right and left cerebral hemispheres. The automated CTP software (Philips IntelliSpace Portal depicting areas of ischemia [voxel values for MTT $>$ 1.4 times mirror image voxels on the contralateral "normal side"] in the color green and areas predictive of infarction [CBV values $<$ 2.0 mL/100 g] in the color red) showed a moderate-sized infarction in the right middle cerebral artery (MCA) territory and a large peri-infarct ischemia in the right frontoparietotemporal lobes at the watershed distribution of right MCA (Fig. 1). The CTP findings were, however, not compatible with either the patient's clinical findings or the concurrent noncontrast CT which showed loss of differentiation of gray-white matter in left frontoparietotemporal lobes and left basal ganglia. The subsequent CT angiogram showed no flow-limiting stenosis or occlusion in the neck and intracranial arteries. The patient was not a candidate for intra-arterial thrombectomy and was admitted to the Intensive Care Unit for conservative and supportive management.

CT and magnetic resonance imagining were performed on the next day that showed large left MCA and distal left anterior cerebral artery (ACA) distribution infarction with edema (Fig. 2). No evidence of infarction or ischemia was detected in the right cerebral hemisphere by other imaging studies and physical exams, as was suggested by the initial CTP prognostic maps.

Discussion

In recent decades, the major changes in stroke treatment have aimed to reduce the time to treat as well as to extend the time interval for intra-arterial treatment to 24 hours after the stroke onset. Based on the most recent stroke management guidelines, the treatment window for thrombolysis and intra-arterial thrombectomy has been extended up to 24 hours after initial symptoms, and perfusion imaging is recommended in a 6- to 24-hour window by Class of Recommendations of I (strongly recommended) and Levels of Evidence of A (high quality evidence by more than one randomized clinical trial) [5]. These guidelines therefore suggest to perform larger number of CTPs in the acute and subacute phase of stroke. CTP helps to differentiate irreversibly damaged infarcted brain tissue (the core infarction) from brain tissue with reversible ischemia (peri-infarction ischemic penumbra). The patients demonstrated to have a large penumbra benefit most from the thrombolysis and intra-arterial thrombectomy compared to patients without peri-infarct ischemia or relatively small penumbra.

Following is a brief discussion of the CTP technique and post processing. The readers are referred to more comprehensive discussion elsewhere [6]. For CTP, CT image acquisition is repeated multiple times after injection of contrast. The increased parenchymal attenuation is proportional to contrast and arterial blood flow. Generally, 35-50 mL of iodinated contrast is injected via the antecubital vein followed by 20 mL of saline. The CT acquisition starts 5-7 seconds after contrast injection, and it continues up to 75-90 seconds. For interpretation, CTP thresholds are needed to differentiate infarct core and penumbra. The post-processing of CTP can be performed by commercially available software packages. These software packages help the radiologists to detect infarcted tissue as an area of elevated mean transit time (MTT) and time to peak (TTP) and significantly decreased cerebral blood flow (CBF) and cerebral blood volume (CBV) and to detect penumbra as an area of increased MTT and TTP with decreased CBF but normal or even increased CBV. Studies have shown that CBF of less than 25 mL $\times$ 100/g/min and a CBV of less than 2 mL $\times$ 100/g are optimal to define core infarction and a relative MTT of more than 145% of normal is considered as "peri-infarction ischemic penumbra" or tissue at risk [6]. To recognize the abnormal region, the software uses a normal brain as a reference (contralateral hemisphere) [7]. According to Zussman et al [8], different commercial software packages however, do not generate consistently uniform quantitative perfusion results. Most of the current software generate 2 types of maps. The first map the parametric map contains information about the absolute values of MTT, TTP, CBV, and CBF. The second map, the prognostic map compares the region of interest to the normal tissue and marks the areas of increased MTT and TTP with preserved CBV and/or CBF as ischemia and areas of abnormal CBV and/or CBF as infarction. Attention to both parametric and prognostic maps is critical to avoid misinterpretation as describe in present case.

"Luxury hyperperfusion" is a well-known phenomenon in the subacute phase of brain infarction [9,10]. Luxury perfusion after successful recanalization of the thrombosed artery has been reported, but the prevalence is not well known [9]. In this case, the patients received tPA before CTP with successful recanalization of the left MCA and likely left distal ACA (as evidenced by lack of arterial occlusion on the CT angiogram exam). Typically, software algorithms would depict luxury per-

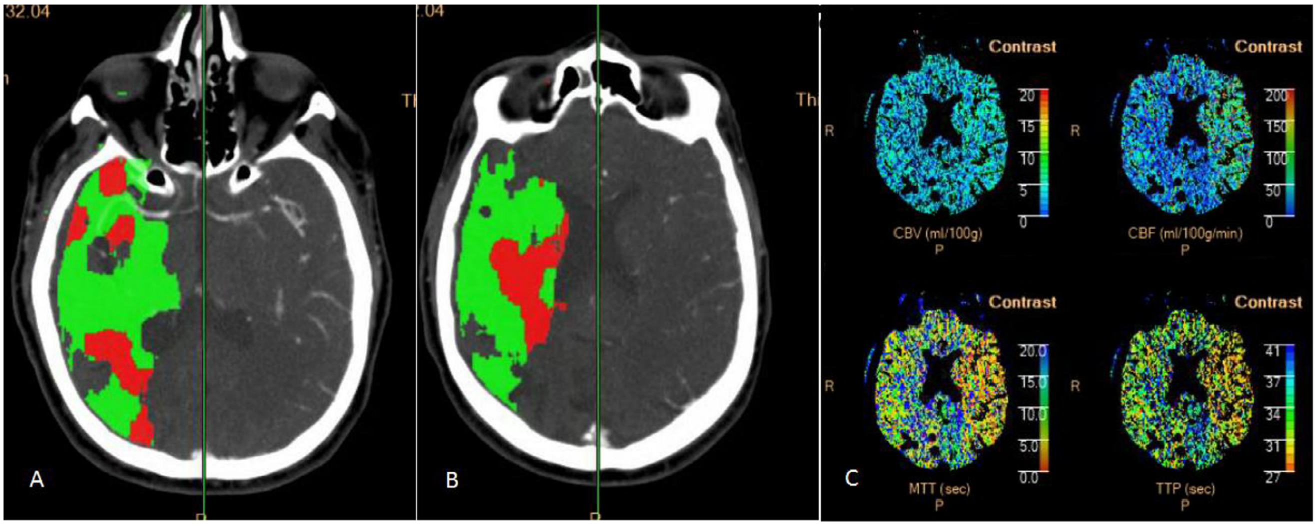

Fig. 1 – The software reconstructed color map from CT perfusion show a moderate-sized infarct (red color) in the right hemisphere in the territory of right MCA and large peri-infarct ischemia (green color) (A and B). The parametric CBV, CBF, MTT, and TTP maps (depicted together in C) show asymmetry between the right and left hemispheres, but it is difficult to appreciate whether the right side is hypoperfused or the left side is hyperperfused just by visual assessment. Measuring the absolute values reveals that the left hemisphere is actually hyper perfused. Color version of figure is available online.

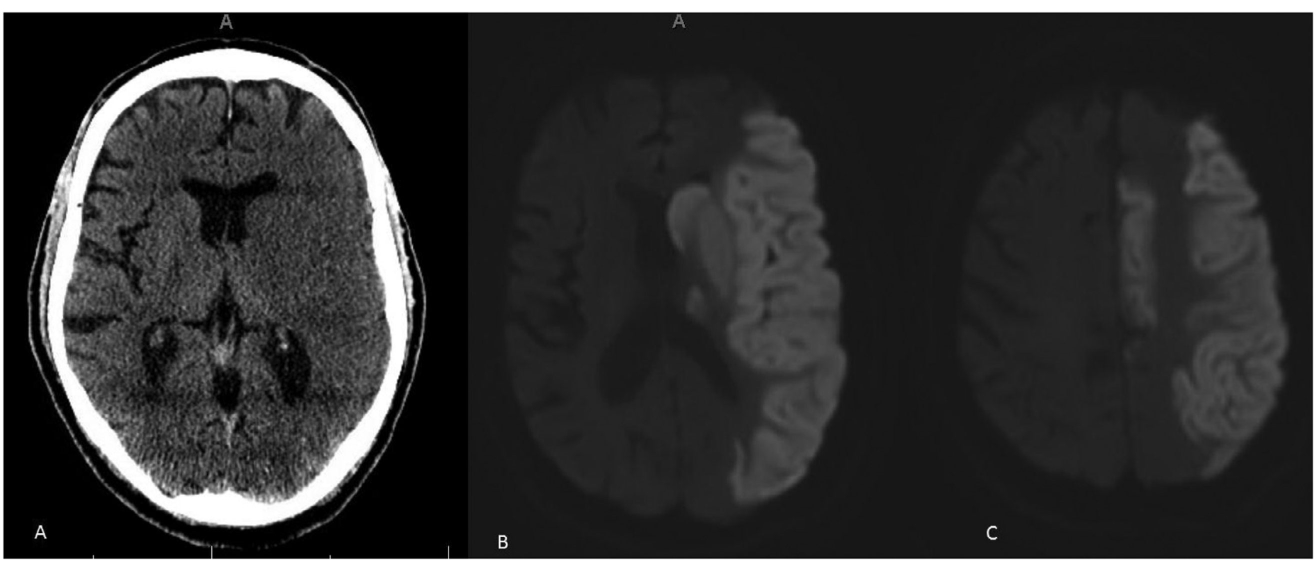

Fig. 2 – The non-contrast CT shows loss of gray-white matter differentiation in the left hemisphere and left basal ganglia with parenchymal edema. The right hemisphere appears normal other than microvascular angiopathy (A). The subsequent MRI diffusion weighted images (B and C) show extensive infarction in the territory of left MCA and distal left ACA and no infarct in the right hemisphere.

fusion as hyperperfusion on the infarcted side but in our case presented here, the automated software considered the luxury perfusion of left cerebral hemisphere as a normal reference and marked the normal right hemisphere as ischemic with a core infarction. Careful retrospective analysis of the parametric maps depicted increased perfusion in the left cerebral hemisphere compared to the right but looking at prognostic maps in isolation mischaracterizes the laterality of ischemia in this case.

In conclusion, to read CTP in "subacute phase" or "post tPA treatment," the awareness of the laterality of the patient's symptoms would aid the radiologist in correct interpretation. Moreover, in addition to the visual assessment of reconstructed prognostic maps, it is crucial to assess the source data and absolute values of TTP, MTP, CBV, and CBF on parametric maps.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.radcr.2018.08.031.

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