Cerebral Ultrasound Perfusion Imaging

Ultrasound Perfusion Imaging is feasible to enable detection of cerebral hypoperfusion after aneurysmal subarachnoid hemorrhage, and the left-right difference of time to peak (TTP) values is the most indicative result of this finding [1)].

Over the past 20 years, ultrasonic cerebral perfusion imaging (UPI) has been introduced and validated by applying different data acquisition and processing approaches. Clinical data were collected mainly in acute stroke patients. Some efforts were undertaken in order to compare different technical settings and validate results to gold standard perfusion imaging. A review illustrates the evolution of the method, explicating different technical aspects and milestones achieved over time. Up to date, advancements of ultrasound technology, as well as data processing approaches, enable semi-quantitative, gold standard proven identification of critically hypo-perfused tissue in acute stroke patients. The rapid distribution of CT perfusion over the past 10 years has limited the clinical need for UPI. However, the unexcelled advantage of mobile applications raises reasonable expectations for future applications. Since the identification of intracerebral hematoma and large vessel occlusion can also be revealed by ultrasound exams, UPI is a supplementary multi-modal imaging technique with the potential of the pre-hospital application. Some further applications are outlined to highlight the future potential of this underrated bedside method of microcirculatory perfusion assessment [2)].

Ultrasound perfusion imaging provides a simple and non-invasive way to detect the VN time window, which increases the feasibility of vascular normalization (VN) in clinical cancer applications [3)].

Reitmeir et al. compared contrast-enhanced ultrasound perfusion imaging with magnetic resonance perfusion-weighted imaging or perfusion computed tomography for detecting normo-, hypo-, and nonperfused brain areas in acute middle cerebral artery stroke. We performed high mechanical index contrast-enhanced ultrasound perfusion imaging in 30 patients. The time-to-peak intensity of 10 ischemic regions of interest was compared to four standardized nonischemic regions of interests of the same patient. A time-to-peak >3 s (ultrasound perfusion imaging) or >4 s (perfusion computed tomography and magnetic resonance perfusion) defined hypoperfusion. In 16 patients, 98 of 160 ultrasound perfusion imaging regions of interest of the ischemic hemisphere were classified as normal, and 52 as hypoperfused or nonperfused. Ten regions of interest were excluded due to artifacts. There was a significant correlation between the ultrasound perfusion imaging and magnetic resonance perfusion or perfusion computed tomography (Pearson's chi-squared test 79.119, $p < 0.001$) (OR 0.1065, 95% CI 0.06-0.18). No perfusion in ultrasound perfusion imaging (18 regions of interest) correlated highly with diffusion restriction on magnetic resonance imaging (Pearson's chi-squared test 42.307, $p < 0.001$). Analysis of receiver operating characteristics proved a high sensitivity of ultrasound perfusion imaging in the diagnosis of the hypoperfused area under the curve, (AUC = 0.917; $p < 0.001$) and nonperfused (AUC = 0.830; $p < 0.001$) tissue in comparison with perfusion computed tomography and magnetic resonance perfusion. They presented a proof of concept in determining normo-, hypo-, and nonperfused tissue in acute stroke by advanced contrast-enhanced ultrasound perfusion imaging [4)].

A review detail the methodology of ultrasound perfusion imaging, discuss aspects of its safety and present the clinical applications of brain perfusion assessment with ultrasound in acute stroke patients [5].

1)
Fung C, Heiland DH, Reitmeir R, Niesen WD, Raabe A, Eyding J, Schnell O, Rölz R, Z Graggen WJ, Beck J. Ultrasound Perfusion Imaging for the Detection of Cerebral Hypoperfusion After Aneurysmal Subarachnoid Hemorrhage. Neurocrit Care. 2022 Feb 24. doi: 10.1007/s12028-022-01460-z. Epub ahead of print. PMID: 35211837.
2)
Eyding J, Fung C, Niesen WD, Krogias C. Twenty Years of Cerebral Ultrasound Perfusion Imaging-Is the Best yet to Come? J Clin Med. 2020 Mar 17;9(3):816. doi: 10.3390/jcm9030816. PMID: 32192077; PMCID: PMC7141340.
3)
Ho YJ, Chu SW, Liao EC, Fan CH, Chan HL, Wei KC, Yeh CK. Normalization of Tumor Vasculature by Oxygen Microbubbles with Ultrasound. Theranostics. 2019 Sep 25;9(24):7370-7383. doi: 10.7150/thno.37750. PMID: 31695774; PMCID: PMC6831304.
4)
Reitmeir R, Eyding J, Oertel MF, Wiest R, Gralla J, Fischer U, Giquel PY, Weber S, Raabe A, Mattle HP, Z'Graggen WJ, Beck J. Is ultrasound perfusion imaging capable of detecting mismatch? A proof-of-concept study in acute stroke patients. J Cereb Blood Flow Metab. 2017 Apr;37(4):1517-1526. doi: 10.1177/0271678×16657574. Epub 2016 Jan 1. PMID: 27389180; PMCID: PMC5453469.
5)
Meairs S, Kern R. Intracranial perfusion imaging with ultrasound. Front Neurol Neurosci. 2015;36:57-70. doi: 10.1159/000366237. Epub 2014 Dec 22. PMID: 25531663.