Medical Case Reports and Reviews

Review Article

ISSN: 2517-7214

Clinical and instrumental indicators of intracranial venous stasis and secondary ischemia in cerebral sinus thrombosis. A review

Semenov SE[1]*, Yurkevich EA[1], Moldavskaya IV[2], SemenovAS[3] and Kokov AN[1]

[1]Federal State Budgetary Institution "Research Institute for Complex Issues of Cardiovascular Diseases", 6, Sosnovy Blvd, Kemerovo, Russian Federation, 650002

[2]Kemerovo State Budgetary Healthcare Institution "Kemerovo Regional Clinical Cardiology Dispensary n.a. academician L.S. Barbarash", 6, Sosnovy Blvd., Kemerovo, Russian Federation, 650002

[3]Praxis Wolfgang Theobald Facharzt für Radiologie, 31, Lothringer Str., Saarlouis, Saarland, Germany, 66740

Abstract

The purpose of the narrative review is to search for confirmation or controversy of the hypothesis according to which venous ischemia developing in cerebral venous sinustrombosis is secondary as a result of mechanical narrowing of arterioles in the area of vasogenic edema. This review discusses the issues of multimodal radiological diagnosis of a rare disease of a non-hemorrhagic ischemic venous stroke based on expert opinion, current recommendations and our experience. As a result of the review no contradictions to this hypothesis have been found, and the most characteristic symptoms of CVT, secondary ischemia, intracranial venous congestion can be identified in the order of their probable clinical manifestation from patient complaints to the results of instrumental studies: headache, subacute development and course of the disease, papilledema optic disc, increase of central venous pressure, hypodensity of the ischemic foci and hyperdensity signs of sinus on CT, earlier development of vasogenic edema on diffusion MRI, symptoms of stop-contrast and filling defect thrombosed sinuses on contrast enhancement CTA or MRA, dilatation of venous regional collaterals, moderate hyperperfusion on CT- or MR-perfusion, elevated maximum blood flow velocity Rosenthal veins; Galen's vein and rectus sinus, decreased cerebrovascular reactivity index, increased peripheral resistance index on Transcranial Doppler, clot visualization on brachiocephalic veins ultrasound duplex scanning, decreasing of brachiocephalic vessels ultrasound index of arteriovenous ratio.

Abbreviations: ADC: apparent diffusion coefficient; AIS: arterial ischemic stroke; AHA/ASA: American Heart Association/American Stroke Association; CBF: cerebral blood flow; CBV: cerebral blood volume; CCA: carotid common artery; CSF: cerebrospinal fluid; CT: computed tomography; CTA computed tomographic angiography; CVP: central venous pressure; CSVT or CVST: cerebral venous sinus thrombosis; CVT: cerebral venous thrombosis; DWI: diffusion weighted imaging; IAVR: brachiocephalic vessels ultrasound index of arteriovenous ratio; IJV: internal jugular vein; MRA: magnetic resonance angiography; MRI: magnetic resonance imaging; MRV: magnetic resonance venography; MTT: mean transit time; NCCT: non-contrast computed tomography; NIHSS: National Institutes of Health Stroke Scale; PCT: perfusion CT; ASL: arterial spin labelling; TCD: Transcranial Doppler; TIA: transient ischemic attack; VIS: venous ischemic stroke

Introduction

The study of the ischemic stroke remains one of the priority areas of neurology because of its prevalence and severity of consequences. In clinical practice much attention is traditionally paid to the issues of arterial pathology of the brain due to the high social significance because of dramatical events that usually occur suddenly and with pronounced negative consequences for the patient's life and health. Despite the fact that at present the arterial stroke is quite well studied, approaches to the diagnosis and treatment of 22-30% of cases in its classification are developed and systematized for cryptogenic stroke [1]. Indeed, the etiology of a stroke cannot always be determined, and the cause of its occurrence remains unknown [2]. Usually the term "stroke" refers to cerebral artery disease. At the same time the formation of a focus of ischemia with the pathology of cerebral venous structures is also possible, but this happens relatively less often and has been studied to a much less extent.

The following terms like "venous ischemia" [3,4] and "venous stroke" [5] as a result of cerebral venous thrombosis (CVT) are usually excreted in conditions that are mimics of stroke. They often develop subacutely. Usually if they talk about venous infarction they mean ischemic damage with intracerebral hemorrhage. This review discusses the diagnosis of the primary non-hemorrhagic ischemic venous stroke, the mechanisms of ischemia development differ from arterial. The impact of CVT on the brain is wide spectrum, ranging from completely normal parenchyma to brain oedema and/or haemorrhage. Multiple factors relate to neuronal injury in CVT or CSVT including increased intracranial pressure, increased venous flow velocities, enlargement of venous collaterals, dural sinuses occlusion, development of cytotoxic and vasogenic oedema [6].

Correspondence to: Stanislav Semenov, Federal State Budgetary Institution "Research Institute for Complex Issues of Cardiovascular Diseases", 6, Sosnovy Blvd, Kemerovo, Russian Federation, 650002, E-mail: dr_semenov_s@mail.ru

Key words: *cerebral venous thrombosis, venous ischemic stroke, intracranial venous congestion, vasogenic edema, TCD, ultrasound duplex scanning, CT, MRI*

Received: August 10, 2021; **Accepted:** August 22, 2021; **Published:** August 31, 2021

Moderate hyperemia according to CT perfusion data and vasogenic edema according to MR diffusion data and intracranial venous congestion rather than oligemia, are the primary damaging factors in the pathogenesis of the venous stroke in contrast to the arterial stroke [7]. It is known that the venous stroke (VIS) accounts for 0.5-1% of all the ischemic strokes [8,9]. The venous stroke occurs mainly in relatively young patients [10]. In the study with the largest number of observations (181 patients) the age range is 14-96 years, the mean age is: 34.64 ± 14.66 years [11]. Venous outflow disorders are often associated with and contribute to the development of edema as well as possible increased risk of bleeding [12]. The venous stroke associated with cerebral venous sinus thrombosis is prone to secondary hemorrhages in 36-40% of cases, which is significantly more likely than arterial [13,14] and due to the severity of vasogenic edema [7,15]. It is important that the main approach to the treatment of VIS which is more prone to secondary hemorrhage [16] is anticoagulant therapy, the safety of which in this group of the patients has not been completely determined [17,18]. Although the mortality rate of CVT has been significantly reduced by improvements in treatment and diagnostic techniques, the mortality rate of severe CVT remains as high as 34.2% [19]. The rarity of this pathology does not contribute to its identification and confident diagnosis [20]. Actually the term "venous stroke" has long caused misunderstanding and rejection among practitioners and scientists, neurologists and radiologists. The development of the modern radiological techniques such as CT and MR perfusion and angiography as well as MR diffusion has made it possible to study the pathophysiological aspects and conditions of the formation of an ischemic focus in the brain that occurs in cerebral venous sinus thrombosis in conditions of intracranial venous congestion, edema of brain tissue in the affected area without signs of damage to the arterial vascular system of the head.

The purpose of this narrative review is to search for confirmation or controversy of the hypothesis according to which venous ischemia developing in cerebral venous sinustrombosis is secondary as a result of mechanical narrowing of arterioles in the area of vasogenic edema, which in its turn develops in the venous stroke earlier than in the arterial stroke against the background of the intracranial venous stasis. Verification of the venous nature of the lesion in some cases makes it possible to classify stroke and reduce the statistics of cryptogenic lesions. The importance of the venous stroke studying is also related to the fact that it develops at a younger age more often than the arterial stroke.

Search methods

We have performed a literature search in the PubMed, eLIBRARY.ru, ResearchGate, Embase and Medline databases through to March 1, 2021. For example, the following search query has been used in PubMed: cerebral venous thrombosis, venous ischemic stroke, intracranial venous congestion, vasogenic edema, TCD, ultrasound duplex scanning, CT, MRI.

Brief characteristics of the features of the venous ischemic stroke clinical symptoms

The manifestation of the venous and arterial stroke occurs unequally, the course of the venous stroke is more often subacute (in 56% of cases - from 48 hours to 30 days) than acute (37%) and chronic (7%) [21]. In case of damage to the sinuses, cerebral symptoms depend on the massiveness and rate of growth of thrombosis, focal neurological symptoms are diverse and are largely determined by the localization of thrombosis and the preservation of collateral blood flow as well as the patient's age and the degree of progression of cerebral edema. The symptoms may appear in relation to increased intracranial pressure imitating a pseudotumorcerebri [4]. General cerebral symptoms are nonspecific, extremely variable [22] and can occur in varying degrees of severity at any localization of the pathological process. Clinical symptoms include headache, double vision, blurred vision, altered consciousness, nausea, vomiting, seizures as well as a papilledema optic disc swelling resulting from increased intracranial pressure [23,24]. Papilledema with raised intracranial pressure has been recorded in 32% patients [25]. Edema of the optical disc in CVT occurs only in 20-40% [22,26] and even less often with the arterial stroke. The manifestation of atypical dystonia [17] is less commonly described.

Headache is the leading symptom. The mean duration of headache is 12.6 ± 26.8 days, and VAS is from 73 ± 16 [27] to 79.38 ± 13.41. Headache onset is acute in 51.1%, subacute in 42.6%, thunderclap in 4.3% and chronic in 2.1% [28]. This symptom occurs among patients' complaints in approximately 75-90% of cases [11,29,30]. In 25% of cases headache is the only complaint of the patient; often there is no connection between the localization of the headache and the site of sinus thrombosis [14]. Moreover, it can imitate migraine [31]. Early diagnosis of the relationship of headache with cerebral venous sinus thrombosis even in the absence of neurological signs is crucial for the timely detection of the disease [32].

It is known that even with a favorable outcome within 6 months approximately 30% of patients experience the development of chronic headache in the presence of hemorrhagic transformation. According to the results of a three-year follow-up the number of patients with chronic headache increases to 60% [33]. Chronic headache can accompany psychopathological states. For example, the association of congestive cerebral hyperemia with schizophrenia exceeds random expectations. A possible causal relationship is noted for both schizophrenia due to hyperemia [34] and thrombosis as a result of coagulopathy and venous thromboembolism in chronic schizophrenia [35,36]. CVT should be considered in the differential diagnosis when a patient complains of orthostatic headache which can be developed in a condition of decreased intracranial CSF volume in both intracranial hypotensive and intracranial hypertensive states [37].

The complexity of the urgent diagnosis of VIS often lies in the absence of specific clinical manifestations [38,39]. At the same time headache is an extremely common symptom and the vast majority of patients with isolated headache do not have cerebral venous sinus thrombosis [40], that is why the economic feasibility of routine imaging remains very uncertain.

Other manifestations of general cerebral symptoms are nonspecific [41] and can occur to varying degrees of severity in arterial pathology of any localization of the pathological process. The use of rating scales such as NIHSS, Bartel, Rankin does not allow to reliably determine the venous nature of the acute ischemic stroke which means that it is not possible to reliably identify any typical clinical differences between the venous ischemic stroke and arterial except for headache. The direct method of measuring central venous pressure [42] is feasible only in the conditions of the intensive care unit and is usually not performed. We can note a tendency towards the increase in central venous pressure in VIS cases up to 190 mm H2O with and without normalization after recanalization. Today a new non-invasive method for determining CVP using Doppler ultrasonography has appeared in the arsenal of instrumental methods. The pilot study has been performed to identify

the relationship between the ratio of the diameter/cross-sectional area of the internal jugular vein (IJV) and carotid artery and the central venous pressure (CVP). These preliminary results suggest the following: if the cross-sectional area of the vein is at least twice that of the artery, then the CVP seems to be ≥8 mm Hg [43]. In another investigation CVP is defined as the ratio of the value of the venous pressure in the brachial vein to the conversion factor (4.5) obtained experimentally [44]. In accordance with the Monro-Kellie doctrine an increase in intracranial venous pressure should lead to CSF hypertension. We have noted CSF hypertension with values > 200 mm H2O in 11 cases of VIS of those 23 patients who have undergone the lumbar puncture. In the clinical course of VIS there is a tendency to a rapid regression of focal symptoms and neurological deficit in most cases, a tendency to less pronounced neurological deficit upon admission and a lighter degree of disability has been observed [39]. Evaluation of micromorphological changes has been made in a very small number of cases of death (2.8%). In contrast to AIS in VIS a picture of pronounced venous plethora more pronounced pericellular and perivascular cerebral edema and multiple microhemorrhages has been described. Hemorrhagic complication affects the survival rate and subsequent quality of life of the patients. The patients with early hemorrhage are less likely to survive without disability until discharge (63%) than those without early hemorrhage (85%) [45]. The immediate cause of death in CVST is malignant cerebral edema [46].

All this explains the need to search for accessible methods of emergency differential diagnosis of the ischemic stroke of arterial and venous origin.

Current recommended algorithms for radiological diagnosis of venous stroke

The importance of neuroimaging in the emergency recognition of the stroke is very high and increases constantly with the development of technology. Brain imaging distinguishes the ischemic stroke from intracranial hemorrhage and stroke mimics and identifies the type and also often the cause of the stroke. Immediate CT scanning is the most cost-effective strategy for imaging acute stroke patients but is not sensitive for old hemorrhage. Overall CT is less sensitive than MRI, but equally specific for early ischemic changes [47]. Two thirds of patients with moderate to severe stroke have visible ischemic changes within the first few hours [48-50], but not more than 50% of patients with minor stroke have a visible relevant ischemic lesion on CT especially within the first few hours of the stroke [51].

Neuroimaging influences among other things the outcome of the stroke [52]. Diagnosis of CVT and VIS is usually limited to native CT followed by duplex scanning of the extracranial brachiocephalic vessels and transcranial Doppler. This situation is associated with the time limitation of the "therapeutic window" and an intuitive medical approach to the algorithm of the applied methods. Different standards of the Russian Federation suggest the likelihood of MRI in the emergency diagnosis of the ischemic stroke in different ways. So, in one standard MRI is regulated in 10% of the permissible performance, CT angiography and CT perfusion - in 30% [53], according to another standard CT perfusion is not included in the list of procedures at all [54]. The standard of medical care for TIA involves performing CT perfusion in 100% of cases and CT angiography in 30% after performing native CT in all the patients which increases the likelihood of diagnosing the venous stroke. Unfortunately MRI is not included in the list of recommended procedures of this standard [55]. All this does not create ideal conditions for detecting the venous nature of the stroke and probably leads to the inclusion of these patients in the arterial stroke registry. In addition, the lack of opportunities to gain experience with such restrictions does not contribute to the willingness of doctors to meet rare types of the ischemic stroke. Recommendations from the AHA/ASA published in 2011 [8] suggest starting radiology diagnostics with native CT if CVT is suspected. The core MRI sequence should include T2*, SWI, SWAN gradient sequences (class IIa; level of evidence B). Besides regardless of whether or not there are foci in the brain and changes in the signal in the projection of the sinuses or veins, CT or MR venography is recommended (class I; level of evidence C), especially if a history of CVT has already been diagnosed (class I; level of evidence C). In cases of doubt adequate diagnosis of CVT the digital subtraction angiography is the only possible method (Class IIa; Level of Evidence C).

The latest 2018 Guidelines for the Early Management of Patients With Acute Ischemic Stroke (AHA/ASA) strongly recommend the inclusion of a radiologist (Class I; Level of Evidence A) in the stroke management team, also noted in the PRACTISE (Penumbra and Recanalisation Acute Computed Tomography in Ischemic Stroke Evaluation) that the use of multiparametric tomographic diagnostics increases the frequency of intravenous thrombolysis, which increased from 12.2% to 13.1% with an increase in the number of CT angiography performed from 3.8% to 9.1% and perfusion CT from 0.05% to 2.9%, the number of patients subjected to thrombolysis increased to 17.6% [52].

Radiological modalities and the most likely symptoms of the venous ischemic stroke. The diagnostic methods and techniques that are able to identify the symptoms of CVT, intracranial venous congestion and vasogenic cerebral edema are presented sequentially in the order of usual practice. Possible algorithms for using a combination of techniques in patients are also presented in accordance with the probability of detecting the symptoms of the venous ischemia with different sensitivity and specificity, provisions of regulatory documents as well as conclusions based on our own experience.

The native CT of the brain is performed everywhere immediately upon admission

Non-contrast CT of the head in combination with the clinical examination is the main tool for the diagnosis of the acute ischemic stroke excluding hemorrhage with a high recommendation for use and evidence (class I, level of evidence B, although no randomized data) [52,56,57]. The sensitivity of CT in the diagnosis of thrombosis of the intracranial dural sinuses in combination with angiographic techniques is estimated quite high - from 80% [57] to 95% [58]. As for the limited performance of the native CT the probability of detecting hypodense ischemic foci under these conditions is only 45% to 65% [59]. The ASPECTS scale works in the diagnosis of the venous stroke as well as the arterial one in terms of a standard assessment of the volume of the brain damage [60,61]. Detected signs of CVT on the native CT are estimated in some studies to be significantly higher. The sensitivity and specificity of the attenuated vein sign for the diagnosis of deep venous thrombosis are considered 100% and 99.4% respectively, whereas the sensitivity and specificity of the cord sign for CVT are considered 64.6% and 97.2% respectively [62]. Reduced density of the ischemic focus (18 - 35 HU) surrounding the thrombosed vessel improves visualization and detection of the symptom of a hyperdense vessel the density of which is usually 60 - 80 HU. In general, pathological manifestations on the native CT (symptoms of a low-density focus and hyperdense vessel) are detected with CVT in about 30% of cases only [63].

On axial images the rounded profile of the dural venous sinuses which usually have the triangular profile may be noticed due to increased venous pressure and venous congestion [64]. We have registered such a symptom in 2/3 of cases of VIS above the occlusion level during CVT and this serves an indirect evidence of an increase in venous pressure which has been confirmed by an increase in central venous pressure (CVP) from 140 to 170 mm of H2O which is above normal.

Visualization of the cerebral edema lesion in close proximity to the "cord" sign of the venous sinus is a rather specific sign of the venous brain damage [65].

Magnetic resonance imaging (MRI) can be an urgent procedure but is performed less frequently than CT in acute cerebral infarction. For example, in accordance with the standard of the Russian Federation its implementation is regulated in not more than 10% of cases although with TIA it is allowed to perform conventional MRI with a probability of up to 30% and MR angiography up to 10% [53,55]. Based on AHA/ASA 2018 recommendations [52] MRI is not recommended for routine use (Class III, level B evidence, no randomized trials). The symptom of an increase in the signal in the projection of the sinuses - if considered separately - can serve the reason for a false-positive conclusion from thrombosis. This symptom combined with the detection of the ischemic focus in the brain tissue near the abnormal sinus as well as the absence of a flow signal on MRI is usually a fairly reliable criterion for CVT and VIS.

The shape of foci of the venous stroke is usually geometrically irregular in contrast to arterial and does not correspond to the usual and typical locations of the arterial territorial lesions. Usually the shape of VIS foci is irregular and the contours are uneven and indistinct with "blurred" boundaries. The contours of arterial AIS on tomographic images are often even and clear. Roughness - "blurring" of the contours can be observed on DWI due to the smaller size of the image matrix and on T1WI due to low contrast between the healthy and diseased tissue which are inherent in this sequence without the use of contrast enhancement. In both VIS and AIS stroke foci are reflected in an obvious increase in the MR signal on T2WI and FLAIR as well as a decrease in T1WI (from subtle to moderate). There is a classification of the venous ischemia [66], which is classified with MRI as Type 1: no abnormality, Type 2: T2WI shows high signal intensity area and Gd-MRI shows no enhancement, Type 3: T2WI shows high signal intensity area and Gd -MRI shows enhancement, Type 4: venous infarction or hemorrhage. This classification does not include the FLAIR and DWI that are now commonly used in the diagnosis of the stroke and therefore can have only limited application. It is rather difficult to distinguish the necrosis focus with cytotoxic edema from vasogenic edema due to the violation of the blood-brain barrier by the degree of signal increase on T2WI; such an assessment is extremely subjective, largely dependent on the experience of the radiologist and can lead to an erroneous opinion.

DWI has demonstrated the sensitivity of 90% and the specificity of 97% for detecting AIS. The overall accuracy has been estimated 95%. Patients (99.5%) who demonstrate abnormal DWI studies are AIS patients and 63% patients with normal DWI studies are stroke mimics [67]. However, the meta-analytic synthesis yieldes a pooled prevalence of DWI-negative AIS in 6.8% [68]. Using a combination of diffusion and perfusion (DWI + PWI) protocols has great advantages [69]. Using coregistered perfusion/diffusion-weighted mismatch is the criterium which is independently associated with improved clinical outcomes at three-months [70]. Diffusion MRI is recommended by AHA/ASA 2018 [52] as mandatory in the absence of CT findings when clinical manifestations of the stroke are evident (class III, level of evidence B, no randomized trials), but cannot be considered optimal in terms of low cost-effectiveness [47,71]. The basis for DWI is the ability to detect violations of the blood-brain barrier and to determine the presence of cytotoxic and vasogenic edema. Vasogenic edema is characterized by hypo- or isointense lesions on DWI, but cytotoxic edema is reflected by a bright signal on DWI. The boundaries of ADC indicators are normally known; in adults they range from 0.59 × 10-3 mm2/s to 0.95 × 10-3 mm2/s. If the calculated ADC tendency is more than 0.95 × 10-3 mm2/s, the conclusion is made about the likelihood of vasogenic edema; if the ADC is less than 0.59 × 10-3 mm2/s, it is concluded that ischemia occurs with the transition of cells to the anaerobic oxidation pathway followed by the development of cytotoxic edema and cell death [72].

Non-hemorrhagic venous infarctions are indicated by the combination of cytotoxic and vasogenic edema on DWI and the signal is inversely correlated with the corresponding ADC value [73]. Signal inversion on DWI and ADC in the area of vasogenic edema develops earlier in the venous stroke than in the arterial stroke and occurs in 2/3 of VIS cases [74].

Changes in the MR signal in the ischemic zone on T2WI and FLAIR (Fluid attenuation inversion recovery) sequences usually develop later in the period from 6 hours to 1 day after the onset of clinical symptoms, and therefore cannot be used for urgent diagnosis of the ischemic stroke. The widespread use of diffusion and perfusion protocols that allow detecting edema and perfusion disorders already in the first hours of the disease has led to the loss of relevance of the classification of venous ischemia based on the abnormality of the T2WI signal on MRI [66]. Lesion localization close to a thrombosed sinus or vein is not typical for the arterial stroke [75]. MR images contrast enhancement allows one to see a symptom similar to empty delta sign symptom on CT in thrombotic sinus occlusion [76] when on T1WI - against the background of contrast-enhanced sinus walls as a thrombus in the sinus lumen - looks much less intense. In addition, indirect signs of increased intracranial pressure can be considered as increased peri-optic cerebrospinal fluid and optic nerve tortuosity [77].

CT and MR angiography are emergency verifying techniques for cases of suspected CVT on the basis of conventional CT or MRI. There is no accurate comparative assessment of MR and CT angiography in comparison with the reference method of digital subtraction angiography [8] due to the fact that the entire set is not performed in large studies, but some experts consider the use of MR-angiography in the diagnosis of CVT equivalent to CT angiography [62,78]. In the study of CT, MRI and MRA findings have been noted and the statistical analysis has been done. Sensitivity, specificity, PPV and NPV of CT have been calculated with respect to MRI in the diagnosis of cerebral venous thrombosis and associated brain parenchymal changes. CT scan is able to diagnose sinus abnormality in 36% and parenchymal abnormality in 42% of cases as compared to 100% and 52% in MRI [79]. AHA/ASA Recommendation 2018 [52] classifies CT angiography for suspected large intracranial vessel occlusion as class IIa with level B evidence (no randomized trials) and therefore cannot be considered a strongly recommended procedure. However expert opinions based on a small number of patients indicate a high sensitivity and specificity of CTA. The venous sinuses can be identified in 99.2% and the cerebral veins in 87.6% of cases by the means of CTA. The sensitivity and specificity of CTA for the diagnosis of CVST are 100% [80].

The main symptom of CVT when performing non-contrast MR venography is the absence of a flow signal in their projection. After that the contrast-enhanced CT angiography is performed and it verifies CVT with occlusion only in 58.2% of cases of suspicion and partial thrombosis even less - in 24%. Thus, the detection of a symptom of signal loss on non-contrast MR angiography is only a pretext/ indication for contrast angiography methods. Symptoms of contrast-enhanced CT and MR angiography such as stop contrast and filling defect in suspicious sinuses can be taken as specific and basic criteria for thrombosis. An additional characteristic symptom of sinus occlusion can be considered a significant enlargement of regional collateral veins, for example, veins of the tentorium of the cerebellum with the occlusion of the transverse sinus or superficial veins with thrombosis of the superior sagittal sinus which is observed in 90% of CVT cases of these venous vessels [64].

CT- and MR-perfusion. In the most important first hours of the ischemic stroke in the acute period the sensitivity of perfusion CT is 96%, the specificity is 98% [81,82] and the accuracy of detecting abnormal foci with PCT is significantly higher and less subjective than the native CT [83], which makes this technique more precise. Therefore in Russia, for example, PCT is included in the national standard of examination for TIA [55]. The complex of lesion patterns in VIS indicates primary moderate hyperperfusion or venous plethora with an increase in all perfusion parameters (CBF, CBV, MTT) in the range from 27% to 48% (on average 30%) in the damaged area without the development of necrosis or perifocal in cases when necrosis with aperfusion already takes place [7]. In cases of the stroke associated with CVT without or before infarction/necrosis of the brain tissue the changes in perfusion reach only the damage threshold, that is, a 30% difference from the conventionally healthy tissue on the opposite side. In our studies a correlation is obtained between the rCBF values in the lesion focus in PCT and the Rankin score of the patient's condition ($r = -0.52$; $p < 0.05$), as well as rCBV ($r = -0.45$; $p < 0$, 05); the relationship between the NIHSS score and rCBF values ($r = -0.48$; $p < 0.05$), as well as rCBV ($r = -0.52$; $p < 0.05$). There is a significant negative correlation between the patient's condition at discharge from the hospital on the NIHSS and rCBV scale ($r = -0.42$; $p < 0.05$). Most likely this relationship happens because of the fact that the NIHSS scale includes gradations of the severity of neurological deficit which in its turn is developed due to perfusion disorders in the focus of the stroke [84]. The risks and associated restrictions can't be ignored at MR or CT contrast perfusion. Recommendations for the use of low- and iso-osmolar contrasts reduce the risk of acute kidney damage [85], and magnetic resonance contrast agents cause significantly fewer acute adverse reactions [86]. Using the contrast, we increase the research as well as the risk of adverse reactions and a kidney damage. It is exploring the possibilities of arterial spin labelling (ASL) - a technique that uses magnetically labeled blood as an endogenous tracer to determine CBF values. Changing the MR signal encoded by CBF is used to detect acute ischemic injury [87]. Improving the signal-to-noise ratio (SNR) in ASL can be achieved using ultra-high-field devices, but this problem is not yet solved [88]. Movement artifacts arising from increased arousal and mobility of patients in the acute stroke as well as artifacts of high-velocity blood flow in the projection of the great arteries are also a problem [89]. Poor SNR, unstable image quality and relative sequence complexity limit the implementation of the technique [90,91].

A more accurate diagnosis of the state of cerebral perfusion often leads to rejection of the active thrombolytic therapy. This is due to the precise determination of the level of perfusion/diffusion mismatch the critical level of which lies at 20% [92]. Regulating the use of numerical values for the threshold of such mismatch and the penumbra is an open question. Arterial penumbra is characterized as oligemia. With the venous stroke there is no penumbra, no oligemia the cerebral infarction is not always developed. The moderate hyperemia/ hyperperfusion is manifested in the acute period throughout the entire territory without the development of cerebral infarction/necrosis or in the perifocal zone if the cerebral infarction is developed. The zone of the cerebral infarction aperfusion shows no different from the arterial one. Early signs of vasogenic edema on days 1-3 of the venous stroke are manifested by an iso-intensive or hypointense signal on DWI and a hyperintense signal on ADC maps associated with anisotropic water movement. This distinguishes vasogenic edema from cytotoxic edema, which is characterized by a high signal on DWI and low on ADC.

It is known that three conditions are necessary for the development of vasogenic cerebral edema: 1) increased capillary permeability; 2) prolonged increased intravascular pressure, contributing to the release of plasma beyond the capillary; 3) the spread of fluid through the intercellular spaces [93]. Vasogenic edema develops in conditions of intracranial venous stasis and increased central venous pressure. The sensitivity (93.7%) and specificity (98%) of the native CT for infarction foci are essentially efficient in detecting edema [62]. It is impossible to say exactly on the basis of the native CT only whether necrosis has developed or not, perhaps at the time of the study still there is edema and ischemia. For the arterial stroke the development of vasogenic edema is usually - but not always - expected only within 5-7 days, but not at the time of the urgent diagnosing [85]. In our observations we have found that according to PCT and the control native CT "cerebral infarction with necrosis of brain tissue is developed in VIS only in 55% with the inability to compensate for blood flow versus 79% in AIS" [84].

Transcranial Doppler (TCD) is not an immediate procedure. The admissibility of performing TCD in a specialized hospital in the Russian Federation with the suspected stroke is 100% [53]. TCD is an accessible, mobile and inexpensive instrument in studying the cerebral hemodynamics. Transcranial duplex scanning is usually performed upon admission to the hospital. Assessment of velocity parameters in the Galen vein and Rosenthal veins during transcranial scanning is an additional indirect sign of intracranial venous stasis, but the use of the method is limited by the absence of an acoustic window [94] according to various data in 10-20% of cases [95-97]. The following indirect signs of intracranial venous stasis are obtained with transcranial Doppler: an increase in the maximum blood flow velocity in one or both Rosenthal veins over 25 cm/s, Galen's vein and straight dural sinus > 30 cm/s, the appearance of a pseudopulsation effect, a decrease in the cerebrovascular reactivity index <40%, resistance index increase > 20%. These signs are indirect, and the revealed low sensitivity (63%) and specificity (65%) can not be relied upon them [64].

The 2018 AHA/ASA guidelines [52] consider non-invasive testing including TCD to be useful in the diagnosis of the acute stroke (class I, level of evidence A).

Ultrasound duplex scanning of brachiocephalic vessels is usually performed not in the most acute period, but on the next day to determine the degree of stenosis of the carotid arteries according to the standard adopted in Russia [53] as well as in accordance with the international recommendations [52]. The permissible frequency of performing ultrasound duplex scanning of brachiocephalic arteries in a specialized hospital is actual for 100% stroke [53]. If internal jugular vein thrombosis is suspected, the supplement study by means of performing

ultrasound duplex scanning is recommended [98]. Thrombosis of IJV may be localized or be a part of a more widespread lesion which is a common cause of the venous stroke. In patients with thrombosis of the internal jugular vein an echo-positive mass of a thrombus has been detected in its lumen in the projection of which the blood flow is not located in the course of color Doppler examination [99]. Ultrasound duplex scanning allows not only to visualize thrombus [100,101], but also to determine its localization in relation to the vessel wall, the blood flow velocity in the preserved lumen of the vessel [102].

Current standards for the differential diagnosis of the stroke do not allow early detection of patients with VIS with sufficient effectiveness. It is noteworthy that the use of non-invasive (including ultrasound) techniques in the AHA/ASA 2018 recommendations is considered preferable in cases where the subsequent implementation of mechanical thromboextraction is not implied, while the use of multimodal (using CT and MRI) approach to the diagnosis of the stroke is not recommended due to a possible delay in the decision to perform thrombolytic therapy (Class III, level of evidence B, randomized trials is no exist) [52].

Brachiocephalic vessels ultrasound index of arteriovenous ratio (IAVR) using data on the blood flow velocity in the internal jugular veins and common carotid arteries has proved to be a good prognostic criterion for diagnosing the ischemic stroke of venous genesis and intracranial venous congestion without radiation exposure and introduction of any contrast medium [103]. The definition of the brachiocephalic vessels ultrasound index of arteriovenous ratio (IAVR) is based on the fact that the normal cross-sectional area of the internal jugular vein exceeds the cross-sectional area of the common carotid artery by 75-100%. It is also known that the maximum blood flow velocity in the IJV is 1/3–1/2 of the peak systolic blood flow velocity (Vps cm/s) by CCA. Knowing the cross-sectional areas of the IJV and CCA as well as the peak systolic velocity of the CCA in each case makes it possible to determine the "optimal" speed from the IJV and compare it with the actual one using formulas (1) and (2) [104]: V max IJV optimal =2S CCA × Vps CCA/ 3S IJV (1); IAVR = max IJV actual / V max IJV optimal ×100% (2), where IAVR - index of arteriovenous ratio (%), Vps CCA - peak systolic velocity of the CCA cm/s, Vmax IJV - maximum blood flow velocity cm/s, S - vessel cross-sectional area cm^2.

Regression analysis has indicated the headache intensity and ultrasonic IAVR from all the ultrasound indirect symptoms as the factors influencing the probability of the patient having VIS. Both factors have a significant impact on the assessment of the predictive probability of the presence of VIS. The patient will be more likely diagnosed VIS associated with cerebral venous sinus thrombosis in the background of headache increase and the IAVR decrease value. According to the data obtained, a decrease in the IAVR of brachiocephalic vessels by 50% and lower, combined with an increase in the intensity of headache according to the visual assessment of more than 4 points, may rather indicate for VIS. "In patients with venous stroke the average IAVR is only 40%, which is one third less than normal with a threshold value of 50% and less than in arterial ischemic stroke at which IAVR values are close to normal (60-67%)" [64]. A decrease in IAVR is recommended as intracranial venous congestion (with a specificity of 98% and a sensitivity of 95.2%). The use of ultrasound IVR in conjunction with the assessment of the intensity of headache on a visual analogue scale in the model developed in the study improves the early diagnosis of the acute ischemic stroke and makes it possible to obtain a predictable probability of the venous stroke. It should be noted that when using the visual analogue scale of headache intensity there are certain limitations: the subjectivity of its assessment, the presence of aphasia as well as impaired consciousness in a patient with a stroke while IAVR is an easy-to-use accessible parameter that can make a significant contribution to diagnosis of VIS [105].

Limitations of multimodality of radiological diagnosis of the venous stroke in clinical practice and possible ways to overcome them

Often the software for post-processing of raw images for creating perfusion maps is installed by the seller only on the operator's console and this leads to a halt in the patient admission process, a temporary stop of the operator's work which negatively affects the operation of the diagnostic unit. This in its turn causes reluctance, other things being equal, to perform PCT. The discrepancy between the absolute perfusion indices obtained on the equipment of different manufacturers, the use of various mathematical post-processing algorithms lead to a scatter of the digital values of MR and CT perfusion. If only absolute values are taken into account then the indicators can be questionable. Therefore it is recommended to read the perfusion maps using relative values comparing the affected side and the contralateral hemisphere as a percentage [106]. The radiologist's experience with the doubtfulness of the absolute values of perfusion indicates the fact that maps are assessed by eye without numerical calculations which can lead to underestimation of small changes such as moderate hyperperfusion or hypoperfusion. Clinicians in its turn may not prescribe PCT not trusting the results. And as a consequence the radiologist has no possibility to get necessary experience.

Neuroimaging nowadays takes one of the first places in the diagnosis of the stroke immediately after clinical assessment. Despite the permanent progress in the development of neuroimaging methods of assessing cerebral hemodynamics, mentioned above, practical medicine often limits the examinations with a native CT scan only. Therefore the search and selection of the optimal set of tools for radiological diagnosis of the ischemic stroke remains relevant. Diagnosis of the venous ischemic stroke is more difficult not only because of its rarity, but also because the changes are less dramatic and often moderate. Expanding the examination protocol by performing not only native CT, but also perfusion CT and diffusion MRI can help optimize the neuroimaging paradigm in the venous stroke. It is likely that such a paradigm will not be formed again due to the non-dramatic manifestations of the disease and the rarity of pathology, and the approbation of new neuroimaging technologies may not keep pace with technical progress. Avoiding the delay in decision-making on possible thrombolytic therapy, which may arise due to the use of multimodality (CT/MRI) in the diagnostic process [52], is also not conducive to gain experience in interpreting the results of perfusion techniques. In contrast to the arterial stroke, when determining the indications for emergency revascularization (systemic thrombolytic therapy or endovascular thromboextraction) with PCT is a prescribed procedure, it can be performed even after 4.5 hours of the therapeutic window [107].

In such circumstances the search for new, fast, possibly non-invasive methods of direct or indirect confirmation of suspected CVT and VIS makes sense and the appearance of an ultrasound assessment of the fact of intracranial venous congestion can play a certain positive role in the diagnosis [105].

The widespread use of teleradiology seems to be one of the "most likely ways to overcome the limitations of diagnosing venous stroke" [64]. Since last year telemedicine has unprecedentedly been developing

especially in connection with the global pandemic COVID-19. Using modern communication technologies for providing people living outside of cities with remote medical care is becoming an excellent solution when there is a shortage of qualified doctors in regional hospitals. Moreover particularly private radiographers need training in interprofessional collaboration. Training must be internal, ongoing and consistent to meet the health needs of teleradiology systems [108]. And as a part of the general direction teleradiology should be developed in the diagnosis of the stroke. Remote discussions, consultation of diagnostic images with more experienced specialists help in this situation to solve many problems. In particular it seems to us reasonable to use teleradiological approaches when the medical staff of regional hospitals are in doubt for patients with the suspected venous stroke, this can have a good effect. In countries with large territories and a predominantly rural population telemedicine technologies can improve the availability of medical care and its quality. These countries include Russia. Telestroke network creation has the highest recommendation level in the AHA/ASA from 2018 (recommendation class - I, level of evidence - A). Of course such a network makes it possible to make a quick decision about the implementation of thrombolytic therapy, which in the conditions of a separate residence is a salvage nature of actions. Government agencies are encouraged to support the telemedicine/teleradiology system (recommendation class IIa, level of evidence - C-EO - expert opinion) due to the high efficiency of work 24 hours/7 days a week (recommendation class - IIa, level of evidence - BR - efficacy has been proven based on randomized trials) [52]. Great potential importance is also attached to the use of artificial intelligence for assessing perfusion-diffusion mismatch in the ischemic stroke in the form of machine learning, creating programs and applications, recognizing such mismatch and determining its level in order to resolve quickly the issue of the need for intravenous thrombolysis or mechanical thromboextraction [109].

Conclusion

Most likely clinical and radiologic symptoms of VIS and intracranial venous congestion associated with CVT.

As a result of the review no contradictions have been found with the hypothesis of a large role of intracranial venous stasis and early vasogenic edema in the pathogenesis of cerebral venous ischemia. Intracranial venous congestion plays an important role in the development, course and outcome of the primary venous non-hemorrhagic stroke and leads to the creation of pathological physiological conditions for the development of vasogenic edema. The edema in its turn plays the first violin in the formation of secondary cerebral infarction becoming a part of the pathogenesis of the venous ischemic stroke. The cerebral venous congestion is the primary factor in damaging the brain with cerebral venous thrombosis. It can be assumed that initially it is not oligemia that underlies the pathogenesis of the venous stroke, as opposed to the arterial one, but congestive venous plethora, and this is accompanied by a lower likelihood of infarction and necrosis in VIS in contrast to AIS. Such a VIS scenario can be associated with secondary externally caused arteriole constriction in vasogenic edema. Therefore VIS is ischemic only secondarily. Venous outflow disorders are often associated with and contribute to the development of edema as well as with a possible increased risk of bleeding.

As a result of the review the most characteristic clinical and radiological symptoms of CVT, VIS, intracranial venous congestion can be identified in the order of their probable manifestation from patient complaints to the results of instrumental studies: predominantly presents in young (an average 34.64 ± 14.66 years), headache - in 90%, subacute development and course of the disease - in 56% cases, papilledema optic disc - in 20-40%, increasing of central venous pressure (up to 140-190 mm H2O), hypodensity of the ischemic focus (cytotoxic or vasogenic edema) on CT, hyperdensity sign of sinus or vein on CT, earlier (1-3 days) development of vasogenic edema on diffusion MRI, symptoms of stop-contrast and filling defect thrombosed sinuses on contrast enhancement (CE) CTA (with 100% sensitivity and specificity) or MRA (100% sensitivity and 52% specificity), expansion of venous regional collaterals on CE CT- and MRA - 90% , moderate hyperperfusion on CT- or MR-perfusion, elevated maximum blood flow velocity Rosenthal veins > 25 cm/s; Galen's vein and rectus sinus > 30 cm/s, decreased cerebrovascular reactivity index (ICR) <40%, increased peripheral resistance index > 20% on TCD (63% sensitivity and 65% specificity), thrombus visualization on brachiocephalic veins ultrasound duplex scanning, brachiocephalic vessels ultrasound index of arteriovenous ratio (IAVR) <50% (with a specificity of 98% and a sensitivity of 95.2%).

Conflict of interest

The authors declare that the research has been conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Competing interests

The authors have declared that no competing interests exist.

Funding information

This research has received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Data availability statement

The data sets used and/or analysed during the current study are available from the corresponding author upon request.

Disclaimer

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of any affiliated agency of the authors.

References

1. Divišová P, Šaňák D, Král M, Bártková A, Hutyra M, et al. (2020) Young cryptogenic ischemic stroke: A descriptive analysis of clinical and laboratory characteristics, outcomes and stroke recurrence. *J Stroke Cerebrovasc Dis* 29:105046. [Crossref]
2. Fonseca AC, Ferro JM (2015) Cryptogenic stroke. *Eur J Neurol* 22: 618-623.
3. Hacke W, Hennerici MG, Gelmers HJ, Krämer G (1991) Cerebral ischemia. Berlin Heidelberg: Springer Verlag, p.238.
4. Alvis-Miranda HR, Milena Castellar-Leones S, Alcala-Cerra G, Rafael Moscote-Salazar L (2013) Cerebral sinus venous thrombosis. *J Neurosci Rural Pract* 4: 427-438.
5. Tarulli A (2010) Neurology. A Clinician's Approach. Cambridge University Press. p. 240.
6. Usman U, Wasay M (2006) Mechanism of neuronal injury in cerebral venous thrombosis. *J Pak Med Assoc* 56: 509-512.
7. Semenov S, Portnov Yu, Semenov A, Korotkevich A, Kokov A (2017) Neuroimaging patterns of cerebral hyperperfusion. *J. Phys Conf Ser* 886: 012014.
8. Saposnik G, Barinagarrementeria F, Brown RD Jr, Bushnell CD (2011) American heart association stroke council and the council on epidemiology and prevention. Diagnosis and management of cerebral venous thrombosis: a statement for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke* 42: 1158-1192.

9. Garland J, Kesha K, Vertes D, Modahl L, Milne D (2018) Empty delta sign on unenhanced postmortem computed tomography scan in cerebral venous thrombosis. *Am J Forensic Med Pathol* 39: 360-363.

10. Capecchi M, Abbattista M, Martinelli I (2018) Cerebral venous sinus thrombosis. *J Thromb Haemost* 16: 1918-1931.

11. Goyal G, Charan A, Singh R (2018) Clinical presentation, neuroimaging findings, and predictors of brain parenchymal lesions in cerebral vein and dural sinus thrombosis: A retrospective study. *Ann Indian Acad Neurol* 21: 203-208.

12. Kim BS, Sarma D, Lee SK, terBrugge KG (2009) Brain edema associated with unruptured brain arteriovenous malformations. *Neuroradiology* 51: 327-335.

13. Bonneville F (2014) Imaging of cerebral venous thrombosis. *Diagn Interv Imaging* 95: 1145-1150.

14. Wasay M, Kojan S, Dai AI (2010) Headache in cerebral venous thrombosis: incidence, pattern and location in 200 consecutive patients. *J Headache Pain* 11, 137-139.

15. Mendel TA, Błażejewska-Hyżorek B, Szpak GM, Stępień T (2017) Intracerebral hemorrhage in the context of cerebral amyloid angiopathy and varied time of onset of cerebral venous thrombosis: a case report. *Folia Neuropathol* 55: 242-248.

16. Kato Y, Takeda H, Furuya D, Nagoya H, Deguchi I (2010) Subarachnoid hemorrhage as the initial presentation of cerebral venous thrombosis. *Intern Med* 49: 467-470.

17. Tsai FY, Kostanian V, Rivera M (2007) Cerebral venous congestion as indication for thrombolytic treatment. *Cardiovasc Intervent Radiol* 30: 675-687.

18. Viegas LD, Stolz E, Canhão P (2014) Systemic thrombolysis for cerebral venous and dural sinus thrombosis: a systematic review. *Cerebrovasc Dis* 37: 43-50.

19. Luo Y, Tian X, Wang X (2018) Diagnosis and treatment of cerebral venous thrombosis: A Review. *Front Aging Neurosci* 10: 2.

20. Sasidharan PK (2012) Cerebral vein thrombosis misdiagnosed and mismanaged. *Thrombosis* 11 p.

21. Ferro JM, Canhão P, Stam J, Bousser MG, Barinagarrementeria F (2004) ISCVT Investigators. Prognosis of cerebral vein and dural sinus thrombosis: results of the International study on cerebral vein and dural sinus thrombosis (ISCVT). *Stroke* 35: 664-670.

22. Zafar A, Ali Z (2012) Pattern of magnetic resonance imaging and magnetic resonance venography changes in cerebral venous sinus thrombosis. *J Ayub Med Coll Abbottabad* 24: 63-67.

23. Whiting AS, Johnson LN (1992) Papilledema: clinical clues and differential diagnosis. *Am Fam Physician* 45:1125-1134.

24. Lee SK, Kim BS, Terbrugge KG (2002) Clinical presentation, imaging and treatment of cerebral venous thrombosis (CVT). *Interv Neuroradiol* 8: 5-14. [Crossref]

25. Al-Hashel JY, John JK, Vembu P (2014) Venous thrombosis of the brain. Retrospective review of 110 patients in Kuwait. *Neurosciences (Riyadh)* 19: 111-117.

26. Einhäupl K, Stam J, Bousser MG, De Bruijn SF, Ferro JM (2010) European Federation of Neurological Societies. EFNS guideline on the treatment of cerebral venous and sinus thrombosis in adult patients. *Eur J Neurol* 17: 1229-1235.

27. ZHuchkova EA, Semenov SE (2015) Headache and ultrasound parameters arteriovenous ratio - additional important factors of stroke diagnostic. *Clinical Physiology of Circulation* 2: 30-35.

28. Botta R, Donirpathi S, Yadav R, Kulkarni GB, Kumar MV (2017) Headache patterns in cerebral venous sinus thrombosis. *J Neurosci Rural Pract* 8: S72-S77.

29. Carangelo B, Lavalle L, Tiezzi G, Branco D, Lippa L (2015) A rare localization of cerebral venous sinus thrombosis. Case report. *G Chir* 36: 79-83.

30. Benabu Y, Mark L, Daniel S, Glikstein R (2009) Cerebral venous thrombosis presenting with subarachnoid hemorrhage. Case report and review. *Am J Emerg Med* 27: 96-106.

31. Alshurafa S, Alfilfil W, Alshurafa A, Alhashim K (2018) Cerebral venous sinus thrombosis in a young female misdiagnosed as migraine ending in a permanent vegetative state: a case report and review of the literature. *J Med Case Rep* 22: 323.

32. Bushnell C, Saposnik G (2014) Evaluation and management of cerebral venous thrombosis. *Continuum (Minneap Minn)* 20: 335-351.

33. Breteau G, Mounier-Vehier F, Godefroy O, Gauvrit JY, Mackowiak-Cordoliani MA (2003) Cerebral venous thrombosis 3-year clinical outcome in 55 consecutive patients. *J Neurol* 250: 29-35.

34. Ingvar DH (1981) Measurements of regional cerebral blood flow and metabolism in psychopathological states. *Eur Neurol* 20: 294-296.

35. Brusov OS, Simashkova NV, Karpova NS, Faktor MI, Nikitina SG (2019) Thrombodynamic parameters of hypercoagulation of blood in children with childhood autism and schizophrenia. *Zh Nevrol Psikhiatr Im S S Korsakova* 119: 59-63.

36. Chow V, Reddel C, Pennings G, Scott E, Pasqualon T (2015) Global hypercoagulability in patients with schizophrenia receiving long-term antipsychotic therapy. *Schizophr Res* 162: 175-182.

37. Kim JB, Kwon DY, Park MH, Kim BJ, Park KW (2013) Paradoxical presentation of orthostatic headache associated with increased intracranial pressure in patients with cerebral venous thrombosis. *Ann Indian Acad Neurol* 16: 85-87.

38. Gunes HN, Cokal BG, Guler SK, Yoldas TK, Malkan UY (2016) Clinical associations, biological risk factors and outcomes of cerebral venous sinus thrombosis. *J Int Med Res* 44:1454-1461.

39. Semenov SE, Moldavskaia IV, Yurkevich EA, Shatokhina MG, Semenov AS (2019) Diagnosis of venous ischemic stroke. Part I (Clinical polymorphism). A review article. *Complex Issues of Cardiovascular Diseases* 8: 125-134.

40. Chinthapalli K, Logan AM, Raj R, Nirmalananthan N (2018) Assessment of acute headache in adults - what the general physician needs to know. *Clin Med (Lond)* 18: 422-427.

41. Sader N, de Lotbinière-Bassett M, Tso MK, Hamilton M (2018) Management of Venous Sinus Thrombosis. *Neurosurg Clin N Am* 29: 585-594.

42. McGee SR (1998) Physical examination of venous pressure: a critical review. *Am Heart J* 136: 10-18.

43. Bailey JK, McCall J, Smith S, Kagan RJ (2012) Correlation of internal jugular vein/common carotid artery ratio to central venous pressure: a pilot study in pediatric burn patients. *J Burn Care Res* 33: 89-92.

44. Shumilina MV (2013) Method for measuring venous pressure - a new method. Patent 2480149, RF.

45. Busch MA, Hoffmann O, Einhäupl KM, Masuhr F (2016) Outcome of heparin-treated patients with acute cerebral venous sinus thrombosis: influence of the temporal pattern of intracerebral haemorrhage. *Eur J Neurol* 23: 1387-1392.

46. Mahale R, Mehta A, Varma RG, Hegde AS, Acharya PT (2017) Decompressive surgery in malignant cerebral venous sinus thrombosis: what predicts its outcome? *J Thromb Thrombolysis* 43: 530-539.

47. Chalela JA, Kidwell CS, Nentwich LM, Luby M, Butman JA (2007) Magnetic resonance imaging and computed tomography in emergency assessment of patients with suspected acute stroke: a prospective comparison. *Lancet* 27: 293-298.

48. von Kummer R, Bourquain H, Bastianello S, Bozzao L, Manelfe C (2001) Early prediction of irreversible brain damage after ischemic stroke at CT. *Radiology* 219: 95-100.

49. Barber PA, Demchuk AM, Zhang J, Buchan AM (2000) Validity and reliability of a quantitative computed tomography score in predicting outcome of hyperacute stroke before thrombolytic therapy. ASPECTS Study Group. Alberta Stroke Programme Early CT Score. *Lancet* 13: 1670-1674.

50. Wardlaw JM, Mielke O (2005) Early signs of brain infarction at CT: observer reliability and outcome after thrombolytic treatment--systematic review. *Radiology* 235: 444-453.

51. Wardlaw JM, West TM, Sandercock PA, Lewis SC, Mielke O (2003) International stroke trials collaborative group. Visible infarction on computed tomography is an independent predictor of poor functional outcome after stroke, and not of haemorrhagic transformation. *J Neurol Neurosurg Psychiatry* 74: 452-458.

52. Powers WJ, Rabinstein AA, Ackerson T, Adeoye OM, Bambakidis NC (2018) American Heart Association Stroke Council. 2018 Guidelines for the early management of patients with acute ischemic stroke: A guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke* 49: e46-e110.

53. Standard for specialized medical care for cerebral infarction (2012) 1740n. Registered 27985. 04.04.2013.

54. Ambulance standard for stroke. (2012) 1692n. Registered 27985. 04.04.2013.

55. Standard of specialized medical care for TIA (2012) 1693n. Registered 27985. 04.04.2013.

56. Masdeu J C, Irimia P, Asenbaum S, Bogousslavsky J, Brainin M (2006) EFNS guideline on neuroimaging in acute stroke. Report of an EFNS task force. *European Journal of Neurology* 13: 1271-1283.

57. Vymazal J, Rulseh AM, Keller J, Janouskova L (2012) Comparison of CT and MR imaging in ischemic stroke. *Insights Imaging* 3: 619-627.

58. Wetzel SG, Kirsch E, Stock KW, Kolbe M, Kaim A (1999) Cerebral veins: a comparative study of CT venography with intraarterial digital subtraction angiography. *Am J Neuroradiol* 20: 249-255.

59. Wardlaw JM, Dorman PJ, Lewis SC, Sandercock PA (1999) Can stroke physicians and neuroradiologists identify signs of early cerebral infarction on CT? *J Neurol Neurosurg Psychiatry* 67: 651-653.

60. Pexman JH, Barber PA, Hill MD, Sevick RJ, Demchuk AM (2001) Use of the Alberta Stroke Program Early CT Score (ASPECTS) for assessing CT scans in patients with acute stroke. *Am J Neuroradiol* 22: 1534-1542.

61. Barber PA, Hill MD, Eliasziw M, Demchuk AM, Pexman JH (2005) ASPECTS Study Group. Imaging of the brain in acute ischaemic stroke: comparison of computed tomography and magnetic resonance diffusion-weighted imaging. *J Neurol Neurosurg Psychiatry* 76: 1528-15 33.

62. Linn J, Pfefferkorn T, Ivanicova K, Müller-Schunk S, Hartz S et al. (2009) Noncontrast CT in deep cerebral venous thrombosis and sinus thrombosis: comparison of its diagnostic value for both entities. *Am J Neuroradiol* 30: 728-735.

63. Bousser MG. (2000) Cerebral venous thrombosis: diagnosis and management. *J Neurol* 247: 252-258.

64. Semenov SE, Yurkevich EA, Moldavskaia IV, Shatokhina MG, Semenov AS (2019) Diagnosis of venous ischemic stroke. Part II (algorithms and semiology of diagnostic radiology. Limitations in clinical practice). A review. *Complex Issues of Cardiovascular Diseases* 8: 104-115.

65. Ford K, Sarwar M (1981) Computed tomography of dural sinus thrombosis. *Am J Neuroradiol* 2: 539-543.

66. Kawaguchi T, Kawano T, Kaneko Y, Ooasa T, Tsutsumi M (2001) Classification of venous ischaemia with MRI. *J Clin Neurosci* 8: 82-88.

67. Brunser AM, Hoppe A, Illanes S, Díaz V, Muñoz P (2013) Accuracy of diffusion-weighted imaging in the diagnosis of stroke in patients with suspected cerebral infarct. *Stroke* 44: 1169-1171.

68. Edlow BL, Hurwitz S, Edlow JA (2017) Diagnosis of DWI-negative acute ischemic stroke: A meta-analysis. *Neurology* 18: 256-262.

69. Campbell BC, Macrae IM (2015) Translational perspectives on perfusion-diffusion mismatch in ischemic stroke. *Int J Stroke* 10: 153-162.

70. Ma H, Wright P, Allport L, Phan TG, Churilov L (2015) Salvage of the PWI/DWI mismatch up to 48 h from stroke onset leads to favorable clinical outcome. *Int J Stroke* 10: 565-570.

71. Heidenreich JO, Hsu D, Wang G, Jesberger JA, Tarr RW (2008) Magnetic resonance imaging results can affect therapy decisions in hyperacute stroke care. *Acta Radiol* 49: 550-557.

72. Moritani T, Ekholm S, Westesson PL (2005) Diffusion-Weighted MR imaging of the brain. Berlin Heidelberg: Springer-Verlag, p. 229.

73. Chu K, Kang D, Yoon B, Roh J (2001) Diffusion-Weighted magnetic resonance in cerebral venous thrombosis. *Arch Neurol* 58:1569-1576.

74. Semenov SE, Bergen TA, Mesropyan NA, Smagina AV, Yurkevich EA (2019) Potential value of perfusion and diffusion methods for solitary white matter lesion. *REJR* 9: 30-46.

75. Semenov S, Moldavskaya I, Shatokhina M, Semenov A, Barbarash L (2011) How to distinguish between venous and arterial strokes and why? *Neuroradiol J* 15: 289-299.

76. Lee EJ (2002) The empty delta sign. *Radiology* 224: 788-789.

77. Onder H, Kisbet T (2020) Neuroimaging findings in patients with idiopathic intracranial hypertension and cerebral venous thrombosis, and their association with clinical features. *Neurol Res* 42: 141-147.

78. Khandelwal N, Agarwal A, Kochhar R, Bapuraj JR, Singh P (2006) Comparison of CT venography with MR venography in cerebral sinovenous thrombosis. *Am J Roentgenol* 187: 1637-1643.

79. Issar P, Chinna S, Issar SK (2017) Evaluation of cerebral venous thrombosis by CT, MRI and MR venography. *J Assoc Physicians India* 65: 16-21.

80. Linn J, Ertl-Wagner B, Seelos KC, Strupp M, Reiser M (2007) Diagnostic value of multidetector-row CT angiography in the evaluation of thrombosis of the cerebral venous sinuses. *Am J Neuroradiol* 28(5):946-52.

81. Koenig M, Kraus M, Theek C, Klotz E, Gehlen W et al. (2001) Quantitative assessment of the ischemic brain by means of perfusion-related parameters derived from perfusion CT. *Stroke* 32: 431-437.

82. Wintermark M, Sesay M, Barbier E, Borbély K, Dillon WP (2005) Comparative overview of brain perfusion imaging techniques. *Stroke* 36: e83-e99.

83. Wintermark M, Albers GW, Alexandrov AV, Alger JR, Bammer R (2008) Acute stroke imaging research roadmap. *Stroke* 39: 1621-1628.

84. Semenov SE (2019) Parametric features of regional cerebral blood flow in venous ischemic stroke. *Acta biomedica scientifica* 4: 138-147.

85. Palkowitsch PK, Bostelmann S, Lengsfeld P (2014) Safety and tolerability of iopromide intravascular use: a pooled analysis of three non-interventional studies in 132,012 patients. *Acta Radiol* 55: 707-714.

86. Hunt CH, Hartman RP, Hesley GK (2009) Frequency and severity of adverse effects of iodinated and gadolinium contrast materials: retrospective review of 456,930 doses. *Am J Roentgenol* 193: 1124-1127.

87. Parkes LM, Rashid W, Chard DT, Tofts PS (2004) Normal cerebral perfusion measurements using arterial spin labeling: reproducibility, stability, and age and gender effects. *Magn Reson Med* 51: 736-743.

88. Essig M, Shiroishi MS, Nguyen TB, Saake M, Provenzale JM (2013) Perfusion MRI: the five most frequently asked technical questions. *Am J Roentgenol* 200: 24-34.

89. Alsop DC, Detre JA, Golay X, Günther M, Hendrikse J (2015) Recommended implementation of arterial spin-labeled perfusion MRI for clinical applications: A consensus of the ISMRM perfusion study group and the European consortium for ASL in dementia. *Magn Reson Med* 73: 102-116.

90. Petersen ET, Zimine I, Ho YC, Golay X (2006) Non-invasive measurement of perfusion: a critical review of arterial spin labelling techniques. *Br J Radiol* 79(944):688-701.

91. Golay X, Guenther M. (2012) Arterial spin labelling: final steps to make it a clinical reality. *MAGMA* 25: 79-82.

92. Hacke W, Albers G, Al-Rawi Y, Bogousslavsky J, Davalos A (2005) DIAS study group. The Desmoteplase in Acute Ischemic Stroke Trial (DIAS): a phase II MRI-based 9-hour window acute stroke thrombolysis trial with intravenous desmoteplase. *Stroke* 36: 66-73.

93. Schilling L, Wahl M (1997) Brain edema: pathogenesis and therapy. *Kidney Int Suppl* 59: S69-S75.

94. Couture EJ, Desjardins G, Denault AY (2017) Transcranial Doppler monitoring guided by cranial two-dimensional ultrasonography. *Can J Anaesth* 64: 885-887.

95. Purkayastha S, Sorond F (2012) Transcranial doppler ultrasound: technique and application. *Semin Neurol* 32: 411-420.

96. Zamboni P (2016) Why current doppler ultrasound methodology is inaccurate in assessing cerebral venous return: The alternative of the ultrasonic jugular venous pulse. *Behav Neurol* 7082856.

97. Director LT, Mackenzie DC (2018) Dural sinus thrombosis identified by point-of-care ultrasound. *Clin Exp Emerg Med* 5: 199-203.

98. Bhatnagar P, Schoombee H, Burgess B (2010) Ultrasound scan in the emergency department revealed rare but potentially dangerous internal jugular vein thrombosis. *Emerg Med J* 27: 124.

99. Semenov SE, Abalmasov VG (2000) The use of magnetic resonance venography in diagnosis of cerebral venous blood flow disorders. *Zh Nevrol Psikhiatr Im S S Korsakova* 100: 44-50.

100. Sheikh MA, Topoulos AP, Deitcher SR (2002) Isolated internal jugular vein thrombosis: risk factors and natural history. *Vasc Med* 7: 177-179.

101. Drakos P, Ford BC, Labropoulos N (2020) A systematic review on internal jugular vein thrombosis and pulmonary embolism. *J Vasc Surg Venous Lymphat Disord* 8: 662-666.

102. Semenov S (2003) Why the Leftside cerebral veins thrombosis is more risky than the rightside. *Rivista di Neuroradilologia* 16: 853-858.

103. ZHuchkova EA, Semenov SE (2017) Method for differential diagnosis of arterial and venous strokes - a new method. Patent 2606597, Application 2015148095, RF.

104. Shumilina MV (2012) Integrated ultrasound diagnosis of peripheral vascular disease. Moscow. 384.

105. Semenov S, Yurkevich E, Semenov A, Korotkevich A, Kokov A (2020) Brachiocephalic Vessels Ultrasound Index of Arteriovenous Ratio (IAVR) and Headache as a diagnostic tool for intracranial venous stasis in arterial/venous ischemic stroke's differentiation. *J Neuroimaging Psychiatry Neurol* 5: 1-5.

106. Parkes LM, Detre JA (2003) ASL: Blood Perfusion Measurements Using Arterial Spin Labeling. In: Quantitative MRI of the brain: measuring changes caused by disease. Tofts P. (Eds.). Chichester. England: John Wiley & Sons Ltd. p.455-473.

107. Powers WJ, Derdeyn CP, Biller J, Coffey CS, Hoh BL (2015) American Heart Association Stroke Council. American Heart Association/American Stroke Association Focused Update of the 2013 Guidelines for the early management of patients with acute ischemic stroke regarding endovascular treatment: A guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke* 46: 3020-3035.

108. Essop H, Kekana M (2020) The experiences of teleradiology end users regarding role extension in a rural district of the North West province: A qualitative analysis. *Afr J Prim Health Care Fam Med* 19: e1-e8.

109. Kim YC, Kim HJ, Chung JW, Kim IG, Seong MJ (2020) Novel estimation of penumbra zone based on infarct growth using machine learning techniques in acute ischemic stroke. *J Clin Med* 24: 1977.

Copyright: ©2021 Semenov SE. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.