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Stroke Imaging: An Updated Data for Radiologists and Healthcare Professionals

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Abstract

For the effective removal of tetracycline (TC) from aqueous solutions, a novel Grafted Polyurethane Foam (GPUF) functionalized with iron or copper metal-organic frameworks (FeMOF-PUF and CuMOF-PUF, respectively) was created. By adjusting experimental parameters such as adsorbent dosage, initial pH, contact time, initial TC concentration, and temperature, the adsorption performance of both GPUF materials was examined. Based on the Langmuir isotherm model, the FeMOF-PUF showed a higher maximum adsorption capacity of 500.0 mg g-1 than the CuMOF-PUF which is 375.0 mg g^{-1}. This finding suggests that the incorporation of MOF into the PUF matrix not only preserves but also improves the base material's adsorption capacity. The spontaneous and endothermic nature of the adsorption process, as demonstrated by thermodynamic measurements, points to a chemically driven interaction between TC and FeMOF-PUF. The synergistic combination of porosity, Lewis acidity of the iron sites within the MOF structure, and electrostatic interactions with TC molecules is responsible for FeMOF-PUF's excellent adsorption capability. The result shows that GPUFs, especially FeMOF-PUF, have a promising future as effective and useful adsorbents for the removal of pharmaceutical pollutants in water treatment applications.

Keywords: Tetracycline, Adsorption, Metal-Organic Frameworks (MOFs), Polyurethane Foam (PUF), Grafted Polyurethane Foam (GPUF), Wastewater treatment, Antibiotic removal, Environmental remediation.

1. Introduction

Stroke, also referred to as cerebrovascular accident (CVA), is an acute injury to the central nervous system (CNS) and stands as one of the primary causes of mortality in developed nations. It is estimated that there are 795,000 new cases of stroke annually, leading to approximately 140,000 deaths each year. According to reports from the Centers for Disease Control and Prevention (CDC), stroke has shifted from being the third leading cause of death in 2007 to the fifth leading cause in 2017 within the United States [1][2][3]. Among stroke cases in the U.S., around 87% are ischemic, 10% are intracerebral hemorrhagic (ICH) strokes, and 3% are aneurysmal subarachnoid hemorrhages (SAH) [1]. Historically, neuroimaging was primarily utilized to rule out hemorrhagic, neoplastic, and infectious etiologies in ischemic strokes, with limited diagnostic and therapeutic utility in the acute management of these events. However, with advancements in the field, neuroimaging has become a crucial component of stroke management. Despite progress in neuroimaging and interventional neuroradiology, which have contributed to declines in stroke mortality and morbidity, the long-term disability and complications associated with stroke remain substantial, imposing an annual cost exceeding $34 billion in the United States [1][2][3][4]. In particular, neuroimaging plays a vital role in managing stroke patients, especially those with acute ischemic strokes. It serves multiple functions, including distinguishing stroke mimics (e.g., migraine headaches, tumors, seizures, metabolic disturbances, and peripheral or cranial nerve disorders), detecting hemorrhagic strokes at early stages, identifying irreversibly infarcted tissues versus salvageable areas, recognizing vascular malformations, planning for intravenous thrombolysis and intra-arterial thrombectomy, and predicting patient outcomes [5][6]. This review explores various neuroimaging modalities and the latest advancements in imaging techniques for stroke diagnosis and management.

Anatomy: Cerebral Arterial Distribution

Understanding the brain's anatomy and arterial distribution is crucial in the acute management of stroke. The brain is supplied by three primary pairs of arteries: the anterior cerebral artery (ACA), middle cerebral artery (MCA), and posterior

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cerebral artery (PCA). These arteries form two major circulatory systems: the anterior and posterior circulations. The Circle of Willis represents the anastomosis between these two systems.

Anterior Circulation Arteries:

The ACA originates from the internal carotid artery, providing blood to the anteromedial surface of the brain, including the midline portion of the frontal lobe, the superior midline of the parietal lobe, and the anterior portion of the internal capsule and basal ganglia. Ischemic lesions in this region result in motor and sensory impairments of the lower limbs, manifesting as contralateral paralysis, sensory loss in the lower limbs, and urinary incontinence. Similarly, the MCA arises from the internal carotid artery and supplies the lateral surface of the brain, including the anterior and lateral temporal lobes, part of the internal capsule, and the basal ganglia. The MCA is subdivided into four segments: M1 (sphenoidal or horizontal), M2 (insular), M3 (opercular), and M4 (cortical). Ischemic lesions in this territory lead to motor and sensory deficits in the upper limb and face, presenting as contralateral paralysis and sensory loss. The MCA also supplies the temporal lobe (Wernicke area) and the frontal lobe (Broca area), with lesions in the dominant hemisphere (typically the left) causing aphasia.

Posterior Circulation Arteries:

The PCA stems from the basilar artery and supplies the posterior and inferior regions of the brain, including the posteromedial portions of the temporal and occipital lobes. Damage to the visual cortex in the occipital lobe, which governs the contralateral visual field, can result in contralateral hemianopia with macular sparing. The cerebellum receives blood supply from branches of the vertebral-basilar circulation, such as the posterior inferior cerebellar artery (PICA), superior cerebellar artery (SCA), and anterior inferior cerebellar artery (AICA). The PICA supplies the lateral medulla, vestibular nuclei, sympathetic fibers, and inferior cerebellar peduncle. Infarcts in this region lead to lateral medullary (Wallenberg) syndrome [7]. In contrast, infarcts in the superior cerebellar artery affect the superior cerebellar hemispheres, cerebellar vermis, and portions of the midbrain. The AICA supplies the lateral pons, vestibular nuclei, sympathetic fibers, and middle and inferior cerebellar peduncles, with infarcts in this area resulting in lateral pontine syndrome.

Plain Films

Plain radiographs of the skull are used to detect fractures, potential depression, and the presence of foreign bodies or tumors. These images can also reveal the skull's foramina and sinuses, and are useful in identifying foreign metallic objects before proceeding with an MRI. However, plain films offer limited value in the context of stroke imaging, as they do not provide sufficient information for the diagnosis or management of strokes.

Summary of Imaging Modalities for Stroke

Several imaging techniques are essential for stroke diagnosis, including Computed Tomography (CT), CT angiography (CTA), CT perfusion (CTP), CT venography (CTV), Magnetic Resonance Imaging (MRI), MR angiography (MRA), MR perfusion (MRP), ultrasonography, nuclear medicine, and conventional angiography. Each of these modalities has distinct advantages and disadvantages depending on the clinical scenario and the stroke type being investigated.

Computed Tomography

Various CT modalities, including non-contrast CT (NCCT), CTA, CTV, and CTP, are pivotal in stroke imaging. CT imaging is quick and relatively insensitive to motion artifacts, except in the case of CTP, which is more susceptible to motion-induced issues. It is widely accessible in emergency departments and produces high-resolution images of the brain, crucial for initial stroke evaluation. Except for NCCT, all CT modalities require intravenous contrast agents, which may be contraindicated in patients with renal impairment or allergies to contrast media [8].

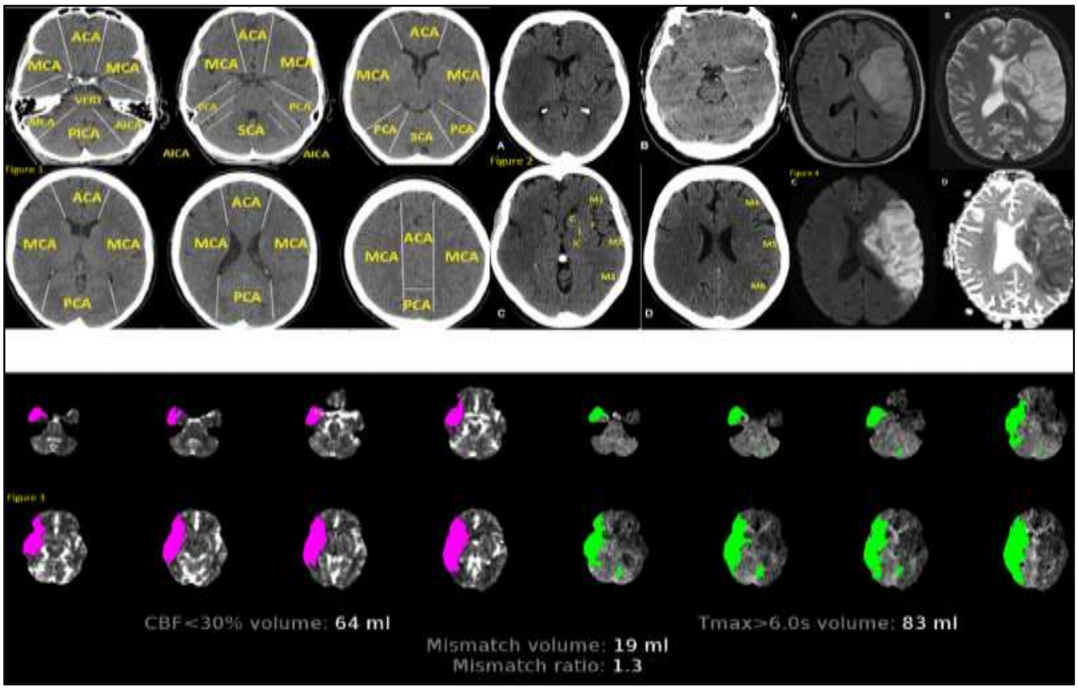

Figure 1: Anatomy of brain vascular regions: ACA (anterior cerebral artery), MCA (middle cerebral artery), PCA (posterior cerebral artery), AICA (anterior inferior cerebellar artery), PICA (posterior inferior cerebellar artery), and SCA (superior

cerebellar artery). Figure 2 displays a non-contrast CT scan showing a loss of gray-white matter differentiation in the right MCA territory, which is indicative of an acute large right MCA infarction. Figure 3 illustrates CTP in stroke imaging, where areas of prolonged MTT, TTP, or Tmax, along with decreased CBV or CBF, are recognized as the infarct core. Figure 4 depicts MRI in stroke, revealing a substantial left MCA infarction. The infarction is marked by hyperintensity on FLAIR (A) and T2 (B) sequences. Additionally, there is a mass effect suggesting subacute infarction. The infarction exhibits "true" diffusion restriction: hyperintensity on DWI (C) and hypointensity on the ADC map (D).

Non-Contrast Computed Tomography

NCCT is the first-line imaging modality used for stroke suspicion, particularly to rule out hemorrhagic strokes. It is highly sensitive to detecting calcifications, aiding in lesion identification. NCCT should be performed once the patient is stabilized in the emergency setting. The findings on NCCT vary with the age of the infarction: hyperacute (less than 12 hours), acute (12–24 hours), subacute (24 hours to 5 days), and chronic (weeks post-stroke). In the hyperacute phase, NCCT primarily excludes intracranial hematomas, and may also detect a hyperdense vessel sign, indicative of an intra-arterial thrombus. In acute infarctions, subtle changes in the gray-white matter interface due to cytotoxic edema may be visible. During the subacute phase, NCCT can reveal vasogenic edema and mass effect, with well-defined margins and an increased risk of herniation. In chronic infarctions, volume loss and hypoattenuation suggest encephalomalacia [9][10][11][12][13][14]. NCCT is crucial in managing ischemic stroke, as it helps identify patients who may not benefit from thrombolysis, particularly those with large infarctions, for whom thrombolytic treatment could increase the risk of intracranial hemorrhage and brain herniation. To guide treatment, scoring systems such as the Alberta Stroke Program Early CT Score (ASPECTS) assess 10 regions within the MCA territory, subtracting one point for each area exhibiting subtle hypodensity. A score below 7 typically indicates a worse prognosis [15][16]. A similar scoring system, PC-ASPECTS, is used for posterior circulation strokes.

Computed Tomography Angiography (CTA)

CTA is performed by administering intravenous contrast media through an antecubital fossa catheter. In the acute stroke setting, CTA is essential for identifying vessel thrombosis, occlusion, vascular malformations, dissection, vasculitis, and aneurysms. Maximum intensity projection (MIP) images and three-dimensional reconstructions are particularly effective for rapidly detecting distal vascular stenosis and clot length. CTA is a reliable technique for identifying stenosis or occlusions in major intracranial vessels, such as the internal carotid artery and the middle cerebral artery trunk, including its secondary (M2) and tertiary (M3) branches [17][18].

Computed Tomography Perfusion (CTP)

CTP involves the rapid injection of contrast into the peripheral vein, typically the antecubital vein, followed by repeated brain CT scans to observe parenchymal enhancement. The rate of parenchymal enhancement correlates with cerebral blood flow, providing valuable data on brain perfusion. CTP quantifies several perfusion parameters, including cerebral blood volume (CBV), cerebral blood flow (CBF), mean transit time (MTT), time to peak transient time (TTP), and time to maximum (T max). CBV refers to the total volume of blood within a unit of brain tissue, encompassing blood in arteries, arterioles, capillaries, venules, and veins, while CBF measures the volume of blood passing through a given brain volume per unit of time. MTT represents the average time it takes for blood to transit through a brain region and is calculated by dividing CBV by CBF. A CBF reduction greater than 30% from normal levels is considered indicative of core infarction by most CTP software. Ischemic penumbra is identified as areas with preserved CBF and CBV but prolonged MTT, TTP, or Tmax surrounding the infarction core. Tmax values exceeding 6 seconds are often used to identify ischemic regions. Although CTP offers rich functional data, it is less reliable for anatomical details, and the radiologist must account for artifacts and challenges in its interpretation [Figure 3].

Magnetic Resonance Imaging (MRI)

MRI, with its superior soft-tissue contrast, is particularly advantageous in the hyperacute and acute phases of stroke. Brain MRI is conducted both with and without gadolinium-based IV contrast to evaluate acute ischemic stroke, transient ischemic attacks (TIAs), and hemorrhagic lesions. Historically, MRI was contraindicated in patients with pacemakers, metallic foreign bodies, aneurysm clips, and implantable devices, as well as in those suffering from claustrophobia. However, recent advancements have made many medical devices MR-compatible or MR-conditional, permitting their safe use under specific conditions. Performing MRI in morbidly obese patients remains challenging, and caution is advised when administering IV gadolinium contrast in patients with renal impairment or contrast allergies [19].

Conventional MRI Sequences

Conventional MRI sequences, such as fluid-attenuated inversion recovery (FLAIR), T2-weighted imaging (T2WI), and T1-weighted imaging (T1WI), may show subtle changes in acute ischemic stroke during the initial hours. FLAIR sequences can detect abnormal signals earlier than other sequences, often revealing changes within three hours after stroke onset [20] [Figure 4 A and B]. High signal intensity on T2WI typically appears around eight hours after stroke onset, while T1WI may require more than eight hours to show low signal intensity [21][22]. Additionally, FLAIR is highly sensitive in detecting subarachnoid hemorrhage, highlighting the sulci in cases of bleeding [23].

Diffusion-Weighted Imaging (DWI)

DWI has become the most effective sequence for detecting brain infarction, outperforming CT and other MRI sequences, especially in the early stages of ischemia. It is one of the most sensitive (88%–100%), specific (95%–100%), and accurate (95%) imaging modalities to identify the ischemic core within minutes of stroke onset, while other imaging modalities may still appear normal at this time [24][25][26][27]. DWI works by measuring the Brownian motion of water molecules within tissue voxels. In infarcted brain tissue, hypoxia and mitochondrial dysfunction impair cellular processes, leading to a disruption in water molecule movement, which is detectable as restricted diffusion, represented as hyperintensity on DWI. It is important to note that not all hyperintensities on DWI indicate true diffusion restriction; for example, brain edema can also produce hyperintense signals, a phenomenon known as the "T2 shine effect." To differentiate true diffusion restriction from the T2 shine effect, an apparent diffusion coefficient (ADC) map is used. True diffusion restriction appears as lower signal intensity on the ADC map compared to the T2 shine effect [Figure 4 C and D].

Magnetic Resonance Angiography (MRA)

MRA, similar to CTA, is employed to evaluate large vessel occlusions and atherosclerotic lesions in stroke patients. It is particularly useful for patients who cannot receive iodinated contrast agents due to allergies. In comparison to CTA, MRA is more time-consuming and is not available in all hospitals. It is most commonly utilized in the subacute phase of infarction [28][15].

Ultrasonography

Duplex ultrasonography is the primary diagnostic tool for screening carotid artery stenosis in individuals suspected of having a stroke. Additionally, transcranial Doppler ultrasonography is frequently employed for the detection of cerebral artery vasospasm following subarachnoid hemorrhage (SAH). Ultrasonography is cost-effective, widely accessible in most emergency settings, and can be performed at the patient's bedside. This imaging modality is non-invasive, radiation-free, and generally considered safer compared to other diagnostic methods. However, ultrasonography is highly dependent on the skill and experience of the operator. Achieving an optimal acoustic window for visualizing the area of interest can sometimes be challenging.

Nuclear Medicine

Positron emission tomography (PET) and single-photon emission computed tomography (SPECT) are valuable imaging modalities that can predict the susceptibility of carotid plaques to rupture. Commonly used tracers in PET imaging include fluorine (F), carbon (C), nitrogen (N), and oxygen (O). Specifically, F-fluorodeoxyglucose (FDG) PET is effective in identifying and predicting the vulnerability of carotid plaques, as FDG accumulates in inflammatory lesions, thereby highlighting atherosclerotic plaques. SPECT is also instrumental in assessing the composition of atherosclerotic plaques, such as the presence of oxidized low-density lipoproteins (LDL) and apoptotic bodies [29]. Oxygen-PET (O-PET) is considered the gold standard for visualizing the ischemic penumbra. In a PET scan, areas with impaired blood flow, such as the ischemic penumbra and infarcted tissue, exhibit abnormal glucose and oxygen metabolism. Perfusion SPECT is another important tool in the management of acute stroke. Using an acetazolamide challenge, SPECT can evaluate reduced vascular reserve and predict the development of ischemic lesions in patients undergoing endarterectomy [29]. While SPECT remains valuable for assessing cerebral blood flow, PET is more commonly used in the acute setting due to its broader availability and favorable cost-effectiveness.

Angiography

The majority of ischemic stroke patients demonstrate arterial stenosis on angiographic imaging, typically conducted 6 to 8 hours following stroke onset [30][31]. Catheter-based cerebral angiography or digital subtraction angiography (DSA) is considered the gold standard for evaluating carotid artery stenosis, vasculitis, cerebral aneurysms, and cerebrovascular malformations. As an invasive procedure, DSA is not the first-line imaging technique, unless used to assess patients presenting with subarachnoid hemorrhage (SAH). In addition to its diagnostic utility, angiography allows for therapeutic interventions, such as the treatment of occluded or stenosed vessels and vascular malformations.

Patient Positioning

Patient Positioning in Brain CT Scan

During a brain CT scan, the patient is positioned supine on the CT table, with the scanner tube rotating around the individual. The patient's head should be placed securely in a head holder. To minimize motion artifacts, it is crucial to ensure the patient remains as comfortable and immobile as possible. To reduce unnecessary radiation exposure, particularly to the eyes, the CT scan is performed with the head positioned at an angle parallel to the base of the skull, known as the glabellomeatal line. The scan begins from this reference point and proceeds superiorly. Brain CT scans can be conducted with or without intravenous contrast enhancement.

Patient Positioning in Brain MRI

Before performing an MRI, the patient must be questioned regarding any history of pacemakers, metallic foreign bodies, aneurysm clips, or implantable devices. Additionally, if gadolinium contrast is to be used, the patient's history of contrast allergies should be reviewed, and the risks and benefits of the contrast material should be discussed. Renal function must also be assessed prior to gadolinium administration, as it is only safe for patients with a glomerular filtration rate (GFR) above 30. The patient should be asked to remove all metal objects, including jewelry, keys, and hearing aids. If the patient has a history of claustrophobia, arrangements for a chaperone or sedation should be made. The patient is positioned supine with the receiver coil placed around the head, and immobilization is achieved using cushions. Additional cushions may be used for added comfort, particularly under the knees. The laser beam should be aligned with the glabella to ensure accurate scanning.

Clinical Significance

Imaging plays a crucial and timely role in the management of stroke patients, as it is essential for confirming the diagnosis and initiating the appropriate therapeutic interventions as early as possible. Stroke imaging is conducted for three primary purposes:

1. To distinguish between ischemic and hemorrhagic strokes, as well as intracerebral hemorrhages; non-contrast CT is typically the first imaging modality used for this purpose.
2. To rule out other potential causes of neurological symptoms (i.e., stroke mimics such as tumors, seizures, etc.).
3. To assess the volume and location of infarcted tissue and identify tissue at risk for further infarction.

Additionally, imaging is used to identify the occluded artery in ischemic stroke cases, aiding in treatment planning. In most medical centers, non-contrast CT (NCCT) is the first-line imaging modality, performed immediately after the patient is admitted and stabilized in the emergency room. NCCT is essential for excluding hemorrhagic stroke and intracranial hemorrhage. Subsequent imaging includes computed tomography perfusion (CTP) and computed tomography angiography (CTA). In modern CT scanners, both CTP and CTA can be performed simultaneously with a single contrast dose, although in many stroke centers, these procedures still require two separate contrast infusions. Non-contrast CT, CTA, and CTP form the cornerstone of ischemic stroke imaging protocols in many centers [32]. Guidelines for ischemic stroke treatment generally favor extending the treatment window for tissue at risk (ischemic penumbra) up to 24 hours following the initial insult, which has led to an increase in the use of CTP and CTA. Brain MRI with diffusion-weighted imaging (DWI) provides the highest sensitivity and specificity for diagnosing acute stroke and is considered superior to NCCT for early detection of acute ischemic strokes. However, MRI/MRA may not be accessible in all centers and is time-consuming, making it less commonly used in the hyperacute phase of stroke. Despite this, it remains invaluable in the subacute phase. Digital subtraction angiography (DSA) is regarded as the gold standard for evaluating carotid and vertebral arteries, intracranial vascular narrowing or occlusion, vasculopathy, and vasculitis. Given the advancements in non-invasive imaging techniques, the primary role of DSA has shifted from diagnosis to treatment. Duplex Doppler ultrasonography is primarily employed for monitoring patients with subarachnoid hemorrhage (SAH) to detect vasospasm as a complication of SAH.

Other CT Modifications for Stroke Imaging:

In addition to the conventional non-contrast CT (NCCT), which is the standard first-line imaging modality in the acute setting for suspected stroke, there are several modified CT techniques that have significantly advanced the diagnostic accuracy, prognostic assessment, and treatment decision-making in stroke patients. These modified CT approaches, including computed tomography perfusion (CTP), computed tomography angiography (CTA), and CT-based imaging protocols, provide additional value in identifying ischemic regions, vascular occlusions, and the overall stroke burden. These modifications allow clinicians to not only confirm the stroke diagnosis but also to estimate the extent of brain injury and identify salvageable brain tissue, ultimately guiding therapeutic strategies.

Computed Tomography Perfusion (CTP)

CTP is a highly valuable imaging technique for assessing cerebral perfusion, providing critical information on the severity of ischemia and the viability of brain tissue. This modality measures blood flow, volume, and transit time within the cerebral vasculature and offers insights into areas at risk of infarction (ischemic penumbra) and irreversibly damaged tissue (infarct core). By using rapid sequential imaging after intravenous contrast administration, CTP maps regions with reduced blood flow and provides a quantitative assessment of perfusion parameters, which are crucial for deciding the appropriate treatment window for interventions like thrombolysis or thrombectomy. One of the major advantages of CTP over other imaging techniques is its ability to differentiate between areas with ischemic penumbra and those with infarcted tissue. The ischemic penumbra, which is the brain tissue at risk but still viable, can be rescued with timely intervention. On the other hand, infarcted tissue is irreversibly damaged. The ability to visualize these two distinct regions in a single scan enhances clinicians' ability to make informed decisions about the timing and type of interventions to pursue. Furthermore, CTP can help predict the outcome of treatment and inform decisions about patient eligibility for reperfusion therapies, especially in patients with large vessel occlusion.

Computed Tomography Angiography (CTA)

CTA is another critical modification of traditional CT imaging, which provides detailed visualization of the cerebral vasculature. It is particularly useful in identifying large vessel occlusions, which are often the primary cause of ischemic strokes. CTA is also employed to evaluate the extent of vascular stenosis or other vascular abnormalities that may contribute to stroke risk. The high-resolution images generated by CTA allow for the detection of intracranial arterial occlusions, aneurysms, arteriovenous malformations, and other abnormalities, providing essential information for treatment planning, particularly in the context of endovascular interventions such as thrombectomy. In acute ischemic stroke management, CTA serves as a powerful diagnostic tool to map out the site and severity of arterial occlusion. The identification of large vessel occlusions, especially in the internal carotid artery (ICA) or middle cerebral artery (MCA), is particularly important as it often necessitates advanced interventional procedures. Furthermore, CTA can help clinicians assess collateral circulation, which plays a significant role in the salvageability of brain tissue. The extent of collateral circulation can inform decisions about whether a patient is likely to benefit from aggressive reperfusion therapies.

Dual-Phase Imaging (CTP and CTA Combined)

Combining CTP and CTA in a dual-phase imaging protocol provides a comprehensive approach to assessing both the perfusion and anatomy of the brain vasculature. This combined technique is particularly useful in acute ischemic stroke cases, as it allows clinicians to evaluate both the ischemic penumbra and the location of vascular occlusions simultaneously. This dual approach can help predict the tissue at risk for infarction, guide therapy, and assess the collateral circulation in real time. The dual-phase imaging modality is especially advantageous in the decision-making process regarding the timing of intervention. For instance, in patients with acute ischemic stroke and large vessel occlusion, the combination of CTP and CTA helps in determining the best window for mechanical thrombectomy or thrombolysis. Furthermore, this combined approach allows for more accurate identification of the infarct core, ischemic penumbra, and the cerebral vasculature’s status, thereby providing a more complete picture of the stroke’s pathophysiology.

CT-Based Imaging Protocols for Acute Stroke

In addition to the aforementioned modifications, stroke imaging protocols have been further refined to optimize diagnostic efficiency and enhance clinical outcomes. One example is the streamlined “code-stroke” protocols that use a combination of NCCT, CTP, and CTA to rapidly assess the extent and type of stroke. These protocols aim to minimize delays in imaging and treatment, which are crucial for improving outcomes in stroke patients. For instance, while NCCT is used to rule out hemorrhagic stroke and intracranial hemorrhage, CTP and CTA can be simultaneously performed to assess perfusion and vascular occlusion, respectively. The ability to execute these imaging techniques in tandem with minimal patient movement or delay is a significant advantage in time-sensitive stroke management.

Challenges and Limitations of CT Modifications

While these CT modifications offer substantial benefits, they are not without limitations. For one, CTP and CTA rely on the use of intravenous contrast, which may not be suitable for all patients, especially those with renal insufficiency or allergies to contrast agents. Additionally, these imaging techniques require specialized equipment and expertise, and their availability may be limited in certain healthcare settings, particularly in resource-constrained environments. Furthermore, although CTP is highly useful for visualizing the ischemic penumbra, its accuracy can be influenced by several factors, including the timing of the scan and the technical quality of the images. Similarly, CTA requires high-quality imaging to ensure accurate assessment of vascular anatomy and pathology. Despite these limitations, the continued development of CT technologies, such as advanced reconstruction algorithms and faster scanning techniques, is improving the accuracy, accessibility, and clinical utility of CT modifications in stroke imaging. As these technologies evolve, their role in acute stroke management is expected to become even more integral, providing clinicians with the tools they need to make precise and timely decisions that ultimately improve patient outcomes. In conclusion, CT modifications, particularly CTP, CTA, and dual-phase imaging, have revolutionized the approach to stroke diagnosis and management. These techniques provide valuable insights into the ischemic core, penumbra, and cerebral vasculature, which are essential for guiding acute interventions and predicting patient outcomes. Despite their limitations, these advanced imaging modalities are now indispensable tools in the rapid and effective treatment of stroke, underscoring the continued importance of imaging in clinical decision-making.

Conclusion:

Stroke remains one of the leading causes of mortality and long-term disability worldwide. Neuroimaging plays a pivotal role in modern stroke management, providing clinicians with the necessary tools to diagnose, differentiate, and manage patients effectively. The importance of timely imaging cannot be overstated, as it influences treatment decisions that can significantly improve patient outcomes. Computed tomography (CT) remains the first-line modality in stroke evaluation due to its widespread availability, speed, and ability to detect hemorrhagic strokes. Non-contrast CT (NCCT) is particularly useful in ruling out intracranial hemorrhages and identifying large infarctions that may preclude thrombolysis. Furthermore, CT angiography (CTA) and CT perfusion (CTP) offer additional insights into vascular occlusions, blood flow, and ischemic penumbra, which are crucial for making decisions regarding interventions like thrombectomy or thrombolysis. In contrast, magnetic resonance imaging (MRI) has become a valuable tool, particularly in the early detection of ischemic strokes. Diffusion-weighted imaging (DWI) stands out as one of the most sensitive modalities for detecting ischemic changes, even within the first few minutes of stroke onset. This makes it an essential imaging technique for acute stroke patients. MRI is also highly effective in identifying small infarcts and assessing brain structures with superior soft-tissue contrast, providing valuable information for assessing stroke severity and prognosis. While MRI provides superior diagnostic information, its accessibility, time constraints, and contraindications for certain patients can limit its use. On the other hand, CT imaging, with its rapid acquisition and ability to identify hemorrhages and large ischemic areas, remains indispensable in the acute setting. Advanced techniques, such as CT perfusion and MRI perfusion, provide dynamic information on cerebral blood flow and tissue viability, which are crucial for optimizing treatment strategies and predicting outcomes. Overall, the integration of various neuroimaging techniques into routine stroke care has enhanced the precision of stroke diagnosis, improved patient selection for intervention, and facilitated more effective treatment planning. Future advancements in imaging technologies, particularly those focusing on perfusion and tissue viability, hold the promise of further improving outcomes by offering more refined insights into the pathophysiology of stroke. With the continuous evolution of these imaging modalities, clinicians will be better equipped to deliver personalized, timely, and effective care for stroke patients.

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