***Review Article***

**Clinical Significance of CT and MR Perfusion Imaging in Cancer Diagnosis: Techniques, Parameters, and Diagnostic Implications**

**Abstract**

Perfusion imaging is an advanced technique for evaluating the perfusion of the microvasculature of any tissue or pathology. It refers to the passing of blood from the arterial system to the vascular system through the microvasculature of tissues. It may be affected in abnormal tissues; thus, perfusion imaging techniques prove helpful in disease characterization. Many authors have mentioned perfusion techniques and their significance in different diagnoses. However, there is a lack of information about the fundamentals of perfusion and its parameters, particularly the relationship between perfusion parameters when diagnosing diseases, such as cancer. This review fills this gap and will provide information about fundamentals, different parameters, and their clinical relationships. It focuses on techniques of CT and MR perfusion imaging and is helpful in the diagnosis of altered perfusion in different tissues. Cancer is one of the leading causes of death across the world. Tumor increases the vascular permeability, which alters the perfusion. So, perfusion imaging proves to be very helpful in tumor identification, differentiation, and grading. It is also beneficial for other diseases that alter the normal tissue perfusion. The results of the perfusion study are based on perfusion maps. Perfusion maps include blood flow (CBF), blood volume (CBV), time to peak (TTP), and mean transit time (MTP). Different perfusion maps provide specific information about the tissue or pathology. CT imaging and MRI are commonly used modalities for perfusion imaging. MR perfusion has an ASL technique as a special advanced technique for perfusion study.

**Keywords:** Arterial Spin Labeling, Cancer Diagnosis, CT Perfusion, MR Perfusion,

**1.** **Introduction**

Perfusion is the flow of blood from arteries to the veins, passing through the microvessels of any tissues (Yuan & Rigor, 2010). It is essential for tissue to fulfill the requirements of nutrients and oxygen, and also helps in eliminating the toxic wastes from the cells of a tissue (*Perfusion Culture - an Overview | ScienceDirect Topics*, n.d.). In early 1980, the theoretical foundations of image-based Arterial input function (AIF) measurements were first explained by Leon Axel. AIF is the basis of CT Perfusion, and later, with the advancement of digital infrastructures, the CT perfusion technique became clinically reliable. Also, Ischemic stroke, which is primarily caused by poor perfusion, was one of the first pathologic disorders to be studied using MRI-based methods for brain perfusion research in the 1980s and 1990s (Copen et al., 2011). Computed Tomography Perfusion (CT Perfusion) and Magnetic Resonance Perfusion (MR Perfusion) techniques are sophisticated methods that are used to assess microcirculation in stroke, tumors, cerebrovascular diseases, pre-surgical planning, neurodegenerative diseases, coronary artery disease (CAD), psychiatric disorders (Schizophrenia), identifying ischemic penumbra and vascular malformations. Tissue perfusion may be affected in abnormal tissues, such as tumors (Steen, 1992). Perfusion study aids in the characterization of several diseases. Tumor grade, aggressiveness, differentiation, ischemia, prognosis, and responsiveness to therapy may all be measured by assessing tumor perfusion imaging, and also a key factor in differentiation between benign and malignant tumors (El Backry et al., 2015). An important first step in treating acute circulatory insufficiency is monitoring tissue perfusion (Hasanin et al., 2017). Information on cerebral hemodynamic parameters, including cerebral blood flow (CBF) and relative cerebral blood volume (rCBV), is provided by perfusion imaging. In addition, it provides an efficient way for rapidly assessing CBF's response to brain activity or other stimuli and monitoring it non-invasively (S.-G. Kim, 2012). Perfusion imaging can be performed with a variety of different imaging modalities, including magnetic resonance imaging (MRI), computed tomography (CT), ultrasound, and nuclear imaging (Kaechele & Chakko, 2025). Compared to a conventional CT scan, a dual-energy CT scan conducts perfusion imaging, comes with greater accuracy (Thieme et al., 2012). MR Perfusion has become a more reliable and commonly used technique since it provides the facility to assess the blood flow of a whole organ, such as the liver (Thng et al., 2010). In MRI, the arterial spin labelling (ASL) technique offers the ability to measure perfusion without the use of an exogenous contrast agent (Petcharunpaisan et al., 2010). On the other hand, a pressure injector is used to administer the contrast at high pressure, which is the most important component of a perfusion study in any modality, and administers the contrast at a constant flow rate (Indrajit et al., 2015). The basic categorization of perfusion techniques on different modalities is shown in **Fig. 1.** It is easier to accurately monitor the perfusion of microvasculature when contrast is administered at a steady flow rate. In the future, researchers need to focus on enhancing the image quality, reducing acquisition time, and improving accuracy. This review article is all about understanding perfusion techniques and their basic perfusion parameters. It shows how perfusion parameters are helpful in cancer diagnosis. It briefly explains the technique of CT perfusion and MR perfusion, along with their advantages and disadvantages.



**Fig. 1.** This figure shows the classification of perfusion imaging techniques used in various modalities, including Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Nuclear Medicine (including SPECT and PET), and Ultrasound

**2. Perfusion Maps**

Perfusion maps are hemodynamic parameters and are represented as colour-coded maps overlying the scans (Demeestere et al., 2020). The advanced software generates various color-coded perfusion maps from the final acquired images (Huisa et al., 2014). The basic perfusion parameters are CBF, cerebral blood volume (CBV), time to peak (TTP), and mean transit time (MTT) as given in **Table 1**. The basis of the generation of the perfusion map is the time attenuation curve (Halil, 2023) as shown in **Fig. 2**. It is possible to map the changes in any tissue or tumor at the microvascular level during the administration of the contrast media (*Quantification of Viable Tumor Microvascular Characteristics by Multispectral Analysis - Berry - 2008 - Magnetic Resonance in Medicine - Wiley Online Library*, n.d.). The time attenuation curve allows the estimation of blood flow through a specific region over a specific duration of time (*Automated Processing of Head CT Perfusion Imaging for Ischemic Stroke Triage: A Practical Guide to Quality Assurance and Interpretation | AJR*, n.d.). CBV and CBF are generally named based on the part of the examination. Similarly, in the case of prostate perfusion, it is known as prostate blood flow (PBF) and prostate blood volume (PBV) (Liu et al., 2023).

**Table 1.** This table summarizes the principal quantitative parameters derived from perfusion imaging techniques (CT, MRI, or PET). These parameters are crucial in assessing tissue vascularity, hemodynamics, and pathophysiology of tissues.

|  |  |
| --- | --- |
| CBF | It is the volume of blood that passes through tissue during a specific time. It is measured in ml/100g of tissue. |
| CBV | It is the amount of blood present in a specific tissue. It is measured in ml/100g of tissue. |
| TTP | The time for the contrast agent to reach its highest concentration or density. It is measured in seconds. |
| MTT | It is the average time taken by blood to pass through a specific tissue or the mean time blood takes to float around within tissue. It is measured in seconds. It is calculated mathematically. |



**Fig 2.** Concentration-time (time-attenuation) curves illustrating tissue perfusion dynamics. Each voxel’s curve reflects a distributed form of the arterial input function (AIF).

**2.1 Cerebral Blood Flow (CBF)**

It is the volume of blood that passes through a particular area over a certain amount of time (*Cerebral Blood Flow and Autoregulation: Current Measurement Techniques and Prospects for Noninvasive Optical Methods - PMC*, n.d.). A decrease in CBF will reflect in insufficient blood supply to that specific region, which suggests an infarct. It is commonly measured as millilitres/100g of tissue per minute (Fantini et al., 2016). In normal adult brain tissue, approximately 55 mL/100g tissue is normal CBF per minute (McClain & Soriano, 2019). Blood flow variations are generally seen inside solid tumors (Østergaard et al., 2013). Tumor heterogeneity is a factor in determining how effectively a patient responds to therapy. Homogeneous administration of anticancer drugs requires blood flow. Tissue hypoxia brought on by decreased perfusion can lessen the tumor's susceptibility to radiation therapy (Graham & Unger, 2018). The relation between CBF and neuronal activity, along with metabolism, is known as neurovascular coupling. Age-related variations in CBF rely on risk factors for Alzheimer's and vascular disease (Nicolakakis & Hamel, 2011). Maintaining consistent brain perfusion requires proper CBF regulation (*Cerebral Blood Flow - an Overview | ScienceDirect Topics*, n.d.). Nearly all of the energy used by the brain comes from oxidative sources (Lushchak et al., 2021).

**2.2 Cerebral Blood Volume (CBV)**

It is the amount of blood present in a specific region, tissue or voxel (*Blood Volume - an Overview | ScienceDirect Topics*, n.d.). It measures the volume of blood over time in tissue and is measured in millilitres/100g of tissue (Muizelaar et al., 1997). The amount of blood contained inside each image voxel can be measured using perfusion imaging methods and can be expressed in terms of percentage. In normal gray matter, approximately 4-6% of gray matter is filled by blood, and 1-3% of the tissue of white matter is filled by blood (Copen et al., 2016). It is associated with cerebral perfusion pressure (CPP). CPP is the difference between cerebral arterial volume and cerebral venous volume. Generally, an increase in CBV leads to a decrease in CPP (Gwinnutt & Saha, 2005). A shift from hypervolemic to hypovolemic is known as a transitional stage. CBV is quite helpful in benign and malignant tumors. Schwannomas can be differentiated from meningiomas by CBV measurements, but CBV is insufficient for finalising any diagnosis, other parameter correlations are also required (J. H. Lee et al., 2020).

**2.3 Time to Peak (TTP)**

TTP is the time for the contrast agent to reach its highest concentration or density to reach its maximum. Increases in regional TTP have been employed in several studies to potentially identify the brain tissue that is at risk of ischemia (Copen et al., 2011). An increase in TTP and a delay in tracer arrival are characteristics of ischemic regions. In patients with chronic stroke, a correlation is found between the TTP delay and reduced perfusion (Sobesky et al., 2004). In MRI, the DWI map shows tissue damage, and TTP is useful in measuring the blood flow limit. Together, both help in a better understanding of the affected areas (B. J. Kim et al., 2014). TTP plays a very small part in grading and differentiating tumors, but along with CBF and CBV, it helps in the assessment of grading glial tumors. Change in TTP indicates the response to treatment (Qin et al., 2022).

**2.4 Mean Transit Time (MTT)**

It is the time taken by blood to pass through a specific region (*Mean Transit Time - an Overview | ScienceDirect Topics*, n.d.). It is an average value, as each RBC needs a bit more time depending on the route it takes to reach the same point. It is measured in seconds (*Mean Transit Time - an Overview | ScienceDirect Topics*, n.d.) and approximately 6 seconds in normal adult brain tissue (Kherallah, 2024). Increased MTT is suggestive of stenosis or occlusion (Lythgoe et al., 2000). There is a relation between CBV, CBF and MTT, which helps in MTT calculation.

CBV= CBF ✕ MTT

MTT = CBV/CBF

To calculate MTT, the majority of perfusion postprocessing software first computes CBV and CBF, then divides the CBV by the CBF. Artifacts in CBV and CBF maps may be transferred to MTT maps in this situation (Divel et al., 2021).

**3. CT Perfusion Technique**

CT perfusion is an emerging functional imaging technique that evaluates characteristics associated with the vascular perfusion of tissues (Wang et al., 2015). A multi-slice (16 or 64-slice) scanner with high temporal resolution is a basic requirement for a reliable CT Perfusion scan. Regarding tumor vascular estimations, CT Perfusion has two benefits: the blood volume estimation and the permeability, both can be obtained simultaneously (Ellika et al., 2007). Furthermore, it provides a linear relationship between the contrast agent administered and the tissue signal intensity and AIF availability. In early 1980, Leon Axel described a theoretical explanation of the foundation of image-based AIF measurements and then employed it (*History and Evolution of Brain Tumor Imaging: Insights through Radiology | Radiology*, n.d.). With the advancement in digital systems, CT Perfusion imaging became reliable for clinical use and started measuring AIF and VOF (venous output flow) on console software. Each voxel's concentration-time curve **Fig. 2** represents a distributed version of the AIF. Brief quantitative and qualitative information can be acquired regarding tumor angiogenesis by CT perfusion (*Perfusion CT – A Novel Quantitative and Qualitative Imaging Biomarker in Gastric Cancer - European Journal of Radiology*, n.d.). Tumor angiogenesis promotes progression, growth, and invasion. Angiogenesis observation helps clinicians understand the aggressiveness of the tumor and plan the treatment and therapies (*Tumor Angiogenesis: Causes, Consequences, Challenges and Opportunities - PMC*, n.d.).

**3.1 Technique of CT Perfusion**

The technique requires a Multi-slice CT scanner that should be at least 16 slices (or 64 slices) with at least 1 second gantry rotation time is required along with a power injector to administer the contrast agent at a constant flow rate under high pressure (4-5 ml/s).A low-dose NCCT (non-contrast CT) is performed for the localization of the perfusion slice (Harvey & Li, 2020). After the localization of the tumor or other pathologic region of interest, the CT perfusion field of view (FOV) must be adjusted so that it includes both the largest visible portion of the tumor along the micro-vessels of the cancer.During the procedure, approximately 50-70 ml of contrast agent (depending on patient weight) should be administered intravenously through a power injector at a flow rate of 4-5 ml/sec (*Dynamic CT Myocardial Perfusion Combined with Coronary CT Angiography for Detecting Hemodynamical Significance of Coronary Artery Stenosis: A Comparative Study | Scientific Reports*, n.d.). A dual-head power injector is preferred for better perfusion.After a 5-second delay of contrast administration, a cine scan is started to capture the tumor enhancement with respect to time for approximately 50 seconds.

In the case of the thorax or abdomen, a breath-hold technique needs to be used to avoid motion artifact(Jensen et al., 2013). A delayed scan should also be taken at 60 seconds and 5-7 minutes to observe the delayed enhancement and flush out of contrast. With the aid of software, a region of interest (ROI) should be selected on an appropriate artery as the artery input to obtain the concentration-time curve(Li et al., 2023). The software creates coloured perfusion maps (CBF, CBV, TTP and MTT) with various parameters, which are then superimposed on an axial slice (Halil, 2023).

**4. MR Perfusion**

One of the earliest pathologic conditions to be investigated utilizing MRI-based techniques for brain perfusion research in the 1980s and 1990s was ischemic stroke, a condition predominantly brought on by inadequate perfusion (Copen et al., 2011). MR perfusion imaging offers the ability to evaluate brain perfusion in acute stroke patients at a time when treatment choices based on these measures may significantly impact outcomes. Currently, there are two primary perfusion MRI techniques available. One uses an exogenous contrast agent, and the other does not use any exogenous contrast agent (Jahng et al., 2014). Some features, such as sensitivity, wider field of view, imaging detail, and especially the Spin Arterial Labeling (ASL) technique, make the MRI a preferable perfusion modality. ASL is an alternative technique that uses radiofrequency pulses to identify the protons in arterial blood without the need for an external contrast agent injection (Grade et al., 2015). Similar to CT perfusion, CBV, CBF, MTT and Tmax maps are provided by MR perfusion. One major advantage of employing MRI as a perfusion test is that the core may be defined using the region of diffusion restriction on the DWI sequence rather than depending on perfusion data. The volume difference between DWI core and Tmax images is known as the operational DWI-PWI mismatch or the MRI correlate of an ischemic penumbra (more than 6 s) (*Perfusion Weighted Imaging - an Overview | ScienceDirect Topics*, n.d.).

**4.1. Technique of MR Perfusion**

MR perfusion can be done with an exogenous contrast agent as well as without an exogenous contrast agent, unlike a CT scan. The exogenous contrast agent technique includes perfusion dynamic enhanced contrast (DEC) and dynamic susceptibility contrast (DSC) perfusion (Floriano et al., 2013; *Reproducibility of Perfusion Parameters in Dynamic Contrast-Enhanced MRI of Lung and Liver Tumors: Effect on Estimates of Patient Sample Size in Clinical Trials and on Individual Patient Responses | AJR*, n.d.). ASL is a perfusion technique that can be done without an exogenous contrast agent (Ferré et al., 2013).

**4.1.1 Exogenous Contrast Agent Technique**

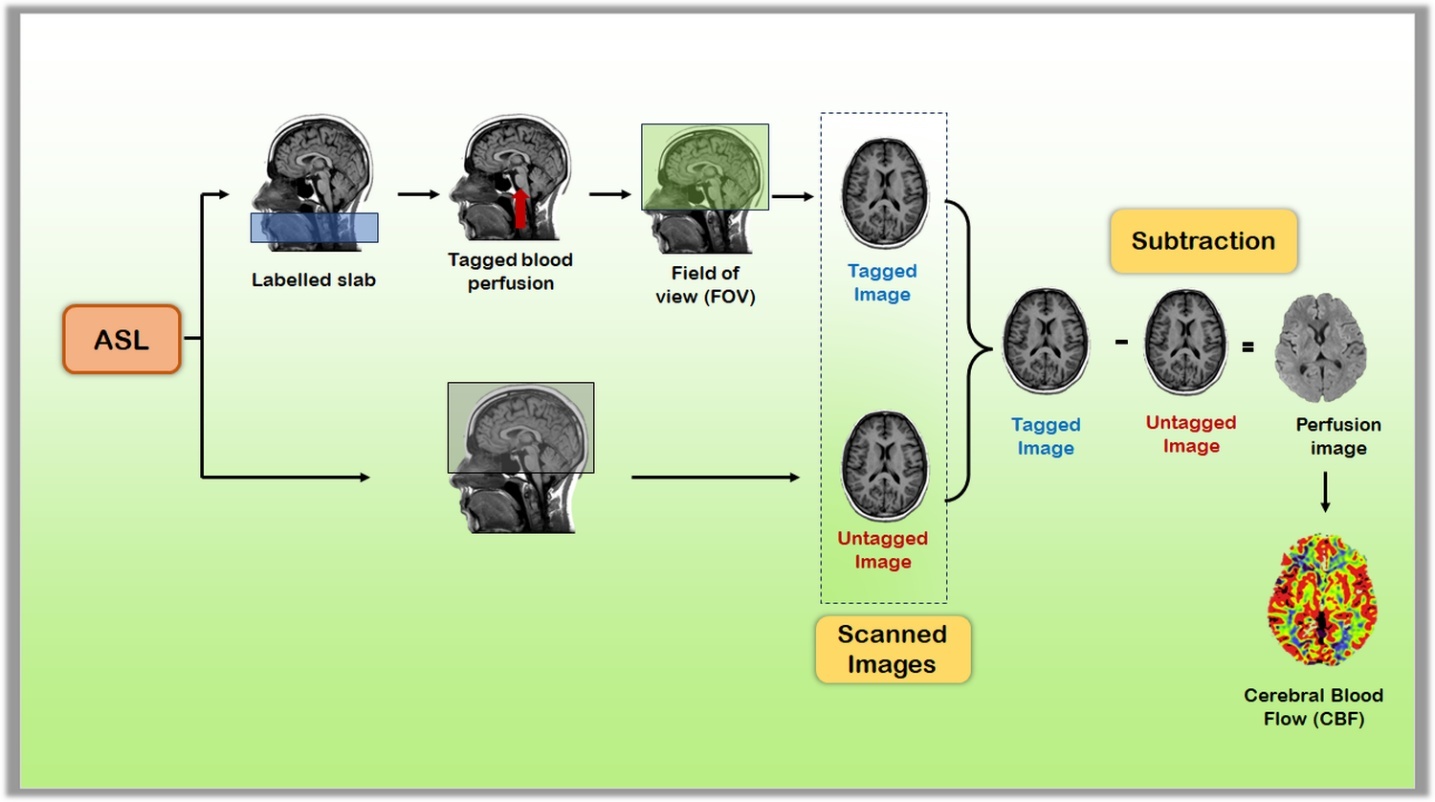
Gadolinium-based contrast media is injected with a flow rate of ~5ml/sec intravenously with the help of a power injector to maintain the flow. The dose of contrast must be ~ 0.1 mmol/kg (Ibrahim et al., 2025). A fast sequence starts to run, and after some fractions of time, contrast administration is also started (*Perfusion Magnetic Resonance Imaging - an Overview | ScienceDirect Topics*, n.d.). The fast sequence captures the images of contrast passing through tissue or pathological conditions, such as a tumor (Jahng et al., 2014). The sequence acquires 15–20 slices covering the region of interest in 1-2 seconds, and it acquires images for approximately 60 seconds during and after the dynamic injection of contrast media. The difference between DSC and DEC is the use of the fast sequence for image acquisition. A fast T1-weighted fat-sat sequence is used in DEC (Gordon et al., 2014). Perfusion parameters are calculated by the evaluation of T1 shortening, which is induced by gadolinium-based contrast passing through the tissue (*Brain Perfusion Imaging: How Does It Work and What Should I Use? - McGehee - 2012 - Journal of Magnetic Resonance Imaging - Wiley Online Library*, n.d.). Perfusion and contrast enhancement are deeply correlated. Perfusion is considered to be higher for increased enhancement.

Fast T2\* weighted echo planar imaging (EPI) is used in DSE (Gordon et al., 2014). Perfusion parameters are calculated by the evaluation of the shortening of T2\* relaxation time (Boxerman et al., 2020; Petrella & Provenzale, 2000). When a gadolinium-based contrast agent passes the microvessels of tissues or tumors, a signal drop is seen surrounding the tissues (Boxerman et al., 2020). This signal drop is directly proportional to perfusion. At the final stage, the software converts the acquired slices into color-coded maps (perfusion maps). DSC is the most preferred MR perfusion technique(Welker et al., 2015). It becomes crucial in case of high-grade tumors and provides perfusion maps with high SNR and high spatial resolution, which is helpful in tumor detection, differentiation, and defining tumor boundaries. Also provides accuracy in tumor perfusion, diffusion, and microstructure analysis (*Comparison of ASL and DSC Perfusion Methods in the Evaluation of Response to Treatment in Patients with a History of Treatment for Malignant Brain Tumor | BMC Medical Imaging | Full Text*, n.d.).

**4.1.2 Arterial Spin Labeling (ASL)**

ASL uses water protons of arterial blood to measure the blood flow (*Arterial Spin Labeling: Techniques, Clinical Applications, and Interpretation | RadioGraphics*, n.d.). Different types of ASL methods are continuous ASL (CASL), pseudo-continuous ASL (PCASL), pulsed ASL (PASL), and velocity selective ASL (VSASL) (Pollock et al., 2009).John A. Detre, John S Leigh, Allen P Koretsky, and Donald S William discovered the technique of ASL in 1992 (Detre et al., 2009). It is a non-invasive MR perfusion technique that doesn’t require any exogenous contrast agent (Álvarez et al., 2024). Two images are required for the ASL technique: one is the Tag image and the other is the control image (*Arterial Spin-Labeling in Routine Clinical Practice, Part 1: Technique and Artifacts | American Journal of Neuroradiology*, n.d.). Labeling is important for acquiring a tag image. A slab is kept before the part of interest, which is placed perpendicular to the artery (*A Neuroradiologist’s Guide to Arterial Spin Labeling MRI in Clinical Practice - PMC*, n.d.). This plane causes magnetization inversion to blood molecules passing through the labeled plane using a saturation pulse. Post-labeling delay to allow the perfusion of tagged blood through the tissue of the part of interest (*Arterial Spin-Labeling in Routine Clinical Practice, Part 1: Technique and Artifacts | American Journal of Neuroradiology*, n.d.). After tagged blood perfusion, an image is acquired in the desired volume to image the tagged blood in addition to static tissues. This acquired image is named the tag image. Apart from this, the desired volume is also scanned without tagging the blood molecules, thus providing an image of only static tissues, named the control image (Petcharunpaisan et al., 2010). The tag image is subtracted from the control image to get a subtracted image. The subtracted image is a perfusion image of tagged blood that flowed through the microvasculature of the tissues of the part of interest (Alsaedi et al., 2018). Further, the subtracted image is combined with a proton density weighted image and several parameters such as labeling efficiency and label duration, and the software generates color perfusion maps. The analysis of ASL is mainly done by the same tool that is used for the analysis of functional MRI. BASIL (Bayesian inference for arterial spin labeling MRI) is one such tool that is used to assist in the subtraction and averaging of the tag/control pair (Chappell et al., 2023).Steps oftheASL technique as shown in **Fig. 3.**

Since ASL doesn’t require a contrast agent, it is the best choice of technique for perfusion in case of abnormal renal function test (RFT). It is also beneficial for repeated perfusion for follow-up purposes in case of cancer treatment (van Dijken et al., 2019). It is also preferred for avoiding blooming artifacts (susceptibility artifacts). Another advantage of ASL is that it provides absolute CBF measurement, unlike DSE, which provides relative CBF and relative CBV (Borogovac & Asllani, 2012). Even low-grade tumor perfusion is also well detectable through the ASL technique (Falk Delgado et al., 2018).

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**Fig. 3.** This diagram illustrates the basic workflow of the ASL perfusion imaging technique, a non-invasive MRI method for quantifying cerebral blood flow (CBF) without contrast agents.

**5. Perfusion in Cancer Diagnosis**

Angiogenesis characteristics, including microvessel density (MVD) and VEGF, are directly correlated with tumor perfusion parameters (Turkbey et al., 2009). Tumor perfusion imaging provides information on tumor vascular permeability (Jain, 2011). Higher perfusion in any tissue indicates the possibility of angiogenesis(Martín et al., 2012). Angiogenesis is the process of tumor proliferation and growth (Zameer et al., 2025). The endothelium of tumor vessels is generally damaged and perforated (Bhat et al., 2024; Hida & Maishi, 2018). Tumor growth is rapid, which leads to hyperglycemia and hypoxia, causing the expression of vascular endothelial growth factor (VEGF). VEGF causes the formation of complex and undeveloped neoangiogenic vasculature (Johnson & Wilgus, 2014). Due to the presence of smooth muscles, wide endothelial cell gaps, and an incomplete basement membrane, permeability increases to macromolecules (Claesson-Welsh et al., 2021). So, the assessment of tumor vascular permeability in abnormal blood vessels of the tumor can be used as an indicator for tumor diagnosis and tumor grading. Increased permeability in new immature blood vessels is a sign of neo-angiogenesis, this information facilitates the tumor grading (Johnson & Wilgus, 2014). By evaluating the perfusion, early angiogenesis identification can aid in early cancer diagnosis. Any tumor with low perfusion has poor chemotherapeutic drug delivery, which reduces the effectiveness of chemotherapeutic treatment. Due to hypoxia, radiotherapy also gives poor results in tumors with poor perfusion (*Hypoxic Microenvironment in Cancer: Molecular Mechanisms and Therapeutic Interventions | Signal Transduction and Targeted Therapy*, n.d.). Tumor vascular permeability measurement makes it easier to develop plans for altering the BBB to enhance drug delivery (Blethen et al., 2021). Perfusion studies have proven helpful in predicting responses and the therapeutic evaluation of chemotherapy and radiotherapy (D. H. Lee et al., 2019). Parameters of perfusion imaging in normal and abnormal conditions as given in **Fig. 4.**

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**Fig. 4.** This figure demonstrates diagnostic interpretations based on perfusion parameters, including cerebral blood flow (CBF), cerebral blood volume (CBV), time to peak (TTP), and mean transit time (MTT), which are crucial in assessing tissue viability in cerebral perfusion imaging. In A, all parameters - CBF, CBV, TTP, and MTT- are within normal limits, indicating normal, healthy brain tissue. In B, both CBF and CBV are decreased, with TTP and MTT increased, a pattern consistent with nonviable or dead tissue due to severely impaired perfusion. In C, CBF is decreased while CBV remains normal, and both TTP and MTT are elevated, suggesting viable but hypoperfused tissue; this may represent tissue at risk that is still salvageable. D represents a scenario of ischemic infarction. The central region shows decreased CBF, normal CBV, and increased TTP and MTT, indicative of the infarct core- reversibly damaged tissue. In contrast, the surrounding peripheral area demonstrates decreased CBF and CBV with increased TTP and MTT, representing the ischemic penumbra- a zone of potentially viable tissue that may benefit from timely intervention**.**

**Conclusion**

CT perfusion and MR perfusion are emerging techniques for evaluating the hemodynamics of abnormal tissues. Various techniques exist across different modalities, such as CT scans and MRI. The CT perfusion technique is commonly used due to its speed, affordability, and accessibility, especially in cases of stroke and other emergencies. It is also preferred for patients with any implants to avoid susceptibility artifacts. DEC and DSC are two MR perfusion techniques that require an exogenous contrast agent. The DCE perfusion technique is not as widely used as the DSC technique. High-grade tumors are best diagnosed with DSC. In addition to providing accurate tumor perfusion, diffusion, and microstructure analysis, it delivers perfusion maps with high SNR and spatial resolution, which are extremely useful for tumor identification, differentiation, and delineating tumor boundaries. ASL is highly recommended for contrast-free quantitative and repeatable perfusion imaging and is preferred for low-grade tumor detection. DSC is the preferred technique for high-resolution perfusion mapping and angiogenesis analysis of high-grade or aggressive tumors.

**Disclaimer (artificial intelligence)**

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during the writing or editing of manuscripts.

**Consent and ethical approval**

Not required

**Competing interests**

Authors have declared no conflict of interest

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