Arab American University
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Department of Health Sciences
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Assessing the Feasibility and Perceptions of Brain Perfusion Imaging with Computed Tomography

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Declaration

I declare that, except where explicit reference is made to the contribution of others, this thesis is substantially my own work and has not been submitted for any other degree at the Arab American University or any other institution.

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Dedication

To Palestine, my beloved homeland, the cradle of my identity and the root of every aspiration I carry. Your history, your beauty, and your enduring struggle have always been my silent companion. In every step of this academic journey, I carried you in my thoughts, your resilience inspired my strength, and your hope nourished my determination. This work is a modest offering to your legacy and a reflection of my deep gratitude for belonging to your soil.

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Assessing the Feasibility and Perceptions of Brain Perfusion Imaging with Computed Tomography

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Abstract

This study aimed to assess the feasibility and perceptions of brain perfusion imaging using CTP among healthcare professionals in governmental hospitals across the West Bank, Palestine. Conducted in 2025, the research adopted a quantitative, cross-sectional design targeting radiographers, radiologists, and neurologists. A structured and validated questionnaire was used to evaluate participants' KAP regarding CTP, and to explore institutional and technical barriers limiting its clinical application.

A total of 152 professionals participated. The majority were radiographers, 85.5%, followed by radiologists, 8.6%, and neurologists, 5.9%. While 75% reported familiarity with CTP, only 50.4% could identify key perfusion parameters accurately, and just 48% expressed confidence in interpreting CTP results. Awareness of contraindications was moderate, 66.4%, while 78.9% reported inadequate training opportunities. Additionally, 65.1% expressed concern about radiation exposure, and 40.8% cited limited access to advanced imaging equipment.

Despite challenges, 88.1% of participants believed CTP effectively evaluates cerebral perfusion, and 87.5% trusted its diagnostic value; knowledge correlated significantly with attitudes ($r = 0.501$, $p < 0.01$) and practice ($r = 0.199$, $p < 0.05$). The study recommends targeted training, standardized protocols, and infrastructure investment to bridge the gap between perceived value and clinical use of CTP as a fast, accessible alternative to MRI in resource-limited settings like Palestine.

Keywords: Computed Tomography Perfusion, Stroke Imaging, Clinical Practice, Palestine, Healthcare Professionals.

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List of Definitions of Abbreviations

Abbreviations	Title
AIS	Acute Ischemic Stroke
ASPECT	Alberta Stroke Program Early Computed Tomography Score
BBB	Blood-Brain Barrier
CBF	Cerebral Blood Flow
CBV	Cerebral Blood Volume
CT	Computed Tomography
CTA	Computed Tomography Angiography
CTP	Computed Tomography Perfusion
DCE	Dynamic Contrast-Enhanced
DSA	Digital Subtraction Angiography
DWI	Diffusion-Weighted Imaging
EVT	Endovascular Thrombectomy
GDP	Gross Domestic Product
GRE	Gradient Echo
HU	Hounsfield Unit
ICA	Internal Carotid Artery
KAP	Knowledge, Attitudes, and Practices
LMIC	Low- and Middle-Income Countries
LVO	Large Vessel Occlusion
MRA	Magnetic Resonance Angiography
MRI	Magnetic Resonance Imaging
MTT	Mean Transit Time
NCCT	Non-Contrast Computed Tomography
NICE	National Institute for Health and Care Excellence
NPV	Negative Predictive Value
PT	Patient
PET	Positron Emission Tomography
PPV	Positive Predictive Value

RAPID	Rapid Processing of Perfusion and Diffusion
SPSS	Statistical Package for the Social Sciences
SPECT	Single Photon Emission Computed Tomography
SWI	Susceptibility-Weighted Imaging
Tmax	Time-to-Maximum
TOF	Time of Flight
tPA	Tissue Plasminogen Activator
TTP	Time to Peak
WM	White Matter

Chapter One: Introduction to The Study

1.1 Introduction

Computed Tomography Perfusion (CTP) is a method of functional imaging that produces numerical maps of hemodynamic factors like blood flow, blood volume, and mean transit time. CTP was first introduced by Leon Axel in 1980 and has rapidly gained widespread use in various diagnostic applications. It is of particular value in characterizing diseases associated with inadequate blood flow, monitoring disease progression, and differentiating between viable and non-viable tissues (Chung et al., 2023). The regions were divided according to blood flow to the areas with more active areas that show higher blood, oxygen, and glucose levels, and less active or injured areas display lower values. It is often used to evaluate conditions such as epilepsy, dementia, stroke, head injury, and brain tumors, or to assist with brain or neck vessel surgeries (Saint Luke's Health System, n.d.).

Computed Tomography Perfusion tracks alterations in Hounsfield unit (HU) values per pixel to measure multiple perfusion parameters such as Mean Transit Time (MTT), Cerebral Blood Flow (CBF), Cerebral Blood Volume (CBV), and Time to Peak (TTP). By repeatedly scanning, pixel concentration versus time curves is created. These curves are used to calculate different perfusion measures for each pixel, resulting in various perfusion maps. Quantitative tissue perfusion values are determined based on the correlation between the contrast concentration versus time patterns in inflowing arteries, the tissue being supplied, and draining veins (Parsons, 2008).

Evidence from previous trials suggests that patients have better clinical outcomes if they have a salvageable brain when symptoms first appear and if they receive it. Each additional half-hour of waiting for treatment increases the likelihood of adverse clinical outcomes by about 14%. Hence, the importance of choosing an early detection method for brain ischemia using accurate methods (Menon et al., 2015). Compared to other imaging techniques like magnetic resonance imaging (MRI), MRI offers superb sensitivity and diagnostic precision, although it is less readily accessible, has specific contraindications, and usually takes more time to complete, typically around 20 to 30 minutes as opposed to just 10 to 15 minutes for computed tomography (CT) scans (McVerry, 2014).

While brain CTP has its benefits, there are difficulties related to radiation exposure (Zensen et al., 2020). Further, the contrast agents utilized in CTP examinations have the potential to cause negative responses, such as nephropathy and temporary decline in renal function (White & Sheth, 2017). With these dangers in mind, it is crucial to evaluate the practicality and medical approval of CTP to confirm that its advantages surpass its possible risks.

The human brain, despite representing only two and a half percent of body weight, is highly metabolically active, accounting for about 25% of the body's metabolic demands. Due to this, the brain is susceptible to disruption in blood flow (DeSai & Hays Shapshak, 2021). This is normally maintained at a stable rate of approximately 50 ml/ 100g of brain tissue per minute through cerebrovascular autoregulation (Claassen et al., 2021). When cerebral blood flow is compromised, cerebral ischemia occurs, leading to brain dysfunction and damage. The severity of neuronal injury depends on both the extent and duration of the reduced blood flow.

The main cause of focal brain ischemia is usually a blockage in the arterial blood supply to the brain, typically caused by thrombosis or embolism. If the ischemia continues for an extended time, it leads to irreversible neuronal damage, which causes an ischemic stroke (Alakbarzade & Pereira, 2018). Cerebral ischemia is a leading cause of brain injury, if it continues for 24 hours or more, it leads to death (Sacco et al., 2013). Stroke ranks as the second most common cause of mortality and the third most common cause of disability. It occurs when a blockage or rupture of a blood vessel leads to the sudden death of brain cells due to a lack of oxygen supply (Johnson et al., 2016). Worldwide, an estimated 12 million new strokes occur annually, with an estimated one out of every four adults who are older than 25 having a stroke during their lifetime (GBD 2019 Stroke Collaborators, 2021).

The approximate worldwide expense of stroke exceeds US $ 721 billion (equivalent to 0.66% of the global GDP) (Feigin et al., 2022). The number of stroke cases continued to rise from 1990 to 2019, with an increase in low and middle-income countries, and the decline slowed from 2010 to 2019 (GBD 2019 Stroke Collaborators, 2021). It is expected that the global burden of stroke will continue to grow without the wide deployment of stroke prevention strategies and interventions in low- to middle-income countries (Sacco et al., 2013).

In 2019, ischemic stroke accounted for 62.4% of all new strokes, while intracranial hemorrhage accounted for 27.9%, and subarachnoid hemorrhage accounted for 9.7% (GBD 2019 Stroke Collaborators, 2021). The care and handling of patients with ischemic and hemorrhagic stroke are very significant. This thesis specifically addresses ischemic strokes, excluding the discussion of hemorrhagic stroke.

The care of stroke patients is influenced by the idea that time is crucial for their treatment. This idea highlights the significance of promptly administering medical care to individuals who have had a stroke (Yang et al., 2022), predominantly based on neuroimaging. Rowley 2001 introduced the concept of the Four P's, referring to parenchyma, pipes, perfusion, and penumbra as the focus of stroke imaging.

The United Kingdom National Institute for Health Care and Excellence (NICE) guidelines recommend using CT as the primary method for diagnosing hyperacute stroke. This involves utilizing non-contrast computed tomography (NCCT), computed tomography angiography (CTA), and CTP to determine eligibility for thrombectomy and differentiate between ischemic and hemorrhagic stroke. However, MRI is primarily utilized for producing detailed and high-quality anatomical brain images. MRI-based methods, like magnetic resonance angiography (MRA) and diffusion-weighted imaging (DWI), offer in-depth data on the size and position of a clot and produce a precise image of acute infarction, according to several studies (Kakkar et al., 2021).

In Palestine, a lower-middle-income country (LMIC) in the Middle East, statistics from 2014 indicate that cerebrovascular disease accounted for 11% of deaths in public hospitals, ranking as the second leading cause of death following coronary heart disease (Khatib et al., 2018). A study conducted in 2018 at the Palestinian Ministry of Health hospitals in Ramallah and Nablus found that only 25% of patients were brought to the hospital by emergency medical services, with just 61% arriving within the critical three-hour timeframe for reperfusion therapy. Out of those who were punctual, just 57% got imaging within the recommended 45 minutes for tPA therapy according to European and American guidelines. Although every patient got a head CT scan, just 8% also got an MRI, and 4% had carotid Doppler imaging (Rosenbloom & Leff, 2022).

The gap attached to this thesis, and despite the recognized benefits of CTP in identifying viable brain tissue and supporting timely intervention in stroke management, its practical integration within healthcare systems, particularly in lower-middle-income countries (LMICs) like Palestine, remains underexplored. Current literature underscores the advantages of CTP over other modalities such as MRI in terms of speed and accessibility. However, no research has been done to assess the readiness, knowledge, and attitudes of healthcare professionals in government hospitals in the West Bank toward using CTP for stroke management.

The gap lies in understanding how institutional and technical barriers such as limited expertise, workflow challenges, and resource constraints may impede the effective use of CTP in these settings. This study seeks to address this gap by evaluating healthcare professionals' perceptions and practices around CTP, providing insights into the potential barriers that limit its adoption, and proposing strategies to facilitate its integration in acute stroke care, particularly within resource-limited healthcare environments.

This study aims to evaluate healthcare professionals' (Radiographers, Radiologists, and Neurologist) knowledge, attitudes, and practices regarding CTP analysis in stroke management within government hospitals in the West Bank. By assessing the current understanding and application of CTP among radiologists, radiographers, and neurologist, the research seeks to identify practical challenges that may hinder its effective utilization, such as technical expertise and workflow barriers. The findings will provide insights to enhance diagnostic practices and treatment pathways, ultimately improving patient outcomes in stroke care. Additionally, the research may inform future educational initiatives and policy recommendations to optimize the use of advanced imaging techniques in resource-limited settings.

Feasibility, in this context, pertains to more than just the technical aspects of image capture and quality. It also encompasses patient safety, the efficacy of diagnostic information, and the cost ramifications of widespread utilization. Moreover, this research delves into healthcare providers' opinions on the usefulness and safety of CTP.

1.2 Significance of The Study

The importance of this thesis lies in its exploration of the critical role of CTP in improving the diagnosis and treatment of stroke. Stroke remains a leading cause of death and disability worldwide, and timely intervention is crucial for reducing its impact. By assessing the feasibility of CTP in early stroke detection, the thesis highlights how this imaging technique can facilitate faster decision-making in emergency care, improving patient outcomes by identifying salvageable brain tissue. Additionally, it evaluates CTP’s practicality in low- and middle-income countries (LMICs), like Palestine, where more advanced imaging tools such as MRI are less accessible. The search results seek to demonstrate how CTP, as a cost-effective and widely available tool, could be a viable alternative to more expensive and slower diagnostic methods in resource-limited settings.

Moreover, the thesis addresses concerns about patient safety, particularly the risks of radiation exposure and the use of contrast agents in CTP, balancing these risks against the diagnostic benefits. Understanding healthcare provider perceptions of CTP is another critical aspect, as their acceptance of the technology will influence its integration into clinical practice. Additionally, by exploring economic considerations, the thesis may offer valuable insights into the cost effectiveness of CTP, emphasizing its role in reducing healthcare expenses by improving diagnostic accuracy and minimizing delays in treatment. This research could contribute to shaping future stroke management strategies, particularly in regions with constrained healthcare resources.

1.3 Problem Statement

The dynamic and rapidly evolving field of medical imaging, especially in acute stroke management, requires healthcare professionals, including radiographers, radiologists, and neurologists, to continuously update their skills and knowledge. However, there may be significant gaps in understanding and utilizing advanced imaging techniques like CTP in government hospitals, which could negatively impact the quality of stroke care. This study aims to assess the knowledge, attitudes, and practices of healthcare providers regarding CTP and identify the practical, institutional, and technical barriers they face. Addressing these issues can lead to improved diagnostic accuracy, better patient outcomes, and enhanced satisfaction among healthcare professionals, contributing to more effective integration of CTP into clinical practice and improved stroke survival rates.

1.4 Research Objectives

Main Objective:

1. To evaluate the knowledge levels, the attitudes toward practices, and the potential challenges for the target group regarding CTP.
2. To draw conclusions and recommendations to enhance diagnostic practices, streamline treatment pathways, and capitalize on the advantages of advanced imaging techniques in acute stroke cases.

Secondary Objectives:

1. Assess training and educational needs available for healthcare professionals regarding CTP to identify gaps and opportunities for improvement.

2. Investigate healthcare professionals' perceptions of the effectiveness and safety of CTP compared to other imaging modalities, such as MRI or standard CT scans.
3. Assess institutional barriers (e.g., equipment availability, budget constraints) and cultural attitudes that may hinder the effective integration of CTP into clinical practice.
4. Explore the relationship between healthcare professionals' knowledge and attitudes toward CTP and patient outcomes in acute stroke cases to establish evidence of its impact on care quality.
5. Collect qualitative feedback from radiographers, radiologists, and specialists regarding their experiences and challenges with CTP, which can inform future training and policy recommendations.

1.5 Research Questions

1. What are the knowledge levels, perceptions, and practices of healthcare professionals regarding CTP of the brain analysis for brain perfusion assessment?
2. What potential challenges exist that may hinder the effective integration and application of Computed Tomography Brain Perfusion Analysis CTP for brain perfusion analysis among healthcare professionals?
3. What training and educational needs do healthcare professionals identify regarding CTP to improve their knowledge and practices?
4. How do healthcare professionals perceive the effectiveness and safety of CTP compared to other imaging modalities, such as MRI or standard CT scans?
5. What recommendations can be proposed to improve the application of CTP in clinical practices?

1.6 Hypotheses

1. H0 (Null Hypothesis): There is no significant relationship between the knowledge levels and attitudes of healthcare professionals regarding CTP and their practices in the management of acute stroke cases. This means that variations in knowledge and

attitudes do not lead to significant differences in the effective utilization of CTP in clinical settings.

2. H1 Alternative Hypothesis) There is a significant relationship between the knowledge levels and attitudes of healthcare professionals regarding CTP and their practices in the management of acute stroke cases. Specifically, it is hypothesized that as the knowledge and positive attitudes of healthcare professionals increase, the effective utilization of CTP in clinical practice will also increase.

1.7 Study Limitations

This research has multiple constraints. In terms of concepts, the focus is on the understanding, beliefs, and behaviors of healthcare workers about CTP for treating ischemic stroke. Furthermore, the diversity in opinions among different categories, like radiologists and radiographers, may impact the applicability of the results. Geographically, the study focuses only on government hospitals in the West Bank, so findings may not apply to private hospitals or other areas, and variations in hospital facilities could impact the outcomes.

The data will be gathered during a set timeframe, potentially missing out on advancements in CTP technology or changes in stroke management practices that could happen afterward. The study participants will consist of healthcare workers, such as radiologists, radiographers, and stroke care specialists, selected through a non-probability convenience sampling approach. Those without relevant professional experience in imaging or stroke management will be excluded to ensure that participants have focused insights.

1.8 Conceptual Definitions

2. Computed Tomography Perfusion (CTP): A method of functional imaging that creates quantitative maps of hemodynamic factors like blood flow, blood volume, and mean transit time. Regular blood flow is essential for proper tissue function, and changes in it could indicate an underlying health condition (Chung et al., 2023).

3. Cerebral Ischemia: Cerebral ischemia, or brain ischemia, happens when the brain doesn't receive enough blood flow to meet its metabolic needs. This results in reduced oxygen delivery, causing cerebral hypoxia and resulting in brain tissue death, cerebral infarction, or ischemic stroke (Columbia Neurosurgery, n.d.).

4. Acute Stroke**:** A period of noticeable neurological dysfunction due to focal brain, retinal, or spinal cord ischemia or hemorrhage with proof of acute infarction or hemorrhage on imaging (MR, CT, retinal photomicrographs), regardless of how long symptoms have been present (Canadian Stroke Best Practice, 2022).

5. Neuroimaging: A branch of medical imaging that focuses on the brain. In addition to diagnosing disease and assessing brain health (University of Utah Health, n.d.).

6. Cerebral Blood Flow (CBF): The blood volume that flows per unit mass per unit time in brain tissue and is typically expressed in units of ml blood / (100 g tissue min) (Fantini et al., 2016).

7. Time-to-peak (TTP): This is the moment when the concentration of contrast material reaches its peak (Murphy, 2020).

8. Mean transit time (MTT): The mean duration, measured in seconds, that red blood cells remain in a specific amount of capillary circulation (Deng, 2022).

9. Cerebral Blood Volume (CBV): The amount of blood in a specific quantity of brain tissue, typically measured as milliliters of blood per 100 grams of brain tissue (Sharma, 2020).

Chapter Two: Literature Review

2.1 Introduction

Cerebrovascular disease encompasses various conditions affecting blood flow to the brain, including strokes and brain aneurysms. The most common type is stroke, which can result in significant disability or death, highlighting the critical need for prompt medical intervention. In the United States, cerebrovascular disease is a leading cause of morbidity and mortality, contributing to over 160,000 deaths annually. Major risk factors include hypertension, atherosclerosis, and blood clots, which can impede or rupture blood vessels, disrupting cerebral blood supply (Cleveland Clinic, 2022).

In 2022, stroke emerged as a major cause of mortality in both the West Bank and the Gaza Strip, according to data from the Palestinian Central Bureau of Statistics. In the West Bank, strokes accounted for 10.5% of all deaths, ranking fourth after ischemic heart disease at 25.3%, cancer at 13.8%, and complications of diabetes at 12.8%. In the Gaza Strip, strokes were responsible for 11.6% of total deaths, similarly placing third behind ischemic heart disease at 17.8% and cancer at 15.1%. These figures underscore the substantial burden of stroke in the Palestinian territories, highlighting the critical need for enhanced stroke prevention, timely diagnosis, and effective treatment interventions to reduce stroke-related morbidity and mortality (Palestinian Central Bureau of Statistics, 2023).

The current Palestinian health system consists of five primary healthcare providers: The Ministry of Health (MOH), Palestinian Military Medical Services (PMMS), United Nations Relief and Works Agency for Palestine Refugees (UNRWA), Palestinian non-governmental non-profit organizations (NGOs), and the private for-profit sector (World Health Organization, 2021).

Due to Palestine's status as an occupied country in a constant state of conflict, the impacts of war on health extend beyond physical harm, affecting healthcare systems by targeting facilities and disrupting services. This limits access to medical treatments, hinders the development of essential care pathways, and exacerbates health inequalities. Research is needed to address gaps in emergency care, alongside policies that uphold Palestinian human rights and dignity to mitigate structural barriers (Rosenbloom & Leff, 2022).

Neuroimaging plays a crucial role in directing thrombolytic and interventional treatment for stroke. Positive results can only be achieved in a relatively brief period of less than three to four and a half hours from when symptoms first appear (Ogbole et al., 2015).

A 2022 study by Montaser Ahmed 2022, Evaluation of Advanced Medical Imaging Services at Government Hospitals-West Bank, assessed medical imaging services in the West Bank. It found 28 radiology technicians operating CT and MRI devices across seven government hospitals, with MRI devices available in 42.8% of hospitals compared to CT in all hospitals. Of the technicians, 17.9% worked on MRI and 82.1% on CT. The study concluded that imaging quality in Palestine is low, with self-development rates among workers at 59.2%-65.8%, and MRI availability is insufficient to meet the population's needs compared to other countries (Abushab et al., 2018).

Based on the context provided, the hypothesis of the study focuses on assessing the feasibility, perceptions, and decision-making processes of radiographers, radiologists, and neurologist regarding neuroimaging techniques, particularly CTP, in the management of cerebrovascular diseases such as stroke in Palestine. The study hypothesizes that the current infrastructure and limited availability of advanced neuroimaging services significantly hinder the effective diagnosis and treatment of strokes. It posits that these limitations, including the low availability of MRI devices and a shortage of trained technicians, impact the confidence and perceptions of healthcare professionals in utilizing neuroimaging for timely interventions.

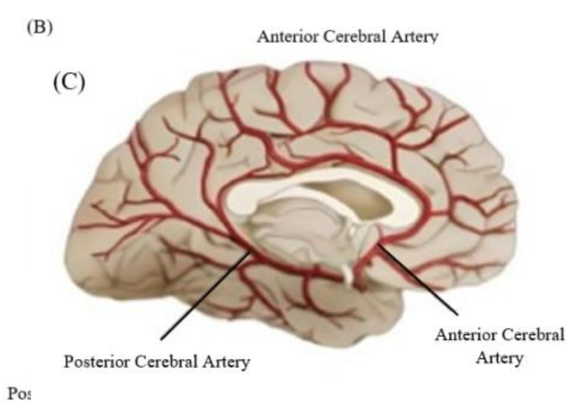
Consequently, this may lead to delayed or inadequate responses to cerebrovascular emergencies, ultimately affecting patient outcomes. The objectives of the thesis will include evaluating the current state of neuroimaging services in Palestine, understanding the perceptions and attitudes of key healthcare professionals, analyzing how these perceptions influence clinical decision-making, identifying gaps in emergency care pathways, and proposing policy interventions to enhance access to neuroimaging services. By investigating these aspects, the study aims to contribute valuable insights into improving emergency care for patients with cerebrovascular diseases, especially stroke, and addressing the critical health challenges faced in the region.

2.2 Cerebral Vessel Anatomy

The following sections describe the anatomical structure of the cerebral circulation. They highlight the main arterial pathways and the organization of the capillary networks within the brain.

2.2.1 Arterial and Capillary Systems

The brain receives its blood supply from two internal carotid arteries (ICAs) and two vertebral arteries, which together form the circle of Willis at the skull base, uniting anterior and posterior circulations (Figure 2.1). The ICAs, supplying 80% of the brain's blood, enter through the carotid canal, traverse the dura mater near the cavernous sinus, and bifurcate into the middle and anterior cerebral arteries in the subarachnoid space. The vertebral arteries enter the vertebral foramina at the sixth cervical vertebra (C6), exit at the first cervical vertebra (C1), loop around the atlas, and merge to form the basilar artery (BA), which divides into posterior cerebral arteries (Agarwal & Carare, 2021).



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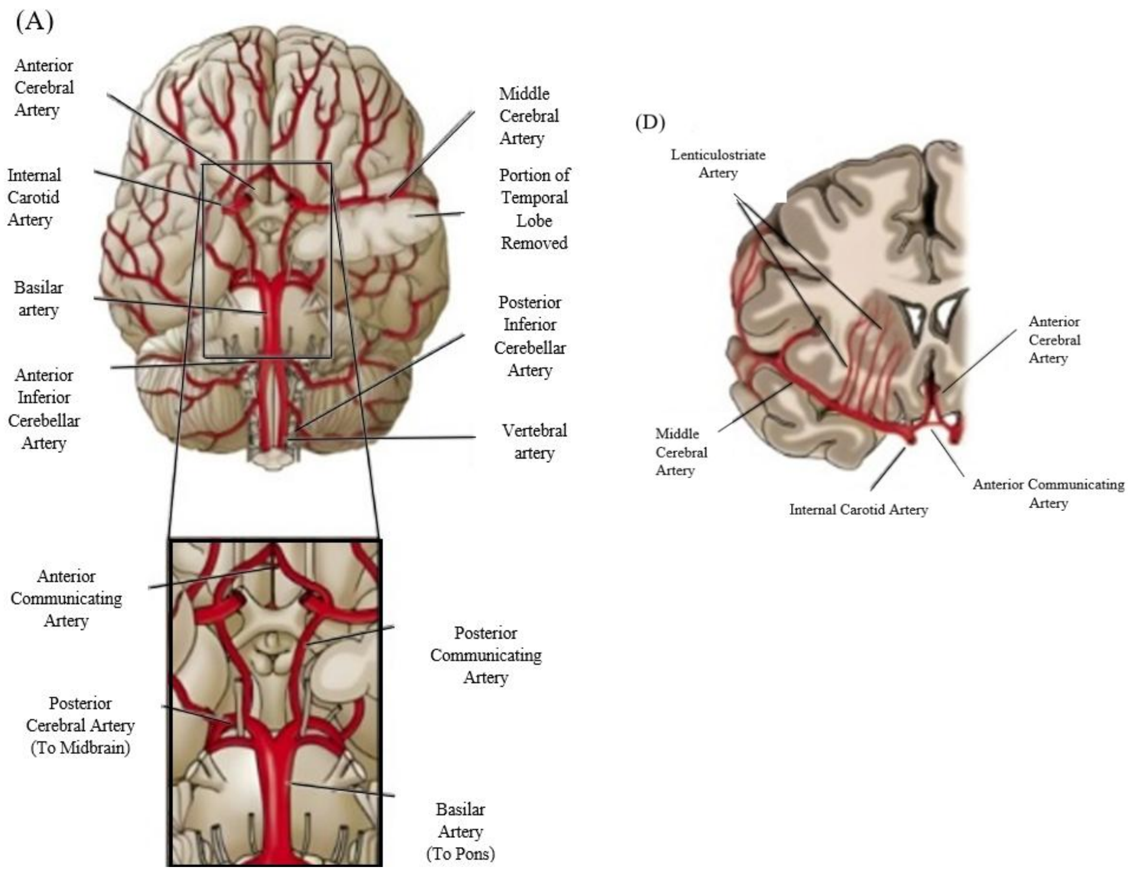

Figure 2.1: The main blood vessels in the brain. Lateral (A) and (B) midline views display frontal, central, and rear cerebral arteries. (C) The circle of Willis is visible in the ventral view of the enlarged boxed area. (D) Diagram of a frontal section illustrating the path of a middle cerebral artery (Purves et al., 2001).

The brain's capillary system consists of an intricate network of small blood vessels that play a crucial role in maintaining the brain's microenvironment. Gray matter (GM) has a higher density of capillaries than white matter (WM) due to its greater energy demands. The capillary walls comprise a single layer of endothelial cells, pericytes, and basal lamina, forming the blood-brain barrier (BBB) (Wong et al., 2013). This barrier tightly regulates the movement of ions, solutes, and other substances between the bloodstream and the brain, protecting the neural tissue from fluctuations in the surrounding environment. Additionally, astrocytic end feet, containing aquaporin four water channels, are closely associated with the abluminal surface of the capillaries, facilitating the regulation of water and solute exchange within the brain parenchyma (Agarwal & Carare, 2021).

2.2.2 Venous System

The microvasculature in the parenchyma carries oxygen-depleted blood from the ventricular ependymal wall outwards towards the cortex. Significant cortical bridging veins, like the Labbè vein and the Trolard vein, drain into the superficial dural venous sinuses (Agarwal & Carare, 2021). The superior sagittal sinus divides into right and left transverse sinuses before merging with sigmoid sinuses, eventually connecting to the internal jugular veins, neck vessels, and spinal venous plexi, carrying deoxygenated blood to the right atrium (Bayot et al., 2023).

The inferior sagittal sinus, the vein of Galen, and the straight sinus are formed by deep internal veins and drain into the superior sagittal sinus at the back. Venous drainage in the front happens via the cavernous sinus and sigmoid sinuses (Figure 2.2). There are numerous anatomical differences in veins, including variations in quantity, size, symmetry between hemispheres, and how they drain outside the brain, which all contribute to the intricate nature of the cerebral venous system. It should be recognized that dural venous sinuses lack valves, allowing for retrograde flow towards the head in situations where downward flow is obstructed (Agarwal & Carare, 2021).

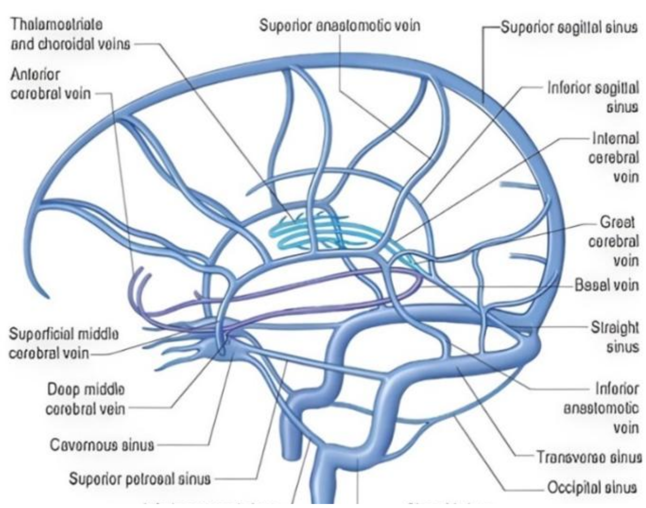

Figure 2.2: The Venous sinuses that return blood to the internal jugular vein are the superior sagittal sinus, inferior sagittal sinus, straight sinus, transverse sinus, and sigmoid sinus (Neurology Needs. n.d.).

2.3 Stroke Pathophysiology

Ischemia occurs when there is a decrease in blood flow due to a blockage in any artery, resulting in a lack of oxygen and nutrients to the surrounding tissues, or occurs when there is a blockage in the neck or cerebral arteries, resulting in localized cerebral ischemia. If the arterial blockage is not repaired quickly, the brain tissue will not receive enough oxygen and glucose, depleting its supply and not being able to meet the metabolic needs of the brain (Campbell et al., 2019). During a stroke, if left untreated, the average patient loses about 1.9 million neurons per minute (Saver, 2006).

As previously mentioned, decreased cerebral blood flow in stroke is due to a blockage in the blood vessels, which reduces blood flow and causes ischemia (Claassen et al., 2021), cerebral blood flow measures the amount of blood flow to a specific area of brain tissue over a specific period of time and is usually expressed in ml/100 g/min (Fantini et al., 2016), the normal rate of cerebral blood flow is about 50 ml/100 g/min, and loss of function is observed at least 22 ml/100 g/min, this loss is responsible for the onset of clinical symptoms 10 seconds after the onset of ischemia (Claassen et al., 2021).

The normal range in human gray matter is about 60 ml/100 g/min, which means that about one ml of blood is delivered to 100 g of brain tissue every second. With an average brain tissue density of one g/ml, about 1% of the total tissue volume receives new blood delivered every second (Joris et al., 2018). With a lower level of white matter of about 20 ml/100 g/min (Fantini et al., 2016). The brain can detect changes in cerebral blood flow and can regulate them through vasodilation or vasoconstriction to adjust cerebral blood flow levels accordingly (Wang et al., 2022). In ischemic stroke, when the main source of blood flow to the brain is blocked, other vascular pathways known as collateral circulation can provide a temporary supply of blood flow at reduced levels (Maguida & Shoaib, 2023).

The brain's critical dependence on a continuous supply of oxygen and glucose makes it highly vulnerable to disruptions in CBF, such as those occurring during a stroke. The sudden reduction in CBF rapidly exhausts energy stores, particularly within the ischemic core, where the breakdown of ionic gradients can swiftly lead to irreversible cellular damage and death if not promptly addressed (Sifat et al., 2022).

Surrounding this core is the penumbra, a region that, despite reduced perfusion, retains some blood flow through collateral vessels. This residual perfusion offers a crucial, albeit limited, opportunity for neuronal recovery (Yang & Liu, 2021). However, the survival of neurons in the penumbra is precarious, threatened by two major factors: the failure of glutamate transporters to effectively clear excess glutamate, leading to excitotoxicity, and the occurrence of peri-infarct depolarizations (PIDs), which increase both energy consumption and glutamate release, exacerbating neuronal damage (Rakers & Petzold, 2016; Passlick et al., 2021).

As ischemia progresses, the energy depletion further disrupts the Na+/K+ homeostasis, leading to cellular dysfunctions that manifest as cytotoxic and ionic edema. Cytotoxic edema, driven by the intracellular accumulation of water, Na+, and Cl-, occurs when CBF falls below approximately 30 ml/min/100 g, resulting in cell swelling, reduced extracellular space, and depletion of extracellular Na+ (Rakers & Petzold, 2016). If the ischemic insult persists, this condition can progress to ionic edema, characterized by extracellular water accumulation due to osmotic gradients.

This condition eventually progresses to vasogenic edema, which precedes hemorrhagic transformation, a severe and often fatal complication of acute ischemic stroke (Gu et al., 2022). The breakdown of the blood-brain barrier (BBB) during vasogenic edema allows macromolecules to leak into the brain tissue, further exacerbating swelling and increasing the risk of catastrophic outcomes such as fatal herniation (malignant infarction). This complex interplay between CBF, energy metabolism, and ionic balance underscores the urgent need for timely intervention to mitigate ischemic damage and preserve brain function during stroke (von Kummer & Dzialowski, 2017).

2.4 Ischemic Core and Penumbra

The ischemic core in stroke refers to brain tissue that has suffered irreversible damage, primarily consisting of apoptotic and necrotic cells. This region experiences critically low CBF, typically identified as 8–10 ml/100g/min, below which neuronal death becomes permanent across various species (Jaffer et al., 2011). Surrounding the core is the penumbra, a zone of electrically silent but viable tissue where neurons are unable to transmit signals due to reduced blood flow. However, essential functions, such as membrane cell pump activity and ionic gradient maintenance, are preserved despite compromised perfusion (d'Esterre et al., 2013). Grey matter in the penumbra is more vulnerable to ischemia than white matter, with critical CBF thresholds of approximately 10–12 ml/100g/min/ for grey matter and five ml/100g/min/for white matter (Arakawa et al., 2006).

The penumbra plays a pivotal role in ischemic stroke management, as it represents the area where therapeutic interventions aim to prevent progression to irreversible infarction. The upper threshold for electrical silence and neuronal dysfunction in the penumbra is estimated at a CBF of 22–25 ml/100g/min (Heiss, 2014). Without timely reperfusion, the penumbra gradually converts into the ischemic core, leading to permanent functional loss. However, with prompt restoration of blood flow typically within 30 minutes, the penumbra can recover fully, preserving brain function and minimizing neurological deficits (Liu et al., 2010; Goyal et al., 2020). This highlights the importance of rapid intervention, as it provides a critical window to salvage viable brain tissue and improve outcomes.

Several factors influence the fate of the penumbra. Time is crucial, as nearly two million neurons are lost every minute during ischemia. Thrombolytic treatments are most effective within four point five hours of symptom onset, beyond which their efficacy declines. Other factors include blood glucose levels, where hyperglycemia (> 7 mmol/L) is associated with larger infarct volumes and poorer outcomes, possibly as a marker rather than a direct cause of damage. Age also increases the risk of penumbral infarction, with a 0.65%

higher risk per additional year of age. Lastly, strong collateral circulation in the ischemic area can mitigate damage and improve tissue salvage (McVerry, 2014).

2.5 Treatment of Acute Ischemic Stroke

The possibility of rescuing brain tissue and function through prompt restoration of CBF prompted the study of therapies that provided immediate reopening of the blocked vessel. In addition to medical treatment for stroke symptoms, there are two primary interventions for acute ischemic stroke: Intravenous thrombolysis (IVT) with a recombinant tissue plasminogen activator known as alteplase and endovascular thrombectomy (EVT). Because brain infarction is time-sensitive, the effectiveness of treatment is dependent on time, and getting treated earlier increases the chances of a positive functional outcome (Jauch, 2024). The first line standard of care for patients with AIS within four and a half hours of symptom onset remains intravenous thrombolysis (Shafie & Yu, 2021).

2.5.1 Intravenous Thrombolysis (IVT)

Thrombolysis is the process of breaking down a blood clot that is rich in fibrin by using a thrombolytic agent, commonly alteplase. The tissue plasminogen activator (tPA) is named for its function of initiating plasminogen to attach to fibrin in a clot, resulting in a cleaved plasmin entity. After the clot forms, plasmin breaks down the main structure of the clot, which is fibrin, resulting in its dissolution (Baig & Bodle, 2023).

Fibrinolytic therapy in AIS focuses on dissolving blood clots to restore cerebral blood flow before the affected brain tissue suffers irreversible damage. The American Heart Association (AHA) and American Stroke Association (ASA) guidelines recommend intravenous (IV) alteplase, commonly known as tPA, as the primary thrombolytic treatment for AIS. When administered within four and a half hours of symptom onset, alteplase significantly improves functional outcomes. The efficacy of alteplase is highly time-dependent, with earlier treatment leading to better outcomes (Chester et al., 2019).

The Food and Drug Administration (FDA) approved IV-tPA for AIS in 1996 after the NINDS trial demonstrated that patients treated within three hours of stroke onset had over a 30% chance of achieving minimal or no disability after 90 days compared to those who did not receive the treatment. Despite its benefits, IV-tPA is associated with a two to seven percent risk of symptomatic intracranial hemorrhage, which can be fatal. Furthermore, it is less effective in recanalizing large vessel occlusions (LVOs), which are associated with higher mortality and disability rates (Chester et al., 2019; Schwamm et al., 2013).

2.5.2 Endovascular Thrombectomy (EVT)

Endovascular stroke therapy, which involves using mechanical devices to remove blood clots, is a successful method for treating acute stroke. The primary benefit of endovascular treatment is its high recanalization rate. Modern thrombectomy devices have a success rate of up to 88% in restoring blood flow. This is about twice as efficient as IV tPA, with a recanalization rate of 10-50% based on the blood clot's location (Albers et al., 2017). Endovascular thrombectomy has fundamentally changed the outlook for individuals suffering from acute ischemic stroke. Reperfusion of LVO in the anterior and posterior circulations can significantly enhance patients' functional outcomes (Dhar, 2023).

Several randomized trials of EVT combined with intravenous thrombolysis have shown very positive outcomes for anterior circulation stroke within six hours of onset, regardless of patient characteristics. Rapid implementation of EVT in clinical settings is highly effective, with few patients requiring treatment. In the 6-24-hour time frame after the initial event, the effect is most significant for patients in whom brain tissue can still be salvaged (Wassélius et al., 2022).

Mechanical thrombectomy can result in various intra-procedural and postoperative complications, which must be minimized to optimize patient outcomes. These include access-site issues such as vessel or nerve injury, hematoma, and infection, as well as device-related complications like vasospasm, arterial perforation, or device misplacement. Serious risks like intracerebral or subarachnoid hemorrhage and embolization to new vessels also exist. Additional complications can arise from anesthesia or contrast use. Some are life-threatening, prolonging hospital stays and delaying rehabilitation, necessitating close monitoring and management by neurointerventionists and stroke teams (Balami et al., 2017).

2.6 Imaging in Acute Ischemic Stroke

Medical imaging plays an important role in the management of patients with acute ischemic stroke because it provides information for treatment decisions. The success of reperfusion therapies has been attributed in part to acute stroke imaging. Through patient selection, rapid diagnosis, and treatment delivery (Zerna et al., 2018).

2.6.1 Nuclear Medicine

A brain perfusion scan evaluates blood flow in specific brain regions using radiotracers in Single Photon Emission Computed Tomography (SPECT) or Positron Emission Tomography (PET) imaging. PET provides detailed metabolic data using tracers like F18 Fluorodeoxyglucose (FDG), while SPECT employs technetium-99m compounds to assess regional CBF. Radiotracers are administered via injection or inhalation, with cameras detecting changes in blood flow and oxygen use. These techniques are vital for diagnosing and treating neurological disorders. While generally safe, risks include mild discomfort, rare allergic reactions, and radiation exposure, underscoring the importance of medical evaluation to ensure the benefits outweigh the risks. Patient cooperation and safe positioning are crucial for successful imaging (Kaechele & Chakko, 2023).

Furthermore, PET imaging might encounter difficulties in visualizing tiny structures like blood vessel walls because of tissue-like collinearity and position bonding, causing image blurring. Despite the development of technologies like PET or MRI scanners, which combine two imaging techniques, the partial volume effect continues to pose a challenge as it causes signal scattering in small lesions. This results in a change in the signal, not a reduction, which can affect the measurement of lesion size and tracer uptake values. Innovations like attenuation correction using hybrid PET or CT scanners and spatial resolution improvement through algorithms have enhanced the quality of PET imaging, but challenges remain in small-scale imaging due to spatial restrictions (Pedersen et al., 2013).

2.6.2 Digital Subtraction Angiography (DSA)

Digital Subtraction Angiography (DSA) This technique involves inserting a small catheter into an artery in the leg and directing it to the blood vessels in the brain. A contrast dye is then injected through the same catheter, and X-rays are taken to see the blood vessels and identify any irregularities (Stanford Health Care, n.d.). DSA is a medical imaging method utilized to identify and validate abnormal lesions of cerebral blood vessels, like aneurysms, stenosis, fistula, malformations, etc. It is the gold standard for evaluating intracranial vascular problems and aids in treatment planning for patients with suspected vascular issues (Shaban et al., 2021). DSA is often used for planning treatments involving endovascular or open surgeries when noninvasive imaging is inconclusive or inconsistent (Nam et al., 2022).

Following DSA, various complications like stroke, allergic reaction from contrast dye, and bleeding or infection at the insertion site may arise. Cerebral angiography provides detailed, three-dimensional information on the cerebral vasculature and enables real-time examination of blood circulation. Nevertheless, severe neurologic issues like hemiparesis or dysarthria may arise following the DSA procedure as a result of either ischemic or hemorrhagic stroke. Groin hematoma is the most frequent complication in numerous studies, while there is a risk of kidney damage from the contrast agent used in DSA, especially in patients with pre-existing kidney dysfunction. Having a thorough grasp of the challenges linked to DSA can enhance the approach to treatment (Alakbarzade & Pereira, 2018).

2.6.3 Ultrasonography

Duplex ultrasound is typically used to screen for carotid artery stenosis in patients with suspected stroke. Transcranial Doppler ultrasound is frequently utilized to screen for cerebral artery vasospasm following subarachnoid hemorrhage. Ultrasonography is inexpensive and typically accessible in every emergency room, able to be conducted right at the patient's bedside. It does not have radiation, is not invasive, and is a secure method compared to other imaging choices. Yet, ultrasonography greatly relies on the skill of the operator. Achieving the correct acoustic window for visualizing a specific area can be difficult (Shafaat & Sotoudeh, 2023).

2.6.4 Magnetic Resonance Imaging (MRI)

Magnetic Resonance Imaging is a type of imaging technology that creates detailed three-dimensional anatomical images without the need for invasive procedures. It is commonly utilized to identify diseases, diagnose them, and monitor treatment progress (National Institute of Biomedical Imaging and Bioengineering, n.d.). As mentioned earlier, the most common cause of cerebral ischemia has been identified as ischemic stroke. Thrombus position and size can be evaluated using susceptibility-weighted imaging (SWI) with GRE sequences, with the thrombus showing up as a dark blooming artifact because of the paramagnetic characteristics of deoxyhemoglobin in the clot (Park et al., 2016).

Magnetic Resonance Angiography can be done with gadolinium-based contrast agents or non-contrast methods such as time-of-flight (TOF). In time-of-flight magnetic resonance angiography (TOF-MRA), moving blood creates a signal that is brighter than the surrounding stationary tissues. Both contrast-enhanced and non-contrast MRA are efficient methods for assessing vessel patency in AIS, each with its own set of advantages and disadvantages. TOF-MRA can be chosen instead of contrast-enhanced methods if the latter is not an option, but it has drawbacks such as longer scanning times, which raise the chances of motion artifacts, and a narrower field of view, restricting visualization of extracranial vessels (Boujan et al., 2018).

Diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) maps are key tools for detecting early ischemic damage. Cytotoxic edema, a precursor to irreversible tissue injury, occurs when water shifts intracellularly due to elevated sodium and calcium levels following the failure of membrane ion pumps. DWI identifies cytotoxic edema by detecting hyperintense lesions caused by restricted water diffusion (Zhang et al., 2022). However, T2 shine-through can mimic restricted diffusion on DWI, resulting from prolonged T2 decay in tissues, such as in subacute infarctions with vasogenic edema or epidermoid cysts. Comparing DWI with ADC maps helps distinguish between true restricted diffusion, where high DWI signals correspond to low ADC values, and T2 shine-through, where ADC values remain normal or increase (Petrovic, 2022).

There are two main categories of perfusion MRI techniques: contrast-based methods like dynamic susceptibility contrast (DSC) and dynamic contrast-enhanced (DCE) MRI, and non-contrast methods like arterial spin labeling (ASL). DSC-MRI assesses cerebral blood flow by monitoring signal reduction in T2 or T2*-weighted images after intravenous injection of a contrast agent, while DCE-MRI captures T1-weighted images in real-time before, during, and after contrast administration to evaluate tissue physiology. ASL, on the other hand, measures cerebral blood flow by labeling blood magnetically without invasive methods, allowing for the determination of hemodynamic parameters like blood flow, blood volume, and mean transit time, which are crucial for evaluating conditions like acute stroke and brain tumors. Perfusion MRI can detect changes in blood flow before structural changes appear in conventional MRI, providing valuable diagnostic data (Jahng et al., 2014).

Time-to-Maximum (Tmax) is a perfusion imaging parameter that measures the delay between the arrival of a contrast bolus in large arteries and brain tissue. It is commonly used in both CT and MRI perfusion to identify tissue at risk during acute ischemic stroke (Deng, 2024). Changing the Tmax range to four to six seconds enhances the precision of estimating ischemic penumbra and forecasting clinical outcomes in stroke patients who undergo imaging three to six hours after onset. This more stringent cutoff provides improved associations with the size of the infarct and the rescue of the penumbra (Olivot et al., 2009).

The evaluation of core and penumbra volumes with CTP and MRI methods, including DWI and perfusion-weighted imaging (PWI), is essential in deciding whether acute ischemic stroke (AIS) patients qualify for IVT and EVT in longer time frames. Automated software programs are used in randomized controlled trials (RCTs) to calculate volumes with predefined thresholds, emphasizing the significance of automated imaging processing in addressing the lack of standardization in advanced imaging (Fainardi et al., 2023).

The use of advanced imaging technology for patient selection is still a topic of debate, despite its importance, requiring a comprehensive assessment of its advantages and drawbacks. The DWI or PWI mismatch is a commonly utilized method in neuroimaging for the treatment of AIS patients. It involves calculating infarct and penumbra volumes from initial DWI and PWI scans using RAPID software. DEFUSE (diffusion and perfusion imaging evaluation for understanding stroke evolution) three recently demonstrated that patients with LVO and a mismatch on admission DWI/PWI or CTP (infarct volume < 70mL, infarct/penumbra ratio > 1.8, and penumbra volume > 15 mL) can still receive positive effects from IAT up to 16 hours after symptoms begin (Fainardi et al., 2023).

The Fluid-attenuated Inversion Recovery (FLAIR) sequence emphasizes the signal difference between lesions and surrounding tissues by using an Inversion Time (TI) that reduces the signal in cerebrospinal fluid (CSF) and tissues with matching T1 values. When combined with DWI, the FLAIR-DWI mismatch, where DWI lesions appear brighter than FLAIR images, helps assess the duration of ischemia. FLAIR images usually show infarct cores and may not detect lesions within the first 3 hours after onset, while DWI lesions are visible within the initial hour. This mismatch is particularly useful in AIS cases with unknown onset times. Recent studies have shown that patients with FLAIR-DWI mismatch who received IVT had positive outcomes despite a higher risk of symptomatic intracerebral hemorrhage, making it a valuable tool in identifying candidates for thrombolysis (Zhang et al., 2022).

2.6.5 Computed Tomography (CT)

As previously mentioned, diagnostic imaging is essential in the diagnosis and management of acute AIS and reperfusion, with CT being preferred due to its speed, simplicity, availability, and cost effectiveness. In contrast, MRI is less commonly used in the acute phase of stroke, primarily due to the challenges of maintaining 24-hour availability without interfering with other critical care services. The accessibility and efficiency of CT make it the imaging modality of choice for the evaluation of patients with stroke-like symptoms. Randomized controlled trials of IV-tPA and EVT have largely relied on CT-based patient selection (Cheng & Kim, 2015). Multimodal computed tomography, which includes NCCT, CTA, and CTP, is often used to determine eligibility for treatment in acute ischemic stroke.

2.6.6 Non-Contrast Computed Tomography (NCCT)

Non-contrast CT is the primary imaging tool for suspected stroke, distinguishing between ischemic and hemorrhagic types, and is essential for ruling out intracranial hemorrhage before reperfusion therapy. The patient should undergo NCCT promptly after stabilization in the emergency room. NCCT is sensitive in detecting calcifications and abnormalities. Ischemic stroke varies based on infarction timing: hyperacute (under 12 hours), acute (12-24 hours), subacute (24 hours to five days), and old (weeks after stroke). In the hyperacute phase, NCCT primarily rules out intracranial hematoma, which is known as the "hyperdense vessel sign". In acute infarction, NCCT shows a slight loss of the gray-white matter border due to cytotoxic edema (Shafaat & Sotoudeh, 2023). While in subacute infarction, it reveals vasogenic edema, mass effect, and tissue volume loss. There is a high likelihood of mass effect and herniation in this phase (Birenbaum et al., 2011).

Non-contrast CT is pivotal in managing ischemic strokes, as it helps assess the risk of complications like post-treatment infarction, intracranial hematomas, which can lead to brain herniation and death. The Alberta Stroke Program Early CT Score (ASPECT), introduced in 2000, is the most widely used method for stroke diagnosis. This system evaluates 10 regions within the middle cerebral artery territory, where each hypo-dense region observed on an NCCT scan results in a one-point deduction. Patients with an ASPECT score below 7 are typically associated with poorer clinical outcomes (Schröder & Thomalla, 2017).

However, the ASPECT scoring system depends significantly on the diagnostician's expertise in assessing specific domains. To enhance standardization, Brainomix Ltd. introduced e-ASPECT, a CE-certified, fully automated tool for ASPECT scoring (Herweh et al., 2016). Despite their advantages, automated systems face limitations due to technological variability, with differences in vendor algorithms affecting the consistency of target mismatch parameter assessments (Fainardi et al., 2023).

Another feature that can aid in distinguishing sudden neurological deficits is the " dense artery sign", which could indicate acute arterial blockage by a blood clot (Hurford et al., 2020). In an NCCT scan of the head, a greater density is found in the artery's interior, ranging from 60 to 90 HU, caused by a thrombus high amount of red blood cells, and typically unclothed blood has soft tissue HU values ranging from 30 to 60 HU (Kucinski, 2005). Nevertheless, the lack of this indication doesn't eliminate the possibility of a blood clot, so a follow-up CTA is necessary to pinpoint the blockage in the brain artery.

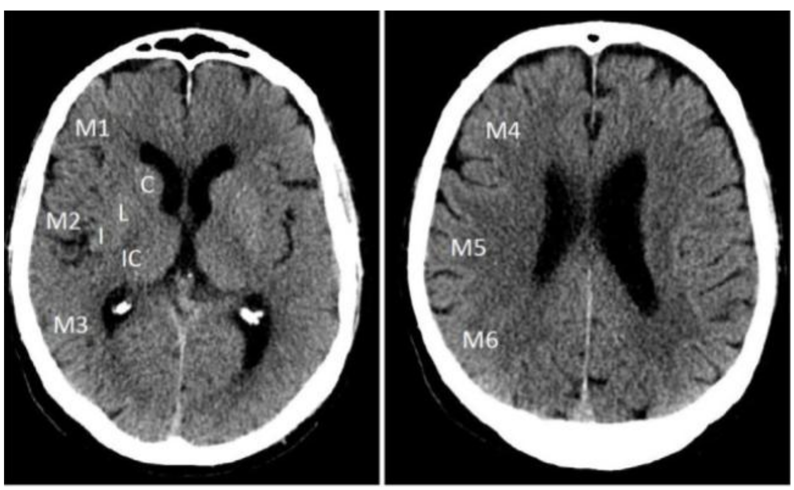

Figure 2.3: Template for Alberta Stroke Program Early Computed Tomography Score on non-contrast CT includes 10 regions spread across MCA territory at ganglionic and supraganglionic levels (Schröder & Thomalla, 2017).

2.6.7 Computed Tomography Angiography (CTA)

The Computed Tomography Angiography is an imaging test that combines a CT scan with an injection of contrast media to visualize blood vessels and tissues. The dye enhances the visibility of blood vessels, helping diagnose conditions like aneurysms, narrowed arteries, blood clots, and vascular abnormalities. It is widely used to assess the risk of stroke or heart attack and aid in treatment planning for various conditions. The procedure is quick, non-invasive, and generally safe, though there are minor risks of allergic reactions or tissue irritation from the contrast dye. Preparation involves fasting for a few hours and informing the radiologist of any allergies or kidney issues (Johns Hopkins Medicine, n.d.).

The Computed Tomography Angiography accuracy specificity of approximately 95%-97%, showing consistent agreement among observers (Duvekot et al., 2021). Understanding the usual results, helpful tips, and potential errors in interpreting CT imaging is essential for radiologists, stroke neurologists, and emergency department staff to make timely and precise decisions regarding treatment options after a stroke. This includes administering intravenous tissue plasminogen activator within 4.5 hours at primary stroke centers and transferring patients with large vessel blockage identified through CTA to comprehensive stroke centers for endovascular thrombectomy within 24 hours. Furthermore, in cases where diffusion-weighted MRI is not available, alternative methods such as multiple-phase CTA of collateral vessels and source image evaluation or CTP can be utilized to approximate core infarct volume. Both can differentiate between patients who will benefit from EVT and those who will not (Potter et al., 2019).

During Computed Tomography Angiography, iodinated contrast is injected as a bolus, and a single CTA (sCTA) is taken from the aorta to the vertex. During multiphase CTA (mCTA), one contrast bolus is used to capture two extra series in the peak venous and late venous phase, which only target the intracranial vasculature from the skull base to the vertex (Zhang et al., 2023).

The multiphase CTA collateral score is a straightforward scoring system that enables rapid assessment of delay in collateral vessel filling in acute ischemic stroke (Table 2.1). In some research, it has been demonstrated to be a more accurate indicator of clinical results and qualification for EVT compared to a choice made solely on sCTA (Figure 2.4) (Botz, 2024).

Table 2.1: A rating is provided on a scale ranging from zero to five, where five is the highest and zero is the lowest (Botz, 2024).

Score	Description
Five	There is no delay in filling compared to the asymptomatic hemisphere; the pial vessels in the affected hemisphere are normal.
Four	In the affected hemisphere, there is a delay of one phase in filling, however, the size and visibility of pial vessels remain unchanged.
Three	A two-phase delay in filling in the affected hemisphere, or a one-phase delay with a markedly decreased vessel count in the ischemic area.
Two	A delay in filling of two phases in the impacted hemisphere with a notably decreased amount of blood vessels in the area affected by ischemia, or a single-phase delay with an absence of visible vessels in specific regions.
One	Just a small number of ships (blood vessels) can be seen in the impacted half of the brain during any stage.
Zero	There are no ships (blood vessels) seen in the impacted half of the brain at any stage.

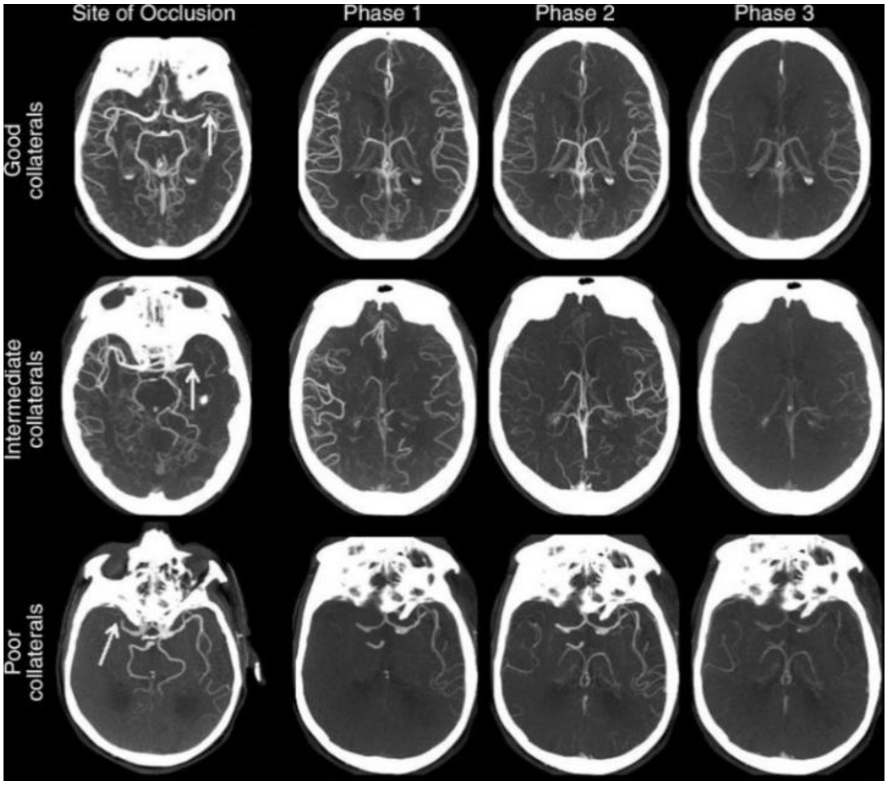

Figure 2.4: Scoring collateral circulation on multi-phase CT angiography in the axial plane. Top row: Occlusion in the left M1 middle cerebral artery with effective collaterals (filling with delay in one phase, but normal coverage); Middle row: Left M1 middle cerebral artery occlusion with moderate collaterals (filling with delay in one phase and reduced coverage); Bottom row: Left M1 middle cerebral artery occlusion with inadequate collaterals (no initial filling and minimal visible collaterals in subsequent phases) (Menon et al., 2015).

Various independent acute stroke software platforms are accessible in clinical settings for detecting large vessel occlusion, including iSchema View (RAPID CTA), Viz.ai (VIZ LVO), Brainomix (e-CTA) (Figure 2.5), Canon (AUTO Stroke Solution LVO), and Stroke Viewer (NICO.LAB). These platforms utilize various artificial intelligence (AI) techniques, such as machine learning (ML), to automatically detect LVOs. Ways to use computer assistance to detect LVO involve directly identifying occlusion sites through local vascular features (such as detecting the clot by spotting the contrast-enhanced vessel's discontinuity) and indirectly identifying occlusion sites by comparing the regional vessel density asymmetry in the affected hemisphere versus the unaffected hemisphere (Karamchandani et al., 2022).

Figure 2.5: Brainomix e-CTA tool shows the detection and location of a blockage in the right MCA, rating of collateral vessels, and a map highlighting areas with inadequate collateral blood flow (orange). Brainomix provided the images (Soun et al., 2021).

2.6.8 Computed Tomography Perfusion (CTP)

The Computed Tomography Perfusion is a test that evaluates the condition of brain tissue by determining the state of cerebral perfusion, providing valuable information on its functional status. Perfusion analysis in clinical practice aims to measure tissue with a notable lack of blood flow, at risk of infarction without reperfusion ischemic penumbra, and pinpoint tissue that is probably permanently damaged ischemic core (Václavík et al., 2022).

Key hemodynamic parameters in CTP examinations:

1. Cerebral Blood Flow (CBF) denotes the amount of blood moving through a unit of brain mass in a specific timeframe, typically expressed as milliliters per 100 grams per minute (mL/100 g/min). Relative CBF is frequently demonstrated as a normalized measure to a presumed normal reference region (in the opposite hemisphere).
2. Cerebral Blood Volume (CBV) is defined as the fraction of tissue that is supplied with blood, measured in milliliters per 100 grams.

3. The Mean Transit Time (MTT) is the average duration it takes for a contrast bolus to pass through the capillary bed, and is measured in seconds as an absolute value.
4. Time-to-Maximum (Tmax) measures the duration from the beginning of scan acquisition to the peak intensity of contrast bolus in every voxel.

Cerebral Blood Flow, Mean Transit Time, and Cerebral Blood Volume are connected mathematically through the equation: MTT = CBV/CBF, which is called the central volume principle (Radiology Key, 2017). Hence, measuring any two of these factors allows for the calculation of the third factor (Figure 2.6).

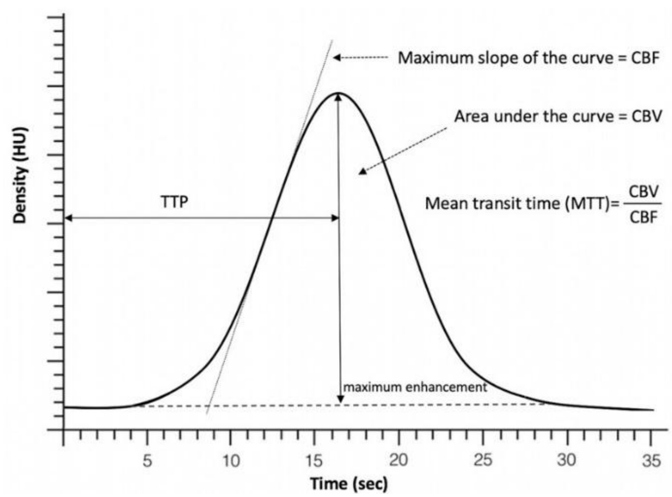

Figure 2.6: Curve showing the attenuation of perfusion time. Time to peak (TTP) is the duration for the contrast to reach its highest level in the observed region. The slope of the curve when contrast enters the brain represents CBF, while the volume/area under the curve indicates CBV. The calculation of MTT involves dividing CBV by CBF (Václavík et al., 2022).

2.6.8.1 Acquiring and Processing CTP Data

Computed Tomography Perfusion is a method that captures the movement of a contrast bolus passing through brain tissue, including its arrival and departure (Vagal et al., 2019). The difference in passage and resulting curves over time is influenced by the flow in the arteries known as the arterial input function (AIF) and the properties of the tissue. Impaired cardiac output, severe carotid stenosis, and factors related to contrast bolus injection (injection rate, saline chase) all influence the arterial flow of contrast media through the tissue. These factors could lead to a delay or scattering of the contrast bolus, potentially causing inaccuracies in measuring CBF (Václavík et al., 2022).

Angiography relies on visually evaluating contrast enhancement, while CTP requires quantifying contrast enhancement in blood vessels and brain tissue. Measuring contrast enhancement in CT scans is simple since the iodine in the contrast agent leads to a direct rise in X-ray absorption that correlates directly with the amount of iodine present. Therefore, measuring the fluctuations in attenuation in HU over a period of time allows for the estimation of the changes in concentration of contrast medium in a specific region of interest (ROI) or volume element (voxel) (Miles, 2004).

For individuals with a blockage in a major blood vessel in the front part of the brain, a z-axis coverage of at least four cm is usually enough to evaluate if there is any tissue that can still be saved. Yet, the entire scope of the ischemic lesion might not be fully captured due to the restricted coverage. As a result, we advise acquiring a minimum of eight cm of z-axis coverage, extending anteriorly from the area above the eyes. The CT detector width, ranging from four to sixteen cm, is the main factor in determining Z-axis coverage (Christensen & Lansberg, 2018).

For scanners with detectors that are relatively narrow, there are a few choices available to increase the z-axis coverage above the width of the detector. An alternative is to get two separate CTP scans at nearby levels, with each one needing its contrast injection. In this scenario, the CT table is stationary during each separate scan but moves between scans. This method is called the Toggling table technique (Figure 2.7) (Jeon et al., 2011). The steady-state method produces higher-quality images by enabling quicker sampling rates and removing artifacts caused by table movement (Christensen & Lansberg, 2018).

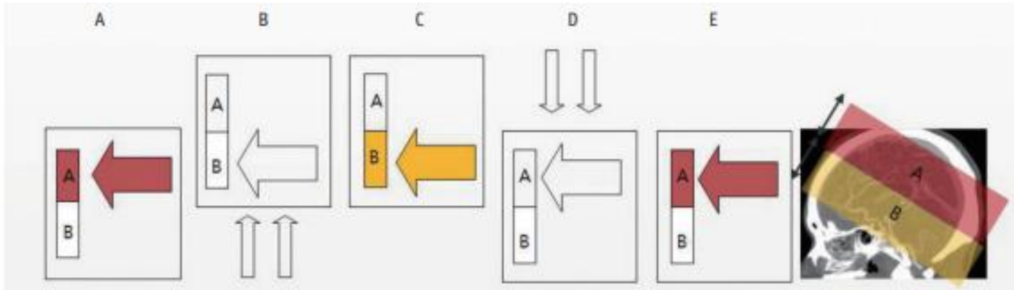

Figure 2.7: A. Images are captured by the scanner as it completes one rotation at position A. B. The table ascends to position the bottom half of the object beneath the X-ray tube. C. Scanner captures images while completing one full rotation at point B. D. Table shifts in the opposite direction from its initial location. E. The second round of scanning is carried out again (Jeon et al., 2011).

It is recommended to perform the CTP scan after the CTA with a brief time gap (typically 60 seconds) to allow the contrast from the CTA to reach a stable concentration before starting the CTP scan, preventing venous contamination from CTP contrast during CTA. From a pragmatic standpoint, performing the CTP scan last helps minimize unnecessary contrast and radiation exposure. CTP can be selectively acquired when needed, such as to identify a mismatch in patients with large vessel blockage on CTA who may benefit from endovascular treatment, confirm ischemia in uncertain clinical cases, or clarify inconclusive CTA findings regarding large vessel blockage (Christensen & Lansberg, 2018).

Two methods, non-deconvolution and deconvolution techniques, can be utilized to produce perfusion maps from raw CTP data. Deconvolution techniques are not used, instead, first-pass iodine extraction measurements are utilized to create a simpler and less computationally intensive processing algorithm. Deconvolution techniques consider changes in arterial flow due to physiology, as well as the impact of collateral flow and venous outflow on cerebral perfusion (Heit & Wintermark, 2016).

Presently, the CTP software packages that are on the market are nearly completely automated. The AIF is typically assessed from a major brain artery perpendicular to the imaging plane to reduce partial volume averaging. The intracranial ICA or ACA is typically chosen as the AIF, depending on the brain area scanned, while the Venous Outflow Function (VOF) is generally extracted from the posterior superior sagittal sinus (Krishnan et al., 2017).

2.6.8.2 Technical Pitfalls

The Computed Tomography tube voltage, total scan acquisition time, contrast bolus injection, brain coverage, frame rate, and scan order all affect the reliability of perfusion maps. A common drawback of CT perfusion is its lower contrast-to-noise ratio in comparison to MR perfusion. To enhance contrast-to-noise and minimize radiation exposure following the As Low as Reasonably Achievable (ALARA) principle, it is advised to obtain CTP scans at a voltage of 70-80 kV. According to the literature, a radiation dose of 300 mGy is usually the minimum needed to produce high-quality perfusion maps and precise volume estimates, although the ideal dose may vary depending on the scanner and software utilized (Christensen & Lansberg, 2018).

Optimizing timing parameters is necessary to capture the entire contrast passage without scanning too early or too late. The best scan should include a brief baseline period of ten seconds without contrast and the entire passage of the contrast bolus through a major brain vein (following the passage of the arterial contrast bolus. The length of total time may differ among patients, but empirical evidence demonstrates that more than 90% of patients reach this within 60 seconds of scanning. Therefore, we suggest a scanning time between 60 and 70 seconds (Kasasbeh et al., 2016).

The timing of the contrast bolus injection dictates the length of the baseline, with observations showing that most patients establish a short baseline (five to ten seconds) within four seconds after the injection begins. Using a power injector ensures consistent image acquisition, with a recommended administration of 40 mL of contrast agent at a rate of four to six mL/s, followed by 40 mL of saline at the same rate. Additionally, frame rates significantly affect perfusion map quality. Sampling intervals faster than two seconds are preferred, though this is unachievable in spiral mode due to table movement time. However, lowering frame rates to intervals of up to three seconds in spiral mode has proven sufficient for quality scans and is widely utilized in experiments (Christensen & Lansberg, 2018).

Scanning the patient with a symmetrical head position and no tilt is advantageous. The CTP software compares the contralateral side to calculate perfusion parameters, and substantial differences between the brain hemispheres may produce inaccurate outcomes (Vagal et al., 2019).

2.6.8.3 Interpretation of CTP

There are several challenges and pitfalls in CTP analysis. Different software packages have used a range of thresholds to define the ischemic core and penumbra. These differences lead to differences in core and penumbra volumes, with one study showing an underestimation of core volumes by more than 50 mL (Austein et al., 2016). Another study showed an overestimation of penumbra volumes by more than 50 mL compared to follow-up infarct volumes (Koopman et al., 2023). Such variances could then impact the choice of patients for reperfusion treatment.

Automated perfusion analyses, like automatic assessment of early ischemic changes on NCCT or LVO detection on CTA, are now being used in clinical practice to identify patients who may benefit from treatment by reducing triage times and detecting potentially salvageable tissue (Kremenova et al., 2022). Utilizing automated software analysis through RAPID-AI. In this program, the ischemic core is characterized by relative CBF < 30% of the contralateral hemisphere value, while the ischemic penumbra region is identified by a Tmax delay of > 6 sec compared to the contralateral hemisphere. The decision was made to select a CBF cut-off value for the RAPID-AI core that wouldn't overestimate the core size too much, as this could result in selecting too many patients. On the other hand, if the core is significantly underestimated, it could raise the chances of hemorrhagic transformation occurring and lower the likelihood of a positive clinical result (Shi et al., 2021).

It is crucial to understand that the CTP thresholds are not set in stone. Perfusion imaging done shortly after symptoms start might overestimate the size of the ischemic core

(García Tornel et al., 2021), and it is important to think about employing stricter thresholds, particularly when the initial imaging was done within the first hour ("golden hour") (Najm et al., 2018).

The overestimation of the ischemic core on CTP was rare and mainly seen in patients who arrived very early, within 90 minutes of the stroke, received quick reperfusion, and were mostly confined to white matter (Sarraj et al., 2022). While it is understood that the white matter is tougher against hypoperfusion, stricter thresholds must be used to differentiate at-risk grey and white matter accurately for infarction (Václavík et al., 2022).

The prediction of tissue outcome is linked to the seriousness of reduced blood flow (Demeestere et al., 2020). Severely hypoperfused Tissue, characterized by a Tmax delay of more than 10 seconds, shows a faster progression compared to tissue with adequate collateral perfusion. The hypoperfusion intensity ratio (HIR) measures the extent of hypoperfusion by quantifying the percentage of perfusion lesions with Tmax >10s over Tmax >6s. A low HIR is linked to decreased infarct expansion and smaller end infarct sizes (Olivot et al., 2014).

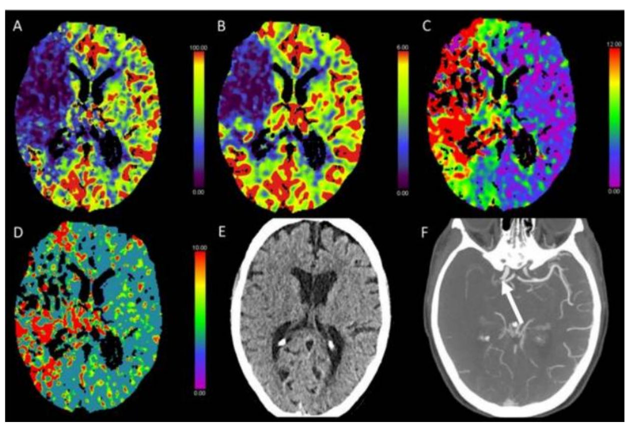

Figure 2.8: Maps produced from brain CT perfusion show: (A) CBF in mL/100 g/min, (B) CBV in mL/100 g, (C) Tmax in seconds, and (D) MTT in seconds. (E) Regular CT scan (NCCT) and (F) CTA. This patient had a cardiac catheterization procedure done to close an atrial septal defect. NCCT displayed a minimal decrease in the differentiation between gray and white matter. Within the middle cerebral artery (MCA) territory on the right side, there was a decrease in CBF while Tmax and MTT were increased. CTA discovered a blockage in the distal internal carotid artery on the right side (Haggenmüller et al., 2023).

The shift from ischemia to infarction is influenced by both CBF levels and how long the decrease in blood flow lasts. Transit times initially slow down during ischemia because of blockages, then become immeasurable as infarction progresses and resistance downstream increases. MTT and TTP are two transit time parameters that show the time it takes for peak enhancement after contrast injection in a specific area. Typically, tissue in danger of infarction will show either normal or reduced CBF, normal or increased CBV, and increased MTT or TTP (Table 2). On the other hand, infarcted tissue will exhibit reduced CBF and CBV while having elevated MTT or TTP (Figure 2.8) (Adamczyk et al., 2021).

Table 2.2: Identifying abnormal perfusion conditions through perfusion imaging.

Tissue State	TTP	CBV	CBF
Normal	—	—	—
Benign Hyperemia	↑	—↑	—
Risk Ischemia	↑	—↑	↓
Infarction	↑	↓	↓

2.7 Feasibility of Brain Perfusion Imaging with CT

Computed Tomography Perfusion imaging is a sophisticated, widely used method to evaluate cerebral blood flow in patients with acute stroke symptoms. It offers rapid assessment of perfusion parameters by utilizing standard CT scanners, which are more accessible and affordable than MRI. This imaging modality involves administering a small amount of contrast medium to trace its dispersion within the cerebral vasculature, enabling the identification of ischemic regions. This rapid diagnostic capability supports timely treatment decisions, such as determining eligibility for thrombolytic therapy. In comparison to PET and MRI, which provide detailed metabolic and functional data but are less practical in emergencies, CTP emerges as a critical tool for the effective management of cerebrovascular disorders (Aetna, 2023).

The research underscores the effectiveness and diagnostic accuracy of CTP imaging in stroke management, highlighting its role in both hyperacute and extended treatment windows. For instance, CTP demonstrated a 100% positive predictive value and specificity for stroke diagnosis in a study analyzing 500 patients, effectively distinguishing true stroke cases from stroke mimics. It was particularly beneficial in promptly guiding treatment for patients in the hyperacute phase while emphasizing the need for careful differential diagnosis in cases of negative findings (Cviková et al., 2024). Automated CTP analysis has further enhanced patient selection processes for ischemic stroke treatment, demonstrating a low technical failure rate of 3.4% and significantly reducing treatment times compared to MRI-based methods (Campbell et al., 2014).

Systematic reviews corroborate the diagnostic reliability of CTP. For instance, a comprehensive analysis involving 13 studies and 1,014 patients revealed high sensitivity (86.7%) and moderate specificity (77.8%) for predicting hemorrhagic transformation, with a particularly high negative predictive value of 92.9%. This highlights CTP's capability to exclude patients at risk of adverse outcomes, thereby optimizing treatment decisions (Mubarak et al., 2023). Another review comparing CTP with non-contrast CT and CT angiography found superior sensitivity for CTP (82%) and comparable accuracy with CT angiography, reaffirming its reliability in acute ischemic stroke diagnosis (Shen et al., 2017).

Computed Tomography Perfusion has also proven valuable in enhancing the accuracy and efficiency of detecting large and medium vessel occlusions. Studies demonstrate that integrating CTP with CT angiography significantly improves diagnostic accuracy, sensitivity, and specificity while reducing interpretation time. This highlights its critical role in the precise and rapid diagnosis of complex arterial occlusions (Alotaibi et al., 2023).

Moreover, comparative analyses with perfusion-diffusion MRI have shown that CTP achieves similar diagnostic precision, suggesting its suitability as an accessible alternative for identifying mismatch patterns in acute stroke patients (Campbell et al., 2012). A validation study further supported these findings, demonstrating that CTP achieved a diagnostic accuracy of 98.83% in detecting acute ischemic infarctions, reinforcing its role as an effective imaging tool for guiding immediate interventions (Junejo et al., 2021).

Lastly, Haggenmüller and others reviewed the use of CTP for diagnosing brain injuries, including strokes and vascular disorders. CTP effectively detects acute ischemic strokes, particularly in larger infarctions, but is less reliable for smaller infarcts and lacunar strokes. It also helps assess collateral blood flow and reperfusion, though it has limitations in posterior fossa infarcts. Additionally, CTP can confirm brain death in cases of global hypoxic-ischemic injury and detect vasospasms, luxury perfusion, and venous thrombosis, although MRI is superior for some conditions. The study emphasized the importance of understanding cerebrovascular anatomy and stroke mimics for accurate CTP interpretation (Haggenmüller et al., 2023).

The feasibility of CTP imaging in stroke management lies in its technical, clinical, and practical advantages. It utilizes accessible CT scanners to rapidly assess cerebral blood flow, provides critical insights for life-saving decisions like thrombolysis, and offers a cost-effective, minimally invasive alternative to MRI and PET. These qualities establish CTP as an essential tool in managing cerebrovascular disorders efficiently and effectively.

2.8 Perceptions and Attitudes of CTP

Perceptions and attitudes toward CTP are influenced by factors like economic concerns, healthcare infrastructure, and radiation exposure. Rising healthcare costs, driven by aging populations and technological advancements, have raised doubts about the sustainability of public healthcare systems in developed countries. Economic evaluation is essential for efficient resource allocation and maximizing health benefits (Reyes-Santias et al., 2023). Cost concerns, especially with advanced imaging technologies, remain significant barriers, as MRIs are often more expensive than CT scans (Chalela et al., 2007).

Additionally, ambiguity persists regarding how healthcare facilities will manage the increasing demand for neuroimaging, particularly in specialized clinics, which could lead to a rise in MRI inquiries and financial strain. Imaging and follow-up for incidental findings contribute to both direct and subsequent costs (González-Rábago et al., 2023). However, integrating advanced methods like CTP could reduce reliance on conventional CT scans, potentially offsetting additional costs (van Voorst & Hoving, 2023).

Limited healthcare infrastructure, especially in rural areas, poses significant challenges, delaying diagnoses and exacerbating health disparities. Centralized neuroimaging facilities in cities result in long travel times for rural patients, leading to higher rates of illness and death (Aderinto et al., 2023). Radiation exposure from CT scans, particularly when advanced techniques like CTA and CTP are used for acute stroke assessment, significantly increases total exposure. Establishing comprehensive diagnostic reference levels (DRLs) is necessary to optimize safety and ensure effective diagnostic protocols (Zensen et al., 2020).

In light of these challenges, this study explores perceptions of CTP and suggests solutions, including targeted education and staff involvement, while assessing the feasibility of using CTP in the Palestinian healthcare system. Evidence highlights CTP's superior diagnostic accuracy compared to NCCT. For instance, Campbell et al. (2013) demonstrated that CTP improved diagnostic rates (80% vs. 50% for NCCT) and reduced unnecessary treatments, emphasizing its value in enhancing diagnostic confidence and patient outcomes.

2.8.1 Radiation Exposure Concern

The evaluation of radiation exposure in patients undergoing CTP for acute ischemic stroke is crucial for enhancing patient safety through dose optimization. A study at King Fahad Medical City (KFMC) involving 320 stroke patients assessed radiation metrics like the CT Dose Index volume (CTDIvol) and Dose Length Product (DLP). The effective dose averaged 13.2 mSv, with CTDIvol averaging 80.5 mGy. Variability in radiation exposure was influenced by factors such as imaging phases and equipment settings. These findings emphasize the need for diagnostic reference levels (DRLs) and better operator awareness to minimize radiation without compromising diagnostic quality (Alomary, 2022).

Another approach aimed to reduce radiation exposure by adjusting CTP scan duration based on carotid CTA timing data. Involving 66 stroke patients, the study simulated shorter

CTP scan durations and found that reducing scans to 26, 28, and 30 scans still yielded comparable results to full-length exams. This reduction lowered radiation exposure while preserving critical diagnostic metrics such as infarct core and penumbra. The study concluded that leveraging temporal data from CTA bolus tracking helps minimize radiation exposure while maintaining diagnostic accuracy (Deak et al., 2022).

Moghari investigated the use of a recurrent Variational Autoencoder-Generative Adversarial Network (VAE-GAN) model to predict final CTP frames, reducing scan duration by 65% and radiation exposure by 54.5%. The model accurately predicted lesion measurements with minor discrepancies and maintained essential clinical metrics, demonstrating its potential to reduce radiation exposure while preserving diagnostic integrity (Moghari et al., 2023).

Lastly, Othman and others reviewed strategies for reducing radiation in CTP imaging. They highlighted the effectiveness of adjusting tube current and voltage. Reducing tube current by 50% lowered radiation exposure, despite an increase in image noise, while decreasing kVp from 120 kVp to 80 kVp significantly reduced radiation (two-point-eight-fold decrease) and improved image quality. These adjustments can lower radiation risks without affecting diagnostic accuracy (Othman et al., 2016).

Collectively, these studies demonstrate the importance of optimizing imaging protocols to reduce radiation exposure in CTP for acute ischemic stroke, ensuring patient safety while maintaining diagnostic accuracy.

2.8.2 Cost Concern

Several studies have evaluated the cost-effectiveness of CTP in ischemic stroke treatment, showing its potential to improve outcomes while reducing costs. Jackson and others developed a decision-analytic model to assess the impact of adding CTP to standard

NCCT for selecting patients for IV tPA. Their study found that CTP increased the likelihood of favorable outcomes by 0.59% and reduced costs by $ 42 per case compared to NCCT alone. The model also demonstrated that CTP was cost-effective (≤ $ 50,000 per QALY) in 89.2% of simulations, supporting its use in enhancing patient selection for IV tPA (Jackson et al., 2010).

Van Voorst and others evaluated the cost-effectiveness of CTP for detecting large vessel occlusion (LVO) in acute ischemic stroke patients eligible for endovascular treatment (EVT). They compared diagnostic pathways involving NCCT, CTA, and CTP with those using only NCCT and CTA. The study showed that adding CTP resulted in significant cost savings (Median ΔCosts: € -2671) and improved health outcomes (Median ΔQALY: 0.073), with a favorable net monetary benefit (Median NMB: € 8436). This suggests that CTP is both cost-efficient and beneficial in detecting LVO for EVT (Van Voorst et al., 2023).

Shen and others compared the cost-effectiveness of CTP, CT, and MRI for selecting stroke patients for thrombolysis across the UK, the US, and China. Their analysis revealed that CTP was more cost-effective than CT alone in the UK and the US, with a cost per QALY of £ 2951.4 for CTP in the UK and $ 99,406.1 for CTP in the US, compared to CT at £ 2983.7 and $ 100,483.5, respectively. In China, CT was slightly more cost-effective than CTP, costing ￥113,492.4 per QALY, compared to ￥113,615 for CTP. MRI was the least cost-effective option at ￥120,831.9 per QALY. Overall, CTP proved to be a cost-effective option for selecting stroke patients for thrombolysis, with some regional variations (Shen et al., 2014).

2.8.3 Knowledge and Training

Due to the lack of published studies on brain perfusion imaging in Palestine, we relied on studies focused on awareness of CT use in emergency departments of government hospitals in Palestine.

Nazzal and others conducted an analytical study to investigate the use and potential overuse of urgent brain CT scans in Palestinian government hospitals, highlighting concerns about unnecessary radiation exposure and increased healthcare costs. The study involved 66 emergency physicians and residents from three hospitals and analyzed the frequency of CT scan orders, adherence to guidelines, and healthcare providers' knowledge of radiation risks. The findings revealed that only 33.3% of CT scans were ordered according to guidelines, and 10.6% were requested for non-medical reasons. Furthermore, 39.4% of healthcare providers had limited knowledge about the risks of radiation exposure. The study emphasized the need for educational initiatives to raise awareness about radiation risks and adherence to CT guidelines. It recommended implementing local protocols, organizing radiation safety seminars, setting exposure limits, and hiring night-shift radiologists to improve image interpretation and reduce unnecessary costs (Nazzal et al., 2024).

Similarly, Sabarna and others conducted a retrospective analysis of unnecessary brain CT requests in the emergency department of Hebron Governmental Hospital, Palestine. They reviewed 6,152 brain CT scans ordered in the emergency department throughout 2021, with a sample of 500 cases selected for detailed analysis. Radiologists evaluated 100 of these cases to determine whether the scans were necessary. The study found that 78% of the evaluated scans were deemed unnecessary. A significant factor contributing to unnecessary CT requests was the involvement of non-specialized physicians who lacked training in appropriate imaging practices. The study recommended implementing stricter guidelines for CT referrals in emergency settings and improving clinical training for non-specialized physicians on the risks associated with excessive imaging (Sabarna et al., 2023).

2.8.4 Infrastructure in Palestine for Purchasing Imaging Services Outside Government Hospitals

The Palestinian Ministry of Health (PMOH) service purchase unit study (2018) analyzed the structure of healthcare delivery in the Palestinian Territories, focusing on the laws regulating health services and the referral system for medical imaging. The research examined the Public Health Law (2004) and the Health Insurance and Treatment Abroad

Law (2004), which mandate that essential health services be provided to all individuals in the West Bank and Gaza. The study reviewed referral patterns for medical imaging services over nine months and the availability of MRI and CT scan services in PMOH hospitals.

The study found that the existing regulatory framework ensures that healthcare services are accessible to all residents, regardless of socioeconomic status. Between January and September 2017, 4,608 referrals for medical imaging were recorded, averaging 512 referrals per month. Among these, MRI was the most frequently requested service with 2,303 referrals, followed by endoscopy procedures 2,478 and CT scans 944, with the highest number of CT referrals for brain scans 425 and MRI referrals for brain imaging 1,144. Additionally, CT and MRI services were available in several PMOH hospitals, with specific hospitals designated for MRI services in different regions of the West Bank (Jenin, Ramallah, and Hebron). However, the study noted a shortage of MRI devices compared to the patient demand, which led to the need for outsourcing imaging services from the private sector, thereby increasing diagnostic costs for uninsured patients.

The study emphasizes the PMOH's commitment to providing comprehensive healthcare services and the importance of a structured referral process to ensure access to necessary treatments. Although the research provides insights into the state of medical imaging services, it does not cover the use of CTP examinations, presenting an opportunity to further explore decisions and perceptions regarding CTP's application in Palestine and its potential to improve clinical practice.

2.9 Future Direction of CTP

Several global studies have examined the application of CTP with artificial intelligence (AI) and automated programs to enhance diagnostic efficiency and treatment planning. Hu and others investigated the effectiveness of deep learning-based CTP in guiding thrombolytic therapy for patients with acute cerebral infarction of unspecified onset time. In their study, 100 patients were divided into two groups: one utilizing AI-based image processing and the other using traditional methods. The AI group demonstrated improved diagnostic outcomes, with better image quality and superior therapeutic effects on neurological impairment, as measured by the National Institutes of Health Stroke Scale (NIHSS). Additionally, the AI group exhibited a lower rate of symptomatic intracranial hemorrhage, highlighting its superior safety profile. These findings suggest that deep learning-based CTP significantly enhances diagnostic and treatment efficacy, improving stroke management outcomes (Hu et al., 2022).

In another study, Temmen and others evaluated an AI-supported automated stroke CT workflow designed to detect intracranial LVOs during stroke assessments. This study involved 100 acute stroke patients and compared the performance of an automation platform (AP) against five radiologists with varying expertise. The AP processed CTA images and CTP maps significantly faster than the radiologists, with an average processing time of 60 seconds for CTA and 196 seconds for CTP, compared to the longer times of the radiologists. However, the AP's sensitivity for LVO detection was lower 77% than the radiologists' 87%, and it missed several occlusions, suggesting that AI tools, while accelerating image processing, still require refinement for optimal diagnostic accuracy (Temmen et al., 2023).

Lei and others assessed the value of a deep learning image reconstruction (DLIR) algorithm in improving the quality of whole-brain CTP and CTA images in acute ischemic stroke (AIS) patients. The study involved 54 patients, with CTP datasets reconstructed using different levels of adaptive statistical iterative reconstruction-Veo (ASIR-V) and DLIR algorithms. The results showed that DLIR significantly improved the signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR), and noise reduction, particularly with higher levels of DLIR. DLIR-H demonstrated the highest noise reduction rate and detection accuracy for infarction core lesions. Furthermore, subjective evaluations indicated that DLIR-H and DLIR-M reconstructions produced higher-quality CTA images than conventional methods. This study suggests that DLIR enhances the overall image quality of CTP and CTA, facilitating more accurate diagnoses of AIS while potentially reducing contrast agent usage and radiation exposure (Lei et al., 2023).

These studies collectively demonstrate the growing role of AI and automated systems in enhancing CTP imaging efficiency, diagnostic accuracy, and treatment planning, while also highlighting areas for further development in AI integration for stroke management.

2.10 Linking The Previous Literary Review with The Current Study

Based on the literature review provided, previous studies highlight the pressing need for accessible neuroimaging services to manage cerebrovascular diseases, especially stroke. The research underscores the importance of timely intervention, with studies like the Cleveland Clinic emphasizing rapid diagnosis to reduce mortality.

The Palestinian Central Bureau of Statistics and Abushab shed light on the limitations in Palestinian healthcare, specifically the shortage of MRI devices and trained professionals, which hinders stroke care. This body of work connects directly to the study by emphasizing how these gaps affect local stroke management and the decision-making processes of Palestinian healthcare providers. The study builds on this foundation by assessing the feasibility and perceptions of neuroimaging practices, especially CTP, specifically exploring how these systemic challenges impact clinical efficacy and patient outcomes in Palestine.

The present study builds upon previous research by integrating key findings on the critical role of neuroimaging in stroke management and the existing limitations in Palestinian healthcare infrastructure, as highlighted in earlier studies. While agreeing with past research on the need for improved imaging resources, Montaser Ahmed and this study uniquely examine the perspectives of Palestinian radiographers, radiologists, and neurologists, an aspect not deeply explored previously. This focus reveals a knowledge gap regarding the impact of limited neuroimaging services on healthcare professionals' clinical decision-making processes. By addressing this gap, the current study aims to provide targeted insights that can inform policy and training efforts, thereby advancing emergency stroke care in Palestine and contributing new perspectives to the field.

The conceptual framework for this study centers on understanding the role of neuroimaging, particularly CTP, in stroke management. Grounded in the knowledge-attitude-practices (KAP) model, this framework examines how healthcare professionals' knowledge and attitudes toward neuroimaging influence their clinical decisions. This study explores how the limitations in Palestinian healthcare, such as resource scarcity, restricted access to MRI, and a shortage of trained personnel, impact diagnostic and treatment practices. By highlighting these interconnected variables, the framework supports evaluating and addressing the infrastructural and training needs in neuroimaging for improved stroke care.

2.11 Conclusion

This literature review highlights the pivotal role of neuroimaging, particularly CTP, in the effective management of cerebrovascular diseases, especially stroke. It underscores the necessity for timely and accurate diagnostics to improve clinical outcomes and reduce mortality rates associated with acute ischemic strokes. The studies reviewed elucidate significant advancements in imaging technologies and methodologies, such as deep learning algorithms and automated workflows, which promise to enhance diagnostic efficiency and accuracy.

Despite these advancements, the literature reveals persistent challenges in the accessibility and availability of neuroimaging services, particularly within the Palestinian healthcare system. Studies indicate that the scarcity of advanced imaging modalities and trained professionals directly impacts the clinical decision-making processes of healthcare providers. Moreover, knowledge gaps among medical personnel regarding the optimal use of neuroimaging tools further exacerbate these issues, leading to potential delays in patient care and increased healthcare costs.

This review connects these challenges to the present study, which seeks to explore the perceptions and practices of healthcare professionals regarding CTP in Palestine. By investigating the knowledge, attitudes, and practices of radiologists, radiographers, and neurologists, the current research aims to illuminate the systemic limitations that hinder effective stroke management. Additionally, it emphasizes the need for targeted educational initiatives to bridge the knowledge gaps identified in the literature.

Ultimately, the findings from this literature review and the subsequent study are expected to contribute valuable insights into the optimization of neuroimaging practices and the enhancement of emergency stroke care in Palestine. By addressing the ide identified gaps in infrastructure, training, and resource allocation, this research aspires to inform policy and practice, paving the way for improved patient outcomes in a resource-limited setting.

Chapter Three: Research Methodology

3.1 Overview

This chapter outlines the research methodology adopted to explore healthcare professionals' KAP regarding CTP imaging in stroke management within government hospitals in the West Bank. The study utilizes a quantitative, cross-sectional, and descriptive design, allowing for precise measurement and statistical analysis of data collected from a diverse sample of radiologists, radiographers, and neurologists. The design ensures a comprehensive understanding of the current practices and perceptions of CTP imaging, providing valuable insights for improving stroke management in resource-limited settings.

The chapter details the study setting, focusing on government hospitals across the West Bank to ensure the representation of diverse healthcare practices and resource availability. It describes the target population and the sampling method, including the inclusion and exclusion criteria. A structured questionnaire was designed and rigorously tested for reliability and validity to ensure it effectively measures the intended variables. Data collection procedures, both electronic and in person, were tailored to the local context to maximize participation while maintaining ethical standards.

Finally, the chapter explains the data analysis procedures, emphasizing the use of statistical methods such as descriptive statistics and Cronbach's alpha to ensure robust results. Ethical considerations are thoroughly addressed, ensuring the confidentiality, voluntary participation, and integrity of the research process. Together, these elements provide a clear and structured framework for addressing the study's objectives and contributing to evidence-based improvements in stroke care.

3.2 Research Design

This study adopts a quantitative, cross-sectional, and descriptive design. The quantitative method was selected to accurately measure and analyze the KAP of healthcare professionals regarding CTP imaging in stroke management. This approach relies on numerical data, enabling statistical analysis to uncover patterns and relationships within the gathered information (Babbie, 2013).

The cross-sectional design is well-suited for this study as it collects data at a single point in time, offering a clear snapshot of the current perceptions and practices within the target population (Setia, 2016). This design efficiently examines multiple variables simultaneously, such as healthcare professionals' knowledge, attitudes, and practices, without necessitating an extended study period. Additionally, it aligns with the study's aim to assess the feasibility and perceptions of CTP imaging in resource-limited settings, providing timely insights that can guide future policies and practices.

A descriptive framework was also employed to offer a thorough overview of the current level of awareness and application of CTP imaging. Descriptive studies are useful for mapping out the landscape of a phenomenon, allowing for the identification of gaps and opportunities that can inform interventions and training programs (Neuman, 2013). The combination of a quantitative approach, cross-sectional design, and descriptive framework ensures that the research design is both comprehensive and methodologically strong. This well-structured design is particularly effective in addressing the research questions, as it helps uncover existing gaps, trends, and opportunities for improving the use of CTP imaging in resource-limited settings.

3.3 Study Variables

In this study, several variables will be examined to assess the feasibility and perceptions of CTP imaging among healthcare professionals in government hospitals in the West Bank. The independent variables include Knowledge, Attitudes, and Challenges related to CTP imaging, such as understanding CTP principles, awareness of alternative techniques, and barriers like cost and training needs, as shown in (Table 3.1). Dependent variables will include Practices and Patient Outcomes, focusing on CTP utilization frequency, adherence to protocols, and the impact of CTP on patient outcomes.

Additionally, the study will assess influencing factors like Training, Safety, and Effectiveness. These factors will help determine how training programs, safety concerns, and perceived effectiveness impact healthcare professionals' knowledge, attitudes, and practices regarding CTP imaging. By analyzing these variables, the study aims to identify the key elements that influence the adoption and utilization of CTP in stroke management.

Table 3.1: Variables in the Study

Variable Category	**Variables**
Independent	Knowledge, Attitudes, Challenges
Dependent	Practices, Patient Outcomes
Influencing	Training, Safety, Effectiveness

3.4 Study Setting

This research was carried out in several governmental hospitals throughout the West Bank, Palestine, with a focus on evaluating the KAP of healthcare professionals concerning CTP imaging, as shown in (Table 3.2).

Table 3.2: Governmental Hospitals in the West Bank, Palestine.

Hospital Name	**Location (Governorate)**
Khalil Suleiman Governmental Hospital	Jenin
Turkish Government Hospital	Tubas
Thabet Thabet Governmental Hospital	Tulkarem
Attil Governmental Hospital	Tulkarem
National Hospital	Nablus
Rafidia Hospital	Nablus

Darwish Nazzal Governmental Hospital	Qalqilya
Yasser Arafat Governmental Hospital	Salfit
Palestine Medical Complex	Ramallah
Beit Jala Hospital	Bethlehem
Alia Governmental Hospital	Hebron
Yatta Governmental Hospital	Hebron
Mohammed Ali Al-Muhtaseb Governmental Hospital	Hebron
President Mahmoud Abbas Hospital	Hebron
Dura Governmental Hospital	Hebron
Jericho Governmental Hospital	Jericho

3.5 Population and Sampling Method and Related Procedures

The target population for this study consisted of healthcare professionals, specifically radiologists, radiographers, and neurologists, working in government hospitals in the West Bank, Palestine. A simple random sampling technique was employed to select participants from various hospitals across the region (Scribbr, 2023). To ensure accurate representation, the sample size was determined based on the actual number of these professionals in the selected hospitals, as confirmed through direct communication with each hospital's administration. The total population included 204 radiographers, 32 radiologists, and 8 neurologists, ensuring that the sample accurately reflected the distribution of these healthcare professionals across the targeted hospitals.

The sample size was calculated using an online sample size calculator (Raosoft, n.d.), applying a 5% margin of error, a 95% confidence level, and a 50% response distribution (which results in the largest sample size). After the calculation, the required sample size for this study was determined to be 150 participants.

- **Inclusion Criteria**

The inclusion criteria for this study were as follows:

1. Radiographers, radiologists, and neurologists working in governmental hospitals in the West Bank.
2. Full-time employees working in radiology or neurology departments in the selected governmental hospitals.

- **Exclusion Criteria**

The exclusion criteria for this study included:

1. Participants work part-time or as volunteers in the selected governmental hospitals.
2. Individuals working in other departments within the hospitals.

3.6 Data Collection Method

Data for this study were collected using a structured questionnaire designed to assess healthcare professionals' KAP in government hospitals in the West Bank regarding brain perfusion imaging using CTP. The questionnaire was developed to understand how healthcare professionals view the feasibility of CTP in stroke management, their perceptions of its effectiveness, and how their knowledge, attitudes, and practices shape the integration of this imaging technique into clinical practice.

In addition to the survey data, further information regarding the availability of CTP and MRI machines was gathered through direct communication with hospital management in the study area. This data, presented in the results section, is crucial for understanding how the availability of equipment influences the use of CTP in the diagnosis of ischemic stroke, as the presence or absence of these imaging tools can significantly affect the timely and accurate detection of such conditions.

3.6.1 Data Collection Tool

A structured questionnaire was meticulously designed based on a thorough review of the relevant literature and the specific needs of this study. The questionnaire is organized into distinct sections, each addressing key aspects of healthcare professionals' engagement with brain perfusion imaging using CTP. These sections include demographic information, knowledge of CTP techniques, attitudes toward the use of CTP in stroke assessment, and medical practices related to the implementation of CTP in clinical settings. The structure of the questionnaire ensures a comprehensive evaluation of the participants' perspectives on CTP, as outlined in (Table 3.3). The full questionnaire is provided in Appendix K.

Table 3.3: Presents the structure of the questionnaire used to assess healthcare professionals' KAP and perceptions regarding the use of CTP in stroke

Section	Focus Area	Question Types	Objective
Demographic Information	Participant characteristics (age, gender, specialty, experience).	Closed-ended multiple-choice	Provides background context for analysis and allows for segmentation.
Knowledge of CTP Techniques	Understanding of CTP principles, techniques, and clinical applications.	Multiple-choice, True/False	Assesses the participants' technical knowledge regarding CTP.
Attitudes and Perceptions of CTP	General views on CTP's utility, its impact on stroke diagnosis and patient outcomes, and overall feasibility.	Likert scale, open-ended	Examines how participants perceive CTP in terms of effectiveness and feasibility in stroke management.
Practice and Implementation of CTP	Current practices, usage, and implementation challenges of CTP in clinical settings.	Multiple-choice, Likert scale, open-ended	Identifies the practical aspects and obstacles faced by healthcare professionals in using CTP.
Future Directions and Improvements of CTP	Insights on future use, improvements, and potential for broader implementation.	Open-ended questions	Gathers feedback on the participants' expectations and suggestions for enhancing CTP usage.

The questionnaire includes closed-ended multiple-choice questions to quantify knowledge, attitudes, and practices; open-ended questions for detailed insights; and Likert scale questions to assess participants' attitudes and perceptions, allowing responses from strongly disagree to strongly agree. This mixed-format approach ensures clear, consistent, and reliable data collection, enabling healthcare professionals across specialties to respond easily and precisely.

3.6.2 Establishing The Reliability and Validity of The Questionnaire

The questionnaire was presented to a group of experts in relevant fields to evaluate its quality and ensure its alignment with the research content. This group included three radiologists, two radiology technicians, and three statisticians. The experts were asked to assess the clarity of the questions, the comprehensiveness of the topics covered, and the appropriateness of the questions for measuring the intended concepts of the study. Additionally, the statisticians specifically examined the validity of the measurement of the questionnaire. Based on their positive feedback, which confirmed that the questionnaire was "very good" in terms of design and accuracy, it can be concluded that the questionnaire meets the necessary academic standards and serves as a reliable tool for data collection.

To assess the reliability of the questionnaire, internal consistency was measured using Cronbach's Alpha coefficient. This measure reflects the degree to which the responses to different questions in the questionnaire that assess the same construct are consistent. The Cronbach's Alpha coefficient was calculated using SPSS, with a result of 0.803 (Table 3.5), indicating good reliability of the tool (Table 3.4) (Statisticshowto, n.d.).

Table 3.4: Cronbach's Alpha values indicating the reliability of the questionnaire (Statisticshowto, n.d.).

Cronbach's Alpha	Internal Consistency
$a \geq 0.9$	Excellent
$0.9 > a \geq 0.8$	Good
$0.8 > a \geq 0.7$	Acceptable
$0.7 > a \geq 0.6$	Questionable
$0.6 > a \geq 0.5$	Poor
$0.5 > a$	Unacceptable

Table 3.5: Reliability Analysis of the Questionnaire

Cronbach's Alpha	N of Items
0.803	70

3.7 Data Collection Procedure

The data collection process commenced following the approval of the Research Ethics Committee at the Arab American University. After submitting the necessary documentation, the University's Graduate Studies Department liaised with the Health Education and Scientific Research Unit at the Ministry of Health to facilitate the issuance of a research mission letter. This letter was subsequently circulated by the Ministry to the administration of government hospitals in the West Bank, allowing the research data collection to begin.

After the questionnaire was prepared using Google Forms, the administrations of governmental hospitals were approached to obtain permission for data collection. Upon receiving the necessary approvals, coordination was made with the radiology departments and neurologists. WhatsApp numbers of the targeted professionals were provided, and in cases where contact numbers were unavailable, Facebook accounts of some employees were shared. The electronic questionnaire link was distributed accordingly, and responses were regularly monitored.

In addition to the electronic method, an alternative approach was adopted for hospitals that required an in-person visit prior to data collection. These hospitals, along with others that were more easily accessible given the challenging conditions in the West Bank, were visited accordingly. Following approval from department heads, paper-based questionnaires were distributed to individuals who were unable to complete the electronic version in response to their request.

In both methods of data collection, the study's objectives were clearly explained to participants. They were encouraged to complete the questionnaire voluntarily, with an assurance of confidentiality regarding their responses. The average time required to complete the questionnaire was between 5 and 10 minutes.

3.8 Data Analysis Procedures

The data collected for this research were analyzed using the Statistical Package for the Social Sciences (SPSS), version 20. The analysis aimed to address the study objectives and provide reliable and valid insights into healthcare professionals' knowledge, attitudes, and practices regarding CTP. Descriptive statistics were employed to summarize participants' demographic characteristics and key variables, such as frequencies and percentages, offering an overview of the dataset and highlighting patterns in the responses.

Since the data did not follow a normal distribution, non-parametric tests were applied. The median was calculated, and Spearman's rank correlation was used for further analysis. The normality of the data distribution was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Hypotheses were tested using the Kruskal-Wallis test, as it is suitable for comparing variables across multiple groups when the data do not follow a normal distribution.

3.9 Ethical Considerations

ensure the rights, confidentiality, and autonomy of all participants. Approval for the research was obtained from the Research Ethics Committee at the Arab American University before the commencement of data collection (see Appendix L). Additionally, authorization was secured from the Palestinian Ministry of Health to facilitate access to government hospitals in the West Bank (see Appendix M).

Participants were informed about the purpose, objectives, and scope of the study before providing their consent. Participation was entirely voluntary, and individuals had the right to withdraw at any time without any consequences. Confidentiality was ensured by anonymizing the data, removing any identifiers, and securely storing all responses. For electronic responses, the Google Forms platform was used with restricted access to ensure data protection, while paper-based responses were handled with similar levels of care and security.

Efforts were made to provide clear communication about the nature of the study, and participants were encouraged to ask questions or seek clarification. The study strictly followed ethical standards and ensured that the research process upheld the principles of respect and justice. This approach helped foster trust and ensured the ethical integrity of the research.

Chapter Four: Data Analysis and Results

4.1 Introduction

This chapter examines findings from a study evaluating healthcare professionals' perceptions and the feasibility of implementing CTP in West Bank government hospitals for stroke management. It assesses equipment availability, institutional support, and radiologists' KAP. The analysis begins with participant demographics and professional backgrounds, followed by a detailed presentation of KAP related findings, including statistical variations across professional groups, experience levels, and institutional factors.

4.2 Demographic and Professional Characteristics of Participants

This section overviews participants' demographic and professional characteristics, including age, gender, occupation, experience, education, and workplace. These factors are analyzed to identify trends or relationships that may influence perceptions and practices regarding CTP in brain perfusion imaging. The following subsections detail these characteristics, offering context for interpreting the study's findings.

4.2.1 Personal Demographic Characteristics

A total of 152 healthcare professionals from governmental hospitals across the West Bank participated in the study. The majority were male (78.3%, n = 119), with females representing 21.1% (n = 32), and one participant (0.7%) not disclosing gender. Most participants were aged 30–39 (48.7%, n = 74), followed by those aged 20–29 (25.7%, n = 39), 40–49 (19.7%, n = 30), 50–59 (4.6%, n = 7), and 60+ (0.7%, n = 1), with one participant (0.7%) not reporting age. This demographic profile as shown in (Table 4.1) suggests potential gender- and experience-related differences in knowledge, attitudes, and practices toward brain perfusion imaging.

Table 4.1: Gender Distribution of Study Participants.

Personal Demographic Characteristics		Frequency	Percent
Gender	Male	119	78.3%
	Female	32	21.1%
	I don't want to answer	1	0.7%
Age	20-29	39	25.7%
	30-39	74	48.7%
	40-49	30	19.7%
	50-59	7	4.6%
	60 or older	1	0.7%
	I don't want to answer	1	0.7%

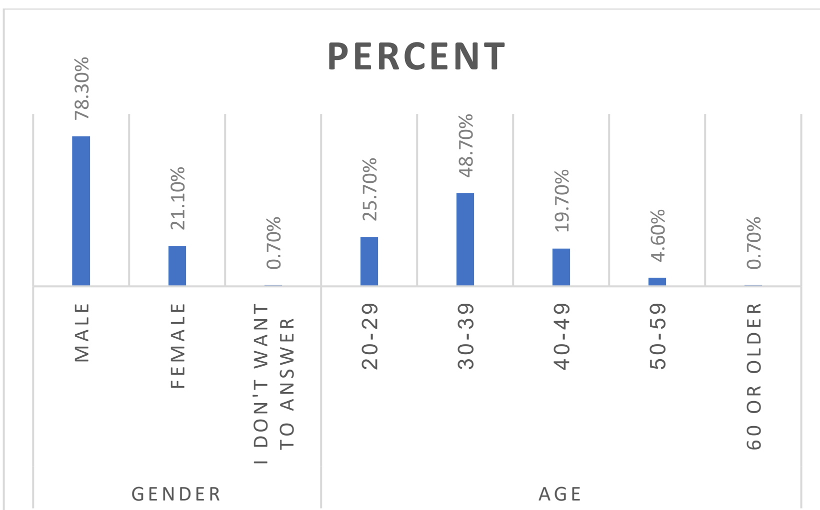

Figure 4.1: Demographic Distribution of Participants by Gender and Age.

4.2.2 Professional Characteristics

The profession distribution, as illustrated in (Table 4.2) and (Figure 4.2), shows that 85.5% (n=130) of participants are radiographers, 11.2% (n=17) are radiologists, and 3.3% (n=5) are neurologists. In terms of experience, 45.4% (n=69) have over 10 years of experience, 32.9% (n=50) have 1-5 years, 19.7% (n=30) have 6-10 years, and 2.0% (n=3) have less than one year. Regarding education, 81.6% (n=124) hold a bachelor's degree, 10.5% (n=16) have a master's degree, 3.9% (n=6) hold a diploma, and 2.6% (n=4) have a doctorate. These distributions provide a clear statistical overview of the sample's professional, experiential, and educational characteristics.

Table 4.2: Distribution of Participants by Profession.

Professional Characteristics		Frequency	Percent
profession	Radiologist	17	11.2%
	Radiographer	130	85.5%
	Neurologist	5	3.3%
Experience	Less than 1 year	3	2.0%
	1-5 years	50	32.9%
	6-10 years	30	19.7%
	More than 10 years	69	45.4%
Education Degree	Diploma Degree	6	3.9%
	Bachelor's Degree	124	81.6%
	Master's Degree	16	10.5%
	Doctorate (PhD/MD) Degree	4	2.6%

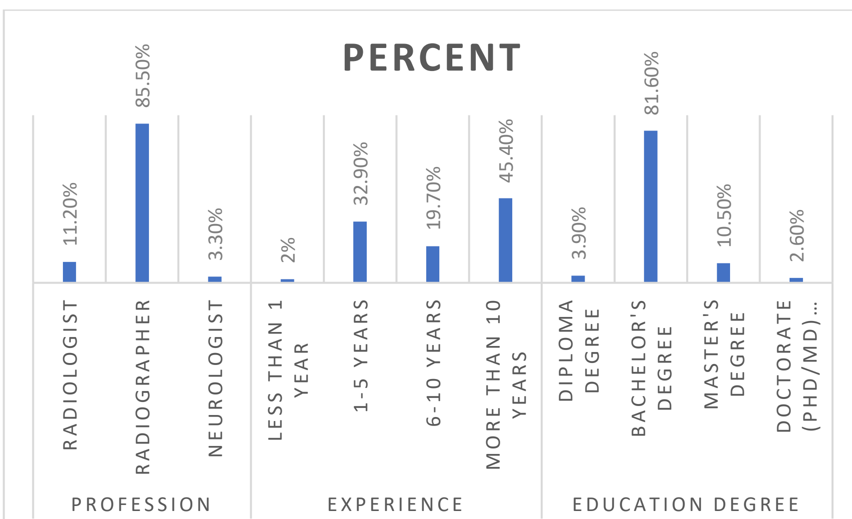

Figure 4.2: Professional Distribution of Participants by Profession, Experience, and Education Level

The employment distribution, shown in (Table 4.3), highlights the variety of healthcare institutions where participants are employed. The largest proportion, 24.3%, works at the Palestine Medical Complex in Ramallah, followed by Rafidia Hospital in Nablus, 11.8%, and Alia Governmental Hospital in Hebron, 10.5%. Other hospitals with notable representation include Khalil Suleiman Governmental Hospital in Jenin, 9.2%, Thabet Thabet Governmental Hospital in Tulkarem, 5.9%, and Beit Jala Hospital in Bethlehem, 4.6%. The remaining hospitals have smaller representations, accounting for 1-5% of the sample. This distribution reflects the diversity of healthcare facilities in the study sample and may influence the generalizability of the findings.

Table 4.3: Distribution of Participants by Employment (Healthcare Facility).

Professional Characteristics		**Frequency**	**Percent**
Employment	Khalil Suleiman Governmental Hospital - Jenin	14	9.2%
	Turkish Government Hospital - Tubas	6	3.9%
	Thabet Thabet Governmental Hospital - Tulkarem	9	5.9%
	Attil Government Hospital- Tulkarem	4	2.6%
	National Hospital - Nablus	2	1.3%
	Rafidia Hospital - Nablus	18	11.8%
	Darwish Nazzal Governmental Hospital - Qalqilya	7	4.6%
	Yasser Arafat Governmental Hospital - Salfit	5	3.3%
	Palestine Medical Complex - Ramallah	37	24.3%
	Beit Jala Hospital (Al-Hussein) - Bethlehem	7	4.6%
	Alia Governmental Hospital - Hebron	16	10.5%
	Yatta Governmental Hospital - Hebron	2	1.3%
	Mohammed Ali Al-Muhtaseb Governmental Hospital - Hebron	4	2.6%
	President Mahmoud Abbas Hospital - Hebron	3	2.0%
	Dura Government Hospital- Hebron	7	4.6%
	Jericho Governmental Hospital - Jericho	7	4.6%
	Missing System	4	2.6%

4.3 Normality Test of the Data

The normality of the data was evaluated using the Kolmogorov-Smirnov and Shapiro-Wilk tests. As shown in (Table 4.4), both variables (Practices: KS $p < 0.000$, SW $p < 0.000$; Patient Outcomes: KS $p < 0.000$, SW $p = 0.003$) significantly deviated from normality ($p <$

0.05), violating the assumptions of parametric tests. This deviation impacts the validity of mean-based comparisons, justifying the use of non-parametric tests such as the Mann-Whitney U and Kruskal-Wallis tests, which provide robust statistical analysis for skewed distributions.

Table 4.4: Tests of Normality for Dependent Variables

	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Statistic	df	Sig.	Statistic	df	Sig.
Practices	0.182	136	0.000	0.932	136	0.000
Patient Outcomes	0.115	136	0.000	0.969	136	0.003

a. Lilliefors Significance Correction

4.4 Knowledge, Attitudes, and Practices Regarding CTP

This section will explore healthcare professionals' knowledge, attitudes, and practices regarding CTP. It will begin by examining their understanding and awareness of CTP and then by investigating their attitudes and perceptions toward its use in clinical settings. Finally, the section will address how CTP is perceived and utilized in practice, highlighting its benefits and the challenges professionals face in implementing it.

4.4.1 Knowledge and Awareness of CTP

The results in (Table 4.5) show that 75% of participants are familiar with Brain Perfusion Imaging using CT. However, only 50.4% were familiar with key parameters like CBF and MTT, while 88.1% recognized CTP's effectiveness in assessing cerebral blood flow. Knowledge sources were primarily university education, 45.4%, and online courses, 16.4%, with limited engagement in medical journals, 20.4%, and conferences, 9.9%. Other sources 4.9% cited informal/practical training, self-experience, or a lack of prior education on CTP .Clinically, 70.4% acknowledged CTP’s role in early stroke detection, but only 36.8% associated it with detailed brain mapping, and 47.4% recognized its real-time blood flow analysis.

Technically, 63.1% were familiar with contrast media usage, and 66.4% were aware of CTP contraindications. The median response for procedural characteristics was "Neutral," with 50% viewing CTP as non-invasive. These findings highlight significant gaps in knowledge and clinical application, emphasizing the need for targeted training and improved educational resources to enhance CTP adoption in stroke management.

Table 4.5: Frequency Distribution and Median Values for Knowledge of Brain Perfusion Imaging and Related Aspects.

Questions	Median	Frequency Distribution (%)
I am familiar with Brain Perfusion Imaging using CT.	2.00	Strongly Agree (15.8%), Agree (59.2%), Neutral (11.2%), Disagree (13.8%)
Sources of learning about CTP:		
Medical journals.	0.00	Yes (20.4%), No (79.6%)
Conferences.	0.00	Yes (9.9%), No (90.1%)
University education.	0.00	Yes (45.4%), No (54.6%)
Online courses.	0.00	Yes (16.4%), No (83.6%)
Other.	0.00	Yes (4.9%), No (95.1%)
Benefits of CTP:		
Early stroke detection.	1.00	Yes (70.4%), No (29.6%)
Detailed brain mapping.	0.00	Yes (36.8%), No (63.2%)
Non-invasive procedure.	0.50	Yes (50.0%), No (50.0%)
Real-time blood flow analysis.	0.00	Yes (47.4%), No (52.6%)
Other.	0.00	Yes (0.7%), No (99.3%)
CTP is an effective method for assessing cerebral blood flow.	2.00	Strongly Agree (18.4%), Agree (69.7%), Neutral (11.2%), Disagree (0.7%)
I am familiar with the parameters measured in CTP (e.g., CBF, CBV, MTT, TTP).	2.00	Strongly Agree (16.6%), Agree (33.8%), Neutral (22.5%), Disagree (27.2%)
I am knowledgeable about the technical aspects of CTP (e.g., contrast media usage and imaging protocols).	2.00	Strongly Agree (16.4%), Agree (46.7%), Neutral (21.1%), Disagree (15.8%)
I am aware of the contraindications for using CTP.	2.00	Strongly Agree (18.4%), Agree (48.0%), Neutral (22.4%), Disagree (11.2%)

4.4.2 Participants' Attitudes and Perceptions Toward CTP

The findings in (Table 4.6) reveal strong support for CTP adoption, with 87.5% endorsing its inclusion as a standard practice in stroke management. 87.5% affirmed the reliability of CTP results, and 74.3% recognized its added value over other imaging techniques. However, only 60.6% expressed satisfaction with current brain imaging methods, and less than half, 48%, felt confident in interpreting CTP results, with 35.5% remaining neutral.

A notable 94.1% highlighted the need for increased CTP training, reflecting a critical gap in expertise. Key concerns included radiation exposure 65.1%, limited availability 40.8%, and technical complexity 31.6%. The "Other" category, 0.7%, highlighted concerns about balancing clinical benefits against risks by hospital department evaluators. Despite these challenges, 73.6% agreed that brain perfusion imaging using CT is a valuable diagnostic tool. These results underscore strong support for CTP adoption but emphasize the necessity for targeted training and addressing practical barriers to optimize its clinical integration.

Table 4.6: Frequency Distribution, Median, and Percentages for Respondents' Attitudes Toward CTP.

Questions	Median	Frequency Distribution (%)
I believe that CTP should be included as a standard practice in stroke assessment.	2.00	Strongly Agree (17.1%), Agree (70.4%), Neutral (11.2%), Disagree (1.3%)
To what extent do you agree with the following statement: CTP results significantly influence rapid treatment decisions for acute stroke?	2.00	Strongly Agree (25.7%), Agree (61.8%), Neutral (9.9%), Disagree (1.3%)
Do you believe that CTP provides significant added value over other imaging modalities (e.g., Non-Contrast CT, CTA, MRI)?	2.00	Strongly Agree (16.4%), Agree (57.9%), Neutral (15.8%), Disagree (9.9%)
I am satisfied with the current brain imaging techniques.	2.00	Strongly Agree (8.6%), Agree (52.0%), Neutral (28.3%), Disagree (10.5%)
I feel confident in my ability to interpret CTP results.	3.00	Strongly Agree (12.5%), Agree (35.5%), Neutral (35.5%), Disagree (16.4%)

I believe that increased training on CTP is necessary for healthcare professionals.	2.00	Strongly Agree (38.8%), Agree (55.3%), Neutral (3.9%), Disagree (2.0%)
The potential risks associated with CTP (e.g., radiation exposure) outweigh its benefits.	3.00	Strongly Agree (9.9%), Agree (32.9%), Neutral (32.9%), Disagree (23.7%)
What are your primary concerns about the use of CTP in clinical practice?		
Radiation exposure.	1.00	Yes (65.1%), No (34.9%)
Cost-effectiveness.	0.00	Yes (32.2%), No (67.8%)
Technical complexity.	0.00	Yes (31.6%), No (68.4%)
Limited availability.	0.00	Yes (40.8%), No (59.2%)
Other.	0.00	Yes (0.7%), No (99.3%)
To what extent do you agree with the following statement: "Brain perfusion imaging with CT improves patient outcomes in acute neurological conditions.	2.00	Strongly Agree (19.7%), Agree (53.9%), Neutral (21.7%), Disagree (3.9%)

4.4.3 Perceptions and Utilization of CTP in Clinical Practice

The survey results in (Table 4.7) indicate limited adoption of CTP in clinical practice, with 59.6% reporting no usage and 58.3% having never worked on a CTP scan. Additionally, 58.4% are not involved in CTP decision-making, and the median number of scans performed was 1.00, reflecting low utilization. While 45.4% follow institution-specific protocols, only 11.8% adhere to national guidelines, 5.9% rely on international guidelines, and 40.8% follow no specific protocols.

Integration challenges are evident, with a median ease-of-integration rating of 3.00, 43.3% neutral, and 12.6% finding it difficult or difficult. Key barriers include lack of training 78.9%, financial constraints 42.8%, limited access to equipment 27.6%, and patient safety concerns 29.6%. Qualitative feedback under “Other” noted remarks such as: “This test is rarely ordered, so no obstacles are perceived,” and concerns about “negative impressions due to the absence of CTP in some hospitals.” To address these, 72.4% emphasized additional training programs, 52.0% highlighted regular equipment calibration, and 42.8% called for institutional support. Standardized protocols, 53.3%, were also deemed essential. These findings underscore the need for structured training, financial investment, and standardized guidelines to enhance CTP integration in stroke management.

Table 4.7: Practices and Perceptions of CTP Usage in Clinical Practice: Frequency Distribution and Median Values.

Questions	Median	Frequency Distribution (%)
How often do you use CTP in your clinical practice?	1.00	0 (59.6%), 1-5 (29.8%), 6-10 (6.0%), More than 10 (4.6%)
In the past, how many CTP scans have you worked on?	1.00	0 (58.3%), 1-5 (33.1%), 6-10 (4.6%), More than 10 (4.0%)
What protocols or guidelines do you follow for brain perfusion imaging with CT in your practice?		
Institution-specific protocols.	0.00	Yes (45.4%), No (54.6%)
National guidelines.	0.00	Yes (11.8%), No (88.2%)
International guidelines.	0.00	Yes (5.9%), No (94.1%)
No specific protocols.	0.00	Yes (40.8%), No (59.2%)
Are you involved in the decision-making process for performing CTP scans?	0.00	Yes (41.6%), No (58.4%)
How would you rate the ease of integrating CT perfusion imaging into your clinical workflow?	3.00	Very easy (6.7%), Easy (37.3%), Neutral (43.3%), Difficult (11.3%), Very difficult (1.3%)
What feedback have you received from patients regarding CT perfusion imaging?		
Positive.	0.00	Yes (29.6%), No (70.4%)
Negative.	0.00	Yes (6.6%), No (93.4%)
Concerns about radiation exposure.	0.00	Yes (30.9%), No (69.1%)
Concerns about procedure duration.	0.00	Yes (25.0%), No (75.0%)
Anxiety about the procedure.	0.00	Yes (30.9%), No (69.1%)
Other.	0.00	Yes (16.3%), No (83.7%)
How do you educate patients about the benefits and risks of CT perfusion imaging?		
Brochures/pamphlets.	0.50	Yes (50.0%), No (50.0%)
One-on-one discussions.	1.00	Yes (55.3%), No (44.7%)
Informational videos.	0.00	Yes (30.3%), No (69.7%)
Referral to online resources.	0.00	Yes (32.9%), No (67.1%)
Have you encountered any limitations with CTP imaging in clinical practice?	1.00	Yes (53.7%), No (46.3%)
Please indicate the main barriers you face in utilizing CTP in your practice		
Lack of training.	1.00	Yes (78.9%), No (21.1%)
High cost of the procedure.	1.00	Yes (27.0%), No (73.0%)

Limited access to equipment.	1.00	Yes (27.6%), No (72.4%)
Concerns about patient safety.	0.00	Yes (29.6%), No (70.4%)
Other.	0.00	Yes (3.4%), No (96.6%)
What resources or support would help you overcome these barriers?		
Financial support.	1.00	Yes (42.8%), No (57.2%)
Additional training programs.	1.00	Yes (72.4%), No (27.6%)
Technical support.	1.00	Yes (47.4%), No (52.6%)
Updated equipment.	0.00	Yes (38.2%), No (61.8%)
Institutional support.	1.00	Yes (42.8%), No (57.2%)
Other.	0.00	Yes (0.7%), No (99.3%)
How do you ensure the accuracy and reliability of CT perfusion imaging results in the hospital?		
Regular calibration of equipment.	0.00	Yes (52.0%), No (48.0%)
Continuing education and training.	1.00	Yes (74.3%), No (25.7%)
Standardized protocols.	1.00	Yes (53.3%), No (46.7%)
Peer review of imaging results.	1.00	Yes (39.5%), No (60.5%)
Other.	0.00	Yes (0.7%), No (99.3%)

4.5 Potential Challenges for The Target Group in Utilizing CTP Imaging

This section discusses the key obstacles faced by healthcare professionals in adopting CTP imaging, including both practical challenges and regional differences in resource availability.

4.5.1 Challenges and Support Needs in CTP Implementation

The results, as shown in (Table 4.8), underscore training deficiencies as the foremost barrier to CTP adoption, cited by 78.9% of participants. This aligns with the strong demand for additional training programs, 72.4%, reflecting a critical gap in skill development. While financial constraints 27.0% and limited equipment access 27.6% were less prevalent, they remain notable hurdles, particularly in resource-constrained settings. Patient safety concerns, 29.6%, and the need for technical support, 47.4%, further complicate implementation.

Institutional and infrastructural limitations also hinder progress: 42.8% of respondents emphasized the need for financial and institutional support, while 38.2% identified outdated equipment as a barrier. Only 3.4% cited "other" challenges, highlighting the specificity of these issues.

4.5.2 Geographic Disparities in Imaging Resources

Access to advanced imaging technology varies starkly across the West Bank. While 81.3% of hospitals have CT scanners, only 18.8% possess MRI machines. Northern and central regions (e.g., Nablus, Ramallah) report relatively better CT access, though MRI availability remains sparse. Southern regions (Bethlehem, Hebron) face acute shortages, with hospitals in Yatta and Halhul lacking both modalities entirely. This inequitable distribution exacerbates challenges in CTP utilization, particularly in underserved areas.

Table 4.8: Median Values and Frequency Distribution of Limitations Encountered in CTP Imaging.

Questions	Median	Frequency Distribution (%)
Have you encountered any limitations with CTP imaging in clinical practice?	1.00	Yes (53.7%), No (46.3%)
Please indicate the main barriers you face in utilizing CTP in your practice		
Lack of training.	1.00	Yes (78.9%), No (21.1%)
High cost of the procedure.	0.00	Yes (27.0%), No (73.0%)
Limited access to equipment.	0.00	Yes (27.6%), No (72.4%)
Concerns about patient safety.	0.00	Yes (29.6%), No (70.4%)
Other.	0.00	Yes (3.4%), No (96.6%)
What resources or support would help you overcome these barriers?		
Financial support.	0.00	Yes (42.8%), No (57.2%)
Additional training programs.	1.00	Yes (72.4%), No (27.6%)
Technical support.	0.00	Yes (47.4%), No (52.6%)
Updated equipment.	0.00	Yes (38.2%), No (61.8%)
Institutional support.	0.00	Yes (42.8%), No (57.2%)
Other.	0.00	Yes (0.7%), No (99.3%)

4.6 Training and Educational Needs for CTP in Healthcare

The survey results in (Table 4.9) indicate overwhelming support for the necessity of increased training on CTP among healthcare professionals, with 94.1% of participants either strongly agreeing 38.8% or agreeing 55.3%. Only a small percentage expressed neutrality, 3.9%, or disagreement, 2.0%, reflecting a strong consensus on the importance of enhanced training in this area.

Additionally, an overwhelming majority of participants, 96.7%, expressed interest in participating in further training or workshops on CTP, with only 3.3% declining interest. This highlights a clear demand for continuous education and skill development to improve CTP implementation in clinical practice.

Table 4.9: Training Needs and Interest in CTP Workshops.

Questions	Median	Frequency Distribution (%)
I believe that increased training on CTP is necessary for healthcare professionals.	2.00	Strongly Agree (38.8%), Agree (55.3%), Neutral (3.9%), Disagree (2.0%)
Are you interested in participating in further training or workshops on CT perfusion imaging?	1.00	Yes (96.7%), No (3.3%)

4.7 Healthcare Professionals' Perceptions of CTP Safety and Effectiveness

This section will highlight healthcare professionals' perceptions regarding the safety and effectiveness of CTP compared to other imaging modalities, such as MRI and standard CT scans.

4.7.1 Safety Perceptions of CTP

The results in (Table 4.10) show that 66.4% of participants are aware of CTP contraindications, with 18.4% strongly agreeing and 48.0% agreeing, while 22.4% were neutral and 11.2% disagreed, indicating a need for improved awareness. Regarding CTP risks, such as radiation exposure, 42.8% agreed that the risks outweigh the benefits, while 32.9% were neutral and 23.7% disagreed.

Among CTP-related challenges, radiation exposure was the most frequently cited concern at 65.1%, followed by limited equipment access at 40.8%. Fewer participants highlighted cost-effectiveness 32.2% or technical complexity 31.6% as significant barriers. Only 0.7% mentioned other concerns, emphasizing these as key areas for improvement in CTP implementation.

Table 4.10: Awareness and Perceptions of CTP Contraindications, Risks, and Challenges.

Questions	Median	Frequency Distribution (%)
I am aware of the contraindications for using CTP.	2.00	Strongly Agree (18.4%), Agree (48.0%), Neutral (22.4%), Disagree (11.2%)
The potential risks associated with CTP (e.g., radiation exposure) outweigh its benefits.	3.00	Strongly Agree (9.9%), Agree (32.9%), Neutral (32.9%), Disagree (23.7%)
What are your primary concerns about the use of CTP in clinical practice?		
Radiation exposure.	1.00	Yes (65.1%), No (34.9%)
Cost-effectiveness.	0.00	Yes (32.2%), No (67.8%)
Technical complexity.	0.00	Yes (31.6%), No (68.4%)
Limited availability.	0.00	Yes (40.8%), No (59.2%)
Other.	0.00	Yes (0.7%), No (99.3%)

4.7.2 Effectiveness Perceptions of CTP

The survey results in (Table 4.11) indicate strong agreement on the effectiveness of CTP, with 88.1% of participants agreeing or strongly agreeing that CTP is an effective method for assessing cerebral blood flow. Similarly, 87.5% agreed or strongly agreed that CTP results are reliable, while 74.3% believed CTP provides significant added value over other imaging methods. Regarding brain perfusion assessment, 73.6% agreed or strongly agreed with its utility. Neutral responses ranged from 9.9% to 21.7%, and disagreement was minimal, ranging from 0.7% to 9.9%. These findings highlight strong confidence in CTP's effectiveness and reliability among healthcare professionals.

Table 4.11: Descriptive Statistics and Frequency Distribution on the Effectiveness of CTP.

Questions	Median	Frequency Distribution (%)
CTP is an effective method for assessing cerebral blood flow.	2.00	Strongly Agree (18.4%), Agree (69.7%), Neutral (11.2%), Disagree (0.7%)
To what extent do you agree with the following statement: CTP results significantly influence rapid treatment decisions for acute stroke?	2.00	Strongly Agree (25.7%), Agree (61.8%), Neutral (9.9%), Disagree (1.3%)
Do you believe that CTP provides significant added value over other imaging modalities (e.g., Non-Contrast CT, CTA, MRI)?	2.00	Strongly Agree (16.4%), Agree (57.9%), Neutral (15.8%), Disagree (9.9%)
To what extent do you agree with the following statement: "Brain perfusion imaging with CT improves patient outcomes in acute neurological conditions.	2.00	Strongly Agree (19.7%), Agree (53.9%), Neutral (21.7%), Disagree (3.9%)

4.8 Future Directions for Enhancing CTP Implementation

Based on the survey results presented in (Table 4.12), the majority of participants, 79.6%, believe that enhanced training would improve CTP implementation, with a median response of 1.00. Furthermore, 95.4% expressed interest in attending additional workshops, reflecting a strong desire for ongoing education. When it comes to equipment, 60.5% of participants agreed on its necessity (median 1.00), while 39.5% disagreed, suggesting that better equipment is crucial for the successful adoption of CTP. However, only 34.2% considered reducing costs as a significant factor, indicating that cost reduction is a lesser priority.

Regarding other influencing factors, 52.6% of participants emphasized the need for increased awareness, and 47.4% called for improved protocols, both with a median of 0.00. Despite these needs, 80.3% of participants did not view CTP as cost-effective. On a positive note, long-term patient outcomes 62.5% and technological advancements 53.9% were seen as beneficial. However, protocol standardization and comparative studies were given less attention. Preferred sources of knowledge included conferences and workshops, 71.1%, and online courses, 59.2%, while professional journals were not utilized by any participants. These results underscore the importance of structured training, better equipment, and strategies to address financial concerns.

Table 4.12: Future Directions for CTP Implementation.

Questions	**Median**	**Frequency Distribution (%)**
What improvements do you think are necessary for the wider adoption of CT perfusion imaging?		
Enhanced training.	1.00	Yes (79.6%), No (20.4%)
Better equipment.	1.00	Yes (60.5%), No (39.5%)
Reduced costs.	0.00	Yes (34.2%), No (65.8%)
Increased awareness.	0.00	Yes (52.6%), No (47.4%)
Improved protocols.	0.00	Yes (47.4%), No (52.6%)
Interest in further training/workshops.	1.00	Yes (95.4%), No (3.3%)
What areas of research would you like to see explored further regarding CT perfusion imaging?		
Long-term patient outcomes.	0.00	Yes (62.5%), No (37.5%)
Cost-effectiveness perception.	0.00	Yes (19.7%), No (80.3%)
Technological advancements.	0.00	Yes (53.9%), No (46.1%)
Protocol standardization.	0.00	Yes (33.6%), No (66.4%)
Comparative studies with other imaging methods.	0.00	Yes (41.4%), No (58.6%)
How do you stay updated on the latest advancements and research in brain perfusion imaging?		
Professional journals usage	0.00	Yes (0.0%), No (100.0%)

Conferences and workshops as knowledge sources.	1.00	Yes (71.1%), No (28.9%)
Online courses as a knowledge source.	0.00	Yes (59.2%), No (40.8%)
Professional associations as a knowledge source.	0.00	Yes (29.6%), No (70.4%)

4.9 Correlation of Variables: Knowledge, Attitudes, and Practices Regarding CTP

This section will present the correlation of variables, highlighting the relationships between knowledge, attitudes, and practices regarding CTP. Each of these aspects will be explored in detail to understand how they interact and influence one another in the context of healthcare professionals' perceptions and use of CTP.

4.9.1 Correlation Between Knowledge, Attitudes, and Practices in CTP Implementation

The correlation analysis (Table 4.13) revealed a large, statistically significant positive relationship between Knowledge and Attitudes (Spearman's $r = 0.501$, $p < 0.01$, 95% CI [0.36, 0.62]), indicating that higher knowledge levels are strongly associated with more positive attitudes toward CTP, with the effect size exceeding Cohen's conventional threshold for a large correlation ($r \geq 0.5$). A small but significant positive correlation was observed between Knowledge and Practices ($r = 0.199$, $p < 0.05$, 95% CI [0.03, 0.35]), suggesting that increased knowledge may marginally improve practical implementation. However, the relationship between Attitudes and Practices was non-significant ($r = 0.142$, $p = 0.102$, 95% CI [−0.03, 0.31]), implying that positive attitudes do not directly translate into improved practices.

Regression analysis further assessed the predictive relationship between Knowledge, Attitudes, and Practices. The model explained only 4.2% of the variance in Practices ($R^2 = 0.042$, adjusted $R^2 = 0.027$), reflecting a small effect size (Cohen's $f^2 = 0.044$). The overall model was non-significant with neither Knowledge ($\beta = 0.100$, $p = 0.318$, 95% CI [−0.146, 0.445]) nor Attitudes ($\beta = 0.135$, $p = 0.179$, 95% CI [−0.082, 0.432]) contributing significantly. The unstandardized coefficients indicated negligible practical impacts: a one-unit increase in Knowledge and Attitudes predicted minimal practice changes (B = 0.15 and B = 0.175, respectively). The confidence intervals for both predictors spanned zero, reinforcing the lack of meaningful predictive power and suggesting that unmeasured factors likely drive Practices.

These findings underscore the limited utility of Knowledge and Attitudes alone in explaining the practical implementation of CTP. While enhancing knowledge may foster positive attitudes (large effect), its direct role in improving practices remains modest (small effect), necessitating further exploration of contextual or systemic factors.

Table 4.13: Correlation Analysis Between Total Knowledge, Total Attitudes, and Total Practices.

			Knowledge	Attitudes	Practices
Spearman's rho	**Knowledge**	Correlation Coefficient	1.000	0.501**	0.199*
	Attitudes	Correlation Coefficient	-	1.000	0.142
	Practices	Correlation Coefficient	-	-	1.000

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

4.9.2 The Relationship Between Positive Attitudes Toward CTP and Patient Outcomes

The correlation analysis (Table 4.14) revealed a large, statistically significant positive relationship between Attitudes and Patient Outcomes (PT Outcomes) (Spearman's r = 0.595, $p < 0.01$, 95% CI [0.48, 0.69]), indicating that more positive attitudes toward CTP are strongly associated with improved patient outcomes, with the effect size exceeding Cohen's conventional threshold for a large correlation ($r \geq 0.5$).

Regression analysis further assessed the predictive relationship between Attitudes and PT Outcomes. The model explained 39.6% of the variance in PT Outcomes ($R^2 = 0.396$, adjusted $R^2 = 0.392$), reflecting a large effect size (Cohen's $f^2 = 0.656$). The overall model was statistically significant, with Attitudes demonstrating a strong, positive, and significant influence on PT Outcomes (β = 0.629, $p < 0.001$, 95% CI [0.268, 0.406]). The unstandardized coefficients indicated meaningful practical impacts: a one-unit increase in Attitudes predicted a 0.337-unit improvement in PT Outcomes (B = 0.337). The confidence intervals for Attitudes did not span zero, reinforcing their predictive power.

These findings underscore the critical role of Attitudes in explaining patient outcomes within CTP implementation. While fostering positive attitudes shows substantial potential for improving clinical results (large effect), the presence of conflicting regression outputs (B = 0.116 vs. B = 0.337) highlights the need for further validation. Additional systemic factors (e.g., training, resources) should be explored to address inconsistencies and enhance predictive accuracy.

Table 4.14: Relationship Between Attitudes and Patient Outcomes Using Spearman's Correlation.

			Attitudes	**PT Outcomes**
Spearman's rho	**Attitudes**	Correlation Coefficient	1.000	0.595**
	Patient Outcomes	Correlation Coefficient	0.595**	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

4.9.3 Correlation Between Practices and Patient Outcomes in CTP Use

The correlation analysis (Table 4.15) revealed a moderate positive relationship between Practices and Patient Outcomes (PT Outcomes) ($r = 0.336$, $p < 0.01$, 95% CI [0.19, 0.47]), with a medium effect size (Cohen's $r \geq 0.3$), indicating that improved CTP implementation practices are associated with better clinical results. Regression analysis further demonstrated that Practices significantly predicted PT Outcomes, explaining 10% of the variance ($R^2 = 0.100$, adjusted $R^2 = 0.093$, Cohen's $f^2 = 0.11$ = small effect). A one-unit increase in Practices corresponded to a 0.125-unit improvement in PT Outcomes (B = 0.125, $p < 0.001$, 95% CI [0.06, 0.19]; standardized β = 0.316).

Despite statistical significance, the modest R^2 (10%) highlights that 90% of the variance remains unexplained, suggesting unmeasured factors (e.g., training, resources, systemic support) likely influence PT Outcomes. These findings emphasize the importance of optimizing CTP-related practices while acknowledging the need to address broader contextual factors to achieve meaningful clinical improvements.

Table 4.15: Spearman's Correlation Between Practices and Patient Outcomes in CTP Use.

			Practices	**PT Outcomes**
Spearman's rho	**Practices**	Correlation Coefficient	1.000	0.336**
	Patient Outcomes	Correlation Coefficient	0.336**	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

4.9.4 Correlations Between Demographic Factors and Knowledge, Attitudes, and Practices Toward CTP

Spearman's correlation analysis showed no significant associations between profession and knowledge ($r = 0.044$, $p = 0.599$) or attitudes ($r = -0.009$, $p = 0.911$), but a small negative correlation with practices ($r = -0.187$, $p = 0.028$), suggesting profession-specific barriers to CTP implementation. Gender showed a weak, non-significant correlation with knowledge ($r = 0.163$, $p = 0.052$) and no effect on attitudes or practices.

In contrast, education demonstrated a medium-to-large positive correlation with practices ($r = 0.338$, $p < 0.001$). Knowledge was strongly correlated with attitudes ($r = 0.501$, $p < 0.001$) and modestly with practices ($r = 0.199$, $p = 0.021$). Age, employment status, and experience showed no meaningful relationships with any of the KAP domains. These findings highlight education and knowledge as important factors influencing practice and attitude. Other demographic variables played a limited role in shaping professionals' perceptions or behaviors.

The Spearman's Rank Correlation results revealed varying relationships between Knowledge, Attitudes, and Practices across the different professions. For Radiographers, significant moderate positive correlations were found between Knowledge and Attitudes (rho

= 0.543) and a weak positive correlation between Knowledge and Practices (rho = 0.232), indicating that higher knowledge is associated with better attitudes and practices in this group. Neurologists demonstrated a strong, significant positive correlation between Knowledge and Attitudes (rho = 0.949), while the correlations between Knowledge and Practices (rho = 0.351) and Attitudes and Practices (rho = 0.103) were weak and non-significant.

In contrast, Radiologists showed weak, non-significant correlations between all variables, with no substantial relationships identified. These findings suggest that the relationship between knowledge, attitudes, and practices varies significantly across professions, with Radiographers and Neurologists showing more meaningful associations compared to Radiologists.

A regression model predicting practices was statistically significant, explaining 21.9% of the variance ($R^2 = 0.219$, adjusted $R^2 = 0.166$), with a medium effect size (Cohen's $f^2 = 0.28$). Significant predictors included education ($\beta = 0.294$, $p = 0.001$, 95% CI [1.210, 4.407], unstandardized B = 2.809), employment status ($\beta = 0.199$, $p = 0.018$, 95% CI [0.037, 0.391]), and attitudes ($\beta = 0.209$, $p = 0.034$, 95% CI [0.021, 0.514]). Knowledge, profession, age, gender, and experience showed no significant effects (all $p > 0.05$, CIs spanning zero). Despite the model's significance, 78.1% of the variance remained unexplained, underscoring the need to explore contextual factors (e.g., training and resources). These results emphasize education and employment status as key demographic drivers of CTP practices, with attitudes playing a supplementary role.

4.10 Results of Hypothesis Testing on Knowledge, Attitudes, and Practices

The Kruskal-Wallis test results in (Table 4.16) show no significant relationship between knowledge levels, attitudes, and practices regarding CTP in acute stroke management. The p-values for knowledge 0.366 and attitudes 0.256 exceed the 0.05 significance threshold, indicating that variations in knowledge and attitudes do not significantly influence clinical practices related to CTP. Thus, we retain the null hypothesis, concluding that knowledge and attitudes do not significantly impact CTP utilization in this context.

And here the generalized linear model (GENLIN) analysis revealed that institutional support significantly influences healthcare professionals' practices related to brain perfusion imaging (CTP), with higher support levels improving practices (Wald Chi-Square = 299.503, $p < 0.001$). However, training and CT availability did not have a significant effect on practices (Wald Chi-Square = 1.531, $p = 0.465$; Wald Chi-Square = 0.073, $p = 0.787$, respectively). The results suggest that institutional support, rather than training or CT availability, plays a more critical role in shaping practices related to CTP. The model was a good fit (AIC = 628.736, BIC = 666.310), with a significant likelihood ratio test (Chi-Square = 161.561, $p < 0.001$).

Table 4.16: Hypothesis Testing Results for the Relationship Between Knowledge, Attitudes, and Practices Regarding CTP.

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Knowledge is the same across categories of Practices.	Independent-Samples Kruskal-Wallis Test	0.366	Retain the null hypothesis.
2	The distribution of Attitudes is the same across categories of Practices.	Independent-Samples Kruskal-Wallis Test	0.256	Retain the null hypothesis.

Mediation analyses were conducted to examine whether certain variables acted as mediators in the relationships between key study factors in four models:

In Model one, Knowledge was tested as a mediator between Training and Practice. The results revealed that none of the regression paths (path a, path b, or path c) were statistically significant ($p > 0.05$), indicating no evidence of mediation.

In contrast, Model two examined Practice as a mediator between Knowledge and Patient Outcomes. Both path a (Knowledge → Practice, $p = 0.041$) and path b (Practice → Patient Outcomes, $p < 0.001$) were statistically significant, and the direct effect of Knowledge on Patient Outcomes (path c) became non-significant after including Practice (path c′, $p = 0.203$), suggesting partial mediation.

For Model three, Attitude was tested as a mediator between Institutional Support and Practice. While the direct effect of Institutional Support on Practice and the path from Institutional Support to Attitude were significant ($p < 0.001$ and $p = 0.009$, respectively), the path from Attitude to Practice was not significant ($p = 0.807$), indicating no mediation.

Finally, Model four tested Attitude as a mediator between Training and Practice. Both path a (Training → Attitude, $p < 0.001$) and path b (Attitude → Practice, $p = 0.041$) were significant, while the direct effect of Training on Practice became non-significant when Attitude was included (path c′, $p = 0.539$), indicating full mediation. These findings highlight that Attitude and Practice play important mediating roles in some but not all of the examined relationships.

4.11 Interpretation of Results

This section analyzes the findings, highlighting key correlations and barriers to CTP implementation.

4.11.1 Understanding and Gaps in CTP Knowledge

The results reveal significant gaps in healthcare professionals' knowledge and awareness of CTP, directly impacting clinical practices. While 75% reported being familiar with CTP, only 50.4% demonstrated a clear understanding of key parameters such as CBF and MTT, indicating a superficial grasp of the concept. Their knowledge primarily stemmed from university education, 45.4%, and online courses, 16.4%, while engagement with specialized resources like medical journals, 20.4%, and conferences, 9.9%, remained limited. Although 66.4% were aware of CTP contraindications, inconsistencies in understanding procedural characteristics (with 50% identifying it as non-invasive) and clinical applications (36.8% associating it with brain mapping) reflect fragmented and incomplete expertise.

The weak but significant correlation between knowledge and practices ($r = 0.199$, $p < 0.05$), along with the minimal predictive power of knowledge and attitudes on practices ($R^2 = 0.042$), suggests that systemic barriers play a dominant role in limiting CTP implementation. Notably, 78.9% identified insufficient training as a major limitation, aligning with 94.1% advocating for enhanced education. These gaps contribute to the underutilization of CTP (with 59.6% reporting no use) and reliance on non-standardized protocols 40.8%. Addressing these deficiencies through structured training programs, updated guidelines, and stronger institutional support is essential for optimizing CTP's role in stroke management.

4.11.2 Attitudes Toward CTP

Several barriers limit the broader use of CTP in clinical settings, with a lack of training 78.9% being a major issue that affects understanding of key parameters and protocols. Financial limitations, 42.8%, and unequal access to equipment, especially in under-resourced regions, further complicate matters. Although CT scanners are available in most hospitals 81.3%, MRI machines are scarce 18.8%, restricting advanced imaging. Other concerns, like radiation exposure 65.1%, technical difficulty 31.6%, and patient anxiety 30.9% also reduce usage. The low predictive value of knowledge and attitudes ($R^2 = 0.042$) highlights the influence of systemic challenges. Addressing these through better training, consistent guidelines, and fair resource distribution is essential.

The limited availability of MRI compared to CT directly affects clinical decision-making and confidence. While CT is more accessible, its limitations force professionals to depend on less advanced tools, even when they see the value of CTP. In areas like Hebron and Bethlehem, where both CT and MRI are in short supply, delays in stroke diagnosis are common. Bridging this gap with improved access and training could boost CTP adoption and improve care quality.

4.11.3 Barriers to CTP Implementation

The study reveals a noticeable gap between healthcare professionals' recognition of CTP as a valuable diagnostic tool and its actual use in clinical practice. While 73.6% of participants acknowledged the importance of CTP in stroke management, 59.6% reported never using it, and 58.3% had no experience with CTP scans. Despite its potential to improve diagnostic accuracy, CTP’s underuse highlights significant operational and systemic barriers.

Although 88.1% of healthcare professionals recognized CTP's value in assessing cerebral blood flow, and 74.3% saw its advantages over other imaging techniques, safety concerns, including radiation exposure 65.1% and technical challenges 31.6%, remain substantial. Additionally, only 48% of participants felt confident interpreting CTP results, with 35.5% remaining neutral and 16.4% lacking confidence. These factors contribute to CTP’s limited integration into clinical practice.

Challenges to CTP adoption were rooted in workflow and resource limitations, with geographic disparities in equipment access, especially in southern regions like Hebron and Bethlehem. Patient concerns about radiation exposure 30.9%, procedure duration 25%, and anxiety 30.9% also deterred its use. Educational efforts mostly relied on brochures 50% and one-on-one discussions 55.3%, while videos 30.3% and online resources 32.9% were underutilized, indicating areas for improvement.

Addressing the gap between perception and practice requires tackling these systemic barriers. The weak correlation between knowledge and practice ($r = 0.199$, $p < 0.05$) and the lack of a significant relationship between attitudes and practices ($r = 0.142$, $p = 0.102$) suggest that structural challenges, such as inadequate training 78.9%, financial limitations 42.8%, and a lack of institutional organization (40.8% reporting no protocols), are the key factors limiting the widespread use of CTP.

4.12 Conclusion

This study reveals significant gaps in the knowledge, attitudes, and utilization of CTP among healthcare professionals, highlighting key barriers to its widespread use. While many recognize its value in stroke management, 59.6% of participants have never used CTP, and 58.3% lack experience with CTP scans. The primary obstacles include insufficient training, financial constraints, and limited access to equipment, particularly in southern regions like Hebron and Bethlehem. Safety concerns and technical challenges also deter its use.

Although attitudes toward CTP are generally positive, they do not strongly correlate with actual practices. The weak connection between knowledge, attitudes, and practices suggests that structural issues, such as inadequate training and lack of standardized protocols, are the main factors limiting CTP adoption. Addressing these challenges through targeted education and better resource allocation is essential to improve CTP's role in stroke diagnosis and management.

Chapter Five: Discussion, Recommendations, and Conclusion

5.1 Introduction

This chapter discusses the study findings about the literature. The study was designed to evaluate the feasibility of CTP in brain perfusion imaging within Palestinian governmental hospitals by examining the perception of health professionals. The findings are presented concerning the five research questions of the study, and are interpreted in detail and situated against relevant theoretical perspectives and clinical practices.

5.2 Knowledge, Attitude, Practices, and Perceptions of Healthcare Professionals Regarding CTP

The results of this study reveal that although approximately 75% of healthcare professionals possess a general awareness of brain CTP, only about half, 50.4%, demonstrate detailed knowledge of critical parameters such as CBF and MTT. This gap between general familiarity and in-depth understanding may hinder the effective application of CTP in stroke management. When examining the sources of knowledge, university education, 45.4%, and online courses, 16.4%, were the most commonly cited. In contrast, engagement with more advanced and up-to-date resources, such as medical journals 20.4% and professional conferences 9.9% was notably limited. This reflects insufficient engagement with current clinical advancements and highlights a potential weakness in ongoing professional development.

Supporting this concern, Sabarna et al. (2023) reported that 78% of brain CT scans ordered in emergency departments were unnecessary, primarily due to insufficient training among non-specialized physicians in appropriate imaging practices. These findings underscore the urgent need for enhanced education and stricter referral guidelines to optimize brain imaging utilization and reduce diagnostic errors.

Furthermore, Haggenmüller et al. (2023) emphasize the importance of rapid and accurate interpretation of CT, CTA, and CTP imaging in emergency settings to ensure timely stroke diagnosis and treatment. Together, these insights highlight the critical necessity for comprehensive training and increased awareness among healthcare professionals to improve both the precision and clinical effectiveness of CTP. However, despite these recognized benefits, the confidence of professionals in interpreting CTP scans remains limited. In this study, only 48% of participants reported feeling confident in reading CTP results, while a notable 35.5% remained neutral, indicating a clear gap between theoretical appreciation and practical competence. This observation aligns with Campbell et al. (2012), who noted that although CTP offers diagnostic accuracy comparable to perfusion-diffusion MRI, its interpretation requires a sufficient level of expertise.

Despite the limited depth of knowledge regarding CTP, the overall perception among participants was notably positive. A majority, 87.5%, supported the integration of CTP as a standard tool in stroke management, while 74.3% acknowledged its added value compared to other imaging techniques. These attitudes correspond with findings by Shen et al. (2017), who demonstrated the superior sensitivity of CTP in detecting ischemic strokes and its greater reliability over non-contrast CT and CTA. Such positive attitudes, if coupled with appropriate training, may facilitate broader and more effective adoption of CTP in clinical practice; however, the current disconnect between perceived value and actual implementation highlights a systemic gap where theoretical awareness has not yet translated into routine clinical use.

In terms of actual practice, CTP remains underutilized in the clinical settings surveyed. More than half of the participants, 59.6%, reported never using CTP in practice, and 58.3% had not participated in a CTP scan. Furthermore, 58.4% were not involved in the decision-making process to initiate such scans. This underutilization is particularly concerning in light of international evidence demonstrating that the addition of CTP significantly enhances diagnostic accuracy in stroke assessment. A recent study found that radiology residents achieved markedly higher diagnostic performance, including improved sensitivity and reduced false positives, when CTP was added to the standard stroke imaging protocol (Nicol, 2024). These findings support the integration of CTP as a standard tool in acute stroke evaluation.

5.3 Challenges Hindering Effective Integration of CTP

Despite its proven clinical value, the integration of CTP imaging into routine stroke care remains limited. The findings of this study highlighted several critical challenges that hinder its effective use, most notably limited training and systemic or institutional barriers.

Economic considerations emerged as a notable factor influencing the implementation of CTP imaging in clinical settings. In this study, 27% of participants cited the high cost of the procedure as a barrier to its utilization, while 32.2% expressed concerns about its overall cost-effectiveness in clinical practice. Interestingly, only 19.7% expressed a desire to explore cost-effectiveness further as a research priority, indicating limited engagement with economic evaluation despite its relevance. These findings highlight a perceptual gap: although cost is recognized as a barrier, there appears to be insufficient emphasis on understanding its broader implications through research or structured institutional assessment. This hesitation may stem from limited access to economic data or institutional constraints in lower-resource settings (Reyes-Santias et al., 2023; Chalela et al., 2007; González-Rábago et al., 2023).

Contrastingly, recent economic evaluations present compelling evidence that CTP is a cost-effective addition to standard imaging protocols for acute ischemic stroke. For instance, van Voorst et al. (2024) demonstrated that integrating CTP into diagnostic workflows for detecting large vessel occlusion resulted in significant cost savings (median ΔCosts: € −2671) and improved health outcomes (median ΔQALY: 0.073), yielding a favorable net monetary benefit of €8436. Similarly, Jackson et al. (2010) found that CTP-guided thrombolysis improved patient outcomes and reduced per-case costs by $42 compared to non-contrast CT alone. Shen et al. (2014) also reported that CTP was more cost-effective than CT alone in the UK and US healthcare systems. These international findings contrast with the underutilization observed in this study, where nearly 60% of participants had never used CTP, underscoring the need to address economic misconceptions and promote cost-effectiveness awareness to support wider clinical adoption.

In addition to financial challenges, access to advanced imaging modalities in Palestine is unevenly distributed across the West Bank, significantly affecting the feasibility of implementing CTP imaging. While approximately 81.3% of hospitals are equipped with CT scanners, only 18.8% have MRI machines. This disparity is particularly evident in southern regions such as Bethlehem and Hebron, where hospitals in towns like Yatta and Halhul lack both modalities entirely. In contrast, northern and central regions, including Nablus and Ramallah, report relatively better access to CT, though MRI availability remains limited (Palestinian Ministry of Health [PMOH], 2018). Such geographic inequities present substantial logistical and operational challenges to integrating CTP into routine stroke care, especially in underserved areas.

These findings echo global patterns. A prospective national study conducted in New Zealand by Thompson et al. (2022) found that patients treated in nonurban hospitals experienced poorer access to key stroke interventions, including advanced imaging, and worse functional outcomes at three, six-, and 12-months post-stroke. The study reported higher disability and mortality rates among rural patients, with significantly lower odds of receiving interventions such as endovascular thrombectomy and stroke unit care. Although set in a different context, these results highlight a universally relevant challenge: geographic disparities in infrastructure can directly translate into inequitable stroke outcomes.

In the Palestinian context, a report by the PMOH (2018) also examined the broader healthcare delivery system and referral pathways for imaging services. It revealed that despite legal guarantees for equal access under the Public Health Law (2004) and the Health Insurance and Treatment Abroad Law (2004), actual service distribution remains limited. The majority of MRI referrals (2,303 out of 4,608 imaging referrals) were concentrated in select hospitals such as Jenin, Ramallah, and Hebron, underscoring a critical dependence on inter-hospital transfers and outsourcing to the private sector, particularly for uninsured patients. While this structured referral system helps bridge gaps in access, it does not account for emerging technologies such as CTP, whose inclusion in the national imaging strategy remains unexplored. This gap offers a valuable opportunity for future research and policy planning focused on expanding equitable access to advanced neuroimaging tools.

Another key challenge identified by healthcare professionals relates to radiation exposure. In this study, 65.1% of respondents expressed concern about radiation dose during CTP, a sentiment shared by 30.9% who noted that patients often raise questions about potential harm. These findings reflect a shared awareness among clinicians and patients about the risks associated with ionizing radiation, particularly in sensitive neuroimaging contexts.

Radiation exposure during brain perfusion imaging using CT has been extensively studied, with multiple investigations confirming its significance and proposing various dose-reduction strategies. Alomary (2022), for example, evaluated dose parameters such as CTDIvol and DLP among 320 stroke patients, reporting an average effective dose of 13.2 mSv. Factors such as scan duration and equipment settings contributed to dose variability, reinforcing the need for standard diagnostic reference levels (DRLs) and increased operator awareness.

Innovative methods to reduce dose while maintaining diagnostic accuracy have also been explored. Deak et al. (2022) demonstrated that optimizing CTP scan duration based on carotid CTA timing could reduce dose without compromising visualization of infarct core and penumbra. Moghari et al. (2023) proposed a deep learning model (VAE-GAN) that predicted later CTP frames, reducing scan duration by 65% and radiation dose by 54.5% with minimal clinical compromise.

Other studies support practical dose-reduction approaches, such as those by Othman et al. (2016), who showed that decreasing tube current by 50% and reducing kVp from 120 to 80 could cut radiation exposure by nearly threefold. Yang et al. (2021) found that lowering tube current from 100 mAs to 60 mAs resulted in a 40% dose reduction without affecting map quality.

From a broader perspective, Kapur et al. (2021) confirmed that cumulative doses from standard neuroimaging protocols (NCCT + CTA + CTP) could be reduced by 46.6% using low-dose techniques. Zensen et al. (2021) emphasized revised DRLs and scanner-specific monitoring, while Chen et al. (2021) introduced voxel-level TAC correction to reduce exposure and improve image quality.

According to Admontree et al. (2022) at Ramathibodi Hospital, indicated that using 30% of the original tube current led to more than 30% dose reduction without diagnostic compromise. However, they also underscore the necessity of formal training, highlighted by 94.1% of respondents, to ensure safe and effective implementation of such protocols. In short, optimizing CTP protocols for radiation safety is achievable and essential for broader clinical acceptance and patient protection.

In addition to radiation concerns, institutional limitations and the lack of standardized protocols were significant obstacles noted in this study. Nearly 42.8% of respondents emphasized the need for stronger institutional support to adopt CTP, echoing global findings regarding the importance of infrastructure, administrative endorsement, and investment (Aderinto et al., 2023). Furthermore, outdated equipment, cited by 38.2% of participants, continues to hinder modernization.

The findings also point to inconsistent protocol use. While 45.4% of respondents follow institution-specific protocols, only 11.8% adhere to national guidelines and 5.9% to international ones. Alarmingly, 40.8% reported working without any formal protocol (Christensen & Lansberg, 2018). Such inconsistencies challenge the reliability and reproducibility of CTP across clinical settings.

Technical standards, including scan voltage, duration, contrast injection, and patient positioning, are critical for generating accurate perfusion maps. Best practices recommend 70–80 kV, a scan duration of 60–70 seconds, contrast injection via power injector at 4–6 mL/s followed by saline flush, and symmetrical head alignment (Christensen & Lansberg, 2018; Kasasbeh et al., 2016; Vagal et al., 2019).

Despite these well-defined guidelines, only 47.4% of participants emphasized the need to improve protocols. Most relied on informal learning sources such as conferences (71.1%) and online courses (59.2%), with no one citing peer-reviewed journals. This reflects a broader challenge in translating evidence-based recommendations into daily practice. Thus, there is an urgent need for comprehensive formal training and the development of standardized, evidence-based protocols to enhance CTP quality and support improved decision-making and outcomes in stroke care.

5.4 Training and Educational Needs for Healthcare Professionals

The results of this study underscore a critical educational gap among healthcare professionals regarding CTP imaging. The majority of respondents, 94.1%, agreed or strongly agreed that increased training on CTP is essential. Additionally, an overwhelming 96.7% of participants expressed their willingness to participate in further training or workshops, highlighting a strong collective desire for professional development in this domain.

Moreover, 72.4% of participants identified "additional training programs" as the most important support mechanism to overcome current barriers to CTP implementation, compared to fewer who emphasized equipment improvement, 60.5%, or cost reduction, 34.2%. This suggests that while technological and financial factors remain relevant, structured educational opportunities are viewed as the most urgent and impactful solution.

Interestingly, the study's regression analysis offers further insight. In Model One, knowledge was tested as a mediator between training and practice. However, none of the regression paths were statistically significant ($p > 0.05$), indicating no evidence that knowledge alone could explain the effect of training on actual clinical practice. In contrast, Model Four showed that attitude fully mediated this relationship. Training significantly influenced attitudes ($p < 0.001$), and these positive attitudes were significantly associated with improved practice ($p = 0.041$). The direct relationship between training and practice became non-significant when attitude was included (p = 0.539), suggesting that enhancing attitudes is a key mechanism through which training leads to improved application of CTP.

These findings align with previous studies in Palestine, where limited knowledge and inadequate training among healthcare professionals have been linked to inappropriate CT scan usage. For example, Nazzal et al. (2024) reported that only one-third of urgent brain CT scans adhered to guidelines, with many providers lacking awareness of radiation risks. Similarly, Sabarna et al. (2023) found that most brain CT scans at Hebron Hospital were unnecessary, largely due to insufficient training of non-specialized physicians. Collectively, these studies emphasize that enhancing training and education is crucial for properly implementing and effectively using CT perfusion imaging in clinical settings.

5.5 Perceptions of CTP Effectiveness and Safety

Radiation exposure remains a major safety concern associated with CT imaging, especially when advanced techniques like CTA and CTP are applied for acute stroke assessment. Zensen et al. (2021) highlight that these advanced CT procedures significantly increase cumulative radiation doses, underlining the importance of establishing DRLs to optimize patient safety and diagnostic efficacy. Similarly, in Palestine, Nazzal et al. (2024) reported concerns about unnecessary radiation exposure due to the overuse of urgent brain CT scans, with limited knowledge among healthcare providers about radiation risks, further emphasizing the need for education and guideline adherence.

In line with these concerns, 65.1% of respondents in the present study identified radiation exposure as the main safety issue regarding CTP, followed by limited access to proper imaging equipment. These perceptions align with the literature stressing the necessity of accurate CTP interpretation to avoid treatment complications (Kargiotis et al., 2024). Advances like deep learning-based CTP have shown improved image quality and safety outcomes, reducing risks such as hemorrhage in thrombolytic therapy (Hu et al., 2022).

Supporting the feasibility and safety of low-radiation CT perfusion, van Assen et al. (2021) demonstrated that myocardial CT perfusion imaging with regadenoson is safe and well tolerated, with radiation doses comparable to SPECT, without serious adverse events. This supports the potential for low-radiation CTP protocols in clinical practice. In summary, despite concerns about radiation exposure, optimized imaging protocols and adequate training can enhance the clinical utility and safety of CTP.

The study revealed strong confidence in the effectiveness of CTP imaging, with 88.1% of participants confirming its utility in assessing cerebral blood flow. Similarly, 87.5% considered CTP results reliable, and 74.3% recognized its added value compared to other imaging modalities.

These perceptions are supported by recent literature demonstrating CTP's diagnostic accuracy and clinical relevance. Cviková et al. (2024) reported that CTP and CTA spot signs, performed on 16-slice CT scanners, show high sensitivity 85.7% and specificity 95.8% in predicting acute intracranial hematoma progression, although parametric perfusion maps may be limited by motion artifacts in some cases. Moreover, Furlanis et al. (2025) found CTP effective in detecting acute posterior circulation stroke (PCS), with perfusion abnormalities present in 64.5% of cases, particularly through MTT maps, and associated with key clinical factors like atrial fibrillation and neurological deficits.

These findings align with previous meta-analyses reporting CTP sensitivity of 86.7% and specificity of 77.8% in ischemic stroke detection (Mubarak et al., 2023; Shen et al., 2017). CTP enhances detection of vessel occlusions when combined with CTA (Alotaibi et al., 2023) and offers comparable accuracy to perfusion-diffusion MRI (Campbell et al., 2012). Despite occasional automated postprocessing failures (~11%; Kauw et al., 2020), CTP remains a reliable and effective imaging tool in acute stroke evaluation and management.

5.6 Recommendations

Based on the findings of this study, which explored the feasibility and perceptions of brain perfusion imaging using CTP in governmental hospitals in the West Bank, several practical and actionable recommendations are proposed to enhance its effective adoption in clinical practice, particularly in the management of acute stroke.

First, it is essential to implement structured training programs aimed at improving the knowledge and practical skills of healthcare professionals, especially radiologists, radiographers, and neurologists. The study identified a significant gap in understanding critical CTP parameters such as CBF and MTT, with only about half of the participants demonstrating adequate knowledge. Workshops, certified short courses, and hands-on clinical training sessions should be prioritized, with support from academic institutions and the Ministry of Health. These programs should not only cover technical knowledge but also emphasize the clinical value of CTP in stroke diagnosis and management.

In parallel with training efforts, awareness campaigns are recommended to address the uncertainty and limited confidence observed among some healthcare workers regarding the effectiveness of CTP. These campaigns should highlight evidence-based benefits of CTP, including its higher sensitivity in detecting ischemic changes and its value in guiding thrombolytic treatment. Increasing awareness will help build more positive attitudes and promote broader acceptance of the technique among clinical staff.

Another critical recommendation is to enhance the availability of CTP technology across healthcare institutions. The study revealed that access to advanced imaging tools remains uneven, with geographic disparities particularly affecting hospitals in southern areas such as Hebron and Bethlehem. As a practical approach, it is suggested that hospitals already equipped with CT scanners should receive priority for software upgrades that enable perfusion imaging, which is more cost-effective than purchasing new machines. Furthermore, the Ministry of Health should develop strategic procurement plans and seek partnerships with international donors to support the acquisition and maintenance of CTP equipment, especially in underserved regions.

Financial constraints were cited as a major barrier by many participants. To overcome this, healthcare institutions should integrate cost-effectiveness evidence into policy advocacy and funding proposals. International studies have demonstrated that CTP can reduce stroke-related disability and overall healthcare costs, making a compelling investment case. Therefore, health policymakers should be encouraged to allocate dedicated budgets and explore external funding sources to support both equipment procurement and personnel training.

The development of standardized national protocols for CTP use is another key priority. The study found significant variability in practice, with many professionals operating without formal guidelines. A multidisciplinary committee comprising experts from radiology, neurology, and emergency medicine should be established to develop unified protocols that include clear indications, technical parameters, and workflow integration for CTP imaging. Establishing stroke teams within hospitals and improving interdepartmental coordination will also help streamline decision-making and reduce delays in imaging stroke patients.

Radiation safety remains a major concern among both professionals and patients. It is therefore crucial to implement dose optimization strategies, such as lowering tube current and scan time, applying appropriate contrast injection protocols, and using post-processing techniques that preserve image quality while reducing exposure. Regular audits of radiation dose levels and adherence to DRLs should be conducted, supported by continuous training for radiology staff on low-dose imaging principles.

From a policy perspective, governmental authorities should formally recognize CTP as an essential component of stroke imaging protocols and integrate it into national stroke care strategies. This requires clear policy directives, funding mechanisms, and accountability measures to ensure consistent implementation. Health authorities should also monitor utilization patterns and outcomes to guide future updates to stroke management protocols.

Finally, the integration of artificial intelligence (AI) into CTP analysis should be explored as a long-term strategy to enhance diagnostic accuracy and efficiency. AI-based tools can assist clinicians in identifying perfusion deficits more rapidly and reduce human error, especially in high-pressure emergency settings. Pilot projects can be launched in collaboration with research institutions to test the feasibility and clinical value of AI-powered CTP analysis, with a parallel focus on training staff in AI interpretation and validation.

By addressing these recommendations, healthcare institutions in Palestine can make meaningful progress toward adopting CTP imaging more widely and effectively, thereby improving stroke care outcomes and reducing the burden of cerebrovascular disease across the region.

5.7 Limitations and Future Directions

While this study provides valuable insights into the feasibility and perception of CTP imaging in stroke management, several limitations must be acknowledged. The research focused solely on healthcare professionals working in government hospitals in the West Bank, which may not fully represent the perspectives of those in private or non-governmental sectors, or from other regions such as Gaza. Throughout the data collection phase, the researcher encountered several practical challenges, including administrative delays in obtaining access to hospitals and limited availability of participants due to their demanding schedules. These challenges affected both the timeline and the overall scope of participant inclusion.

Another limitation lies in the use of self-administered questionnaires, which, although efficient, carry the risk of response bias. Participants may have unintentionally overestimated or underestimated their knowledge, attitudes, or the challenges they face within their institutions. This reliance on subjective reporting may influence the accuracy and generalizability of the results, especially in a field where clinical practices and perceptions can vary significantly across departments and institutions.

To build on the findings of this study, future research should aim to include a more diverse and representative sample from various healthcare sectors and geographic regions. A mixed-methods approach, combining quantitative data with qualitative interviews or focus groups, would allow for a deeper exploration of the institutional and clinical factors influencing the use of CTP in stroke care. Collaboration with healthcare authorities could help overcome administrative barriers and expand participation. Furthermore, longitudinal studies would be valuable in tracking changes over time and evaluating the long-term impact of interventions designed to support the integration of CTP in clinical practice.

5.8 Conclusion

This study investigated the feasibility and perceptions surrounding the use of CTP imaging in Palestinian governmental hospitals, with a specific focus on the knowledge, attitudes, practices, and challenges faced by healthcare professionals. The findings reveal a critical gap between the general awareness of CTP and the in-depth understanding required for its effective implementation in stroke management. Despite the high level of support for integrating CTP into routine clinical practice, the actual use remains limited due to several barriers, including insufficient training, financial constraints, geographical disparities, concerns about radiation exposure, and the absence of standardized protocols.

Notably, while most participants expressed positive attitudes toward the clinical value of CTP, less than half reported confidence in interpreting perfusion results. This indicates a pressing need for comprehensive, structured training programs to bridge the gap between theoretical knowledge and clinical competence. Additionally, although economic and equipment-related barriers were acknowledged, the willingness of healthcare professionals to engage in further training suggests that educational interventions may yield the most immediate and sustainable improvements.

Moreover, the study underscores significant institutional and systemic challenges that hinder the broader adoption of CTP, such as outdated infrastructure and inequitable distribution of imaging resources across regions. Despite these challenges, recent international evidence demonstrates that CTP is both clinically effective and cost-efficient, reinforcing its potential role in improving stroke diagnosis and treatment outcomes in low-resource settings like Palestine.

In conclusion, this research highlights that while the feasibility of CTP implementation is currently constrained by logistical and educational limitations, there is strong professional support and foundational awareness that can be leveraged to promote its integration. To advance the clinical utility of CTP, healthcare policymakers and institutions must prioritize targeted training, standardized protocols, and equitable infrastructure development. These efforts are essential to unlock the full potential of CTP imaging and ensure timely, accurate, and safe stroke care for all patients.

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Appendices

Appendix 1: Regression Analysis Results (Predictors: Knowledge & Attitudes; Dependent Variable: Practices)

Variable	B	Std. Error	Beta	t	Sig.	Model Fit	Value
(Constant)	11.678	2.379	-	4.909	0.000	R	0.204
Knowledge	0.150	0.149	0.100	1.002	0.318	R^2	0.042
Attitudes	0.175	0.130	0.135	1.350	0.179	Adjusted R^2	0.027
						Std. Error	4.491

Appendix 2: Regression Coefficients and Confidence Intervals for Practices for Knowledge, Attitudes, and Practices.

Model		95.0% Confidence Interval for B	
		Lower Bound	Upper Bound
	(Constant)	6.971	16.385
	Knowledge	-0.146	0.445
	Attitudes	-0.082	0.432

a. Dependent Variable: Practices

Appendix 3: Regression Analysis Results for PT Outcomes (Predictor: Attitudes)

Variable	B	Std. Error	Beta	t	Sig.	Model Fit	Value
(Constant)	1.974	0.676	-	2.922	.004**	R	0.629
Attitudes	0.337	0.035	0.629	9.752	<.001***	R^2	0.396
					Adjusted R^2		0.392
					Std. Error		1.432

Appendix 4: Regression Coefficients and Confidence Intervals for Practices for Patient Outcomes and Attitudes.

Model		95.0% Confidence Interval for B	
		Lower Bound	Upper Bound
	(Constant)	0.013	3.383
	Attitudes	0.030	0.202

a. Dependent Variable: PT Outcomes

Appendix 5: Regression Analysis Results for PT Outcomes (Predictor: Practices)

Variable	B	Std. Error	Beta	t	Sig.	Model Fit	Value
(Constant)	8.975	0.497	-	18.069	<.001***	R	0.847
Practices	2.097	0.113	0.847	18.545	<.001***	R^2	0.717
					Adjusted R^2		0.715
					Std. Error		2.452

Appendix 6: Regression Coefficients and 95% Confidence Intervals for PT Outcomes Predicting Practices

Model		95.0% Confidence Interval for B	
		Lower Bound	Upper Bound
	(Constant)	7.992	9.957
	PT Outcomes	1.874	2.321

a. Dependent Variable: Practices

Appendix 7: Availability of CT and MRI Machines in Government Hospitals

Hospital Name	Governorate	Number of CT Machines	Number of MRI Machines
Martyr Dr. Khalil Suleiman Hospital	Jenin	1	1
Tubas Turkish Government Hospital	Tubas	1	None
Martyr Dr. Thabet Thabet Hospital	Tulkarem	1	None
Atil Hospital	Atil-Tulkarm	None	None

Darwish Nazzal Hospital	Qalqilya	1	None
Rafidia Surgical Hospital	Nablus	1	Under Installation
National Hospital	Nablus	1	None
Martyr Yasser Arafat Hospital	Salfit	1	None
Palestine Medical Complex	Ramallah	3	1
Jericho Governmental Hospital	Jericho	1	None
Beit Jala Governmental Hospital	Bethlehem	1	None
Martyr Abu Al-Hassan Al-Qasim Hospital	Yatta-Hebron	1	None
Hebron Governmental Hospital (Alia)	Hebron	1	1
Mohammad Ali Al-Muhtaseb Hospital	Hebron	None	None
President Mahmoud Abbas Hospital	Halhul-Hebron	None	None
Dura Governmental Hospital	Dura-Hebron	1	None

Appendix 8: Correlations Between Demographic Factors and Knowledge, Attitudes, and Practices Toward CTP.

			Knowledge	**Attitudes**	**Practices**
Spearman's rho	Profession	Correlation Coefficient	0.044	-0.009	-0.187*
		Sig. (2-tailed)	0.599	0.911	0.028
	Gender	Correlation Coefficient	0.163	-0.017	0.082
		Sig. (2-tailed)	0.052	0.835	0.341
	Age	Correlation Coefficient	-0.150	-0.096	-0.044
		Sig. (2-tailed)	0.075	0.249	0.612
	Employment	Correlation Coefficient	-0.094	-0.092	0.117
		Sig. (2-tailed)	0.267	0.272	0.176
	Experience	Correlation Coefficient	-.083	-.071	-.061
		Sig. (2-tailed)	.326	.392	.478

Appendix 9: Regression Coefficients and 95% Confidence Intervals for Predictors of Practices.

Model		95.0% Confidence Interval for B	
		Lower Bound	Upper Bound
	(Constant)	-7.174	9.675
	profession	-2.274	1.930
	Gender	-0.331	3.161
	Age	-1.059	1.222
	employment	0.037	0.391
	experience	-1.288	0.926
	education degree	1.210	4.407
	Knowledge	-0.149	0.429
	Attitudes	0.021	0.514

a. Dependent Variable: Practices

Appendix 10: Logistic Regression Results

Variable	B	S.E.	Wald	df	Sig.	Exp(B)	95% CI for Exp(B)
Constant	0.031	1.169	0.001	1	0.979	1.031	-
Institutional support	-0.155	0.102	2.278	1	0.131	0.857	0.701 - 1.047
Available CT	-0.082	0.728	0.013	1	0.910	0.921	0.221 - 3.836
Training	0.590	0.339	3.032	1	0.082	1.804	0.929 - 3.503

Appendix 11: Study Questionnaire

Assessing the Feasibility and Perceptions of Brain Perfusion Imaging with Computed Tomography

عزيزي المشارك

أتمنى أن تصلك هذه الرسالة وأنت بخير . أكتب إليك لدعوتك للمشاركة في دراسة بحثية بعنوان "تقييم جدوى وتصورات تصوير تروية الدماغ باستخدام التصوير المقطعي المحوسب". تهدف هذه الدراسة إلى تحسين الممارسات التشخيصية وتوجيه تطوير التدريب والسياسات من خلال تقييم معرفة ومواقف وممارسات فنيي الأشعة وأطباء الأشعة وأخصائي الأعصاب فيما يتعلق بتحليل تروية الدماغ باستخدام التصوير المقطعي المحوسب في المستشفيات الحكومية في الضفة الغربية فلسطين.

إن مشاركتك في هذه الدراسة ذات قيمة كبيرة، وستتطلب منك إكمال استبانة منظمة، تستغرق من 5−10 دقائق، وتهدف هذه الاستبانة إلى جمع معلومات حول خلفيتك الديموغرافية، ومدى معرفتك ب تصوير تروية الدماغ من خلال التصوير المقطعي المحوسب. ستسهم الأفكار التي سيتم الحصول عليها من هذه الدراسة بشكل كبير في تطوير توصيات لتحسين استخدام تقنيات التصوير المتقدمة في حالات السكتة الدماغية الحادة، وإنشاء برامج تدريبية مخصصة وإرشادات سريرية.

لضمان خصوصيتك، ستتم إزالة جميع المعلومات الشخصية واستبدالها بأكواد تعريفية فريدة. وسيتم تخزين البيانات بشكل آمن في قاعدة بيانات محمية بكلمة مرور ، ولن يتم الوصول إليها إلا من قبل المخولين فقط. سيتم إبلاغك بهذه التدابير لضمان عدم الكشف عن الهوية خلال عملية الموافقة على المشاركة، علما أن مشاركتك في هذا البحث هي اختيارية، ويمكن لك إختيارعدم المشاركة أو تغيير رأيك في أي وقت أثناء الدراسة.

يرجى إكمال الاستبانة عبر الإنترنت من خلال المنصة الآمنة في أقرب وقت ممكن. إن خبرتك ومساهمتك ضرورية لنجاح هذه الدراسة، وأقدر جدا وقتك وجهدك.

إذا كان لديك أي أسئلة أو تحتاج إلى مزيد من المعلومات، فلا تتردد في التواصل معي عبر البريد الإلكتروني

o.ajaj1@student.aaup.edu أو عن طريق الهاتف على الرقم +9720595016619. شكراً لك على النظر في المشاركة في هذا البحث المهم.

مع خالص التقدير،

أسامة محفوظ أحمد عجاج
فني أشعة
الجامعة العربية الأمريكية
البريد الإلكتروني: o.ajaj1@student.aaup.edu
الهاتف: +9720595016619

Section 1: Demographic Information
القسم 1: معلومات ديموغرافية

1. What is your profession? (ما هي مهنتك؟)
Mark only one answer
☐Radiologist طبيب إختصاصي أشعة تشخيصية
☐Radiographer فني تصوير طبي
☐Neurologist أخصائي أعصاب

2. Gender (الجنس)
Mark only one answer
☐Male ذكر
☐Female أنثى
☐I don't want to answer لا أريد الإجابة

3. Age (العمر)
Mark only one answer
☐20-29
☐30-39
☐40-49
☐50-59
☐60 or older
☐I don't want to answer لا أريد الإجابة

4. What is the name of your present place of employment?

ما هو إسم مكان عملك الحالي

Mark only one answer

☐Khalil Suleiman Governmental Hospital - Jenin مستشفى خليل سليمان الحكومي – جنين

☐Turkish Government Hospital - Tubas المستشفى الحكومي التركي – طوباس

☐Thabet Thabet Governmental Hospital - Tulkarem مستشفى ثابت ثابت الحكومي – طولكرم

☐Attil Government Hospital مستشفى عتيل الحكومي

☐National Hospital - Nablus المستشفى الوطني – نابلس

☐Rafidia Hospital - Nablus مستشفى رفيديا – نابلس

☐Darwish Nazzal Governmental Hospital - Qalqilya مستشفى درويش نزال الحكومي – قلقيلية

☐Yasser Arafat Governmental Hospital - Salfit مستشفى ياسر عرفات الحكومي – سلفيت

☐Palestine Medical Complex - Ramallah مجمع فلسطين الطبي – رام الله

☐Beit Jala Hospital (Al-Hussein) - Bethlehem مستشفى بيت جالا (الحسين) – بيت لحم

☐Alia Governmental Hospital - Hebron مستشفى عالية الحكومي – الخليل

☐Yatta Governmental Hospital - Hebron مستشفى يطا الحكومي – الخليل

☐Mohammed Ali Al-Muhtaseb Governmental Hospital - Hebron مستشفى محمد علي المحتسب الحكومي – الخليل

☐President Mahmoud Abbas Hospital - Hebron مستشفى الرئيس محمود عباس – الخليل

☐Dura Government Hospital مستشفى دورا الحكومي

☐Jericho Governmental Hospital - Jericho مستشفى أريحا الحكومي – أريحا

5. How many years of experience do you have in your field?

كم عدد سنوات الخبرة في مجالك

Mark only one answer

☐Less than 1 year
☐1-5 years
☐6-10 years
☐More than 10 years

6. What is your educational degree?

ما هي درجتك العلمية؟

Mark only one answer

☐Diploma Degree درجة الدبلوم

☐Bachelor's Degree درجة البكالوريوس

☐Master's Degree درجة الماجستير

☐Doctorate (PhD/MD) Degree درجة الدكتوراه

Section 2: Knowledge Assessment for CTP
القسم 2: تقييم المعرفة CTP

Please indicate your level of agreement with the following statements regarding CTP:
يرجى الإشارة إلى مستوى موافقتك على البيانات التالية فيما يتعلق بـ CTP

7. I am familiar with Brain Perfusion Imaging using CT
أنا على دراية بتصوير تدفق الدم إلى الدماغ باستخدام التصوير المقطعي المحوسب

Mark only one answer

☐Strongly Agree أوافق بشدة

☐Agree موافق

☐Neutral حيادي

☐Disagree غير موافق

☐Strongly Disagree غير موافق بشدة

8. Sources of learning about CTP
مصادر التعلم عن CTP

Mark only one answer

☐Medical journals المجلات الطبية

☐Conferences المؤتمرات

☐University education التعليم الجامعي

☐Online courses الدورات التدريبية عبر الإنترنت

☐Other:

9. Benefits of CTP (select all that apply)
فوائد CTP (اختر كل ما ينطبق)

☐Early stroke detection الكشف المبكر عن السكتة الدماغية

☐Detailed brain mapping رسم خرائط تفصيلية للدماغ

☐Non-invasive procedure إجراء غير جراحي

☐Real-time blood flow analysis تحليل تدفق الدم في الوقت الحقيقي

10. CTP is an effective method for assessing cerebral blood flow

CTPهي طريقة فعالة لتقييم تدفق الدم الدماغي

Mark only one answer

☐Strongly Agree أوافق بشدة

☐Agree موافق

☐Neutral حيادي

☐Disagree غير موافق

☐Strongly Disagree غير موافق بشدة

11. I am familiar with the parameters measured in CTP (e.g., CBF, CBV, MTT, TTP).

أنا على دراية بالمعلمات المقاسة فيCTP (على سبيل المثال TTP، MTT، CBV، CBF)

Mark only one answer

☐Strongly Agree أوافق بشدة

☐Agree موافق

☐Neutral حيادي

☐Disagree غير موافق

☐Strongly Disagree غير موافق بشدة

12. I am knowledgeable about the technical aspects of CTP (e.g., contrast media usage and imaging protocols).

لدي معرفة بالجوانب الفنية لـCTP .(على سبيل المثال، استخدام وسائط التباين وبروتوكولات التصوير)

Mark only one answer

☐Strongly Agree أوافق بشدة

☐Agree موافق

☐Neutral حيادي

☐Disagree غير موافق

☐Strongly Disagree غير موافق بشدة

13. I am aware of the contraindications for using CTP

أنا على علم بموانع استخدامCTP

Mark only one answer

☐Strongly Agree أوافق بشدة

☐Agree موافق

☐Neutral حيادي

☐Disagree غير موافق

☐Strongly Disagree غير موافق بشدة

Section 3: Attitudes Towards CTP

القسم 3: المواقف تجاه CTP

14. I believe that CTP should be included as a standard practice in stroke assessment.

أعتقد أنه ينبغي إدراج CTP كممارسة قياسية في تقييم السكتة الدماغية

Mark only one answer

☐Strongly Agree أوافق بشدة

☐Agree موافق

☐Neutral حيادي

☐Disagree غير موافق

☐Strongly Disagree غير موافق بشدة

15. To what extent do you agree with the following statement: CTP results significantly influence rapid treatment decisions for acute stroke?

إلى أي مدى تتفق مع العبارة التالية: تؤثر نتائج CTP بشكل كبير على قرارات العلاج السريع للسكتة الدماغية الحادة.

Mark only one answer

☐Strongly Agree أوافق بشدة

☐Agree موافق

☐Neutral حيادي

☐Disagree غير موافق

☐Strongly Disagree غير موافق بشدة

16. Do you believe that CTP provides significant added value over other imaging modalities (e.g., Non-Contrast CT, CTA, MRI)?

هل تعتقد أن التصوير المقطعي المحوسب للتروية يوفر قيمة مضافة كبيرة مقارنة بوسائل التصوير الأخرى (على سبيل المثال، التصوير المقطعي المحوسب بدون التباين، التصوير المقطعي المحوسب مع مادة تباين، التصوير بالرنين المغناطيسي)؟

Mark only one answer

☐Strongly Agree أوافق بشدة

☐Agree موافق

☐Neutral حيادي

☐Disagree غير موافق

☐Strongly Disagree غير موافق بشدة

17. I am satisfied with the current brain imaging techniques

أنا راضٍ عن تقنيات تصوير الدماغ الحالية

Mark only one answer

☐Strongly Agree أوافق بشدة

☐Agree موافق

☐Neutral حيادي

☐Disagree غير موافق

☐Strongly Disagree غير موافق بشدة

18. I feel confident in my ability to interpret CTP results

أشعر بالثقة في قدرتي على تفسير نتائج CTP

Mark only one answer

☐Strongly Agree أوافق بشدة

☐Agree موافق

☐Neutral حيادي

☐Disagree غير موافق

☐Strongly Disagree غير موافق بشدة

19. I believe that increased training on CTP is necessary for healthcare professionals

أعتقد أن زيادة التدريب على CTP أمر ضروري لمقدمي الرعاية الصحية

Mark only one answer

☐Strongly Agree أوافق بشدة

☐Agree موافق

☐Neutral حيادي

☐Disagree غير موافق

☐Strongly Disagree غير موافق بشدة

20. The potential risks associated with CTP (e.g., radiation exposure) outweigh its benefits

إن المخاطر المحتملة المرتبطة بـCTP على سبيل المثال التعرض للإشعاع تفوق فوائدها

Mark only one answer

☐Strongly Agree أوافق بشدة

☐Agree موافق

☐Neutral حيادي

☐Disagree غير موافق

☐Strongly Disagree غير موافق بشدة

21. What are your primary concerns about the use of CTP in clinical practice? (Select all that apply)

ما هي مخاوفك الأساسية بشأن استخدام CTP في الممارسة السريرية؟ (اختر كل ما ينطبق)

☐Radiation exposure التعرض للإشعاع

☐Cost-effectiveness فعالية التكلفة

☐Technical complexity التعقيد الفني

☐Limited availability التوفر المحدود

22. To what extent do you agree with the following statement: "Brain perfusion imaging with CT improves patient outcomes in acute neurological conditions

إلى أي مدى تتفق مع العبارة التالية: "يُحسّن تصوير تدفق الدم إلى الدماغ باستخدام التصوير المقطعي المحوسب نتائج المرضى في الحالات العصبية الحادة"

Mark only one answer

☐Strongly Agree أوافق بشدة

☐Agree موافق

☐Neutral حيادي

☐Disagree غير موافق

☐Strongly Disagree غير موافق بشدة

Section 4: Practices Related to CTP

القسم 4: الممارسات المتعلقة بـ CTP

23. How often do you use CTP in your clinical practice?

ما مدى تكرار استخدامك لـ CTP في ممارستك السريرية؟

Mark only one answer

☐0

☐1-5

☐6-10

☐More than 10

24. In the past, how many CTP scans have you worked on?

في الماضي، كم عدد عمليات مسح CTP التي كنت تعمل عليها؟

Mark only one answer

☐0

☐1-5

☐6-10

☐More than 10

25. What protocols or guidelines do you follow for brain perfusion imaging with CT in your practice?

ما هي البروتوكولات أو المبادئ التوجيهية التي تتبعها لتصوير تدفق الدم إلى الدماغ باستخدام التصوير المقطعي المحوسب في ممارستك؟

Mark only one answer

☐Institution-specific protocolsبروتوكولات خاصة بالمؤسسة

☐National guidelines المبادئ التوجيهية الوطنية

☐International guidelines المبادئ التوجيهية الدولية

☐No specific protocols لا يوجد بروتوكولات محددة

26. Are you involved in the decision-making process for performing CTP scans?

هل تشارك في عملية صنع القرار لإجراء فحوصاتCTP؟

Mark only one answer

☐Yes نعم

☐No لا

27. How would you rate the ease of integrating CT perfusion imaging into your clinical workflow?

كيف تقيم سهولة دمج CTPفي سير عملك السريري؟

Mark only one answer

☐Very easy سهل جدا

☐Easy سهل

☐Neutral حيادي

☐Difficult صعب

☐Very difficult صعب جدا

28. What feedback have you received from patients regarding CT perfusion imaging? (Select all that apply)

ما هي التعليقات التي تلقيتها من المرضى بخصوص تصوير تدفق الدم بالأشعة المقطعية؟ (اختر كل ما ينطبق)

☐Positive إيجابي

☐Negative سلبي

☐Concerns about radiation exposure المخاوف بشأن التعرض للإشعاع

☐Concerns about procedure duration المخاوف بشأن مدة الإجراء

☐Anxiety about the procedure القلق بشأن الإجراء

☐Other:

29. **How do you educate patients about the benefits and risks of CTP imaging? (Select all that apply.)**

كيف يمكنك تثقيف المرضى حول فوائد ومخاطر التصوير المقطعي المحوسب للتروية؟ (اختر كل ما ينطبق)

☐Brochures/pamphlets الكتيبات/النشرات

☐One-on-one discussions مناقشات فردية

☐Informational videos فيديوهات إعلامية

☐Referral to online resources المصادر المتاحة عبر الإنترنت

30. **Have you encountered any limitations with CTP imaging in clinical practice?**

هل واجهت أي قيود مع CTP في الممارسة السريرية؟

Mark only one answer

☐Yes نعم

☐No لا

31. **Please indicate the main barriers you face in utilizing CTP in your practice (select all that apply)**

يرجى الإشارة إلى العوائق الرئيسية التي تواجهها في استخدام CTPفي ممارستك (حدد كل ما ينطبق)

☐Lack of training نقص التدريب

☐High cost of the procedure التكلفة العالية للإجراء

☐Concerns are Limited about access to equipment الوصول المحدود إلى المعدات

☐Patient safety المخاوف بشأن سلامة المرضى

32. **What resources or support would help you overcome these barriers? (Select all that apply)**

ما هي الموارد أو الدعم الذي قد يساعدك في التغلب على هذه الحواجز؟ (اختر كل ما ينطبق)

☐Financial support الدعم المالي

☐Additional training programs برامج تدريب إضافية

☐Technical support الدعم الفني

☐Updated equipment تحديث المعدات

☐Institutional support الدعم المؤسسي

33. How do you ensure the accuracy and reliability of CT perfusion imaging results in the hospital? (Select all that apply.)

كيف تضمن دقة وموثوقية نتائج تصوير التروية المقطعي المحوسب في المستشفى؟ (اختر كل ما ينطبق).

☐Regular calibration of equipment المعايرة المنتظمة للمعدات

☐Continuing education and training التعليم والتدريب المستمر

☐Standardized protocols البروتوكولات الموحدة

☐Peer review of imaging results مراجعة الأقران لنتائج التصوير

Section 5: Future Directions of CTP

القسم 5: الاتجاهات المستقبلية CTP

34. What improvements do you think are necessary for the wider adoption of CT perfusion imaging? (Select all that apply.)

ما هي التحسينات التي تعتقد أنها ضرورية لتبني أوسع لتصوير التروية المقطعي المحوسب؟ (اختر كل ما ينطبق)

☐Enhanced Training التدريب المعزز

☐Better Equipment معدات أفضل

☐Reduced Costs انخفاض التكاليف

☐Increased Awareness زيادة الوعي

☐Improved Protocols تحسين البروتوكولات

35. Are you interested in participating in further training or workshops on CT perfusion imaging?

هل أنت مهتم بالمشاركة في مزيد من التدريب أو ورش العمل حولCTP؟

Mark only one answer

☐Yes نعم

☐No لا

36. What areas of research would you like to see explored further regarding CT perfusion imaging? (Select all that apply)

ما هي مجالات البحث التي ترغب في استكشافها بشكل أعمق فيما يتعلق بتصوير التروية المقطعي المحوسب؟ (اختر كل ما ينطبق)

☐Long-term patient outcomes نتائج المرضى على المدى الطويل

☐Cost-effectiveness فعالية التكلفة

☐Technological advancements التطورات التكنولوجية

☐Protocol standardization توحيد البروتوكولات

☐Comparative studies with other imaging modalities دراسات مقارنة مع وسائل التصوير الأخرى

37. How do you stay updated on the latest advancements and research in brain perfusion imaging? (Select all that apply.)

كيف يمكنك البقاء على اطلاع بأحدث التطورات والأبحاث في مجال تصوير تروية الدماغ؟ (اختر كل ما ينطبق)

☐Professional journals المجلات المهنية

☐Conferences and workshops المؤتمرات وورش العمل

☐Online courses الدورات التدريبية عبر الإنترنت

☐Professional associations الجمعيات المهنية

Appendix 12: Institutional Review Board Approval Letter

Arab American University
Institutional Review Board - Ramallah

الجامعـــة العربيـــة الأمريكيـــة
مجلس اخلاقيات البحث العلمي – رام الله

IRB Approval Letter

Study Title: "Assessing the Feasibility and Perceptions of Brain Perfusion Imaging with Computed Tomography".

Submitted by: Osama Mahfoth Ahmad Ajaj

Date received:	24th October 2024
Date reviewed:	29th October 2024
Date approved:	29th October 2024

Your Study titled **"Assessing the Feasibility and Perceptions of Brain Perfusion Imaging with Computed Tomography"** with the code number **"R-2024/A/155/N"** was reviewed by the Arab American University Institutional Review Board - Ramallah and it was approved on the 29th of October 2024.

Sajed Ghawadra, PhD
IRB-R Chairman
Arab American University of Palestine

الجامعة العربية الأمريكية . فلسطين
مجلس اخلاقيات البحث العلمي . رام الله
IRB-R
ARAB AMERICAN UNIVERSITY-PALESTINE
INSTITUTIONAL REVIEW BOARD - RAMALLAH

General Conditions:

1. Valid for 6 months from the date of approval.
2. It is important to inform the IRB-R with any modification of the approved study protocol.
3. The Bord appreciates a copy of the research when accomplished.

Appendix 13: Mission letter from the Ministry of Health

State of Palestine
Ministry of Health
Education in Health and Scientific Research Unit

دولة فلسطين
وزارة الصحة
وحدة التعليم الصحي
والبحث العلمي

Ref.: ....
Date: ....

الرقم: ٢٠٢٥/٢٩٨٠/١٢ع
التاريخ: ٢٠٢٤/١١/١٧

الأخ مدير عام الادارة العامة للمستشفيات المحترم،،،
عطوفة الوكيل المساعد لمجمع فلسطين الطبي المحترم،،،
تحية واحترام..

<u>الموضــوع: تسهيل مهمة بحث</u>

يرجى تسهيل مهمة الطالب: **أسامة محمفوظ احمد عجاج – برنامج علوم التصوير الطبقي والرنين المغناطيسي**– الجامعة العربية الامريكية، بعنوان:

"تقييم إمكانية وتصورات تصوير تروية الدماغ باستخدام التصوير الطبقي "

حيث سيقوم الطالب بجمع معلومات حول موضوع البحث من خلال تعبئة استبانة، وذلك في:

- **جميع المستشفيات الحكومية**
- **مجمع فلسطين الطبي**

مع العلم ان مشرف الدراسة: د. احمد ابو عرة.
على ان يتم الالتزام بالمحافظة على اخلاقيات البحث العلمي وسرية المعلومات، وعدم التعرض للمعلومات التعريفية للمشاركين.
على ان يتم تزويد الوزارة بنسخة PDF من نتائج البحث، التعهد بعدم النشر لحين الحصول على موافقة وزارة الصحة.

مع الاحترام..

د. عبد الله القواسمي
رئيس وحدة التعليم الصحي والبحث العلمي

نسخة: عميد كلية الدراسات العليا المحترم/ الجامعة العربية الامريكية

تقييم جدوى وتصورات تقنية تصوير تروية الدماغ بالأشعة المقطعية

أسامة محفوظ أحمد عجاج

لجنة الإشراف:

د. أحمد أبو عزّة

د. عبد الناصر عاصي

د. عبد السلام خلف

ملخص

هدفت هذه الدراسة إلى تقييم جدوى وتصورات تصوير تروية الدماغ باستخدام التصوير المقطعي المحوسب بين أخصائي الرعاية الصحية في المستشفيات الحكومية في جميع أنحاء الضفة الغربية، فلسطين. أُجري البحث عام ٢٠٢٥، واعتمد تصميمًا كميًا مقطعيًا يستهدف فنيي الأشعة، وأطباء الأشعة، وأطباء الأعصاب. استُخدم استبيان مُهيكل ومُعتمد لتقييم المعارف والخبرات والممارسات للمشاركين فيما يتعلق بالتصوير المقطعي المحوسب، ولاستكشاف العوائق المؤسسية والتقنية التي تُعيق تطبيقه السريري.

شارك في الدراسة ١٥٢ أخصائيًا. كانت الأغلبية من فنيي الأشعة، بنسبة ٨٥.٥٪، يليهم أخصائيو الأشعة بنسبة ٨.٦٪، ثم أخصائيو الأعصاب بنسبة ٥.٩٪. في حين أفاد ٧٥٪ بمعرفتهم بالتصوير المقطعي المحوسب، لم يتمكن سوى ٥٠.٤٪ من تحديد معايير التروية الرئيسية بدقة، وأعرب ٤٨ ٪ فقط عن ثقتهم في تفسير نتائج التصوير المقطعي المحوسب. كان الوعي بموانع الاستعمال متوسطًا بنسبة ٦٦.٤٪، بينما أفاد ٧٨.٩٪ بعدم كفاية فرص التدريب. بالإضافة إلى ذلك، أعرب ٦٥.١٪ عن قلقهم بشأن التعرض للإشعاع، وأشار ٤٠.٨ ٪ إلى محدودية الوصول إلى معدات التصوير المتطورة.

على الرغم من التحديات، رأى ٨٨.١٪ من المشاركين أن التصوير المقطعي المحوسب يُقيّم تروية الدماغ بفعالية، وأعرب ٨٧.٥٪ عن ثقتهم بقيمته التشخيصية؛ وارتبطت المعرفة ارتباطًا وثيقًا

بالمواقف (معامل الارتباط = ٠,٥٠١، مستوى الدلالة الإحصائية < ٠,٠١) والممارسة (معامل الارتباط = ٠,١٩٩، مستوى الدلالة الإحصائية < ٠,٠٥). توصي الدراسة بتدريب مُستهدف، وبروتوكولات موحدة، واستثمار في البنية التحتية لسد الفجوة بين القيمة المُتصوَّرة والاستخدام السريري للتصوير المقطعي المحوسب كبديل سريع وسهل المنال للتصوير بالرنين المغناطيسي في البيئات محدودة الموارد مثل فلسطين.

الكلمات المفتاحية: تروية التصوير المقطعي المحوسب، تصوير السكتة الدماغية، الممارسة السريرية، فلسطين، أخصائيو الرعاية الصحية.