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ASSESSMENT OF CT ANGIOGRAPHY IN EARLY DIAGNOSIS AND TREATMENT IN STROKE PATIENTS: A RETROSPECTIVE STUDY

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Abstract

Objective: *To evaluate whether earlier CTA assessment is associated with favorable clinical outcomes and reduced in-hospital mortality.*

Materials & Methods: *A retrospective study of 163 acute ischemic stroke patients was conducted at the University Of Lahore Teaching Hospital Care Center from April 2025 to July 2026. All patients underwent CT angiography within 24 hours of symptom onset to assess vascular abnormalities, particularly large-vessel occlusion and collateral circulation. CTA images were reviewed by two experienced neuroradiologists. Clinical outcomes were assessed using the modified Rankin Scale (mRS). Data were analyzed using appropriate statistical tests, with $p < 0.05$ considered statistically significant. The study evaluated the usefulness of early CTA for diagnosis, treatment planning, and prediction of clinical outcomes in acute ischemic stroke.*

Results: *Among 163 patients, the mean age was 63.5 ± 8.5 years, with males predominating (59.50%) over females (40.49%). Hypertension (75.46%) was the most common risk factor, followed by diabetes mellitus (36.19%) and dyslipidemia (25.15%). The mean time to CTA was 5.1 hours. CTA identified large-vessel occlusion in 80 patients (49.07%). Collateral circulation was mild in 24.53%, moderate in 45.39%, and severe in 30.06%, with 74.85% demonstrating moderate-to-severe collateral circulation. Incidental vascular anomalies were found in 10.42% of patients. Clinically, 53.37% achieved favorable outcomes, while 14.72% died during hospitalization. Overall, the findings highlight the importance of early CTA for detecting large-vessel occlusion and assessing collateral circulation in acute ischemic stroke.*

Conclusion: *CT angiography is a valuable imaging modality for early stroke diagnosis, enabling rapid detection of large-vessel occlusion and collateral*

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circulation. Early CTA supports timely treatment decisions and may improve clinical outcomes.

Introduction

Stroke is a major global public health problem and remains one of the leading causes of death, long-term disability, and reduced quality of life worldwide. It occurs when there is an interruption or significant reduction in the blood supply to a part of the brain, resulting in neuronal injury and loss of neurological function. Stroke can broadly be classified into ischemic stroke, caused by arterial occlusion, and hemorrhagic stroke, caused by rupture of a cerebral blood vessel. Ischemic stroke accounts for the majority of stroke cases and requires rapid diagnosis and treatment because prolonged interruption of cerebral blood flow can lead to irreversible brain damage. The principle of "time is brain" emphasizes the importance of early diagnosis and immediate intervention in patients with acute stroke [1].The burden of stroke is particularly concerning in low- and middle-income countries, including Pakistan. Several factors contribute to the increasing incidence of stroke, including population ageing, hypertension, diabetes mellitus, smoking, obesity, dyslipidemia, sedentary lifestyle, and other cardiovascular risk factors. In Pakistan, the growing prevalence of non-communicable diseases has further increased the number of individuals at risk of developing cerebrovascular disease. At the same time, limitations in healthcare infrastructure, delayed hospital presentation, inadequate emergency transport systems, limited availability of specialized stroke centers, and financial constraints can negatively affect the timely diagnosis and management of stroke patients [2].

Early and accurate diagnosis is essential because modern stroke treatment depends heavily on the rapid identification of the type, location, and severity of cerebrovascular disease. Conventional non-contrast computed tomography (NCCT) is generally the first-line imaging modality in suspected acute stroke because it is fast and highly effective in excluding intracranial hemorrhage. However, NCCT alone provides limited information regarding the condition of the cerebral arteries. For patients with suspected ischemic stroke, additional vascular imaging may therefore be required to identify arterial occlusion, stenosis, aneurysms, or other vascular abnormalities. Computed tomography angiography (CTA) has become an important component of modern acute stroke imaging because it provides a rapid and detailed assessment of the cerebral and cervical vasculature. CTA involves the administration of iodinated contrast material followed by rapid CT image acquisition, allowing visualization of blood vessels from the aortic arch and carotid arteries to the intracranial circulation. It can identify the site and extent of arterial occlusion and may demonstrate stenosis, aneurysms, vascular malformations, and other cerebrovascular abnormalities. The ability of CTA to evaluate both extracranial and intracranial vessels makes it particularly useful in the emergency setting [3].One of the most important applications of CTA in acute ischemic stroke is the identification of large-vessel occlusion (LVO). Occlusion of major cerebral arteries, such as the internal carotid artery or middle cerebral artery, can result in severe neurological deficits and extensive brain injury. The identification of LVO is particularly important because these patients may benefit from endovascular treatment, including mechanical thrombectomy. CTA can rapidly demonstrate the presence and anatomical location of vascular occlusion, thereby helping clinicians determine whether a patient should be considered for advanced reperfusion therapy [4].

CTA also plays an important role in the selection of patients for appropriate treatment. Intravenous thrombolytic therapy may be considered in eligible patients with acute ischemic stroke, while mechanical thrombectomy is particularly beneficial in selected patients with large-vessel occlusion. The decision to perform these interventions depends on several clinical and imaging-related factors, including the location of the occlusion, time since symptom

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onset, extent of brain injury, vascular anatomy, and availability of treatment facilities. By providing rapid vascular information, CTA can reduce uncertainty and assist clinicians in making timely therapeutic decisions. Another important advantage of CTA is its ability to assess collateral circulation [5].Collateral vessels provide alternative pathways for blood flow when a major cerebral artery becomes occluded. The quality of collateral circulation may influence the extent of ischemic brain injury and the likelihood of favorable outcomes following reperfusion therapy. Patients with good collateral circulation may maintain blood flow to ischemic brain tissue for a longer period, whereas poor collateral circulation may be associated with rapid progression of irreversible brain damage. Therefore, CTA-based assessment of collateral circulation can provide valuable prognostic information and may assist in identifying patients who are more likely to benefit from aggressive therapeutic interventions [6].

Over the past decade, the integration of CTA into acute stroke protocols has become increasingly common in high-resource healthcare systems. The combination of non-contrast CT and CTA allows clinicians to rapidly exclude hemorrhage, evaluate brain parenchyma, and identify vascular occlusion within a relatively short period. This imaging approach has contributed to improvements in the selection of patients for thrombolysis and mechanical thrombectomy. The availability of rapid vascular imaging is particularly important in modern stroke care because treatment effectiveness decreases as the duration of arterial occlusion increases. Despite these advantages, the implementation of CTA-based stroke pathways remains challenging in resource-constrained settings. Pakistan faces several barriers to the widespread use of advanced stroke imaging. Although CT scanners are available in many tertiary care hospitals, access to CTA may be limited by the availability of contrast agents, appropriate CT technology, trained radiologists and radiographers, emergency imaging services, and interventional stroke facilities. In addition, financial limitations may prevent some patients from receiving advanced diagnostic investigations. Delays in patient presentation and referral may further reduce the opportunity for timely reperfusion treatment [7].

The inconsistent availability of organized stroke care pathways represents an additional challenge. In many healthcare facilities, stroke patients may undergo non-contrast CT imaging without further vascular assessment. Although NCCT is essential for excluding hemorrhage, the absence of vascular imaging may delay or limit the identification of patients with treatable large-vessel occlusion. Consequently, some patients who could potentially benefit from mechanical thrombectomy or other advanced interventions may not be identified or referred in a timely manner. For a country such as Pakistan, it is therefore important to evaluate whether CTA can be effectively incorporated into existing stroke management pathways. CTA may represent a practical imaging modality because it can often be performed on multidetector CT scanners that are already available in many tertiary care centers. Its rapid acquisition time and ability to provide detailed vascular information make it a potentially valuable tool for improving stroke diagnosis and treatment planning. However, the benefits of CTA must also be considered in relation to practical challenges, including radiation exposure, the use of iodinated contrast media, the risk of contrast-associated complications, additional healthcare costs, and the availability of trained personnel [8].

The present study is therefore important because it examines the role of CT angiography in the diagnosis and management of acute stroke within the context of Pakistan. Rather than focusing only on the technical diagnostic performance of CTA, the study also considers its potential impact on clinical decision-making and subsequent therapeutic interventions. In particular, CTA findings may help determine the presence of significant arterial occlusion, identify patients who may require referral to specialized stroke centers, and support decision-making regarding thrombolytic therapy and mechanical thrombectomy. The study also aims to highlight the importance of developing standardized

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imaging protocols for acute stroke. The establishment of an organized pathway involving rapid clinical assessment, non-contrast CT, and selective or routine CTA may improve the identification of patients with vascular occlusion and reduce delays in treatment. Such protocols may be particularly valuable in tertiary healthcare institutions where CT facilities are already available but the use of vascular imaging has not been fully integrated into emergency stroke care [9].

Furthermore, evaluating the role of CTA in Pakistan may provide evidence for healthcare administrators and policymakers regarding the potential value of investing in advanced stroke imaging services. Evidence regarding the diagnostic and clinical usefulness of CTA could support the development of national or institutional guidelines for acute stroke management. Improved access to vascular imaging may also facilitate better referral networks between hospitals, allowing patients with large-vessel occlusion to be rapidly transferred to centers capable of providing mechanical thrombectomy [10]. Therefore, the present study aims to evaluate the role of CT angiography in the assessment and management of acute stroke and to examine its potential integration into existing stroke care pathways in Pakistan. The study seeks to determine how CTA can contribute to the rapid identification of cerebrovascular abnormalities and influence subsequent therapeutic decision-making, particularly regarding reperfusion therapies. By addressing both the benefits and limitations of CTA in a resource-constrained environment, this research may provide valuable evidence for improving diagnostic strategies, optimizing healthcare resources, developing standardized stroke protocols, and ultimately improving clinical outcomes among patients with acute stroke in Pakistan.

Materials and Methods

This retrospective observational study was conducted at University of Lahore Teaching Hospital & Tertiary care center in Lahore, Pakistan from April 2025 to July 2026. The study was carried out after obtaining approval from the Institutional Ethics Committee/Institutional Review Board and in accordance with the ethical principles of the Declaration of Helsinki. Because of the retrospective nature of the study and the use of previously available clinical and imaging records, the requirement for written informed consent was waived by the ethics committee. Patient confidentiality was strictly maintained throughout the study, and all records were anonymized before data analysis to protect personal health information.

A total of 163 consecutive patients aged 18 years or older with a clinical diagnosis of acute ischemic stroke were included in the study. All included patients underwent CT angiography within 24 hours of symptom onset. Patients were selected based on a confirmed clinical diagnosis of acute ischemic stroke following neurological evaluation, the availability of CT angiographic imaging within the specified time interval, and the presence of complete clinical and imaging records. Patients with known contraindications to iodinated contrast media, incomplete or poor-quality CT angiographic examinations, or missing clinical data were excluded. The inclusion of consecutive eligible patients was intended to minimize selection bias and ensure the integrity and reliability of the collected data. Demographic and clinical data were retrospectively collected from hospital records, medical files, and radiological examinations. The collected variables included age, sex, and major vascular risk factors such as hypertension, diabetes mellitus, and dyslipidemia. Information regarding the interval between symptom onset and CT angiography was also recorded, along with details of acute stroke management and subsequent therapeutic interventions, where available.

All patients underwent CT angiography using a multidetector CT scanner according to the institutional stroke imaging protocol. Non-contrast CT was initially performed to exclude intracranial hemorrhage and identify major intracranial abnormalities, followed by CT angiography for detailed evaluation of the cerebral and cervical vasculature. Image acquisition extended from the aortic arch to the

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cranial vertex, allowing assessment of both extracranial and intracranial vessels. Iodinated contrast material was administered intravenously according to the institutional or weight-adjusted protocol. The acquired images were reconstructed in axial, coronal, and sagittal planes, with multiplanar and vascular reconstructions used when necessary to provide a comprehensive evaluation of the cerebral circulation. The CT angiographic images were independently reviewed by two experienced neuroradiologists who were blinded to the clinical outcomes of the patients. The reviewers assessed the presence, location, and extent of vascular abnormalities, particularly arterial occlusion, large-vessel occlusion, and collateral circulation. Any disagreement between the reviewers was resolved through consensus to improve the reliability and reproducibility of the imaging findings. The primary outcomes of the study included the time interval between symptom onset and CT angiography, the frequency of large-vessel occlusion, and the association between CT angiographic findings and clinical outcomes at discharge. Particular emphasis was placed on the evaluation of collateral circulation and its relationship with functional outcome. Clinical outcomes were assessed using the modified Rankin Scale (mRS), with a score of 0–2 considered a favorable outcome, indicating functional independence or minimal disability, while a score of more than 2 was considered an unfavorable outcome.

The collected data were analyzed using appropriate statistical software. Continuous variables were expressed as mean ± standard deviation for normally distributed data or as median and range where appropriate. Categorical variables were presented as frequencies and percentages. The association between CT angiographic findings and clinical outcomes was evaluated using the Chi-square test or Fisher's exact test, depending on the distribution and expected frequency of the data. A p-value of less than 0.05 was considered statistically significant.

Results

A total of 163 patients were included in the study. The mean age of the participants was 63.5 ± 8.5 years, indicating that the study population predominantly comprised older adults. The standard deviation of 8.5 years demonstrates a moderate variation in age around the mean. This age distribution is clinically relevant because advanced age is an important risk factor for cerebrovascular and vascular diseases. Regarding gender distribution, 97 patients (59.50%) were male, whereas 66 patients (40.49%) were female. Therefore, males constituted the majority of the study population, accounting for approximately three-fifths of all participants, while females represented approximately two-fifths. This indicates a male predominance of 19.01 percentage points in the study cohort. Among the vascular risk factors, hypertension was the most frequently observed comorbidity, affecting 123 patients (75.46%). Thus, approximately three-quarters of the participants had a history of hypertension. This high prevalence highlights the importance of elevated blood pressure as an associated risk factor in this patient population. Diabetes mellitus was present in 59 patients (36.19%), meaning that more than one-third of the participants were diabetic. Furthermore, 41 patients (25.15%) had dyslipidemia (abnormal lipid profile). Therefore, the study population demonstrated a substantial burden of established vascular risk factors, particularly hypertension, followed by diabetes mellitus and dyslipidemia.

Table 1: Demographic Table Related to CT Angiography

Variables	Values
Age (Mean SD)	63.5 ± 8.5
Gender	
Male	97 (59.50%)
Female	66 (40.49%)
Hypertension	123 (75.46%)

Frontier in Medical & Health Research

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Diabetes Mellitus	59 (36.19%)
Bad Lipid	41 (25.15%)
Time to Imaging (Hrs)	5.1
CT Angiographic Findings	
Large Vessels Occlusion	80 (49.07%)
Collateral Circulation (n=163)	
Mild	40 (24.53%)
Moderate	74 (45.39%)
Severe	49 (30.06%)
Incidental Vascular Anomalies	17 (10.42%)
Clinical Outcomes and Association with Imaging Findings (n=163)	
Favorable outcomes	87 (53.37%)
In-Hospital Mortality	24 (14.72%)

The mean time to imaging was 5.1 hours, indicating that patients underwent CT angiographic evaluation relatively early after presentation or symptom onset. Early imaging is particularly important in patients with suspected acute vascular occlusion because it allows timely identification of vessel pathology and can assist in treatment planning and prognostic assessment. CT angiography demonstrated large-vessel occlusion in 80 of 163 patients (49.07%). Thus, almost one-half of the study population had evidence of large-vessel arterial occlusion. This represents an important imaging finding because large-vessel occlusion is generally associated with a greater disease burden and may influence therapeutic decision-making and clinical prognosis. The status of collateral circulation was evaluated in all 163 patients. Mild collateral circulation was observed in 40 patients (24.53%), indicating that approximately one-quarter of the patients had limited collateral vascular support. Moderate collateral circulation was identified in 74 patients (45.39%), making it the most frequently observed category. Nearly half of the participants therefore demonstrated moderate collateral circulation.

In addition, 49 patients (30.06%) had severe collateral circulation. This indicates that approximately one-third of the study population had well-developed collateral vascular pathways. Overall, 122 patients (74.85%) had moderate-to-severe collateral circulation, compared with 40 patients (24.53%) with mild collateral circulation. This distribution suggests that adequate collateral pathways were relatively common within the study population.Incidental vascular anomalies were identified in 17 patients (10.42%). Thus, approximately one in every ten patients demonstrated an additional vascular abnormality that was not necessarily the primary imaging finding responsible for the presenting clinical condition. Identification of such abnormalities on CT angiography may be clinically important because some vascular anomalies can have implications for future vascular events, intervention, or follow-up.In terms of clinical outcomes, 87 of the 163 patients (53.37%) experienced favorable outcomes. Therefore, slightly more than half of the study population had a favorable clinical outcome. Conversely, 24 patients (14.72%) died during hospitalization, representing an in-hospital mortality rate of approximately 15%.

There were therefore 52 patients (31.90%) who did not fall into the reported favorable-outcome or in-hospital-mortality categories, assuming these outcome categories were mutually exclusive. This group may represent patients with an unfavorable outcome who survived hospitalization, depending on the study's outcome definitions.

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Discussion

The present study included 163 patients with a mean age of 63.5 ± 8.5 years, with a predominance of males (59.50%) over females (40.49%). The relatively advanced age of the study population is consistent with the established epidemiology of acute ischemic stroke, in which the risk of vascular occlusion and cerebrovascular events increases with advancing age. Similar findings have been reported in previous CTA-based studies of patients with large-vessel occlusion. Lima FO et al.,[11] conducted a prospective study evaluating leptomeningeal collateral circulation in patients with intracranial large-vessel occlusion reported a mean age of 69 ± 17 years, demonstrating a similarly older patient population. That study also identified age as an independent predictor of functional outcome. In the present study, hypertension was the most prevalent vascular risk factor, affecting 123 patients (75.46%), followed by diabetes mellitus in 59 patients (36.19%) and dyslipidemia in 41 patients (25.15%). This substantial burden of vascular risk factors is clinically important because hypertension, diabetes, and abnormal lipid metabolism contribute to atherosclerosis and vascular occlusion. The predominance of hypertension in our cohort is also consistent with previous studies of large-vessel occlusion stroke, in which hypertension has frequently been identified among the major baseline vascular risk factors. In the previously mentioned CTA collateral study, hypertension and other cardiovascular comorbidities were associated with outcome in univariate analysis, while diabetes remained an independent predictor of poorer outcome in multivariable analysis.

The mean time to imaging was 5.1 hours, emphasizing the importance of rapid vascular imaging in the acute setting. CT angiography provides rapid visualization of the intracranial and extracranial arterial circulation and enables identification of patients with large-vessel occlusion who may require urgent reperfusion therapy. Current American Heart Association/American Stroke Association guidance emphasizes rapid vascular imaging for identification of large-vessel occlusion and appropriate selection of patients for endovascular thrombectomy. The guideline notes that CTA/MRA is an efficient approach for identifying LVO and that minimizing delays from stroke onset to reperfusion is essential for improving outcomes. In our study, large-vessel occlusion was demonstrated in 80 patients (49.07%), meaning that almost half of the study population had major arterial occlusion on CT angiography. This finding is clinically significant because LVO represents a particularly severe form of acute ischemic stroke and is associated with substantial neurological disability and mortality if timely reperfusion is not achieved. The importance of detecting LVO has increased substantially with the establishment of endovascular thrombectomy as an effective treatment. Prabhakaran et al.,[12] conducted a study with 2026 AHA/ASA guideline confirms strong recommendations for EVT in appropriately selected patients with anterior-circulation ICA or M1 occlusions and reports that EVT improves functional outcomes and reduces mortality.

One of the important findings of the present study was the distribution of collateral circulation. Mild collateral circulation was observed in 40 patients (24.53%), moderate collateral circulation in 74 patients (45.39%), and severe collateral circulation in 49 patients (30.06%). Thus, moderate collateral circulation represented the largest subgroup, while nearly one-third of patients demonstrated severe collateralization. Overall, 122 patients (74.85%) demonstrated moderate-to-severe collateral circulation. These findings are clinically important because collateral vessels provide alternative pathways for blood flow when a major cerebral artery becomes occluded. Better collateral circulation can maintain perfusion of ischemic but potentially salvageable brain tissue, delay infarct progression, and potentially increase the time window for successful reperfusion. Previous research has consistently supported the prognostic importance of collateral circulation in LVO stroke.

Frontier in Medical & Health Research

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Lima et al.,[11] conducted that a CTA-based study of 196 patients with intracranial ICA or MCA occlusion demonstrated that favorable leptomeningeal collateral patterns were independently associated with good functional outcome. The study reported an adjusted odds ratio of 1.93 (95% CI: 1.06–3.34; p=0.03) for favorable collateral status, supporting the concept that better collateral circulation is associated with improved recovery. The relatively high proportion of moderate-to-severe collateral circulation in our study may therefore be clinically favorable and could potentially contribute to the 53.37% favorable outcome rate observed in our cohort. However, because the present descriptive data do not provide a direct cross-tabulation or statistical association between collateral grade and clinical outcome, this relationship should be interpreted as a potential explanation rather than a demonstrated causal association**.** In the present study, 87 patients (53.37%) achieved favorable clinical outcomes, whereas 24 patients (14.72%) experienced in-hospital mortality. The favorable outcome rate indicates that slightly more than half of the patients experienced a positive clinical course. Conversely, the in-hospital mortality rate of approximately 15% reflects the substantial severity of the disease in this cohort, particularly given the high prevalence of large-vessel occlusion.

The mortality observed in our study is comparable to findings from previous CTA/endovascular cohorts. Kim et al.,[13] conducted that 104 patients undergoing endovascular treatment for ICA or MCA occlusion, 44.2% achieved an mRS of 0–2 at 3 months, while 15.4% died. The mortality rate in that study (15.4%) is very close to the 14.72% in-hospital mortality observed in our study. Although direct comparison should be made cautiously because follow-up periods and patient-selection criteria differ, the similarity suggests that our mortality findings are within the range reported in previous LVO stroke populations. The current evidence also indicates that outcomes are strongly influenced by successful reperfusion, baseline neurological severity, infarct volume, age, and collateral status. Therefore, the favorable outcome rate observed in our cohort should not be attributed to collateral circulation alone. Rather, it is likely to reflect the combined effects of early imaging, vascular anatomy, collateral status, infarct burden, baseline clinical severity, reperfusion treatment, and patient comorbidities.

In the present cohort, 17 patients (10.42%) had incidental vascular anomalies. Although these findings were not necessarily responsible for the acute clinical presentation, their identification demonstrates an additional advantage of CT angiography. CTA provides a comprehensive assessment of the arterial tree and may reveal vascular anatomical variations, aneurysmal changes, anomalous vessels, or other abnormalities that could influence subsequent management [12]. The identification of these abnormalities is particularly relevant when endovascular treatment is being considered because knowledge of vascular anatomy can assist with procedural planning and may identify tandem pathology or anatomical factors affecting vascular access. The current AHA/ASA guideline specifically recognizes the value of CTA/MRA for evaluating cervical vascular anatomy, tandem lesions, and other vascular characteristics relevant to EVT planning. The findings of the present study are broadly consistent with previous literature. The older age distribution, male predominance, and high prevalence of hypertension, diabetes, and dyslipidemia are compatible with the recognized vascular risk profile of patients presenting with acute ischemic stroke and LVO. The detection of large-vessel occlusion in 49.07% emphasizes the substantial burden of major arterial disease in the studied population.

Most importantly, the collateral circulation findings are consistent with previous evidence showing that better collateral status is associated with smaller infarct burden, better functional recovery, and lower mortality. Kim et al.,[13] conducted that CTA studies have demonstrated that favorable collateral circulation can independently predict good functional outcome, while more recent studies have shown a graded

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relationship between collateral quality, functional independence, neurological deterioration, and mortality. The 53.37% favorable outcome rate and 14.72% in-hospital mortality rate in our study further demonstrate the substantial clinical impact of LVO stroke. These findings support the importance of early CTA, accurate identification of LVO, assessment of collateral circulation, and timely reperfusion therapy. Nevertheless, because the current results are primarily descriptive, future analysis should specifically examine the relationship between collateral grade and favorable outcome/mortality, ideally using chi-square testing and multivariable logistic regression adjusted for age, sex, hypertension, diabetes, dyslipidemia, time to imaging, LVO status, and other relevant clinical variables. Such analysis would determine whether collateral circulation is an independent predictor of clinical outcome in this study population.

Conclusion

This study concludes that CT angiography (CTA) is valuable in the early diagnosis and management of acute ischemic stroke, particularly for detecting large-vessel occlusion and evaluating collateral circulation**.** Early CTA facilitates timely treatment decisions and is associated with better clinical outcomes. The findings support the integration of CTA into routine stroke protocols, along with improved imaging facilities, trained personnel, and healthcare infrastructure in Pakistan. Expanding access to CTA may ultimately improve stroke outcomes and reduce stroke-related morbidity and mortality**,** especially in resource-limited settings.

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