

## Role of Radiology in the Cardiovascular and Neurological Investigation of Ischemic Stroke

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### ABSTRACT

Ischemic stroke (IS) is a time-dependent neurological emergency in which imaging methods play a fundamental role from initial diagnosis through etiological investigation and secondary prevention. The aim of this review was to analyze the contribution of neuroimaging, vascular assessment, and cardiovascular imaging to the management of ischemic stroke. This is a descriptive and analytical systematic literature review conducted according to the PRISMA 2020 recommendations. PubMed/MEDLINE, Scopus, Web of Science, Cochrane Library, BVS, and SciELO were searched, prioritizing publications from 2021 to 2026. The results showed that non-contrast computed tomography remains the main initial method for excluding hemorrhage and assessing early ischemic changes, whereas CT angiography plays a decisive role in identifying large-vessel occlusions and planning thrombectomy. CT perfusion and magnetic resonance imaging expand the assessment of the ischemic core, penumbra, and tissue viability, particularly in late therapeutic windows or when onset time is unknown. In cardiovascular investigation, echocardiography remains central and is complemented by cardiac computed tomography and magnetic resonance imaging for identifying intracardiac thrombi, cardiomyopathies, interatrial septal abnormalities, and aortic sources of embolism. It is concluded that the ideal approach should be multimodal and individualized, integrating cerebral, vascular, and cardiovascular findings. Rational and sequential use of imaging methods can optimize reperfusion, improve etiological accuracy, and guide secondary prevention strategies in ischemic stroke.

**KEYWORDS:** Ischemic Stroke; Neuroimaging; Computed Tomography; Magnetic Resonance Imaging; Echocardiography; Cardiac Embolism; Secondary Prevention.

### 1 INTRODUCTION

Ischemic stroke (IS) is a time-dependent neurological emergency in which rapid diagnostic identification and etiological definition directly influence the possibility of reperfusion, the extent of brain injury, and functional prognosis. In this context, imaging methods play a central role from the first minutes of care, allowing exclusion of intracranial hemorrhage, identification of early signs of

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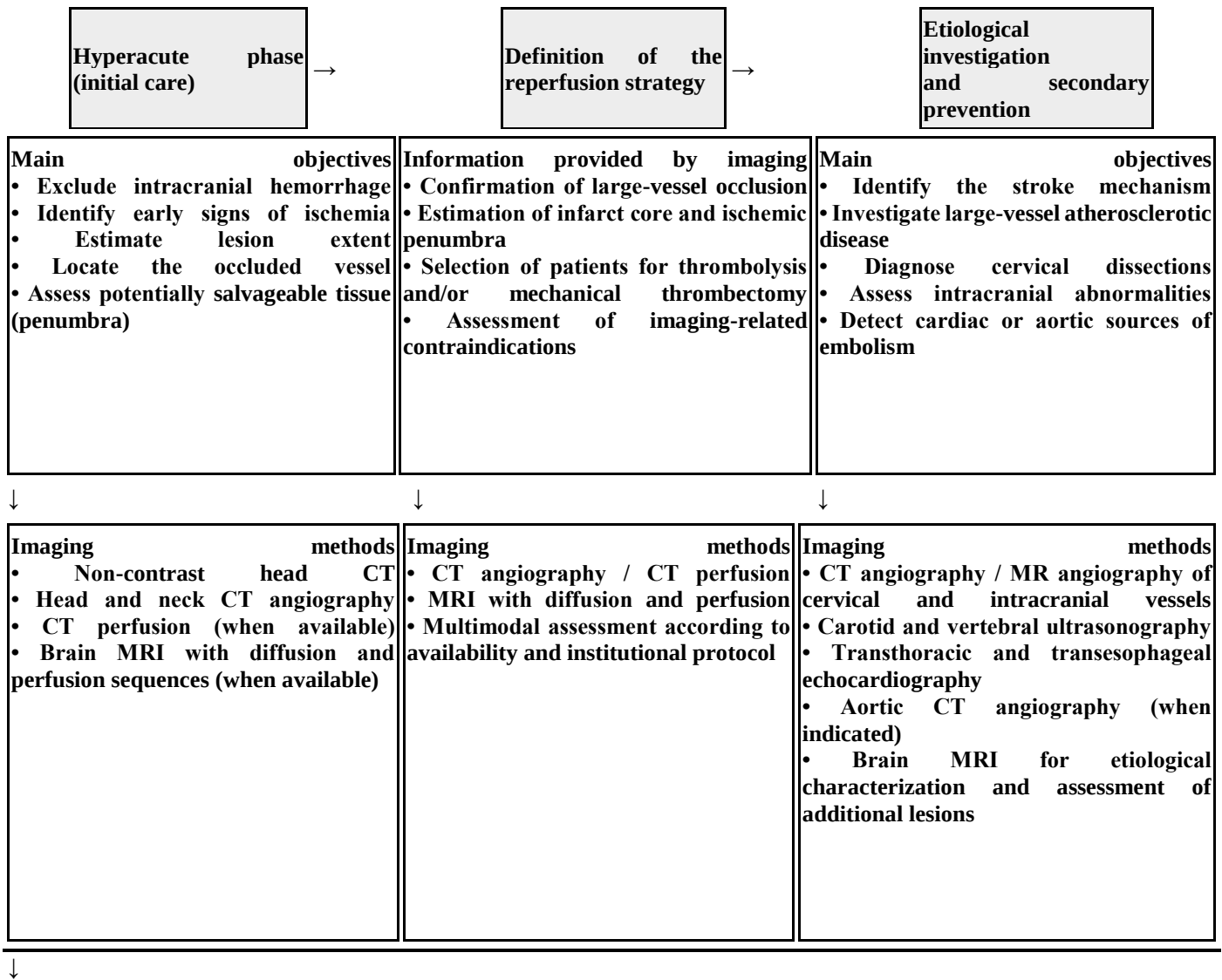
ischemia, localization of the occluded vessel, estimation of infarct-core extent, and assessment of potentially salvageable brain tissue (PRABHAKARAN et al., 2026).

Imaging investigation in ischemic stroke is not limited, however, to confirmation of the brain lesion. After initial stabilization and definition of the reperfusion strategy, the mechanism responsible for the event must be investigated, including large-vessel atherosclerotic disease, cervical dissections, intracranial abnormalities, and potential cardiac or aortic sources of embolism. Thus, radiology and cardiovascular imaging participate in both the hyperacute phase and the etiological investigation and secondary prevention (FIGURE 1) (NTAIOS et al., 2024; CANALI et al., 2023).

The AHA/ASA guideline published in 2026 reinforces that non-contrast CT is sufficient, in most patients eligible for intravenous thrombolysis within the conventional therapeutic window, to exclude hemorrhage and allow a rapid decision regarding reperfusion. Multimodal imaging studies should not delay initiation of thrombolysis in clearly eligible patients, emphasizing that the benefit of advanced imaging depends on its integration into care pathways capable of preserving the principle that time is brain (PRABHAKARAN et al., 2026).

Computed tomography angiography of the cervical and intracranial vessels represents a fundamental extension of the initial evaluation, especially when large-vessel occlusion is suspected. This method makes it possible to identify the site of arterial obstruction, characterize extracranial and intracranial stenoses, recognize tandem occlusions, assess dissections, and provide relevant anatomical information for planning mechanical thrombectomy (SARRAJ; PUJARA; CAMPBELL, 2024; PRABHAKARAN et al., 2026).

Imaging assessment in ischemic stroke should be understood in an integrated manner, encompassing both the hyperacute phase and the subsequent etiological investigation. Initially, neuroimaging methods help exclude intracranial hemorrhage, identify vascular occlusion, estimate lesion extent, and select patients for reperfusion strategies. Subsequently, vascular, cardiac, and aortic investigation broadens the possibility of defining the mechanism of the event, contributing to treatment planning and secondary prevention. This evaluation sequence is summarized in Figures 1 and 2.



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### Integration of imaging findings

- Confirmation of diagnosis
- Definition of therapeutic strategy
- Identification of etiology
- Planning of secondary prevention

**Figure 1 – Role of imaging methods in ischemic stroke: from the hyperacute phase to etiological investigation and secondary prevention. Source: Authors.**

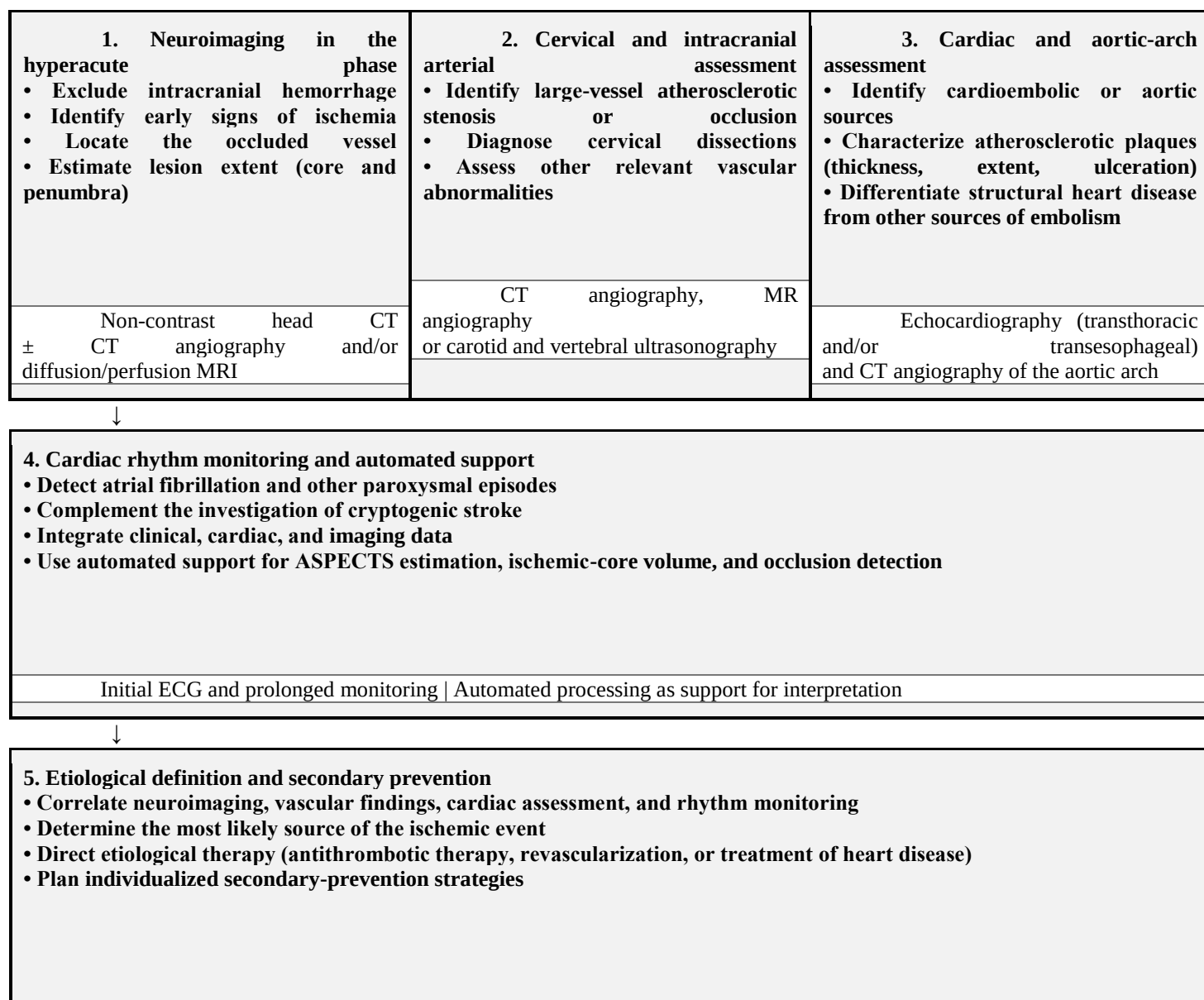


**Figure 2 – Integrated imaging approach to etiological investigation and secondary prevention of ischemic stroke.**

Non-contrast head computed tomography remains one of the most widely used initial methods because of its broad availability, rapid acquisition, and high ability to exclude intracranial hemorrhage. Although very early ischemic changes may be subtle, signs such as sulcal effacement, loss of gray-white matter differentiation, and parenchymal hypodensity allow estimation of the extent of initial injury. The ASPECTS score remains particularly relevant for systematic assessment of early changes in the anterior circulation and for selecting patients for reperfusion strategies (PRABHAKARAN et al., 2026).

The development of mechanical thrombectomy has further increased the importance of vascular imaging in ischemic stroke. Currently, identification of proximal anterior-circulation occlusions and, in selected situations, posterior-circulation occlusions allows rapid determination of eligibility for endovascular therapy. Contemporary recommendations include selected patients treated

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within six hours as well as those evaluated in the six- to 24-hour window, provided clinical and imaging characteristics indicate the possibility of therapeutic benefit (PRABHAKARAN et al., 2026).

CT perfusion adds functional information to the anatomical assessment. Analysis of hemodynamic parameters makes it possible to estimate the irreversibly injured ischemic core and distinguish it from the penumbra, characterized by hypoperfused tissue that may still be salvageable. This distinction is particularly relevant in patients with unknown symptom onset or those presenting in late therapeutic windows (PANICKER et al., 2024; PRABHAKARAN et al., 2026).

Despite its usefulness, CT perfusion should not be considered mandatory in every patient with large-vessel occlusion in the early window. Contemporary evidence shows that thrombectomy trials have demonstrated benefit even with selection based predominantly on non-contrast CT and identification of arterial occlusion. Thus, perfusion imaging should complement, and not necessarily replace, rapid anatomical assessment, particularly when performing it could delay endovascular treatment (DHILLON et al., 2024; PRABHAKARAN et al., 2026).

Magnetic resonance imaging has high sensitivity for detecting acute cerebral ischemia, particularly with diffusion-weighted sequences. Diffusion abnormalities may become evident within minutes of ischemia onset, making it possible to identify small lesions, posterior-circulation infarcts, and areas that may not be clearly visualized on the initial CT. The combination of diffusion, FLAIR, and perfusion also enables identification of mismatch patterns useful in patients with unknown onset time or a prolonged therapeutic window (SARRAJ; PUJARA; CAMPBELL, 2024; PRABHAKARAN et al., 2026).

The distribution of lesions observed on CT or MRI may also provide clues to the etiological mechanism of stroke. Extensive cortical infarcts, multiple lesions in different vascular territories, bilateral involvement, and coexistence of anterior- and posterior-circulation infarcts increase suspicion of an embolic mechanism, particularly cardioembolism. Thus, neuroimaging not only confirms the presence of stroke but can also guide subsequent cardiovascular investigation (XIAO et al., 2024; NTAIOS et al., 2024).

This aspect is particularly important in cryptogenic strokes and so-called embolic strokes of undetermined source, in which no definite cause is initially identified after conventional investigation. A European consensus document published in 2024 highlighted that approximately one in six patients with ischemic stroke may have a presentation compatible with an undetermined embolic source, a situation in which integration of neuroimaging, vascular investigation, and cardiovascular assessment becomes essential to establish etiology and guide secondary prevention (NTAIOS et al., 2024).

Potential cardioembolic sources include atrial fibrillation, thrombi in the atrium or left atrial appendage, ventricular thrombi, cardiomyopathies, valvular abnormalities, infective endocarditis, intracardiac tumors, thrombosed prosthetic valves, patent foramen ovale, and complex atherosclerotic disease of the aortic arch. Identification of these abnormalities can substantially alter management, potentially indicating anticoagulation, patent foramen ovale closure, treatment of endocarditis, or intervention for other cardiovascular disorders (CANALI et al., 2023; NTAIOS et al., 2024).

Transthoracic echocardiography is generally one of the first modalities used in cardiovascular investigation because of its availability and ability to assess ventricular function, chamber dimensions, cardiomyopathies, valvular abnormalities, and ventricular thrombi. However, certain embolic sources, particularly left atrial appendage thrombi, interatrial septal abnormalities, small vegetations, and complex aortic arch plaques, may be better assessed by transesophageal echocardiography (CANALI et al., 2023; VAN DER MATEN et al., 2021).

Contrast echocardiography and microbubble studies are particularly important in the investigation of right-to-left communication and patent foramen ovale. In selected patients, especially those with cryptogenic stroke and no defined atherosclerotic or arrhythmic cause, demonstration of an intracardiac shunt may provide a plausible explanation for paradoxical embolism and influence secondary prevention strategies (NTAIOS et al., 2024; CANALI et al., 2023).

Cardiac computed tomography has been gaining ground as a complementary method in the investigation of cardioembolic sources. Its high spatial resolution allows assessment of intracardiac thrombi, left atrial appendage morphology, cardiac anatomy, calcifications, prostheses, and thoracic aortic structures. Recent studies suggest high performance for thrombus detection and potential utility when transesophageal echocardiography is inconclusive, contraindicated, or poorly tolerated (RINKEL et al., 2022; GHOZY et al., 2024).

Cardiac magnetic resonance imaging represents another relevant complementary modality, particularly when cardiomyopathy, myocardial scar, ventricular thrombus, or cardiac tumor is suspected. Tissue characterization provided by MRI allows differentiation of thrombi from neoplastic masses and identification of fibrosis or structural abnormalities that may not be fully characterized by echocardiography (CANALI et al., 2023; NTAIOS et al., 2024).

Assessment of the aortic arch also deserves emphasis, because complex atherosclerotic plaques may constitute a source of cerebral embolization. Transesophageal echocardiography, CT angiography, and, in selected situations, cardiovascular MRI can characterize plaque thickness, extent, ulceration, and mobile components, helping distinguish atherothrombotic disease from possible cardiac sources of embolism (NTAIOS et al., 2024; CANALI et al., 2023).

Integrated interpretation of cerebral, vascular, and cardiac findings is particularly important because isolated identification of a cardiovascular abnormality does not automatically establish causality. Patent foramen ovale, mild ventricular dysfunction, or

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aortic plaques may coexist incidentally with cerebrovascular disease of another etiology. Therefore, the infarct pattern observed on neuroimaging should be correlated with cardiovascular findings and arterial investigation to determine the most likely source of the event (NTAIOS et al., 2024; CANALI et al., 2023).

Imaging assessment also directly affects secondary prevention. Demonstration of significant carotid atherosclerotic disease may indicate the need for vascular intervention; identification of a cardioembolic source may change antithrombotic therapy; the presence of patent foramen ovale in certain profiles may lead to evaluation for closure; and identification of dissections, thrombi, or other structural abnormalities determines specific treatment and follow-up strategies (NTAIOS et al., 2024; PRABHAKARAN et al., 2026).

Investigation of cryptogenic stroke should also be complemented by cardiac-rhythm monitoring, because paroxysmal episodes of atrial fibrillation may not be detected during the initial assessment. Contemporary etiological evaluation combines imaging of the head and neck arteries, echocardiography, and prolonged cardiac monitoring, demonstrating that etiological definition of stroke requires integration of imaging diagnosis with functional cardiovascular assessment (NTAIOS et al., 2024).

Advances in artificial intelligence and automated processing techniques are also changing the interpretation of stroke neuroimaging. Software capable of estimating ASPECTS, ischemic-core volume, penumbra extent, and the presence of large-vessel occlusion can speed communication between centers and reduce time to thrombectomy. However, these tools should support radiological and clinical interpretation rather than replace specialist assessment or multidisciplinary judgment (PRABHAKARAN et al., 2026).

In this context, radiology ceases to play merely a confirmatory role and assumes a strategic position throughout the care pathway of ischemic stroke. In the hyperacute phase, it defines the presence and extent of injury and guides reperfusion; during etiological investigation, it characterizes cerebral and cervical circulation and provides clues to embolic mechanisms; in cardiovascular investigation, it complements echocardiography through cardiac CT and MRI; and, finally, it contributes to decisions aimed at preventing recurrence (PRABHAKARAN et al., 2026; NTAIOS et al., 2024).

Given the multiplicity of mechanisms related to ischemic stroke, integration among neuroradiology, cardiovascular radiology, neurology, cardiology, and interventional medicine has become essential. Rational combination of CT, CT angiography, perfusion imaging, brain MRI, echocardiography, and advanced cardiac imaging methods makes it possible not only to diagnose the ischemic event but also to understand its origin, select reperfusion treatments, and establish more individualized secondary-prevention strategies (PRABHAKARAN et al., 2026; NTAIOS et al., 2024; CANALI et al., 2023).

## 2. RATIONALE

Ischemic stroke is one of the leading causes of acquired neurological disability and mortality in adults, requiring a rapid and highly structured diagnostic approach. Early definition of stroke type, lesion extent, affected vascular territory, and the possibility of reperfusion depends directly on imaging methods, making radiology a central element in the initial management of these patients (PRABHAKARAN et al., 2026).

Non-contrast head CT remains a widely used initial examination because of its speed and availability, allowing exclusion of intracranial hemorrhage and identification of early signs of ischemia. However, the development of advanced methods such as CT angiography, CT perfusion, magnetic resonance imaging, and MR angiography has expanded the ability to identify arterial occlusions, estimate the ischemic core and penumbra, and select patients for reperfusion therapies in different time windows (PRABHAKARAN et al., 2026).

The relevance of radiological investigation has become even greater with the expansion of indications for mechanical thrombectomy. Identification of large-vessel occlusion and assessment of the extent of potentially salvageable brain tissue are fundamental for selecting patients who may benefit from endovascular treatment, including those in late therapeutic windows. In this context, imaging has moved beyond a purely diagnostic role to participate directly in therapeutic decision-making (PRABHAKARAN et al., 2026).

Magnetic resonance imaging has complementary importance, especially when the initial CT is inconclusive, in posterior-circulation stroke, in small ischemic lesions, and in patients with unknown symptom onset. Diffusion-weighted sequences have high sensitivity for detecting acute infarcts, whereas the relationship between diffusion and FLAIR can provide information about the probable timing of lesion onset and assist therapeutic selection (SARRAJ; PUJARA; CAMPBELL, 2024; PRABHAKARAN et al., 2026).

In addition to confirming the cerebral event, the distribution pattern of lesions can provide relevant etiological information. Multiple, bilateral, cortical infarcts or lesions distributed across different vascular territories suggest a higher likelihood of an embolic mechanism, directing investigation toward cardiac, aortic, or proximal arterial sources. Thus, neuroradiology can contribute not only to diagnosing stroke but also to establishing its probable origin (XIAO et al., 2024; NTAIOS et al., 2024).

Cardiovascular investigation is particularly important because a significant proportion of ischemic strokes are cardioembolic in origin. Atrial fibrillation, intracardiac thrombi, cardiomyopathies, valvular abnormalities, endocarditis, patent

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foramen ovale, and complex aortic-arch atheroma are mechanisms capable of causing cerebral embolization and substantially modifying secondary prevention (NTAIOS et al., 2024; CANALI et al., 2023).

Transthoracic and transesophageal echocardiography occupy a central position in this investigation, allowing characterization of cardiac structure and function and identification of potential embolic sources. However, incorporation of cardiac CT and cardiac MRI has expanded diagnostic possibilities, especially when there are uncertainties concerning intracavitary thrombi, cardiac masses, cardiomyopathies, or aortic-arch abnormalities (CANALI et al., 2023; NTAIOS et al., 2024).

Evaluation of patent foramen ovale is an example of the importance of integration between neurology and cardiology. Its presence may be incidental, especially in the general population, and should not automatically be considered responsible for the stroke. Clinical relevance increases when the neuroimaging pattern is compatible with embolism and when other causes are not identified, reinforcing the need to correlate cardiac, vascular, and cerebral findings before establishing causality (NTAIOS et al., 2024).

The same principle applies to atherosclerotic disease of the aortic arch. Complex, ulcerated, or mobile plaques may serve as an embolic source, but they should be interpreted together with the cerebral infarct pattern and assessment of the cervical and intracranial arteries. Transesophageal echocardiography, CT angiography, and cardiovascular MRI can provide complementary information about these abnormalities (NTAIOS et al., 2024; CANALI et al., 2023).

Integration of imaging methods is especially relevant in cryptogenic stroke. In these cases, the absence of an evident cause after initial investigation requires a broader approach, including detailed neuroimaging, evaluation of the cervical and intracranial vessels, echocardiography, and, when indicated, advanced cardiac imaging. This investigation may reveal previously unrecognized embolic sources and directly alter the secondary-prevention strategy (NTAIOS et al., 2024).

Another point that justifies analysis of the topic is the need to optimize use of the different available methods. Not all patients require every examination, and indiscriminate use of advanced studies may increase costs, radiation exposure, and time to treatment. The choice should be guided by the clinical phase, etiological suspicion, and the ability of each method to modify therapeutic management (PRABHAKARAN et al., 2026; NTAIOS et al., 2024).

Technological evolution has also changed radiological practice. Automated systems capable of identifying large-vessel occlusions, calculating ASPECTS, and estimating core and penumbra volumes can accelerate the diagnostic workflow and transfer of patients to thrombectomy centers. However, these technologies should function as support tools, with specialist interpretation remaining fundamental to clinical decision-making (PRABHAKARAN et al., 2026).

The relevance of the topic therefore derives from the need to understand radiology not as an isolated step but as a cross-cutting component of ischemic-stroke care. From initial diagnosis through etiological definition and prevention of recurrence, imaging methods provide decisive information for neurologists, radiologists, cardiologists, vascular surgeons, and endovascular-therapy teams (PRABHAKARAN et al., 2026; NTAIOS et al., 2024).

Thus, an updated review of the role of radiology in the neurological and cardiovascular investigation of ischemic stroke is justified, addressing the contributions of computed tomography, CT angiography, perfusion imaging, magnetic resonance imaging, echocardiography, and advanced cardiac imaging. Integrated analysis of these modalities may help establish a more rational, rapid, and individualized diagnostic approach, with potential impact on reperfusion, etiological definition, and secondary prevention (PRABHAKARAN et al., 2026; NTAIOS et al., 2024; CANALI et al., 2023).

### 3 OBJECTIVES

#### 3.1 General objective

To analyze the role of imaging methods in the neurological and cardiovascular investigation of ischemic stroke, highlighting their contribution to early diagnosis, selection of reperfusion therapies, identification of etiology, recognition of embolic sources, and definition of secondary-prevention strategies (PRABHAKARAN et al., 2026; NTAIOS et al., 2024).

#### 3.2 Specific objectives

- ✓ To analyze the importance of non-contrast head computed tomography in the initial evaluation of ischemic stroke and in the exclusion of intracranial hemorrhage (PRABHAKARAN et al., 2026).
- ✓ To evaluate the role of the ASPECTS score in identifying and quantifying early ischemic changes in patients with suspected anterior-circulation stroke (PRABHAKARAN et al., 2026).
- ✓ To describe the contribution of CT angiography of the cervical and intracranial arteries in identifying large-vessel occlusions, stenoses, dissections, and other vascular abnormalities related to ischemic stroke (PRABHAKARAN et al., 2026).
- ✓ To analyze the use of CT perfusion in differentiating the ischemic core from the penumbra and in selecting patients for reperfusion therapies in extended therapeutic windows (PANICKER et al., 2024; PRABHAKARAN et al., 2026).
- ✓ To evaluate the importance of brain MRI and diffusion sequences in the early detection of ischemic stroke, especially in small lesions, posterior-circulation stroke, and cases with inconclusive initial CT (SARRAJ; PUJARA; CAMPBELL, 2024).

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- ✓ To discuss the role of diffusion-FLAIR mismatch and other advanced MRI parameters in the assessment of patients with unknown symptom onset (PRABHAKARAN et al., 2026).
- ✓ To analyze how the distribution pattern of cerebral lesions can help differentiate atherothrombotic, cardioembolic, and other etiologies of ischemic stroke (XIAO et al., 2024; NTAIOS et al., 2024).
- To evaluate the role of transthoracic echocardiography in identifying structural cardiac abnormalities associated with risk of cerebral embolization (CANALI et al., 2023).
- To analyze the contribution of transesophageal echocardiography to the investigation of atrial thrombi, interatrial septal abnormalities, endocarditis, patent foramen ovale, and aortic-arch atheromatosis (VAN DER MATEN et al., 2021; SHAH et al., 2021).
- To discuss the importance of contrast echocardiography and microbubble studies in detecting right-to-left shunts and investigating paradoxical embolism (NTAIOS et al., 2024).
- To evaluate the applicability of cardiac computed tomography in identifying intracardiac thrombi, left atrial appendage abnormalities, aortic plaques, and other potential sources of embolism (RINKEL et al., 2022; GHOZY et al., 2024).
- To analyze the role of cardiac magnetic resonance imaging in characterizing cardiomyopathies, fibrosis, thrombi, tumors, and other structural abnormalities potentially related to cardioembolic stroke (CANALI et al., 2023).
- To discuss the importance of aortic-arch assessment in the investigation of ischemic stroke with a probable embolic mechanism (NTAIOS et al., 2024).
- To evaluate integration of neuroimaging, vascular imaging, and cardiovascular imaging findings in the investigation of cryptogenic stroke and embolic stroke of undetermined source (NTAIOS et al., 2024).
- To analyze the contribution of imaging to selection of patients for intravenous thrombolysis and mechanical thrombectomy, considering different treatment time windows (PRABHAKARAN et al., 2026).
- To discuss the importance of imaging in identifying carotid stenosis, arterial dissection, and other conditions capable of modifying secondary-prevention strategies (PRABHAKARAN et al., 2026).
- To evaluate the role of automated tools and artificial intelligence in recognizing arterial occlusions, calculating ASPECTS, and analyzing cerebral perfusion (PRABHAKARAN et al., 2026).
- To compare the advantages, limitations, and relative indications of computed tomography, magnetic resonance imaging, echocardiography, cardiac CT, and cardiac MRI in the investigation of ischemic stroke (PRABHAKARAN et al., 2026; NTAIOS et al., 2024).
- To identify current gaps in the literature and future perspectives related to multimodal integration of neurological and cardiovascular imaging in the diagnosis and management of ischemic stroke (PRABHAKARAN et al., 2026; NTAIOS et al., 2024).

## 4 METHODOLOGY

The present study was developed as a descriptive and analytical systematic literature review with the aim of gathering, organizing, and interpreting the main evidence related to the role of imaging methods in the neurological and cardiovascular investigation of ischemic stroke. The methodological design followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses – PRISMA 2020 recommendations, seeking to ensure transparency in the search strategy, selection, and synthesis of included studies (PAGE et al., 2021).

The guiding question was structured around two complementary axes. The first comprised neurological and cerebrovascular investigation of ischemic stroke, including non-contrast computed tomography, CT angiography, CT perfusion, brain MRI, and MR angiography. The second focused on cardiovascular investigation of possible embolic sources, including transthoracic and transesophageal echocardiography, cardiac CT, cardiac MRI, and assessment of the aortic arch (PRABHAKARAN et al., 2026; NTAIOS et al., 2024).

The PICO strategy was adapted to the diagnostic nature of the review. The population (P) consisted of adults with suspected or confirmed ischemic stroke; the intervention or index test (I) comprised the different neurological, vascular, and cardiovascular imaging methods; the comparison (C) included alternative imaging methods, conventional investigation, or diagnostic reference standards; and the outcomes (O) involved diagnostic accuracy, identification of vascular occlusion, determination of ischemic core and penumbra, selection for reperfusion, recognition of cardioembolic sources, and impact on etiological definition and secondary prevention (PRABHAKARAN et al., 2026; NTAIOS et al., 2024).

The literature search was conducted in PubMed/MEDLINE, Scopus, Web of Science, Cochrane Library, the Virtual Health Library (BVS), and SciELO, prioritizing publications from January 2021 to September 2026. Consensus documents, guidelines, and recommendations from scientific societies published during this period were also considered, especially when they had a direct impact on the organization of imaging investigation in ischemic stroke (PRABHAKARAN et al., 2026; NTAIOS et al., 2024).

For the neurological axis, controlled Medical Subject Headings (MeSH) descriptors and free-text terms related to stroke and brain imaging were used, including: “Ischemic Stroke”, “Acute Ischemic Stroke”, “Neuroimaging”, “Computed Tomography”, “CT Angiography”, “CT Perfusion”, “Magnetic Resonance Imaging”, “Diffusion Weighted Imaging”, “FLAIR”, “Magnetic Resonance

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Angiography”, “Large Vessel Occlusion”, “ASPECTS”, “Ischemic Core”, “Penumbra”, and “Mechanical Thrombectomy” (PRABHAKARAN et al., 2026).

For the cardiovascular axis, the following terms were used: “Cardioembolic Stroke”, “Cardiac Source of Embolism”, “Echocardiography”, “Transthoracic Echocardiography”, “Transesophageal Echocardiography”, “Cardiac Computed Tomography”, “Cardiac Magnetic Resonance”, “Left Atrial Appendage Thrombus”, “Patent Foramen Ovale”, “Aortic Arch Atherosclerosis”, “Cryptogenic Stroke”, and “Embolic Stroke of Undetermined Source” (NTAIOS et al., 2024; CANALI et al., 2023).

The descriptors were combined using the Boolean operators AND and OR, with specific adaptations according to the syntax of each database. Among the strategies used were combinations such as: (“ischemic stroke” AND “computed tomography” OR “CT angiography” OR “CT perfusion” OR “magnetic resonance imaging”) and (“ischemic stroke” OR “cryptogenic stroke”) AND (“echocardiography” OR “cardiac computed tomography” OR “cardiac magnetic resonance” OR “cardioembolic source”) (PAGE et al., 2021; PRABHAKARAN et al., 2026).

Clinical trials, prospective and retrospective observational studies, diagnostic-accuracy studies, cohorts, systematic reviews, meta-analyses, guidelines, and consensus documents addressing the use of imaging methods in the investigation of ischemic stroke were included. Studies assessing the influence of imaging findings on selection for thrombolysis or thrombectomy, etiological definition, and secondary prevention were also included (PRABHAKARAN et al., 2026; NTAIOS et al., 2024).

For the neurological axis, priority was given to studies evaluating the ability of imaging methods to exclude hemorrhage, identify early signs of ischemia, detect large-vessel occlusions, quantify lesion extent, estimate ischemic core and penumbra, and select candidates for reperfusion therapies. Studies on posterior circulation, wake-up stroke, and the use of automated image-analysis tools were also considered (PRABHAKARAN et al., 2026).

For the cardiovascular axis, studies investigating potential cardiac or aortic sources of embolism were included, such as atrial fibrillation associated with structural abnormalities, thrombi in the left atrium or ventricle, cardiomyopathies, valvular abnormalities, endocarditis, patent foramen ovale, cardiac tumors, and complex aortic-arch atheroma. The comparative usefulness of echocardiography, cardiac CT, and cardiac MRI was also considered (NTAIOS et al., 2024; CANALI et al., 2023).

Isolated case reports, series with very small samples, editorials without original data, exclusively experimental or preclinical studies, research involving only hemorrhagic stroke, and articles in which imaging assessment had no direct relationship with diagnosis, treatment, or etiological investigation of ischemic stroke were excluded (PAGE et al., 2021).

Studies in which the imaging method was used exclusively to follow late complications unrelated to etiological investigation or selection for reperfusion were also excluded. Studies published before 2021 were used only when considered fundamental references for understanding methods that remain in current use (PAGE et al., 2021; PRABHAKARAN et al., 2026).

Article selection occurred in successive stages. Initially, records identified in the databases were gathered and duplicates were removed. Titles and abstracts were then assessed for thematic relevance and eligibility criteria. Potentially relevant studies underwent full-text review, and those directly related to the objectives of the review were included (PAGE et al., 2021).

Selected studies were organized in an extraction matrix containing author, year, methodological design, population, imaging method used, diagnostic objective, main findings, test performance, limitations, and impact on decision-making. In acute-phase studies, aspects related to the therapeutic window, identification of vascular occlusion, ASPECTS, cerebral perfusion, and selection for thrombectomy were also recorded (PRABHAKARAN et al., 2026).

In the cardiovascular investigation, extraction covered the type of examination performed, cardiac or aortic structures assessed, ability to detect an embolic source, relationship with the neuroimaging pattern, and impact on etiological definition. Advantages and limitations of each method were also recorded, particularly transthoracic echocardiography, transesophageal echocardiography, cardiac CT, and cardiac MRI (NTAIOS et al., 2024; CANALI et al., 2023).

The results were grouped into previously defined thematic axes: non-contrast computed tomography; cerebral and cervical CT angiography; CT perfusion; brain MRI; imaging in selection for thrombolysis and thrombectomy; neuroimaging patterns and etiology; transthoracic echocardiography; transesophageal echocardiography; cardiac CT; cardiac MRI; investigation of patent foramen ovale; aortic-arch disease; cryptogenic stroke; and multimodal integration of cerebral, vascular, and cardiovascular imaging (PRABHAKARAN et al., 2026; NTAIOS et al., 2024).

Data synthesis was performed narratively and comparatively. Imaging methods were compared in terms of acquisition speed, availability, sensitivity, capacity for anatomical or functional characterization, usefulness in the hyperacute phase, identification of embolic sources, and influence on management. This approach allowed the examinations to be evaluated not in isolation but within the complete diagnostic pathway of the patient with ischemic stroke (PRABHAKARAN et al., 2026; NTAIOS et al., 2024).

No new quantitative meta-analysis was performed because of heterogeneity among studies regarding design, population, imaging method, diagnostic outcome, time window, and criteria used to define an embolic source or eligibility for reperfusion. Therefore, a qualitative critical synthesis was chosen, emphasizing convergence and divergence among different studies and contemporary recommendations (PAGE et al., 2021).

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Methodological quality assessment was planned according to the design of the included studies. QUADAS-2 may be used for diagnostic-accuracy studies, whereas observational studies may be assessed using Joanna Briggs Institute (JBI) tools. Systematic reviews and meta-analyses were interpreted considering risk of bias, heterogeneity, number of studies, and clinical applicability of the results (PAGE et al., 2021).

The final analysis sought to clearly distinguish the role of imaging in the hyperacute phase, primarily focused on excluding hemorrhage and selecting patients for reperfusion, from its later role in defining the etiological mechanism. This distinction made it possible to understand how neuroradiology and cardiovascular imaging act complementarily throughout the investigation of ischemic stroke (PRABHAKARAN et al., 2026; NTAIOS et al., 2024).

Because this review was based exclusively on previously published studies and scientific-domain data, without direct inclusion of participants or use of identifiable individual information, submission to a Research Ethics Committee was not required, in accordance with principles applicable to research developed exclusively from secondary sources (PAGE et al., 2021).

### 5 RESULTS

Analysis of the included studies showed that imaging investigation in ischemic stroke has two complementary functions: rapidly defining the presence, extent, and hemodynamic impact of cerebral ischemia and, subsequently, contributing to identification of the etiological mechanism responsible for the event. Non-contrast CT, CT angiography, and MRI were the main methods used in neurological investigation, whereas echocardiography, cardiac CT, and cardiac MRI were more relevant in the search for cardioembolic sources (SARRAJ; PUJARA; CAMPBELL, 2024; NTAIOS et al., 2024).

#### 5.1 Non-contrast computed tomography in the hyperacute phase

Non-contrast head CT remained the main initial method in the studies and guidelines evaluated. Its primary function was to rapidly exclude intracranial hemorrhage and identify signs of early ischemia, allowing decisions regarding intravenous thrombolysis without mandatory advanced imaging in clearly eligible patients. The 2026 AHA/ASA guideline reaffirmed that non-contrast CT is sufficient for thrombolysis decision-making in most patients within the conventional therapeutic window (PRABHAKARAN et al., 2026).

Early signs of ischemia found on CT included loss of gray-white matter differentiation, sulcal effacement, parenchymal hypodensity, and changes in the affected arterial territory. ASPECTS remained a tool used to systematize the extent of early changes, especially in the anterior circulation, and was incorporated into the assessment of patients considered for reperfusion (SARRAJ; PUJARA; CAMPBELL, 2024; PRABHAKARAN et al., 2026).

**Table 1 – Role of non-contrast CT in ischemic stroke**

| Aspect assessed                 | Main contribution                                                        |
|---------------------------------|--------------------------------------------------------------------------|
| Intracranial hemorrhage         | Rapid exclusion                                                          |
| Early signs of ischemia         | Identification of edema and loss of cortical-subcortical differentiation |
| Lesion extent                   | Assessment using ASPECTS                                                 |
| Decision regarding thrombolysis | Generally sufficient within the conventional window                      |
| Main limitation                 | Lower sensitivity for very early and small lesions                       |

#### 5.2 CT angiography of the cervical and intracranial arteries

CT angiography played a decisive role in identifying proximal arterial occlusions, especially large-vessel occlusions, while also allowing assessment of stenoses, tandem occlusions, and dissections. Demonstration of an occlusion in a large- or medium-caliber artery is one of the main criteria for referral for mechanical thrombectomy evaluation, making CT angiography a central component of contemporary acute-stroke protocols (SARRAJ; PUJARA; CAMPBELL, 2024; PRABHAKARAN et al., 2026).

Sarraj, Pujara, and Campbell (2024) emphasized that identification of medium- and large-vessel occlusions by CT angiography or MR angiography triggers consideration of endovascular therapy. The authors also noted that the optimal strategy may vary according to institutional infrastructure, reinforcing that imaging protocols should be rapid and should not create avoidable delays in access to reperfusion (SARRAJ; PUJARA; CAMPBELL, 2024).

**Table 2 – Main applications of CT angiography in ischemic stroke**

| Finding                | Clinical relevance                              |
|------------------------|-------------------------------------------------|
| Large-vessel occlusion | Selection for thrombectomy                      |
| Carotid stenosis       | Etiological definition and secondary prevention |
| Tandem occlusion       | Endovascular planning                           |
| Arterial dissection    | Identification of a vascular cause              |
| Intracranial anatomy   | Planning of access and therapeutic strategy     |

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### 5.3 CT perfusion and penumbra assessment

CT perfusion added physiological information to the anatomical assessment, making it possible to estimate areas of ischemic core and potentially salvageable hypoperfused tissue. Panicker et al. (2024) highlighted that perfusion provides parameters related to cerebral blood flow and helps delineate irreversibly injured tissue from ischemic penumbra, contributing to more individualized therapeutic selection (PANICKER et al., 2024).

The relevance of perfusion was greater in late therapeutic windows, particularly after six hours from symptom onset or in patients with uncertain onset time. Sarraj, Pujara, and Campbell (2024) observed that perfusion methods can identify salvageable brain tissue in patients for whom chronological time alone would not be sufficient to determine eligibility for reperfusion (SARRAJ; PUJARA; CAMPBELL, 2024).

However, the results also indicated that perfusion does not necessarily need to be performed in every patient. Dhillon et al. (2024) evaluated thrombectomy in late-presenting patients selected only by non-contrast CT and CT angiography, demonstrating that simplified imaging strategies can be used in certain situations. These results support selection based on anatomy and infarct extent when advanced studies are not immediately available (DHILLON et al., 2024).

### 5.4 Brain magnetic resonance imaging

Magnetic resonance imaging showed greater sensitivity for detecting small areas of ischemia, especially through diffusion-weighted sequences. The review by Sarraj, Pujara, and Campbell (2024) showed that MRI can assist both in the diagnosis of acute stroke and in differentiating true ischemia from stroke-mimicking conditions (SARRAJ; PUJARA; CAMPBELL, 2024).

DWI and FLAIR sequences were particularly useful in patients with unknown onset time. Diffusion restriction without a corresponding significant FLAIR abnormality may suggest a relatively recent lesion, whereas perfusion techniques associated with MRI allow assessment of remaining viable tissue. This concept contributed to the transition from strategies based exclusively on time to approaches also based on tissue viability (SARRAJ; PUJARA; CAMPBELL, 2024; PRABHAKARAN et al., 2026).

MRI was also particularly useful in small infarcts, posterior-circulation lesions, and situations in which the initial CT was negative despite persistent suggestive neurological deficits. Its main limitations remained availability, examination duration, contraindications, and greater logistical difficulty in unstable patients (SARRAJ; PUJARA; CAMPBELL, 2024).

### 5.5 Integration of imaging in selection for reperfusion

The studies showed that contemporary imaging strategy should be adapted to the time window and clinical profile. In the early phase, non-contrast CT combined with CT angiography often provides sufficient information to exclude hemorrhage and identify large-vessel occlusion. In late windows, CT or MR perfusion techniques may add information on tissue viability, particularly when there is uncertainty about the extent of the ischemic core (PRABHAKARAN et al., 2026; SARRAJ; PUJARA; CAMPBELL, 2024).

Contemporary evidence also showed a progressive reduction in dependence on extremely complex protocols for all patients. Recent studies and meta-analyses indicate that selected individuals may benefit from thrombectomy even when evaluation is based predominantly on non-contrast CT and CT angiography, reinforcing that advanced imaging should expand selection capability without delaying time-dependent procedures (DHILLON et al., 2024; PRABHAKARAN et al., 2026).

**Table 3 – Comparison of the main neuroimaging methods**

| Method          | Main advantage                        | Main limitation                  | Predominant role                  |
|-----------------|---------------------------------------|----------------------------------|-----------------------------------|
| Non-contrast CT | Speed and availability                | Lower early sensitivity          | Exclusion of hemorrhage           |
| CT angiography  | Rapid identification of occlusion     | Contrast/radiation use           | Selection for thrombectomy        |
| CT perfusion    | Assessment of core/penumbra           | May increase time and complexity | Late-window selection             |
| MRI-DWI         | High sensitivity for ischemia         | Lower availability               | Confirmation and small lesions    |
| MR perfusion    | Tissue viability                      | Logistics and duration           | Selection in specific cases       |
| MR angiography  | Vascular assessment without radiation | Availability and time            | Complementary vascular assessment |

### 5.6 Neuroimaging pattern and etiological investigation

The distribution of cerebral lesions proved useful in guiding etiological investigation. Cortical lesions, multiple ischemic areas in distinct vascular territories, and bilateral infarcts increased suspicion of embolization, whereas territorial patterns related to specific arterial disease suggested atherothrombotic or local vascular mechanisms. Therefore, topographic interpretation of neuroimaging provided useful information for directing complementary cardiovascular examinations (XIAO et al., 2024; NTAIOS et al., 2024).

In cryptogenic stroke, this integration became even more relevant. A cerebral pattern suggestive of embolism in the absence of a responsible arterial stenosis increased the indication for more in-depth investigation of cardiac and aortic sources, including transesophageal echocardiography and, in selected situations, cardiac CT or MRI (NTAIOS et al., 2024).

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### 5.7 Transthoracic and transesophageal echocardiography

Echocardiography remained the central method of cardiovascular investigation after ischemic stroke. Transthoracic echocardiography was most useful for assessing ventricular function, cardiomyopathies, valvular disease, and ventricular thrombi, whereas transesophageal echocardiography provided superior visualization of the left atrial appendage, interatrial septum, prosthetic valves, and aortic arch (CANALI et al., 2023; NTAIOS et al., 2024).

The systematic review by van der Maten et al. (2021), involving patients with stroke or transient ischemic attack of undetermined cause, identified major cardioembolic sources in 1.3% of patients undergoing transthoracic echocardiography and in 5.9% of those assessed by transesophageal echocardiography. Minor sources were found in 12.3% and 20.6%, respectively, suggesting a higher diagnostic yield of the transesophageal approach, although with substantial heterogeneity among studies (VAN DER MATEN et al., 2021).

These findings reinforce that transesophageal echocardiography should be considered especially when transthoracic echocardiography is negative or when there is high suspicion of an embolic source located in structures poorly accessible by the transthoracic route. On the other hand, the semi-invasive nature of the examination, the need for sedation in some cases, and variable availability limit its indiscriminate application (CANALI et al., 2023; NTAIOS et al., 2024).

**Table 4 – Comparison between transthoracic and transesophageal echocardiography**

| Characteristic        | Transthoracic                 | Transesophageal                 |
|-----------------------|-------------------------------|---------------------------------|
| Invasiveness          | Noninvasive                   | Semi-invasive                   |
| Ventricular function  | Excellent                     | Complementary                   |
| Ventricular thrombus  | Good assessment               | Less advantageous               |
| Left atrial appendage | Limited                       | Superior                        |
| Patent foramen ovale  | Can be detected with contrast | Greater anatomical detail       |
| Vegetations           | Good for larger lesions       | Superior for small lesions      |
| Aortic arch           | Limited                       | Superior                        |
| Initial use           | Frequent                      | Selected according to suspicion |

### 5.8 Cardiac computed tomography in the search for embolic sources

Cardiac computed tomography has grown substantially as a complementary method to echocardiography. Its high spatial resolution and the possibility of integrated acquisition with cerebral vascular investigation make it possible to assess intracardiac thrombi, the left atrial appendage, septa, valves, and thoracic aorta. Contemporary reviews highlighted its potential particularly when echocardiography is inconclusive or technically limited (CANALI et al., 2023; NTAIOS et al., 2024).

Rinkel et al. (2022) compared ECG-gated cardiac CT with transthoracic echocardiography in patients in the acute phase of stroke. High-risk cardioaortic sources were detected in 11.4% of patients by cardiac CT versus 4.9% by transthoracic echocardiography. Cardiac thrombi were found in 7.1% by CT and in only 0.6% by echocardiography, suggesting a higher yield for certain embolic sources (RINKEL et al., 2022).

In the same study, the additional cardiac CT acquisition added a median of approximately six minutes to the protocol and had inadequate quality in only 3% of examinations. Among patients initially classified as having cryptogenic stroke after conventional investigation, cardiac CT identified a possible cause in 6.3%, suggesting potential benefit from selective incorporation into the acute protocol (RINKEL et al., 2022).

A 2024 meta-analysis involving 43 studies and 9,552 patients found an overall sensitivity of 98.38% and specificity of 96.0% for cardiac CT in the detection of intracardiac thrombus compared with echocardiography. The best results were observed with ECG-gated protocols and delayed acquisition, although study heterogeneity and the absence of randomized trials were highlighted as limitations (GHOZY et al., 2024).

**Table 5 – Evidence related to cardiac computed tomography**

| Study                   | Population            | Main result                                                 |
|-------------------------|-----------------------|-------------------------------------------------------------|
| Rinkel et al. (2022)    | Acute ischemic stroke | High-risk cardioaortic source: 11.4% CT vs 4.9% TTE         |
| Rinkel et al. (2022)    | Acute stroke          | Cardiac thrombus: 7.1% CT vs 0.6% TTE                       |
| Ghozy et al. (2024)     | 9,552 patients        | Sensitivity 98.38%; specificity 96.0% for thrombus          |
| Delayed-phase protocols | Selected patients     | Better differentiation between thrombus and contrast stasis |

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### 5.9 Cardiac magnetic resonance imaging

Cardiac MRI played a complementary role, especially for tissue characterization. Studies and recommendations demonstrated usefulness in assessing cardiomyopathies, myocardial fibrosis, ventricular thrombi, cardiac tumors, and complex structural abnormalities, with the ability to differentiate tumor masses from thrombi more accurately in certain situations (NTAIOS et al., 2024; CANALI et al., 2023).

Despite its high characterization capability, cardiac MRI had lower applicability in the hyperacute setting because it requires longer acquisition time, specialized equipment, and clinical stability. Thus, the studies analyzed positioned it mainly as a complementary method when echocardiography or CT does not sufficiently clarify a possible cardioembolic source (NTAIOS et al., 2024; CANALI et al., 2023).

### 5.10 Patent foramen ovale and paradoxical embolism

Investigation of patent foramen ovale was particularly important in younger patients with cryptogenic stroke. Echocardiographic microbubble studies made it possible to demonstrate right-to-left shunting, whereas transesophageal echocardiography provided better anatomical characterization of the interatrial septum. However, identifying a patent foramen ovale in isolation did not establish causality, and correlation with clinical characteristics and the neuroimaging pattern was required (NTAIOS et al., 2024; CANALI et al., 2023).

The results showed that joint assessment of septal morphology, shunt magnitude, presence of atrial septal aneurysm, and absence of another probable cause of stroke increases the etiological relevance of the finding. Thus, the role of cardiac imaging is not merely to detect the communication, but to contextualize it within a multimodal etiological investigation (NTAIOS et al., 2024).

### 5.11 Aorta and other cardioaortic sources

Aortic-arch atheromatosis was another potential source of embolism identified by imaging. Transesophageal echocardiography, CT, and MRI made it possible to characterize complex plaques, ulcerations, thickening, and mobile components, although the isolated presence of atheroma does not automatically establish a causal relationship with stroke (NTAIOS et al., 2024; CANALI et al., 2023).

European recommendations further emphasized that multiple cardioaortic sources may coexist in the same patient and that identification of a potentially embolic finding should be interpreted together with the neuroimaging pattern and concomitant vascular disease (NTAIOS et al., 2024).

### 5.12 Cryptogenic stroke and multimodal integration

In strokes of undetermined cause, multimodal investigation had a higher yield when neuroimaging, vascular imaging, and cardiac assessment were combined. The contemporary approach includes echocardiography to assess possible embolic sources, prolonged rhythm monitoring for atrial fibrillation, and, in selected patients with cryptogenic stroke or ESUS, consideration of transesophageal echocardiography, cardiac CT, or cardiac MRI (NTAIOS et al., 2024).

This approach was relevant because a potential cardiac source alone does not establish the mechanism of stroke. Patients may simultaneously have a potential cardiac source and atherosclerotic cerebrovascular disease, requiring integration of the cerebral infarct pattern, vascular anatomy, cardiac findings, and clinical data before definitive etiological attribution (NTAIOS et al., 2024).

**Table 6 – Integration of methods in the etiological investigation of stroke**

| Clinical situation                           | Most useful imaging method    |
|----------------------------------------------|-------------------------------|
| Suspected acute stroke                       | Non-contrast CT               |
| Suspected large-vessel occlusion             | CT angiography/MR angiography |
| Late window or uncertain onset               | CT perfusion or MRI           |
| Small lesions/posterior circulation          | MRI-DWI                       |
| Ventricular dysfunction/ventricular thrombus | TTE                           |
| Left atrial appendage thrombus               | TEE or cardiac CT             |
| Patent foramen ovale                         | TTE/TEE with microbubbles     |
| Aortic-arch atheroma                         | TEE or CT                     |
| Cardiomyopathy/fibrosis/tumor                | Cardiac MRI                   |
| Cryptogenic stroke                           | Multimodal strategy           |

### 5.13 Synthesis of the main results

The synthesis of evidence showed that non-contrast CT maintains a central role in the initial phase of ischemic stroke because of its speed and ability to exclude hemorrhage, while CT angiography plays a decisive role in identifying large-vessel occlusions. CT perfusion and MRI expand the ability to select patients with potentially salvageable tissue, especially in late windows or when onset time is unknown (SARRAJ; PUJARA; CAMPBELL, 2024; PANICKER et al., 2024; PRABHAKARAN et al., 2026).

In cardiovascular investigation, echocardiography remained the most commonly used initial method, but transesophageal echocardiography had greater ability to characterize structures such as the left atrial appendage, interatrial septum, and aortic arch. Cardiac CT showed a high yield for intracardiac thrombi and, in some studies, detected more high-risk cardioaortic sources than

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transthoracic echocardiography, whereas cardiac MRI had greater value for tissue characterization and cardiomyopathies (RINKEL et al., 2022; CANALI et al., 2023; GHOZY et al., 2024).

The results also indicated that no method should be analyzed in isolation. The most consistent etiological identification occurred when the pattern of brain injury was compared with findings from the cervical and intracranial circulation and with potential cardiac or aortic sources. This integration was particularly important in cryptogenic stroke, in which incidental abnormalities may be incorrectly considered causal if interpreted outside the clinical and neuroradiological context (NTAIOS et al., 2024; XIAO et al., 2024).

Overall, the findings showed that the role of radiology in ischemic stroke extends from emergency decision-making to etiological investigation and secondary prevention. The current trend is toward multimodal integration, using simplified and rapid protocols in the hyperacute phase and more specific, targeted methods later, according to the suspected etiological mechanism and the ability of each examination to modify clinical management (PRABHAKARAN et al., 2026; SARRAJ; PUJARA; CAMPBELL, 2024; NTAIOS et al., 2024).

## 6 DISCUSSION

The results of this review demonstrate that radiology occupies a central and increasingly comprehensive position in the management of ischemic stroke. Imaging has moved beyond the exclusive role of confirming the presence of brain injury and excluding hemorrhage to participate directly in selection for reperfusion, thrombectomy planning, etiological investigation, and secondary prevention. This change is particularly evident when considering the integration of computed tomography, CT angiography, perfusion imaging, brain MRI, and cardiovascular imaging methods (SARRAJ; PUJARA; CAMPBELL, 2024; PRABHAKARAN et al., 2026).

In the hyperacute phase, non-contrast computed tomography maintains a strategic position because of its speed, broad availability, and ability to exclude intracranial hemorrhage. Prabhakaran et al. (2026) reaffirm that in most patients considered for intravenous thrombolysis within the conventional window, non-contrast CT provides sufficient information to start treatment, and reperfusion should not be delayed for indiscriminate acquisition of multimodal examinations. This perspective reinforces that technological sophistication adds value only when it does not compromise speed of care (PRABHAKARAN et al., 2026).

Sarraj, Pujara, and Campbell (2024) converge with this approach by emphasizing that initial neuroimaging should rapidly answer fundamental questions: is there hemorrhage, is there a large ischemic area, and is there an arterial occlusion amenable to endovascular treatment? Thus, simple CT remains the starting point of the protocol in many centers, whereas advanced methods should be incorporated according to the clinical question and therapeutic window (SARRAJ; PUJARA; CAMPBELL, 2024).

The role of CT angiography is particularly relevant because identification of a large-vessel occlusion immediately changes the therapeutic pathway. While non-contrast CT predominantly evaluates the parenchyma, CT angiography provides anatomical information about the site of obstruction, cervical and intracranial circulation, stenoses, dissections, and tandem occlusions. Therefore, the association of non-contrast CT with CT angiography represents one of the most efficient combinations in contemporary screening of patients potentially eligible for thrombectomy (SARRAJ; PUJARA; CAMPBELL, 2024; PRABHAKARAN et al., 2026).

Expansion of the indications for mechanical thrombectomy has further increased the importance of vascular imaging. Current guidelines show that selected patients may benefit from endovascular treatment even in situations previously considered unfavorable, including broader time windows and some patients with larger ischemic cores. In this context, imaging has evolved from a purely diagnostic tool to an element of prognostic stratification and therapeutic selection (PRABHAKARAN et al., 2026).

CT perfusion adds a functional dimension to the process by estimating the ischemic core and the amount of potentially salvageable hypoperfused tissue. Panicker et al. (2024) emphasize that perfusion maps allow analysis of hemodynamic parameters that complement anatomical assessment, being particularly useful when time since symptom onset is prolonged or unknown. This concept helped partially replace an exclusively chronological view of stroke with a strategy also based on tissue viability (PANICKER et al., 2024).

However, the need for perfusion in all patients evaluated for thrombectomy has been questioned. Dhillon et al. (2024) demonstrated, in a systematic review and meta-analysis of late-presenting patients, that individuals selected by non-contrast CT and CT angiography also benefited from thrombectomy. These findings do not eliminate the value of perfusion, but suggest that its absence should not necessarily preclude endovascular treatment when anatomical and clinical information is sufficient (DHILLON et al., 2024).

This observation is particularly important in hospitals that do not have advanced software or 24-hour CT perfusion availability. Protocols excessively dependent on sophisticated techniques may create inequality in access to thrombectomy, especially in health systems with heterogeneous resources. Thus, the ideal strategy should balance diagnostic accuracy, technological availability, and time to reperfusion, avoiding situations in which the pursuit of the supposedly ideal examination prevents delivery of a potentially beneficial therapy (DHILLON et al., 2024; PRABHAKARAN et al., 2026).

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Magnetic resonance imaging, on the other hand, has specific diagnostic advantages. Diffusion-weighted sequences have high sensitivity for acute ischemia and are particularly useful for small lesions, posterior circulation, and cases in which the initial CT does not show enough abnormalities to explain the clinical deficit. Sarraj, Pujara, and Campbell (2024) also highlight its ability to help differentiate stroke from mimicking conditions, increasing diagnostic accuracy in selected scenarios (SARRAJ; PUJARA; CAMPBELL, 2024).

DWI-FLAIR mismatch illustrates how MRI can directly contribute to therapeutic selection. The presence of a diffusion lesion without a corresponding marked FLAIR abnormality allows inference that the event likely occurred within a relatively recent window, supporting consideration of reperfusion in patients whose onset time is unknown. The 2026 AHA/ASA guideline retains this strategy among imaging paradigms applicable to selected patients in extended windows (PRABHAKARAN et al., 2026).

Despite this high diagnostic capability, MRI does not universally replace CT in the hyperacute phase. Acquisition time, access to equipment, monitoring of unstable patients, contraindications, and the need for internal transfer may limit its use. Therefore, comparison between CT and MRI should not be reduced to asking which method has greater sensitivity, but should consider which modality provides the necessary information within the shortest interval compatible with decision-making (SARRAJ; PUJARA; CAMPBELL, 2024).

Neuroimaging also has an etiological role. Patterns of cortical infarcts, multiple vascular territories, bilateral involvement, or simultaneous involvement of the anterior and posterior circulations may increase suspicion of embolization, whereas lesions associated with territorial arterial stenosis suggest atherothrombotic mechanisms. Xiao et al. (2024) emphasize that MRI can contribute significantly to the investigation of cryptogenic stroke and ESUS by characterizing cerebral patterns and vascular abnormalities that guide subsequent stages of investigation (XIAO et al., 2024).

This interpretation is particularly relevant because the diagnosis of cardioembolism cannot be established solely by identifying a cardiac abnormality. Ntaios et al. (2024) highlight that multiple potential sources may coexist in the same individual with ESUS, which means that attributing causality to an isolated abnormality may lead to inappropriate simplification. The brain-imaging pattern should be compared with vascular, cardiac, aortic, and clinical findings before defining the most likely mechanism (NTAIOS et al., 2024).

In cardiovascular investigation, transthoracic echocardiography remains important because it is noninvasive, widely available, and capable of assessing ventricular function, cardiomyopathies, valvular abnormalities, and ventricular thrombi. Canali et al. (2023) consider echocardiography a fundamental step in the search for a cardioembolic source but emphasize that the choice between a transthoracic and transesophageal approach should depend on the suspected anatomical structure and clinical context (CANALI et al., 2023).

Transesophageal echocardiography has an advantage over transthoracic echocardiography in assessing posterior structures, especially the left atrial appendage, interatrial septum, and aortic arch. Van der Maten et al. (2021) identified major cardioembolic sources in 1.3% of patients assessed by transthoracic echocardiography and in 5.9% of those undergoing transesophageal assessment. Although the authors highlighted heterogeneity and the small number of studies, the data demonstrate a higher yield of the transesophageal approach for certain embolic sources (VAN DER MATEN et al., 2021).

Shah et al. (2021) added important evidence by specifically analyzing patients with cryptogenic stroke or transient ischemic attack and normal transthoracic echocardiography. Transesophageal echocardiography revealed additional cardiac findings in approximately 37.5% of patients and changed clinical management in a relevant proportion of cases. These results demonstrate that a normal transthoracic echocardiogram does not necessarily end the investigation when strong suspicion of cardioembolism persists (SHAH et al., 2021).

On the other hand, the higher diagnostic yield of transesophageal echocardiography does not mean that it should be performed indiscriminately. It is a semi-invasive procedure, with discomfort, occasional need for sedation, and limitations in certain patients. Selection should therefore consider age, radiological stroke pattern, possibility of patent foramen ovale, endocarditis, atrial thrombus, or aortic disease and, above all, the likelihood that the result will modify secondary prevention (CANALI et al., 2023; SHAH et al., 2021).

Cardiac CT emerges as a particularly relevant alternative in this scenario. Rinkel et al. (2022) demonstrated a higher yield of ECG-gated cardiac CT compared with transthoracic echocardiography in identifying high-risk cardioaortic sources. High-risk sources were identified in 11.4% of patients by CT versus 4.9% by echocardiography, while cardiac thrombi were observed in 7.1% and 0.6%, respectively (RINKEL et al., 2022).

In addition to diagnostic yield, Rinkel et al. (2022) demonstrated the logistical feasibility of incorporating cardiac CT into the acute evaluation. The median additional acquisition time was approximately six minutes, and inadequate quality occurred in only a small proportion of examinations. These data suggest that CT protocols simultaneously including the brain, cervical vessels, and heart may, in certain centers, advance etiological investigation without causing substantial delay (RINKEL et al., 2022).

Ghozy et al. (2024) reinforced the potential of cardiac CT in a meta-analysis of 43 studies involving 9,552 patients. Pooled sensitivity for detection of intracardiac thrombus was 98.38% and specificity was 96.0%, with better performance in ECG-gated

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protocols and with delayed acquisition. These results place cardiac CT close to echocardiography as a highly accurate method for investigating intracardiac thrombi (GHOZY et al., 2024).

However, the meta-analysis by Ghazy et al. (2024) also has limitations that prevent cardiac CT from being considered a universal substitute for echocardiography. There was substantial heterogeneity among protocols, there were no randomized trials, and the analysis focused mainly on intracardiac thrombi, without equivalent assessment of cardiac function, valvular abnormalities, and aortic-arch disease. The main interpretation is therefore one of complementarity rather than absolute replacement between methods (GHOZY et al., 2024).

Cardiac MRI has a different profile of usefulness. Its greatest contribution lies in tissue characterization, assessment of cardiomyopathies, myocardial fibrosis, tumors, and differentiation between masses and thrombi. However, logistics, longer acquisition time, and more limited availability mean that its use is predominantly directed to selected cases after initial assessment with echocardiography or CT (CANALI et al., 2023; NTAIOS et al., 2024).

Patent foramen ovale exemplifies the need for integrated interpretation. PFO is relatively common and, in isolation, does not prove that it caused the cerebral event. Its relevance increases in a younger patient, in the absence of an alternative arterial or arrhythmic cause, when higher-risk anatomical characteristics are present, and when the cerebral pattern is compatible with embolism. Thus, microbubble studies and transesophageal characterization should be interpreted together with neuroimaging and the other components of the etiological investigation (NTAIOS et al., 2024; CANALI et al., 2023).

Similar reasoning applies to aortic-arch atheromatosis. Complex, ulcerated, or mobile plaques have greater embolic potential, but their presence should be correlated with other risk factors and with the distribution of cerebral lesions. Transesophageal echocardiography and CT have complementary capabilities for assessing the aorta, again reinforcing that no single modality answers all etiological questions in stroke (NTAIOS et al., 2024).

Strokes classified as ESUS perhaps represent the scenario in which this integration is most necessary. Ntaios et al. (2024) emphasize that approximately one in six ischemic strokes may fit this concept and propose an approach that considers all identified thromboembolic sources simultaneously rather than seeking a single presumed cause. This conceptual shift directly values integration among neuroradiology, vascular radiology, and cardiovascular imaging (NTAIOS et al., 2024).

The use of artificial intelligence and automated processing systems represents another important frontier. Tools capable of detecting large-vessel occlusions, calculating ASPECTS, and quantifying ischemic core and penumbra can accelerate identification of patients who are candidates for transfer or thrombectomy. However, contemporary guidelines maintain the need for specialized clinical and radiological interpretation, since artifacts, anatomical variations, and inadequate automated results can lead to incorrect decisions when used without supervision (PRABHAKARAN et al., 2026).

The growing use of these technologies reinforces the need for protocols adapted to institutional realities. A tertiary center with neuroradiology, automated perfusion, emergency MRI, and cardiac CT has different possibilities from a hospital without these resources. The evidence from Dhillon et al. (2024) is relevant precisely because it shows that simplified protocols can preserve therapeutic-selection capability when advanced perfusion is unavailable, avoiding excessive concentration of access to therapy in only a few centers (DHILLON et al., 2024).

Another important issue is distinguishing diagnostic yield from clinical impact. An examination may identify numerous abnormalities without necessarily changing management. Van der Maten et al. (2021) observed that major cardioembolic sources were relatively uncommon even after echocardiography, whereas Shah et al. (2021) showed that TEE identifies many additional findings, but only some necessarily lead to a therapeutic change. Future studies should therefore assess not only how many findings are detected but how many actually modify secondary prevention and reduce recurrence (VAN DER MATEN et al., 2021; SHAH et al., 2021).

The same principle should guide adoption of cardiac CT. Despite the high sensitivity demonstrated by Ghazy et al. (2024) and the yield observed by Rinkel et al. (2022), studies are still needed to determine whether routine incorporation of this examination reduces stroke recurrence, improves functional outcomes, or offers greater cost-effectiveness than traditional pathways. High diagnostic performance is an important argument but does not complete the assessment of clinical effectiveness (RINKEL et al., 2022; GHOZY et al., 2024).

The main limitations of the literature are related to heterogeneity of imaging protocols, differences among populations, diversity of etiological-classification criteria, and lack of complete standardization in defining which cardiovascular findings are truly causal. In the acute phase, debate persists regarding the amount of imaging needed to select patients in late windows; in etiological investigation, uncertainty remains about which sequence of examinations offers the best balance among yield, cost, invasiveness, and therapeutic impact (SARRAJ; PUJARA; CAMPBELL, 2024; NTAIOS et al., 2024; GHOZY et al., 2024).

In an integrated view, Sarraj, Pujara, and Campbell (2024) and Prabhakaran et al. (2026) demonstrate that neuroimaging should prioritize speed and appropriate selection for reperfusion; Panicker et al. (2024) show the value of perfusion assessment; Dhillon et al. (2024) question the need for advanced perfusion in every context; Canali et al. (2023) and Shah et al. (2021) reinforce the role of echocardiography; Rinkel et al. (2022) and Ghazy et al. (2024) demonstrate the growing contribution of cardiac CT; and Ntaios et al. (2024) integrate this evidence into a multidimensional concept of embolic risk.

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Thus, the main contemporary advance is not replacement of one modality by another, but rational and sequential use of complementary methods. Non-contrast CT rapidly addresses the initial need to exclude hemorrhage; CT angiography identifies vascular anatomy; perfusion and MRI refine assessment of tissue viability; echocardiography investigates structural sources; and cardiac CT or MRI provide deeper evaluation in specific situations. Integration of these findings allows radiology to participate throughout the patient's trajectory, from the emergency setting to prevention of a new stroke (PRABHAKARAN et al., 2026; NTAIOS et al., 2024).

Therefore, the ideal investigation of ischemic stroke should be multimodal but not necessarily maximalist. The value of each examination depends on its ability to answer a concrete clinical question and modify management without introducing unnecessary delays. Contemporary radiology thus assumes a strategic role both in the immediate preservation of brain tissue and in identifying the mechanism responsible for the event, bringing diagnosis, treatment, and secondary prevention together within a single care pathway (PRABHAKARAN et al., 2026; SARRAJ; PUJARA; CAMPBELL, 2024; NTAIOS et al., 2024).

### 7 CONCLUSION

Analysis of the evidence demonstrates that imaging methods play an indispensable role at every stage of ischemic-stroke management, from diagnostic confirmation and exclusion of hemorrhage to selection of patients for reperfusion, etiological definition, and planning of secondary prevention. Radiology therefore goes beyond a merely diagnostic function and participates directly in the main clinical decisions related to ischemic stroke (SARRAJ; PUJARA; CAMPBELL, 2024; PRABHAKARAN et al., 2026).

Non-contrast computed tomography remains a fundamental initial method because of its speed, availability, and ability to exclude intracranial hemorrhage. CT angiography complements this assessment by identifying large-vessel occlusions, stenoses, dissections, and abnormalities of the cervical and intracranial circulation, being particularly relevant for planning mechanical thrombectomy (PRABHAKARAN et al., 2026).

CT perfusion and magnetic resonance imaging allow assessment of aspects that extend beyond structural anatomy, including tissue viability, ischemic core, and penumbra. These methods are more relevant in patients with unknown onset time or extended therapeutic windows, although recent evidence shows that absence of advanced perfusion should not necessarily preclude thrombectomy in patients appropriately selected by CT and CT angiography (PANICKER et al., 2024; DHILLON et al., 2024).

Brain MRI provides additional value in detecting small lesions, posterior-circulation infarcts, differentiating stroke mimics, and etiological assessment of cryptogenic stroke. The distribution of lesions on neuroimaging may suggest embolic mechanisms and direct cardiovascular investigation, demonstrating that the brain itself also provides important clues to the origin of the embolus (SARRAJ; PUJARA; CAMPBELL, 2024; XIAO et al., 2024).

In cardiovascular assessment, transthoracic echocardiography remains an important initial modality, whereas transesophageal echocardiography has greater ability to investigate the left atrial appendage, interatrial septum, small valvular abnormalities, and aortic arch. The findings of van der Maten et al. (2021) and Shah et al. (2021) demonstrate that TEE can add relevant diagnostic information, especially when the initial investigation does not identify a definite cause (VAN DER MATEN et al., 2021; SHAH et al., 2021).

Cardiac CT is emerging as an important complementary method. Rinkel et al. (2022) demonstrated a higher yield for some high-risk cardioaortic sources compared with transthoracic echocardiography, while Ghozy et al. (2024) observed high sensitivity and specificity for intracardiac thrombus detection. However, protocol heterogeneity and the lack of definitive demonstration of benefit on clinical outcomes support its integrated use with echocardiography rather than indiscriminate replacement (RINKEL et al., 2022; GHOZY et al., 2024).

In patients with cryptogenic stroke or ESUS, multimodal interpretation becomes even more important. Cardiac sources, arterial disease, aortic abnormalities, and other mechanisms may coexist, making it inappropriate to assign causality to a single finding without correlation with the neuroimaging pattern and vascular assessment. The contemporary approach should consider the full set of potential thromboembolic factors present in the patient (NTAIOS et al., 2024).

It is concluded that the most appropriate radiological strategy for ischemic stroke is not indiscriminate performance of every available examination, but construction of a rational diagnostic sequence guided by clinical questions. In the hyperacute phase, speed and identification of candidates for reperfusion should be prioritized; subsequently, investigation should integrate neuroimaging, vascular assessment, and cardiovascular methods to establish the etiological mechanism and guide secondary prevention. This integration strengthens the role of radiology as an essential component of personalized medicine in ischemic stroke (PRABHAKARAN et al., 2026; NTAIOS et al., 2024).

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