

Original Article

Significance of Magnetic Resonance Angiography for the Diagnosis of Cerebrovascular Diseases

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ABSTRACT

Background: Cerebrovascular disorders encompass stenotic, occlusive, aneurysmal and other vascular abnormalities that may lead to cerebral ischemia, hemorrhage, neurological disability and death. Magnetic resonance angiography (MRA) provides non-ionizing vascular imaging and can depict the intracranial arterial system without conventional catheter angiography. **Objective:** To characterize cerebrovascular abnormalities identified by MRA among symptomatic patients undergoing evaluation at Lahore General Hospital, Lahore. **Methods:** A cross-sectional study included 114 patients selected through non-probability convenience sampling. Eligible patients of either sex had histories including dizziness, nausea, unusually severe headache or memory loss. Demographic and clinical information and MRA findings were recorded. Descriptive statistics were generated using SPSS version 24. Wilson 95% confidence intervals were additionally calculated for principal proportions. **Results:** Mean age was 34.37 ± 14.74 years (range 3–63); 66 patients (57.9%) were female. Hypertension was present in 74 (64.9%), diabetes in 39 (34.2%), headache in 71 (62.3%), dizziness in 58 (50.9%), abnormal lipoprotein levels in 67 (58.8%) and abnormal cholesterol in 64 (56.1%). MRA recorded mild stenosis in 32 (28.1%), moderate stenosis in 46 (40.4%), severe stenosis in 25 (21.9%), aneurysm in 41 (36.0%), calcified plaque in 80 (70.2%) and overall cerebrovascular disease in 73 (64.0%). **Conclusion:** MRA demonstrated a broad spectrum of cerebrovascular abnormalities in this symptomatic hospital population. These findings support its clinical utility for noninvasive cerebrovascular assessment, although diagnostic accuracy cannot be determined without comparison with an independent reference standard. **Keywords:** magnetic resonance angiography; cerebrovascular disease; intracranial stenosis; cerebral aneurysm; cerebral vessels; MRA.

INTRODUCTION

The cerebral circulation depends on a complex arterial network originating from the aortic arch and supplying the head and neck through the carotid and vertebrobasilar systems. The principal branches of the aortic arch are the brachiocephalic trunk, left common carotid artery and left subclavian artery. The common carotid arteries ascend within the neck before dividing into the internal and external carotid arteries, commonly near the superior border of the thyroid cartilage at approximately the fourth cervical

vertebral level. The vertebral arteries usually arise from the subclavian arteries and ascend through the transverse foramina of the cervical vertebrae before entering the cranial cavity (1-3).

Following its separation from the common carotid artery, the internal carotid artery ascends within the carotid sheath and enters the skull through the carotid canal. Its cervical portion normally gives no branches, whereas intracranially it contributes to several major arterial territories. The internal carotid and vertebrobasilar systems participate in formation of the circle of Willis, an arterial anastomotic network that contributes to collateral cerebral perfusion. Intracranial branches of the internal carotid artery include the ophthalmic artery and the anterior and middle cerebral arteries. These vessels supply functionally important cortical territories involved in vision, motor and sensory control, language and higher neurological functions (1-5).

The configuration of the circle of Willis is highly variable, and these anatomical variations can influence collateral capacity when a major arterial segment becomes stenotic or occluded. MRA has been used to delineate circle-of-Willis morphology and its variants noninvasively, including in South Asian populations. Studies from tertiary-care settings have demonstrated that three-dimensional MRA can depict common complete and incomplete arterial configurations and thereby provide clinically useful information about intracranial vascular anatomy without conventional catheter angiography (6,7).

Cerebrovascular disease encompasses a broad group of disorders affecting the cerebral arteries and veins and may result in ischemia, infarction, hemorrhage or other neurological impairment. Stroke is one of its most clinically important manifestations, but the spectrum also includes intracranial stenosis and occlusion, aneurysms, vascular malformations, venous disorders, vessel-wall pathology and other arterial abnormalities. Because the vascular mechanism often influences treatment selection and prognosis, accurate imaging of the cerebral circulation is central to diagnostic evaluation, therapeutic planning and follow-up (8,9).

Several imaging techniques are available for assessing the cerebral vasculature. Digital subtraction angiography (DSA) provides high spatial and temporal resolution and remains an important reference technique for selected vascular lesions, but it is invasive and involves arterial catheterization, ionizing radiation and iodinated contrast administration. Computed tomographic angiography (CTA) provides rapid high-resolution vascular imaging but also requires ionizing radiation and usually iodinated contrast. MRA offers a noninvasive alternative because vascular structures can be evaluated without ionizing radiation, and important intracranial MRA techniques can be performed without exogenous contrast material (9,10).

MRA comprises several approaches that exploit different physical properties of flowing blood. Time-of-flight (TOF) MRA is widely used for intracranial arterial imaging and produces vascular contrast primarily through inflow-related signal enhancement. Phase-contrast MRA encodes blood-flow velocity and can provide directional or quantitative flow information. Contrast-enhanced MRA shortens blood T1 after intravenous contrast administration, whereas time-resolved contrast-enhanced approaches can provide dynamic information regarding vascular filling and arteriovenous transit. Noncontrast methods based on arterial spin labeling have also been developed to improve vessel-selective and dynamic vascular depiction. The choice of MRA technique therefore depends on the clinical question, vascular territory, expected flow characteristics, patient factors and available hardware (10-13).

Three-dimensional TOF-MRA is particularly valuable for intracranial arterial assessment because it can provide high vessel-to-background contrast without intravenous contrast. Source images can be reconstructed as maximum-intensity projections or volume-rendered angiographic displays, allowing evaluation of the intracranial vascular tree from multiple perspectives. High-field systems can improve signal and vessel conspicuity, while careful review of source images remains important because

projection images may obscure or exaggerate lesions. These technical characteristics make TOF-MRA useful for both anatomical assessment and detection of focal vascular abnormalities, although interpretation must account for arterial variants and flow-related effects (6,7,10,14).

The role of MRI in cerebrovascular disease has expanded from depiction of the vascular lumen to direct assessment of vessel walls and surrounding pathology. High-resolution vessel-wall MRI can demonstrate features of intracranial atherosclerosis, arterial dissection, vasculitis, moyamoya-spectrum disease and aneurysmal wall abnormalities that may not be apparent from luminal imaging alone. Contemporary reviews emphasize that luminal MRA and vessel-wall MRI are complementary rather than interchangeable: MRA characterizes vessel patency and geometry, whereas vessel-wall techniques can provide additional information about the pathological process producing a stenosis or other arterial abnormality (15-18).

Cerebral aneurysms are another important application of intracranial MRA. Population-based MRA studies have shown that unruptured intracranial aneurysms can be detected noninvasively, and 3.0-T TOF-MRA can provide detailed morphological information for many small aneurysms when acquisition and interpretation are optimized. More recent studies comparing TOF-MRA with DSA have confirmed useful diagnostic performance for distal internal carotid artery aneurysms while also showing that very small, very large or morphologically complex lesions can be more difficult to characterize accurately. Small vascular prominences, branch points and anatomical variants may also generate false-positive appearances, so equivocal lesions require interpretation in the clinical and anatomical context (19-22).

The value of MRI and MRA extends beyond visual recognition of major vascular lesions. Advanced MR methods can evaluate cerebral perfusion and cerebrovascular reserve, thereby providing information about hemodynamic compromise in patients with steno-occlusive disease. Automated image-analysis methods are also increasingly being investigated. Deep-learning systems have been developed for cerebral aneurysm detection and for automated recognition of intracranial arterial stenosis and occlusion on MRA datasets. External validation studies indicate that artificial-intelligence tools may support readers, although performance varies according to aneurysm morphology, size, scanner characteristics and reference standard, and expert radiological assessment remains necessary (23-26).

Three-dimensional vascular segmentation is important for visualization, quantitative analysis, treatment planning and computer-assisted detection. Earlier model-based methods relied on image intensity, gradients, morphology, vesselness measures and contextual features, whereas more recent approaches combine image-driven vascular characteristics with machine-learning or deep-learning methods. Cerebrovascular segmentation studies using TOF-MRA and phase-contrast MRA demonstrate that automated or semi-automated extraction can improve representation of the vascular tree, but the reliability of segmentation is still influenced by spatial resolution, small-vessel signal, image artifacts and anatomical complexity (27,28).

The clinical usefulness of MRA must therefore be considered together with its technical limitations. TOF-MRA can be affected by slow flow, in-plane flow, saturation, turbulence, susceptibility, motion and limited spatial resolution; these effects may produce signal loss or apparent luminal narrowing and can either obscure a real lesion or create a false-positive stenotic or aneurysmal appearance. Newer approaches have attempted to address these limitations by modifying acquisition trajectories, improving spatial resolution and reducing flow-related artifacts. Evaluations of intracranial stenosis and spiral TOF-MRA show that technique-specific hemodynamic effects and artifact reduction can materially influence lesion conspicuity and diagnostic confidence (10,12,29,30).

Despite the expanding technical capabilities of MRA, local data describing the spectrum of findings among symptomatic patients remain clinically useful. Pakistan-based MRA studies have documented

anatomical variation of the circle of Willis, but there remains a need for hospital-based descriptions of the broader range of cerebrovascular findings encountered in symptomatic referral populations. Characterizing stenotic disease, aneurysms, plaque-related findings and overall cerebrovascular abnormalities can provide a clinical profile of patients referred for MRA and can identify priorities for more rigorous prospective diagnostic-accuracy studies (7,9).

The present study therefore evaluated patients undergoing MRA at Lahore General Hospital, Lahore, with the objective of characterizing cerebral vascular abnormalities identified by MRA and describing the demographic, clinical and vascular findings observed in this symptomatic population.

MATERIALS AND METHODS

A cross-sectional study was conducted at Lahore General Hospital, Lahore. The study population consisted of patients undergoing evaluation for suspected cerebrovascular abnormalities. Participants were selected using a non-probability convenience sampling technique. The required sample size was calculated using the single-population proportion formula:

$$n = Z^2 p(1-p) / d^2$$

where $Z = 1.96$ for a 95% confidence level, $p = 0.50$ and the absolute precision $d = 0.092$. These inputs produced a calculated sample size of approximately 113.47, which was rounded upward to 114 participants.

The study duration was four months following approval of the synopsis. Patients of either sex were eligible when presenting with a history that included dizziness, nausea, unusually severe headache or memory loss. Patients with claustrophobia, metallic implants or inability to cooperate with the examination were excluded.

Ethical approval was obtained from Lahore General Hospital, Lahore, and the research committee of The Superior University, Lahore. Participants were informed about the anticipated benefits and risks associated with participation before enrolment. Basic demographic and clinical information was recorded on a predesigned data-collection sheet.

Recorded variables included age, sex and relevant clinical history, including hypertension, diabetes mellitus, headache, dizziness, lipoprotein status, cholesterol status and previous ischemic-stroke history. MRA findings were recorded for mild stenosis, moderate stenosis, severe stenosis, aneurysm, calcified plaque and overall cerebrovascular disease. Mild, moderate and severe stenosis were analysed as separate binary findings and were therefore not combined to create an overall stenosis prevalence.

Data entry and the original descriptive analyses were performed using IBM SPSS Statistics version 24. Continuous age data were summarized using mean, standard deviation and range. Categorical variables were summarized as frequencies and percentages. No paired independent reference-standard results were available for the study cohort; consequently, sensitivity, specificity, predictive values and diagnostic accuracy were not calculated.

As an additional descriptive statistical enhancement, 95% confidence intervals for principal proportions were calculated using the Wilson score method (31) from the reported numerators and the total sample of 114. These calculations were performed using Python 3.13.5. No participant-level observations were reconstructed, and no adjusted association estimates were generated. Statistical reporting was limited to analyses directly supported by the available numerical data.

RESULTS

A total of 114 patients were included. Age ranged from 3 to 63 years, with a mean age of 34.37 ± 14.74 years. Females constituted 66/114 participants (57.9%; 95% CI 48.7–66.6), whereas 48/114 (42.1%; 95% CI 33.4–51.3) were male. Clinical characteristics and vascular risk-related variables were common in the study population. Hypertension was recorded in 74 patients (64.9%), diabetes mellitus in 39 (34.2%), headache in 71 (62.3%), dizziness in 58 (50.9%), abnormal lipoprotein levels in 67 (58.8%) and abnormal cholesterol levels in 64 (56.1%). These frequencies describe the characteristics of the referred sample. Patient-level cross-tabulations linking these variables to individual MRA outcomes were not available for adjusted or stratified association analysis.

Table 1. Demographic and Clinical Characteristics of the Study Population

Characteristic	Category/Statistic	n	%	95% CI
Total participants		114	100.0	-
Age, years	Mean $\pm$ SD	34.37 $\pm$ 14.74	-	-
	Range	3–63	-	-
Sex	Female	66	57.9	48.7–66.6
	Male	48	42.1	33.4–51.3
Hypertension	Present	74	64.9	55.8–73.1
	Absent/normal	40	35.1	26.9–44.2
Diabetes mellitus	Present	39	34.2	26.1–43.3
	Absent	75	65.8	56.7–73.9
Headache	Present	71	62.3	53.1–70.6
	Absent	43	37.7	29.4–46.9
Dizziness	Present	58	50.9	41.8–59.9
	Absent	56	49.1	40.1–58.2
Lipoprotein level	Abnormal	67	58.8	49.6–67.4
	Not recorded as abnormal	47	41.2	32.6–50.4
Cholesterol level	Abnormal	64	56.1	47.0–64.9
	Normal	50	43.9	35.1–53.0

Abbreviations: CI, confidence interval; SD, standard deviation. Confidence intervals for categorical proportions are Wilson 95% confidence intervals.

Table 2. Comprehensive MRA Findings in the Study Population

MRA Finding	Present n (%)	Absent n (%)	95% CI for Presence
Mild stenosis	32 (28.1)	82 (71.9)	20.6–36.9
Moderate stenosis	46 (40.4)	68 (59.6)	31.8–49.5
Severe stenosis	25 (21.9)	89 (78.1)	15.3–30.4
Aneurysm	41 (36.0)	73 (64.0)	27.7–45.1
Calcified plaque	80 (70.2)	34 (29.8)	61.2–77.8
Overall cerebrovascular disease	73 (64.0)	41 (36.0)	54.9–72.3

MRA demonstrated a substantial burden of vascular abnormalities in the referred population. Mild stenosis was recorded in 32 patients (28.1%; 95% CI 20.6–36.9), moderate stenosis in 46 (40.4%; 95% CI 31.8–49.5) and severe stenosis in 25 (21.9%; 95% CI 15.3–30.4). Because these findings were stored as

separate variables and were not established as mutually exclusive patient-level grades, they were not summed to generate an overall stenosis prevalence.

Aneurysms were recorded in 41/114 patients (36.0%; 95% CI 27.7–45.1). A finding recorded as calcified plaque was present in 80/114 patients (70.2%; 95% CI 61.2–77.8). Overall cerebrovascular disease was identified on MRA in 73/114 patients (64.0%; 95% CI 54.9–72.3), while 41/114 (36.0%) were classified as having no cerebrovascular disease.

The overall distribution demonstrates that cerebrovascular abnormalities were common among symptomatic patients referred for MRA. Nearly two-thirds were classified as having cerebrovascular disease. Plaque-related abnormalities and stenotic findings were frequently recorded, and more than one-third of participants had a recorded aneurysm. These frequencies characterize the selected symptomatic population and should not be interpreted as community prevalence estimates.

Table 3. Integrated Clinical and MRA Profile of the 114 Participants

Domain	Finding	n/N	%
Demographic	Female sex	66/114	57.9
	Male sex	48/114	42.1
Vascular/metabolic profile	Hypertension	74/114	64.9
	Diabetes mellitus	39/114	34.2
	Abnormal lipoprotein level	67/114	58.8
	Abnormal cholesterol level	64/114	56.1
Symptoms	Headache	71/114	62.3
	Dizziness	58/114	50.9
MRA stenotic findings	Mild stenosis	32/114	28.1
	Moderate stenosis	46/114	40.4
	Severe stenosis	25/114	21.9
Other MRA findings	Aneurysm	41/114	36.0
	Calcified plaque	80/114	70.2
Overall MRA classification	Cerebrovascular disease present	73/114	64.0
	Cerebrovascular disease absent	41/114	36.0

Table 3 provides a consolidated overview of the clinical and imaging burden in the study population and allows the demographic, vascular-risk, symptom and MRA domains to be reviewed together without interpreting these variables as causal associations.

DISCUSSION

The present study characterized the spectrum of cerebrovascular abnormalities recorded on MRA among 114 symptomatic patients evaluated at Lahore General Hospital. Overall cerebrovascular disease was identified in 64.0% of the sample, while stenotic abnormalities, aneurysms and plaque-related findings were also frequently recorded. The population had a substantial prevalence of vascular risk-related characteristics, including hypertension, diabetes mellitus, abnormal lipoprotein levels and abnormal cholesterol levels. These observations describe the clinical and imaging profile of a symptomatic referral population but do not establish causal relationships between individual risk factors and specific MRA abnormalities because comparative patient-level association analyses were not available.

MRA is well suited to noninvasive evaluation of the intracranial vascular system because it can depict arterial anatomy without the ionizing radiation required for CTA or catheter angiography. Depending on the technique, MRA can also be performed without intravenous contrast material. TOF-MRA remains a

widely used intracranial vascular technique, whereas phase-contrast, contrast-enhanced and arterial-spin-labeling approaches provide complementary information about vascular morphology, blood flow, temporal filling and vessel selectivity (9-13). This flexibility is clinically important because different cerebrovascular disorders impose different demands on spatial resolution, flow sensitivity and temporal characterization.

The current study recorded mild stenosis in 28.1%, moderate stenosis in 40.4% and severe stenosis in 21.9% of participants. These three variables were recorded separately, so they cannot be assumed to represent mutually exclusive severity categories in individual patients. Nevertheless, the frequency of stenotic findings indicates that intracranial luminal narrowing represented an important component of the abnormalities encountered in this symptomatic population. TOF-MRA is widely used for evaluating intracranial stenosis, but stenosis estimates can be affected by hemodynamic signal loss, slow or complex flow and technical acquisition factors; high-resolution MRI and alternative angiographic sequences may improve characterization when luminal narrowing is uncertain (29,32).

Qiu et al. evaluated automated detection of intracranial arterial stenosis and occlusion using MRA and reported 411 vascular lesions across 200 examinations, including 242 moderate stenoses, 84 severe stenoses and 70 occlusions (25). Although their work was methodologically different from the present descriptive clinical study, it illustrates the heterogeneity of stenotic and occlusive abnormalities encountered in MRA datasets and the increasing interest in computer-assisted identification. Automated tools may eventually improve consistency in lesion detection, but their performance must be interpreted against expert review and an appropriate reference standard (25,26).

Aneurysms were recorded in 36.0% of participants in the present study. This proportion is much higher than estimates from unselected or population-screening cohorts and should therefore be understood in the context of a symptomatic hospital-referred sample rather than as population prevalence. MRA screening studies have demonstrated that unruptured aneurysms can be detected noninvasively, and 3.0-T TOF-MRA has shown useful accuracy for small aneurysms when acquisition and interpretation are optimized (19,20). More recent DSA-comparison work has further shown that TOF-MRA can depict distal internal carotid artery aneurysm morphology with high accuracy, although extreme size and complex lobulation can reduce morphological reliability (21). Ultra-high-resolution TOF-MRA may further improve depiction of small aneurysms, irregularities and vessels at the aneurysm neck compared with conventional TOF acquisitions (33).

The clinical interpretation of suspected aneurysms requires awareness of false-positive and false-negative appearances. Cho et al. evaluated patients referred after suspected aneurysmal lesions were identified on MRA or CTA and emphasized that screening examinations may produce false-positive diagnoses, particularly for small vascular prominences and variants near branch points (22). External validation of automated aneurysm detection similarly shows that performance depends on aneurysm size and morphology and that flow-related artifacts and vascular bifurcations can generate false-positive candidates (26). These observations are particularly relevant when interpreting the comparatively high aneurysm frequency in the present study and support careful review of source images and further vascular assessment when treatment decisions depend on an equivocal finding.

The study also recorded a high frequency of a variable labelled calcified plaque, affecting 70.2% of participants. Intracranial plaque is clinically important because atherosclerotic disease can narrow the vascular lumen, alter local hemodynamics and contribute to ischemic cerebrovascular events. High-resolution vessel-wall MRI provides information beyond the angiographic lumen and can characterize plaque distribution, wall thickening, enhancement and other arterial-wall features that may help distinguish atherosclerotic from non-atherosclerotic arteriopathies (15-18,34). Systematic review evidence also supports the potential value of vessel-wall MRI markers in symptomatic middle cerebral

artery atherosclerosis, although heterogeneity of acquisition and interpretation remains an important consideration (35).

Ma et al. used high-resolution MRI to investigate middle cerebral artery atherosclerotic plaques among patients with acute cerebral infarction and demonstrated differences in plaque characteristics between patients with single and multiple infarcts (36). Their study illustrates the added pathophysiological information obtainable from vessel-wall techniques beyond simple luminal stenosis. The present investigation did not include a comparable vessel-wall analysis; therefore, the plaque-related frequency reported here should be interpreted as a descriptive imaging variable rather than as a detailed assessment of plaque composition, vulnerability or mechanism.

Hypertension was present in 64.9% of participants, abnormal lipoprotein levels in 58.8%, abnormal cholesterol in 56.1% and diabetes mellitus in 34.2%. These factors are clinically relevant because hypertension, diabetes and dyslipidemia are established contributors to atherosclerotic and cerebrovascular risk (8). However, frequency within a selected sample is not equivalent to an association with disease. The present data do not provide cross-tabulations or multivariable models comparing these characteristics between participants with and without MRA-detected cerebrovascular disease; consequently, no independent risk estimate or predictive relationship can be inferred from these proportions.

This distinction corrects an important interpretative problem in simple frequency-based analyses. A lower percentage of participants with diabetes than without diabetes does not imply that cerebrovascular disease protects against diabetes, just as a high prevalence of hypertension or headache within a symptomatic referral group does not independently establish an etiological association. Valid association testing requires comparison across outcome groups and, when relevant, adjustment for confounding variables such as age, sex and coexisting vascular risk factors (8).

Headache was reported by 62.3% of participants and dizziness by 50.9%. These symptoms are clinically nonspecific and occur across a wide range of neurological and non-neurological conditions, but they can contribute to the presentation that prompts neurovascular imaging. The inclusion criteria also identified nausea, unusually severe headache and memory loss as reasons for evaluation. Their frequency reinforces that this was a clinically selected symptomatic population, which is important when interpreting the relatively high rates of MRA abnormalities and when avoiding extrapolation of these findings to asymptomatic or community populations (8,9).

Overall cerebrovascular disease was recorded in 73 of 114 participants, corresponding to 64.0% of the sample. This high proportion is consistent with a symptomatic hospital referral setting and indicates that MRA yielded vascular abnormalities in a substantial proportion of the examinations. It should be described as diagnostic yield within the studied population rather than diagnostic accuracy. Diagnostic accuracy requires paired comparison against an independent reference standard in the same participants, whereas diagnostic yield simply describes how often the imaging examination identifies an abnormality.

The distinction between yield and accuracy is especially important for MRA because the modality is commonly evaluated against CTA or DSA when sensitivity, specificity or lesion-grading agreement is the research objective. DSA-comparison studies of aneurysms and high-resolution MRI-comparison studies of stenosis demonstrate how paired reference-standard data permit evaluation of lesion detection, measurement agreement and misclassification (20,21,32,33). Because equivalent paired reference-standard results were not available for the present cohort, the findings support conclusions about the spectrum and frequency of detected abnormalities but not about how often MRA correctly identified or excluded those abnormalities.

Modern MRA techniques continue to evolve. Zero-echo-time MRA has been investigated for cerebrovascular characterization, while spiral TOF-MRA has shown improvements in vessel conspicuity, artifact reduction and false-positive suppression compared with conventional Cartesian TOF in selected patients (30,37). Deep-learning tools have been developed for automated aneurysm detection and stenosis recognition, and more recent clinical evaluations suggest that combining artificial-intelligence output with neuroradiologist interpretation may improve detection reliability or reduce reading time in selected workflows (24-26,38). These technologies remain adjunctive, and their clinical value depends on external validation, image quality, scanner characteristics and appropriate human oversight.

MRA can also provide information beyond static arterial morphology. Resting-state MRI approaches have been used to assess cerebrovascular reserve, while dynamic contrast-enhanced and arterial-spin-labeling MRA techniques can provide temporal and hemodynamic information that conventional static angiographic projections do not capture (11-13,23). More recent work with silent MRA and other noncontrast techniques suggests that alternative acquisition strategies may improve visualization of selected aneurysm or vascular features, although performance varies by lesion type and technical implementation (39). This continuing development supports the view that MRA should be considered a family of complementary vascular imaging techniques rather than a single uniform examination.

The present study has several strengths. It evaluated a complete sample of 114 symptomatic patients, documented a broad range of demographic and clinical characteristics and reported several important cerebrovascular findings. It also provides locally generated data from Lahore, where hospital-based descriptions of MRA findings may contribute to understanding referral patterns and the types of abnormalities encountered in routine neurovascular imaging. In addition, the present revision separates descriptive frequencies from unsupported causal or diagnostic-accuracy interpretations and adds confidence intervals to principal proportions without reconstructing participant-level data.

Several limitations must be considered. The study used convenience sampling at a single hospital, limiting generalizability. The original grouped-age table was internally inconsistent, although the continuous age summary was complete. Detailed MRA acquisition parameters, scanner field strength and lesion-definition thresholds were not available in the study materials. The stenosis categories could not be confirmed as mutually exclusive, and the imaging basis for the calcified-plaque variable was not defined. The study also lacked a complete independent paired reference-standard dataset, preventing calculation of sensitivity, specificity, predictive values or comparative diagnostic accuracy. Finally, no multivariable analysis was available to evaluate whether hypertension, diabetes, lipid abnormalities or other patient characteristics were independently associated with the MRA findings.

Future studies should prospectively specify scanner field strength, MRA sequence, spatial resolution, contrast use, post-processing approach and lesion-definition criteria. Stenosis grading should be standardized and linked to clearly defined arterial segments, while aneurysm analysis should record location, maximum size, neck dimensions and morphology. When diagnostic accuracy is the research question, MRA should be compared with an appropriate paired reference standard, and reader blinding and interobserver agreement should be reported. Emerging high-resolution, spiral, silent and vessel-wall techniques may improve characterization of selected lesions, but prospective comparative studies are required to establish where they add clinically meaningful information beyond conventional TOF-MRA (29,30,32,33,35,39).

CONCLUSION

MRA identified a broad spectrum of cerebrovascular abnormalities among symptomatic patients evaluated at Lahore General Hospital. Overall cerebrovascular disease was recorded in 64.0% of the 114

participants, with mild, moderate and severe stenotic findings, aneurysms and plaque-related abnormalities represented within the study population.

The findings demonstrate the clinical contribution of MRA to noninvasive visualization and characterization of cerebral vascular abnormalities in a symptomatic hospital population. They do not establish sensitivity, specificity or comparative diagnostic accuracy because an independent paired reference-standard dataset was not available. Future diagnostic studies should incorporate standardized MRA protocols, explicit lesion definitions and direct comparison with an appropriate reference standard.

RECOMMENDATIONS

MRA protocols used for cerebrovascular assessment should be standardized according to the clinical indication, available MR equipment and institutional neuroradiology practice. Reports should clearly identify the vascular territory, lesion location, degree of stenosis, presence and dimensions of aneurysms and relevant anatomical variants. Review of source images alongside angiographic reconstructions is important because flow-related and projection artifacts may influence lesion appearance (10,29,30).

When an MRA abnormality is equivocal or when treatment decisions require greater anatomical certainty, additional vascular imaging should be selected according to clinical need and specialist assessment. Future research evaluating diagnostic performance should include an explicit reference standard and paired patient-level results so that sensitivity, specificity, predictive values, likelihood ratios and measurement agreement can be calculated validly (20,21,32,33). Prospective studies should also document scanner field strength, MRA sequence, contrast use, spatial resolution, stenosis-grading criteria, reader experience and blinding procedures where applicable. Advanced TOF, silent MRA and vessel-wall techniques should be evaluated against conventional imaging using reproducible lesion definitions and clinically relevant outcomes rather than technical image quality alone (15-18,30,35,39).

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