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Appearance of acute Ischemic stroke on different sequences of MRI

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Ischemic stroke is one of the dominant causes of mortality, affecting millions of people per year. Ischemic stroke is caused by obstruction of an artery supplying blood to the brain, causing necrosis within minutes. MRI remains the most available and reliable modality in the detection of acute ischemic stroke. To determine the appearance of acute ischemic stroke on different sequences of MR. This descriptive study was conducted at the Department of Radiology, Medcare International Hospital, Gujranwala. A total of 100 patients suffering from acute ischemic stroke, with clinical onset within 7 days, were included in this study. SPSS version 22.0 was used for the analysis of data. All the patients included in this study were having a mean ±std age of 59.12 ±15.107 ranging from 19 to 90years, out of which (61)61.0% were male and (39)39.0% female. (61)61% of the acute ischemic lesion were not visible on the T1 weighted image. T2 and FLAIR showed (97)97% hyperintense lesions and (3)3% hypointense. DWI showed (98)98% of the hyperintense lesions and (2)2% were hypointense. ADC showed (95)95% hyperintense, (2)2% hyperintense, and (1)1% isointense. The ischemic territories were located in the frontal lobe (49)49%, temporal lobe (32)32%, occipital lobe (33)33%, parietal lobe (34)34%, and (8)8% in the midbrain. Acute ischemic stroke appears hyperintense on T2, FLAIR, and DWI sequences, while hypointense on T1 and ADC sequences. DWI sequence showed to have a higher ability in diagnosing acute ischemic lesions after FLAIR.

Keywords: acute ischemic stroke, MRI, T1 weighted, T2 weighted, FLAIR, DWI, ADC

INTRODUCTION

Stroke is the dominant root of disability and mortality globally. It is also reported to be the main cause of dementia and depression (Phipps and Cronin, 2020). More than 80 million people suffered from stroke worldwide, out of which 70% were ischemic stroke (Lindsay et al. 2019). The estimated incidence rate of stroke is reported to be higher in older women; > 50% as compared to older men (75 years or older) (GBD 2016 Stroke Collaborators, 2019).

The brain requires an uninterrupted blood supply for its functioning and to work normally the brain relies on its blood supply. Ischemic stroke is caused by an obstruction of an artery supplying blood to the brain (Hinkle and Guanci, 2007). The arterial occlusion reduces the blood supply, depriving a segment of brain of its oxygen, nutrition, and glucose, causing damage to the brain tissue. Necrosis eventuates within minutes in regions with critically decreased blood supply, and the tissue undergoes irreversible damage in the **core** of the ischemic territory. While, cell death in the peripheral area, which was supported by collateral circulation, occurs relatively slowly in the **penumbra**. Without treatment, the penumbra can progress to infarction with time (Dirnagl et al. 1999). According to the TOAST criteria, the most common etiologies for acute ischemic stroke are Atherosclerosis (30-40%); a large vessel disease, Cardioembolic (25%); atrial fibrillation, arteriolosclerosis (20%); small vessel disease. Other less common etiologies of stroke are arterial dissection, hypotension, and hypercoagulable (Silverman and Rymer, 2009).

An ischemic stroke usually presents with rapid onset of neurological deficit, determined by the location of arterial occlusion and the extent of collateral flow. Typical clinical presentation of stroke includes severe headache, one-sided/full body weakness, sudden numbness, confusion, troubled speech, blurred vision, or altered consciousness (Hinkle and Guanci, 2007). There are many other pathologies in the brain that can mimic/ caricature stroke. This includes hemorrhage, hyperglycemia/hypoglycemia, seizures, brain tumor, hypertensive encephalopathy, and migraine (Brott and Bogousslavsky, 2000). Diagnostic imaging covering the major arterial and venous branches from the aortic arch to the base of the brain, is

recommended to confirm stroke, its site, and extent.

The routinely used modalities for the diagnosis and management of acute cerebral ischemia are CT and MRI brain. These modalities are useful in confirming the presence of ischemic stroke and characterizing tissue perfusion i.e. the distinguishing of the ischemic core from reversible ischemic tissue in danger. And lumen imaging is conducted in the evaluation of stroke sources (Kilburg et al. 2017). Initially, a CT scan may be recommended to confirm the presence of stroke or exclude the suspicion of hemorrhage or other pathologies that maybe mimic stroke-like symptoms.

The sensitivity of CT in acute ischemic stroke ranges from 12-95% with a specificity of 56-100% for detecting hyperacute ischemic stroke, which depends upon the imaging features, the onset of symptoms, ischemic territory, study population, and other variables, with an overall estimation of 40-60% for 6-hour window. While the sensitivity of DWI sequence of MRI is 73-92% within the first 3 hours and approximately 100% for the 6-hour window (Schellinger et al. 2010). The detection of early acute ischemic stroke of DWI sequence of MRI is superior to non-contrast CT scan with a sensitivity of approximately 100% in the first 6 hours after clinical onset. MRI imaging protocols for acute ischemic stroke usually include T1 weighted imaging, T2 weighted imaging, FLAIR, DWI, and ADC sequences. T1 weighted images are constructed by short TE and TR, important for anatomy, and T2 weighted images are constructed by long TE and TR, important for pathology. FLAIR sequence similar to a T2 weighted image with further extended TE and TR can illustrate hyperintense signals after 6 hours from the clinical onset. T1 weighted images show acute ischemic lesions as hypointense signals which usually appear 16 hours after the clinical onset of symptoms. Acute ischemic lesions usually appear as hyperintense signals on the T2 weighted images that are generally seen after 8 hours after the clinical onset. Positive FLAIR lesions are identified as hyperintense signals within the 6 hours after the onset of symptoms (Allen et al. 2012). As diffusion-weighted imaging can detect slight changes in water diffusion that usually occur in the ischemic territory, the DWI sequence can detect acute ischemic stroke as early as 30 minutes after the clinical aggression. While ADC maps may illustrate hypointense signals with even more sensitivity and less onset duration than the diffusion-weighted images (Schellinger et al. 2010).

This study will help in the early detection of acute ischemic stroke by acquiring a single sequence using 0.35T.

MATERIALS AND METHODS

This descriptive study was conducted at the Department of Radiology, Medcare International Hospital, Gujranwala. The calculated sample size with a 95% significance level and 5% margin of error is 100. A total of 100 consecutive patients suffering from acute ischemic stroke with a study duration of 4 months were included in this study. The inclusion criteria were patients of acute ischemic stroke with clinical onset within 7 days without any gender specificity. The exclusion criteria of this study were: (1) patients scanned beyond 1 week from the onset of symptoms, (2) patients contraindicated for MRI scanning (3) MRI scans with severe motion/metal artifact. All the MRI brain scans were performed by a 0.35T open MRI machine (Siemens Magnetom C) with 4 channel phased array. The procedure included MRI stroke protocol (T1 weighted coronal, T2 weighted axial & sagittal, T2 FLAIR axial, DWI, and ADC axial). Written informed consent was taken from the patients or an attendant. The patient's identification and details were not published. Microsoft Excel and SPSS version 22.0 was used to record and analyze the data.

RESULTS

Table 1: shows the variation among the signs and symptoms of patients and their age and gender distribution

Variables	Category	Frequency (%)
Age group	N Range Mean Std. deviation	100 71 59.12 15.108
Gender	Female male	39(39.0%) 61 (61.0%)
Weakness	Left Right No	47(47.0%) 39(39.0%) 14 (14.0%)
Headache	Yes No	67(67.0%) 33 (33.0%)
Diabetes Mellitus	Yes No	30(30.0%) 70 (70.0%)
Hypertension	Yes No	45(45.0%) 55 (55.0%)
Vertigo	Yes No	66(66.0%) 34 (34.0%)
Nausea	Yes No	14(14.0%) 86 (86.0%)
Vomiting	Yes No	17(17.0%) 83 (83.0%)
Speech difficulty	Yes No	51(51.0%) 49 (49.0%)
Blurred Vision	Yes No	38(38.0%) 62 (62.0%)
Altered Mental state	Yes No	44(44.0%) 56 (56.0%)

Table 2: shows the appearance of AIS on different sequences of MRI.

Variables	Category	Frequency (%)
T1	Heterogenous Hypointense Isointense No	1 (1.0%) 23 (23.0%) 15 (15.0%) 61 (61.0%)
T2	Hyperintense Hypointense	97 (97.0%) 3 (3.0%)
FLAIR	Hyperintense Hypointense	97 (97.0%) 3 (3.0%)
DWI	Hyperintense Hypointense Isointense	98 (98.0%) 1 (1.0%) 1 (1.0%)
ADC	Hyperintense Hypointense Isointense No	2 (2.0%) 95 (95.0%) 1 (1.0%) 2 (2.0%)

Table 3: shows the distribution of ischemic lesions in the brain concerning lobes

Variables	Category	Frequency
Frontal Lobes	left right bilateral No	21 (21.0%) 23 (23.0%) 5 (5.0%) 51 (51.0%)
Temporal Lobe	left right bilateral No	18 (18.0%) 12 (12.0%) 2 (2.0%) 68 (68.0%)
Occipital lobe	left right bilateral No	15 (15%) 14 (14.0%) 4 (4.0%) 67 (67.0%)
Parietal Lobe	left right bilateral No	20 (20.0%) 11 (11.0%) 3 (3.0%) 66 (66.0%)
Midbrain	left right bilateral No	4 (4.0%) 3 (3.0%) 1 (1.0%) 92 (92.0%)

The mean ±std age of included patients was 59.12 (±15.107), ranging from 19 to 90. There were (61)61.0% males and (39)39.0% females in the data. (47)47% had a left-sided weakness, (39)39% had a right-sided weakness, and (14)14% of patients showed no weakness at all. (67)67% of patients had headaches, (30)30% of patients had diabetes mellitus, (45)45% of patients had hypertension, (66)66% of patients had vertigo, (14)14% of patients had nausea, (17)17% patients had vomiting, (51)51% patients had speech difficulty, (38)38% patients had blurred vision, (44)44% patients had altered mental state. On the T1 sequence, 61 out of 100 AIS were not visible, (1)1% were heterogeneous, (23)23% were hypointense, and (15)15% were isointense. While T2 and FLAIR showed (97)97% hyperintense and (3)3% hypointense. Out of 100 patients, 98(98%) were hyperintense and 1(1%) was hypointense and isointense respectively for DWI. ADC showed (95)95% hypointense, (2)2% hyperintense, (1)1% isointense, and (2)2% were normal. The ischemic territory is located in the frontal lobe (49)49%, temporal lobe (32)32%, occipital lobe (33)33%, parietal lobe (34)34%, and (8)8% in the midbrain.

DISCUSSION

Acute ischemic stroke is the second leading cause of death in the human population, due to a lack of blood supply to the brain cells. Patients typically present with headaches, body weakness, vertigo, and/or altered mental state. MRI scans are used to confirm the site and extent of ischemia.

In our study of 100 cases, there were 61% male and 39% female patients with ages ranging from 19 years to 90 years. On MRI T1 sequence, 61 out of 100 AIS were not visible, 1% were heterogenous, 23% were hypointense, and 15% were isointense. While T2 and FLAIR showed 97% hyperintense and 3% hypointense. Out of 100 patients, 98 were hyperintense and 1 was hypointense and isointense respectively for DWI. ADC showed 95% hypointense, 2% hyperintense, 1% isointense, and 2% were normal. The ischemic territory is located in the frontal lobe 49%, temporal lobe 32%, occipital lobe 33%, parietal lobe 34%, and 8% in the midbrain.

Kambiz Nael et al. 2014 conducted a study implementing a 6-minute MR protocol to assess acute ischemic stroke. A total of 62 patients were included in this study, out of which 37 were male and 25 were female with the mean age of 69.8 ranging from 36 to 94 years. Out of 62, 59 (95%) patients showed DWI-positive lesions, and 43 (73%) patients showed hyperintense FLAIR lesions.(Nael et al. 2014) *Simonsen et al* 2015 conducted a study which included 569 patients of which 62% were male and 38% were female with the age ranging from 56years to 75years. Out of the 565 patients, the frequency of hypertensive patients was 54.7%, 16.6% were posterior circulatory stroke, 83% anterior circulation. DWI lesion was identified in 518 (92%) out of 565 patients, hence the DWI sensitivity and specificity were determined to be 92% and 75% for diagnosing ischemic lesion.(Simonsen et al. 2015) *Lansberg et al* 2000 demonstrated the advantages of adding DWI to a conventional MRI protocol for evaluating of acute ischemic stroke. 49 patients with a mean age of 71 ± 13 years were included in this study. 46 (94%) out of 49 patients, acute ischemic lesion was correctly identified on DWI/ADC sequence, which is slightly higher than the percentage of FLAIR which is 39 (80%) of 49 patients. 34 (71%) out of 48 patients showed acute ischemic lesion on the T2w sequence. There was a

slight difference between the percentages of FLAIR and the T2w sequence. Adding DWI /ADC sequence increases the clinical detection of acute ischemic lesions on MRI.(Lansberg et al. 2000) In another case study conducted by *Thomalla et al* 2011, there were 543 total patients, out of which 251(46%) were female and 292(54%) were male, with ages ranging from 64.7 years to 67.3 years (mean age 66 years). Out of 543, 516(95%) patients showed acute ischemic stroke on DWI sequence of MRI, and 271 (50%) patients showed Acute ischemic stroke on FLAIR. 26(4.0%) cases were of poor quality on DWI sequence, 29(5%) cases on FLAIR sequence, and 7 cases (1%) on both DWI and FLAIR.(Thomalla et al. 2011) In another study conducted by *Mejdoubi M. et al* 2017, 596 patients were included. In this study, 295 males and 239 females were included. 488 had a single-type lesion. 14.8% of the lesions were cortical-subcortical, 14.5% subcortical, 16.6% lacunar. The lesion also involved anterior cerebral 4%, middle cerebral 63.7%, posterior cerebral artery 10.4% with 10.3% simultaneously involving multiple territories, and 4.9% junctional infarction. Etiologies were LAA 11.2%, SVD 10.7%, CE 29.6%, rare 4.5% or undetermined 44.1%. Through this study, we came to know that multiple territory strokes are more recurrent in the MRI population (Mejdoubi et al. 2017). A review study conducted by *Schellinger PD et al* 2017 included articles on the diagnostic and prognostic value of DWI and PWI from 1966 to January 2008. Through this study, we came to know DWI is more useful and should be considered comparing non-contrast CT scans for diagnosis of acute ischemic stroke within 12 hours of symptom onset. On basis of Class II and III evidence, baseline DWI volumes probably predict stroke severity in anterior territory stroke but not in vertebrobasilar artery territory stroke. It also measures infarct volumes along with clinical outcomes. Baseline PWI volumes predict a lesser degree of stroke.(Schellinger et al. 2010)

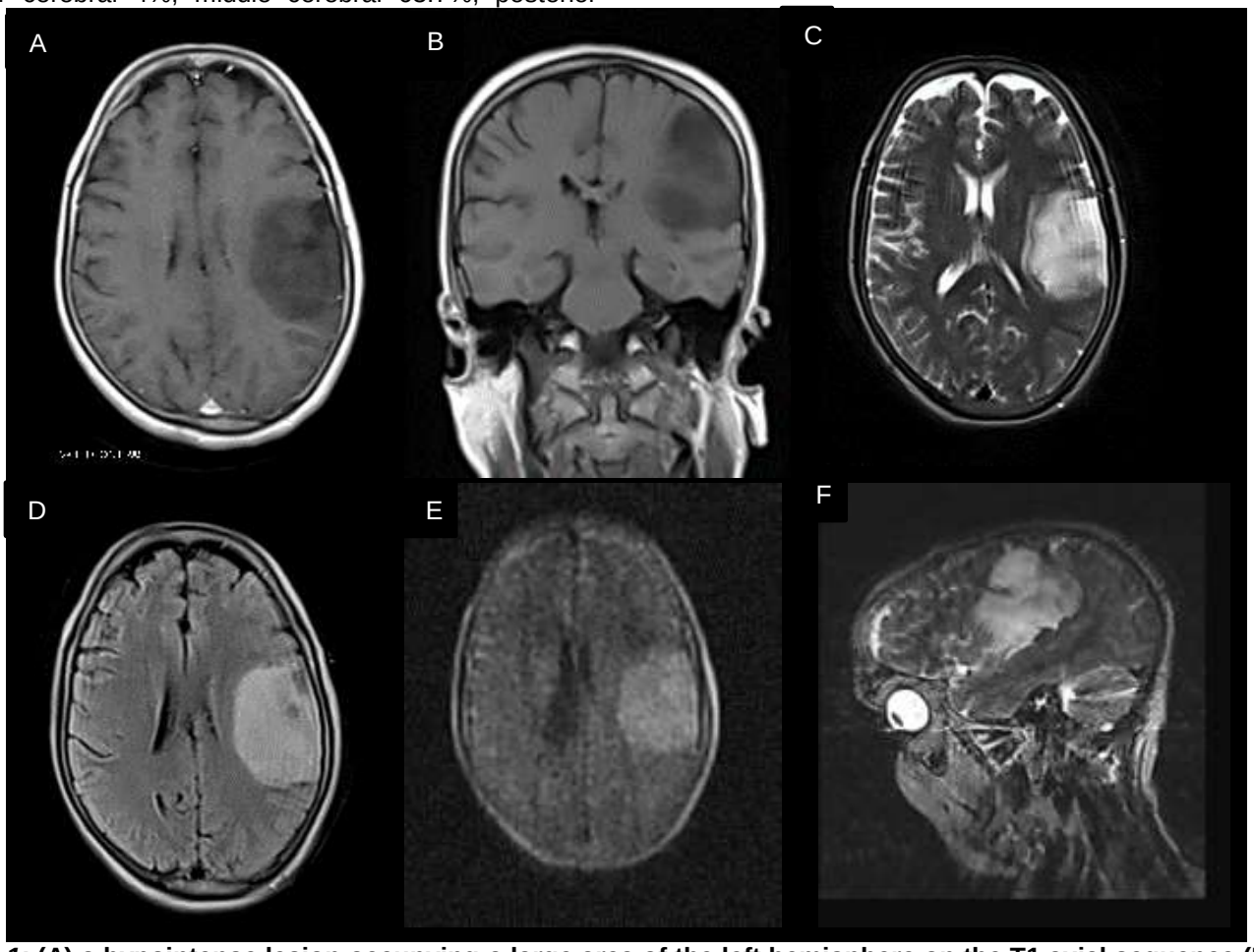

Figure 1: **(A) a hypointense lesion occupying a large area of the left hemisphere on the T1 axial sequence (B) this coronal image of MRI shows a hypointense (dark) lesion in the left side of the brain in the temporal lobe on T1 sequence of MRI. (C) this axial image shows a hyperintense lesion on T2 sequence of MRI (on the left side of brain in the temporal lobe) (D) this axial image of MRI shows a hyperintense (bright) lesion in the left side of the brain in the temporal lobe on FLAIR sequence of MRI (E) this axial image shows a hyperintense lesion on DWI sequence of MRI (temporal lobe) (F) this sagittal image shows a hyperintense lesion on DWI sequence of MRI**

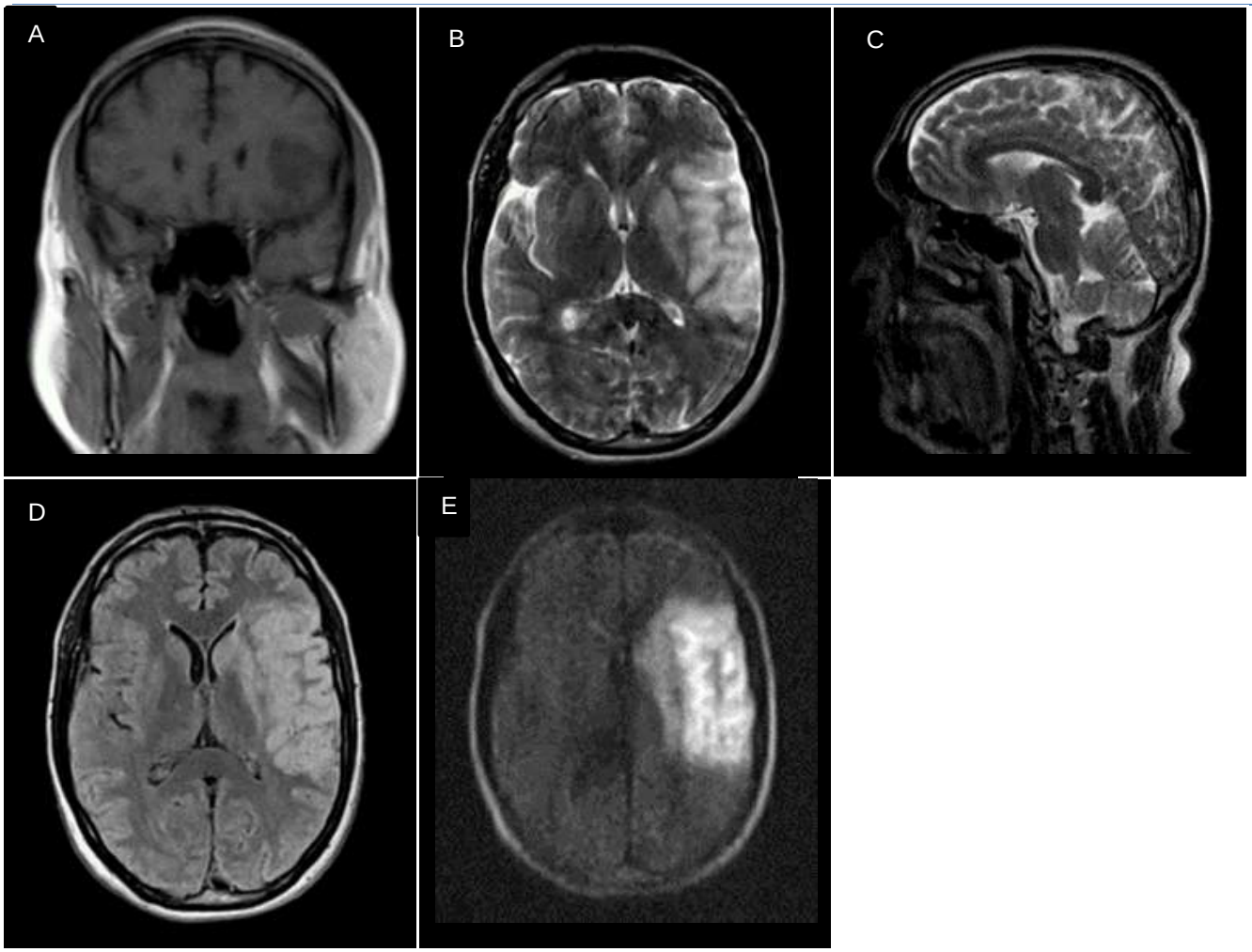

Figure 1: (A) this coronal image of MRI shows a hypointense (dark) lesion in the temporal lobe of the brain, on T1 sequence of MRI. (B) this axial image shows a hyperintense lesion on T2 sequence of MRI (in the temporal lobe) (C) this sagittal image shows a hyperintense (bright) lesion on T2 sequence of MRI (temporal lobe) (D) this axial image of MRI shows a hyperintense (bright) lesion in the temporal lobe on FLAIR sequence of MRI. (E) this axial image of MRI shows a hyperintense lesion in the temporal lobe of brain on DWI sequence of MRI.

CONCLUSION

Acute ischemic stroke appears hyperintense on T2, FLAIR, and DWI sequences, while hypointense on T1 and ADC sequences. DWI sequence showed to have a higher ability in detecting acute ischemic lesion after FLAIR. Most of the ischemic lesions were located in the frontal lobe and were more frequent on the left side. The affected region of the brain may determine the clinical symptoms of the patient.

CONFLICT OF INTEREST

The authors declared that the present study was performed in the absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

HN drafted, wrote, and edited the manuscript, along with the literature search. MN and ZA supervised and reviewed the manuscript. SMYF performed the statistical analysis and reviewed the manuscript. ZJ, HM, and SA performed the formal analysis, technical support, and literature search. QN and FM conceptualized the project and collected the data. All authors read and approved the final version.

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