The Accuracy Level of Transcranial Color Doppler Compared with Magnetic Resonance Angiography in Stroke Infarction

Rachmi Fauziah Rahayu[1], Widiana Feriastuti[2], and Yuyun Yueniwati[3](✉)

[1] Faculty of Medicine, Sebelas Maret University, dr Moewardi Hospital Solo, Surabaya, Indonesia
[2] Faculty of Medicine, Airlangga University, dr Soetomo Hospital Surabaya, Surabaya, Indonesia
[3] Faculty of Medicine, Brawijaya University, dr Saiful Anwar Hospital Malang, Malang, Indonesia
yuyun@ub.ac.id

Abstract. Stroke is a functional disorder affecting of both focal and global part of brain that causes clinical disorders which develops rapidly, more than 24 h or initiate sudden death with no other cause than brain blood vessel disorders. The number of stroke patients in Indonesia based on the diagnosis of health workers was estimated 1,236,825 people (7.0%), while based on symptoms were estimated at 2,137,941 people (12.1%). In this current study, the authors aim to understand the sensitivity and specificity of TCD compared to MRA in the cases of infarction on ACA (Anterior Cerebral Artery), MCA (Middle Cerebral Artery), dan PCA (Posterior Cerebral Artery). This quantitative analytic observational study was conducted with cross sectional approach on the population of 30 patients with infarction stroke, treated in Neurology ward Moewardi Hospital. The sensitivity of TCD to detect stenosis on ACA was 100%, specificity 98The sensitivity of TCD to detect stenosis on MCA was 50%, specificity 94%. The sensitivity of TCD to detect stenosis on PCA was infinity, specificity 100%, positive predictive value infinity, negative predictive value 96,5%. MRA is more sensitive compared to TCD to detect stenosis on MCA, while TCD is more sensitive for examining of both ACA and PCA.

Keywords: MRA · TCD · ACA · MCA · PCA

1 Introduction

Stroke is a functional disorder affecting of both focal and global part of brain that causes clinical disorders (1). The number of stroke patients in Indonesia in 2013 based on the diagnosis of health workers was estimated 1,236,825 people (7.0‰), while based on symptoms were estimated at 2,137,941 people (12.1 ‰) (2). The anterior circulation stroke accounts for 75–80% of all strokes cases which can be easily recognized (3).

The use of TCD (Transcranial Doppler) ultrasound is intended to detect the presence of acute intracranial artery stenosis. This technique as a whole has a specificity of 94%

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and sensitivity of 79% compared to MRA which has a specificity of 88.8% and sensitivity of 82% based on previous research (4). Farahmand et al. suggested that the high sensitivity of the MRA approximates DSA sensitivity in diagnosing a brain vascular abnormality such as intracranial aneurysm, and others.

With the increased availability of MRA, the use of TCD that aims to identify vessel occlusion proximal is comparable to the use of MRA(5).

The purpose of this study was to understand the comparison of sensitivity and specificity between TCD and MRA in cases of infarction stroke affecting ACA, MCA, and PCA.

Conceptual framework

2 Methods

This research is an observational quantitative analytic study with a cross sectional approach. It was conducted at Moewardi Hospital Surakarta from August 2018 - February 2019. The study population are infarction stroke patients who were treated in the Neurology ward of Moewardi Hospital Surakarta during August 2018- February 2019.

The sample size uses the rule of thumb, where the minimum sample size is 30 patients. In this study the sample size was all patients retrieved during the research process. This study utilized randomize purposive sampling techniques of patients who were treated with infraction stroke in Neurology ward Moewardi Hospital Surakarta. The inclusion criteria: stroke patients (both thrombosis and embolism) demonstrated from the plain head CT scan involving the cerebral region vascularized by MCA, ACA and PCA, male and female age $\geq$ 40 years, blood pressure $\leq$ 140/90, blood glucose $\leq$ 200 mg/dl, the LDL-C lipid profile $<$ 100 mg/dl, the leukocyte level $<$ 20,000, and willing to participate in this study.

The exclusion criteria are infarction stroke demonstrated by plain CT Scan, involving cerebral region vascularized by vessels other than MCA, ACA and PCA, head trauma, stroke with neurological improvement less than 24 h, intracerebral haemorrhage, sincope, brain tumor and infection, history of congenital heart disease.

Independent variable are TCD results and MRA results. Meanwhile, dependent variable are infarction sroke involving MCA, ACA and PCA.

3 Result

The study was conducted on 30 patients, who fulfilled the inclusion and exclusion criteria, obtained with age range of 30–39 years as many as 2 people (7%), 40–49 of 5 people (14%), 50–59 of 7 people (24%), 60–69 of 10 people (34%), 70–79 of 5 people (17%), 80–89 of 1 person (4%) (Table 3) and a number of 19 male (64%) and 11 female (36%) (Table 4) (Tables 1 and 2).

3.1 Data Analysis

Agreement testing between observers of MRA are conducted by 2 radiologists with over 5 years of experience, using Kappa Test with following results:

Table 1. Statistical Results for MRA Examination on right ACA

MRA1 * MRA2 Crosstabulation

			MRA2	
			Tidak	Total
MRA1	Stenosis	Count	1	1
		% of Total	3.3%	3.3%
	Tidak	Count	29	29
		% of Total	96.7%	96.7%
Total		Count	30	30
		% of Total	100.0%	100.0%

Symmetric Measures

		Value
Measure of Agreement	Kappa	.[a]
N of Valid Cases		30

a. No statistics are computed because MRA2 is a constant.

Table 2. Statistical Results for MRA Examination on left ACA

MRA1 * MRA2 Crosstabulation

			MRA2		
			Stenosis	Tidak	Total
MRA1	Stenosis	Count	2	0	2
		% of Total	6.7%	.0%	6.7%
	Tidak	Count	0	28	28
		% of Total	.0%	93.3%	93.3%
Total		Count	2	28	30
		% of Total	6.7%	93.3%	100.0%

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	1.000	.000	5.477	.000
N of Valid Cases		30			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

3.2 Sensitivity and Specificity Test of TCD Compared to MRA on ACA, MCA and PCA Using a 2 × 2 Table

4 Discussion

4.1 Sample Distribution Based on Age and Gender

The study involved 30 patients who met the inclusion and exclusion criteria the highest number of participants were within 60- 69 age group (10 patients (34%)) and the lowest within 80–89 years age group (1 patient (4%)) shown in (Table 3), withmore number of male than female (19 patients (64%) vs 11 people (36%)) shown in (Table 4).

4.2 Data Analysis

MRA examination on right ACA performed by two radiologists are shown in Table 5.

Table 3. Statistical results for examining MRAs on right MCA

MRA1 * MRA2 Crosstabulation

			MRA2		
			Stenosis	Tidak	Total
MRA1	Stenosis	Count	11	0	11
		% of Total	36.7%	.0%	36.7%
	Tidak	Count	11	8	19
		% of Total	36.7%	26.7%	63.3%
Total		Count	22	8	30
		% of Total	73.3%	26.7%	100.0%

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.348	.119	2.513	.012
N of Valid Cases		30			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table 4. Statistical Results for MRA Examination on left MCA

MRA1 * MRA2 Crosstabulation

			MRA2		
			Stenosis	Tidak	Total
MRA1	Stenosis	Count	4	0	4
		% of Total	13.3%	.0%	13.3%
	Tidak	Count	0	26	26
		% of Total	.0%	86.7%	86.7%
Total		Count	4	26	30
		% of Total	13.3%	86.7%	100.0%

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	1.000	.000	5.477	.000
N of Valid Cases		30			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table 5. Statistical Results for MRA Examination on PCA are extra

MRA1 * MRA2 Crosstabulation

			MRA2	
			Tidak	Total
MRA1	Tidak	Count	30	30
		% of Total	100.0%	100.0%
Total		Count	30	30
		% of Total	100.0%	100.0%

Symmetric Measures

		Value
Measure of Agreement	Kappa	.[a]
N of Valid Cases		30

a. No statistics are computed because MRA1 and MRA2 are constants.

Table 6. Statistical Results for MRA Examination on Left PCA

MRA1 * MRA2 Crosstabulation

			MRA2		
			Stenosis	Tidak	Total
MRA1	Stenosis	Count	2	0	2
		% of Total	6.7%	.0%	6.7%
	Tidak	Count	0	28	28
		% of Total	.0%	93.3%	93.3%
Total		Count	2	28	30
		% of Total	6.7%	93.3%	100.0%

Table 7. 2 × 2 Table of TCD and MRA in detecting stenosis in the right ACA

Right ACA		MRA examination	
		Stenosis (+)	Stenosis (-)
TCD	Stenosis (+)	1	1
	Stenosis (-)	0	28

The first radiologist (MRA1) found 1 patient (3.3%) had right ACA stenosis and the remaining patients studied (29 patients (96.7%)) were found no right ACA stenosis. The second radiologist (MRA2) found no right ACA stenosis in all patients of the present study (100%). This situation did not allow the calculation of the Kappa coefficient because of the results of examination by the 2nd radiologist (MRA2).

MRA examination on the left ACA was performed by two radiologists as shown in Table 6, the first radiologist (MRA 1) found 2 patients (6.7%) had left ACA stenosis, wherein the second radiologist (MRA2) found the similar stenosis.The remaining

Table 8. 2 × 2 Table of TCD and MRA in detecting stenosis in the left ACA.

ACA Left		MRA examination	
		Stenosis (+)	Stenosis (-)
TCD	Stenosis (+)	2	0
	Stenosis (-)	0	28

Table 9. 2 × 2 Table of TCD and MRA in detecting stenosis in the right MCA.

MCA Right		MRA examination	
		Stenosis (+)	Stenosis (-)
TCD	Stenosis (+)	0	0
	Stenosis (-)	11	19

Table 10. 2 × 2 table of TCD and MRA in detecting stenosis in the left MCA.

Left MCA		MRA examination	
		Stenosis (+)	Stenosis (-)
TCD	Stenosis (+)	4	3
	Stenosis (-)	0	23

Table 11. 2 × 2 Table of TCD and MRA in detecting stenosis at right PCA.

Right PCA		MRA examination	
		Stenosis (+)	Stenosis (-)
TCD	Stenosis (+)	0	0
	Stenosis (-)	0	30

Table 12. 2 x 2 Table of TCD and MRA in detecting stenosis at left PCA

Left PCA		MRA examination	
		Stenosis (+)	Stenosis (-)
TCD	Stenosis (+)	0	0
	Stenosis (-)	2	28

patients (28 patients (93.3%)) were found no left ACA stenosis by both first radiologist

Tabel 13. Table of TCD and MRA in detecting stenosis at ACA

ACA	**MRA examination as a reference standard**	
	Stenosis (+)	Stenosis (-)
TCD Stenosis (+)	2	0
TCD Stenosis (-)	0	28

Table 14. Table of TCD and MRA in detecting stenosis at MCA

MCA	**MRA examination as a reference standard**	
	Stenosis (+)	Stenosis (-)
TCD Stenosis (+)	7	0
TCD Stenosis (-)	4	19

Table 15. Table of TCD and MRA in detecting stenosis at PCA

PCA	**MRA examination as a reference standard**	
	Stenosis (+)	Stenosis (-)
TCD Stenosis (+)	0	0
TCD Stenosis (-)	0	30

(MRA1) and radiologist (MRA2). The Kappa coefficient obtained 1,000 with p-value of 0,000. These results indicate the Kappa coefficient > 0.75 and p-value < 0.05, which means that the consistency of the results of MRA1 and MRA2 examination is excellentand significant. This criterion refers to the strength of agreement interpretation of the Kappa coefficient (κ) according to Fleiss (1981):

- κ 0.40 $\Rightarrow$ bad
- $0.40 \leq \kappa < 0.60 \Rightarrow$ *fair*
- $0.60 \leq \kappa \leq 0.75 \Rightarrow$ *good*
- $\kappa > 0.75 \Rightarrow$ *excellent*

Examination of MRA on right MCA carried out by two radiologists as shown in Table 7, the first radiologist found right MCA stenosis in 11 patients (36.7%), where the similar stenosis was also found by the second radiologist (MRA2). The first radiologist found no right MCA stenosis in 19 patients (63.3%) but on examination of this patient

by the second radiologist (MRA2), it was found that 11 patients (36.7%) had right MCA stenosis and 8 patients (26.7%) did not have right MCA stenosis. The results of the calculation of the Kappa coefficient are 0.348 with a p-value of 0.012. This result revealed that $\kappa < 0.40$ and p-value < 0.05, which indicates that the consistency of the results of MRA1 and MRA2 examination is bad yet statistically significant.

Examination of MRA on the left MCA was conducted by two radiologists as shown in Table 8, the first radiologist found left MCA stenosis in 4 patients (13.3%), where the similar stenosis was also found by the second radiologist (MRA2). The first radiologist found no MCA right stenosis in 26 remaining patients (86.7%) where the second radiologist also had the similar result. The calculation of Kappa coefficient resulted the value of 1,000 with a p-valueof 0,000. With this result, the Kappa coefficient > 0.75 and p-value < 0.05, this indicates that the consistency of the results of MRA1 and MRA2 examination is excellent and significant.

Right PCA examination with MRA was performed by two radiologists as shown in Table 9, neither the first radiologist (MRA1) nor the second radiologist (MRA2) found right PCA stenosis in 30 patients (100%). The calculation of the Kappa coefficient cannot be done, because the results of the MRA2 examination found no stenosis for all patients.

Examination of the MRA on the left PCA was performed on two radiologists as shown in Table 10, the first radiologist found left PCA stenosis in 2 patients (6.7%) where this stenosis was also found in the second radiologist (MRA2). The first radiologist did not find left PCA stenosis in 28 patients (93.3%) where the second radiologist also had the similar result. The calculation results of the Kappa coefficient revealed a value of 1,000 with a p-value of 0,000. With this result, the Kappa coefficient > 0.75 with p-value $<$ 0.05, this indicates that the consistency of the results of MRA1 and MRA2 examination is excellentand significant.

4.3 TCD Sensitivity and Specificity Test Compared to MRA in ACA, MCA and PCA Using a 2x2 Table

After the researchers have completed the data of TCD and MRA from 30 patients who fulfilled the inclusion and exclusion criteria, the diagnostic values of TCD were obtained by tabulating the data and presented in table 2 x 2. Data was calculated based on 2 x 2 tables to find sensitivity, specificity, positive predictive value and negative predictive value.

After the calculations were performed, it was found that the sensitivity of TCD in detecting stenosis in the right ACA was 100%, specificity 96%, positive predictive value 50% and negative predictive value was 100% (Table 11). While the sensitivity value of TCD for detection of stenosis in left ACA is 100%, specificity 100%, positive predictive value 100%, and negative predictive value 100% (Table 12).

The sensitivity value of TCD in detecting stenosis at the right MCA is 0%, specificity is 100%, positive predictive value of infinity and negative predictive value 63% (Table 13). Whereas the sensitivity value of TCD in detecting stenosis in left MCA was 100%, specificity 88%, positive predictive value 57% while the negative predictive value was 100% (Table 14).

The sensitivity value of TCD in detecting stenosis in right PCA is infinity, specificity 100%, positive predictive value also infinity and negative predictive value 100% (Table

15). While the sensitivity value of TCD in detecting stenosis in the left PCA is 0%, specificity 100%, positive predictive value is infinity while the negative predictive value is 93% (Table 16).

From 30 samples that have TCD data and MRA results tabulating the data in 2 × 2 table, without considering which side of cerebral artery that have the stenosis. From the 2 × 2 table, the data is calculated to look for sensitivity, specificity, positive predictive value and negative predictive value.

After calculating the formula it was found that the sensitivity of TCD in detecting stenosis in ACA was 100%, specificity 100%, positive predictive value 100% while negative predictive value was 100%.

While the sensitivity value of TCD in detecting stenosis at MCA was 63%, specificity 100%, positive predictive value was 100% while negative predictive value was 82%.

Whereas the sensitivity value of TCD in detecting stenosis in PCA is ~ (infinity), specificity is 100%, positive predictive value is ~ (infinite) while negative predictive value is 100%.

The results of this study are in line with several previous studies. Sloan et al. stated that TCD had specificity of 100% and sensitivity of 58.6% to assess vasospasm angiography following subarachnoid haemorrhagic, Razumovsky et al. stated TCD had sensitivity of 96% and specificity of 33% in assessing the rate of abnormal cerebral blood flow(6). De Bray et al. stated TCD has sensitivity of 80% and specificity of 97% in assessing atheroma stenosis (7). The latest study showed the accuracy of TCD was 94.5% for stenosis < 50%, 96.2% for stenosis 50–69% and 88.9% for stenosis 70–99%. Finally, a study conducted by Hua et al., which assessed proximal vertebral artery stenosis with colour Doppler suggested that TCD has accuracy of 94.5%, 96.2% and 88.7% for diagnosing stenosis < 50%, 50–69%, and 70- 99%, respectively (8).

Although the above-mentioned studies assessed vascular segments that were different from those performed in this study, this study equally demonstrated that TCD has a high sensitivity and accuracy in assessing vascular stenosis. In our study, TCD was accurate in assessing stenosis in the cerebral arteries. However, MRA is more sensitive than TCD for detecting stenosis in MCA and TCD is more sensitive for ACA and PCA. Meanwhile, specificity TCD in accessing stenosis is high for ACA, MCA and PCA.

5 Conclusions

This study involved the cases of infarction stroke patients with predilection predominantly among male, about 19 patient (64%) with range of age mostly in 60–69 years for about 10 patient (34%) and least of all age is 80–89 years of age about 1 patient (4%), where the ability of TCD to detect stenosis in ACA revealed sensitivity of 100%, specificity of 100%, and positive predictive value of 100%, and negative predictive value of 100%. It was also shown that the ability of TCD to detect MCA stenosis with sensitivity of 53%, specificity of 100%, positive predictive value of 100%, negative predictive value of 82%. The sensitivity of TCD to detect PCA stenosis was infinity, specificity of 100%, positive predictive value of infinity, and negative predictive value of 100%. Based on these results, it can be concluded that MRA is more sensitive than TCD for detecting stenosis in MCA, while TCD is more sensitive for ACA and PCA.

6 Suggestion

It is important to conduct further research to stenosis in ACA, MCA and PCA in stroke patients with larger samples size and more complete data.

Further studies are needed to be carried out by comparing the sensitivity and specificity of diagnostic tool such as TCD, MRA in detecting stenosis in ACA, MCA, PCA in the cases of infarction stroke with other diagnostic tools such as CT Angiographyand gold standards namely Digital Subtraction Angiography.

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