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The relationship between hypercholesterolemia as a risk factor for stroke and blood viscosity measured using Digital Microcapillary®

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Abstract Hypercholesterolemia is a risk factor for stroke, and it is known that patients exhibit elevated blood viscosity after experiencing a stroke. This study examined the relationship between hypercholesterolemia as a risk factor for stroke and increased blood viscosity. Blood viscosity was measured using Digital Microcapillary®. The data used in this cross-sectional study were obtained from the medical records of patients at Pos Binaan Terpadu (Posbindu), and data from healthy controls were obtained from a previous study. The results illustrated that 51.3% (n = 98) and 88.5% (n = 169) of patients had hypercholesterolemia and hyperviscosity, respectively. The results revealed a significant difference in blood viscosity between patients with hypercholesterolemia and healthy subjects, but this difference was not noted between patients with normal cholesterol levels and those with hypercholesterolemia. The study results support the link between cholesterol levels and blood viscosity and confirm the utility of Digital Microcapillary as a tool for screening patients who are at risk of stroke.

1. Introduction

Hypercholesterolemia is caused by a disruption in the metabolic process of lipoproteins, thus resulting in increased lipoprotein concentrations in the blood [1]. In the United States, 98.9 million people aged ≥ 20 years old have cholesterol levels that exceed 200 mg/dL, with 31.9 million people exhibiting levels > 240 mg/dL [2]. In Indonesia, the prevalence of abnormal cholesterol levels among people aged ≥ 15 years old reached 35.9% in 2013 [3]. High and uncontrolled cholesterol levels represent a risk factor for stroke. Hypercholesterolemia tends to lead to early atherosclerosis and is a high risk factor for cardiovascular disease; this information is in line with the finding that stroke is the leading cause of death in Indonesia [4-6].

According to a previous study, blood viscosity levels are higher in patients who experienced an ischemic stroke than in healthy individuals. High cholesterol levels can alter blood viscosity, e.g., LDL-C can cause erythrocyte aggregation and deformability, thus resulting in increased blood viscosity and decreased blood flow [7]. These changes lead to disturbances in the perfusion of tissues, including the brain, thus potentially resulting in ischemic stroke [8].

To date, blood viscosity has been measured in the laboratory by using expensive instruments, with results obtained within a few days. Digital Microcapillary® was developed to easily measure blood viscosity. This tool can be used in small health facilities to provide easy access to patients. Moreover, results are obtained instantly and can be read automatically [5].



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This study examined the relationship between high cholesterol levels as a risk factor for stroke and blood viscosity measured using Digital Microcapillary[®]. If the results reveal a relationship, blood viscosity in patients with hypercholesterolemia could be managed using this information, thus preventing the occurrence of stroke.

6 Methods

The study protocol was approved by the Health Research Ethics Committee, Faculty of Medicine Universitas Indonesia-Cipto Mangunkusumo Hospital. The data used in this cross-sectional study were obtained from the medical records of patients who visited Integrated Community Health Post (Posbindu) in January and March 2015 and from a previous study conducted by Rasyid et al. [5] in 2014. The hypercholesterolemia group in this study consisted of patients who underwent examinations using the Accutrend Plus System[®] and with confirmed cholesterol levels exceeding 200 mg/dL. Data were obtained for a healthy control group consisting of subjects without factors linked to increased blood viscosity such as diabetes, hyperuricemia, obesity, hypertension, or smoking.

Total cholesterol levels were measured using a cholesterol meter, and blood viscosity was measured using Digital Microcapillary[®]. The sampling technique used was consecutive sampling, and the minimum number of samples was 85 subjects.

The potential relationship between hypercholesterolemia and blood viscosity was examined using the chi-squared test and Pearson's correlation analysis. The Kolmogorov–Smirnov normality test was used as needed to determine whether data were normally distributed. SPSS software was used for data processing.

3. Results

A total of 203 respondents were recruited among patients who visited Posbindu in January and March 2015. Among the respondents, four were excluded because of anticoagulant use, and data for eight respondents could not be processed because they exceeded the linear capacity of the tool. Therefore, the total number of respondents was 191. The majority of the respondents were female (150 subjects), and their average age was 60 years old (Table 1).

Table 1. Distribution of Study Subject Characteristics in Posbindu

Characteristic	Frequency	Mean* Median**
Sex		
Male	41 (21.5%)	
Female	150 (78.5%)	
Age		50** (18–79)
<45 years	61 (31.9%)	41** (18–49)
≥45 years	130 (68.1%)	55** (45–79)

* Mean ($\bar{x} \pm 2$ SD)** Median (Min–Max)

Table 2 shows the basic characteristics of the study subjects based on clinical variables. Most of the Posbindu respondents exhibited elevated cholesterol levels, with 98 of 191 subjects displaying hypercholesterolemia. Subjects with hypercholesterolemia were mostly female and older than 45 years old. Among the 191 study subjects, 169 had elevated blood viscosity.

Table 2. Clinical variables of the study subjects

Characteristic	Frequency	Mean* Median**
Cholesterol Level (mg/dL)		203.6 (203.6 \pm 61.8)*

Table 2. *Continue*

Characteristic	Frequency	Mean* Median**
Hypercholesterolemia		
Yes	98 (51.3%)	223 (200–297)**
Male	17 (17.3%)	227.1 (227.1 ± 42.2)*
Female	81 (82.7%)	223 (200–297)**
Age <45 years	27 (27.6%)	
Age ≥45 years	71 (72.4%)	
No	93 (48.7%)	182 (108–199)**
Blood viscosity level		6.1 (3.0–8.6)
Hyperviscosity		
Yes	169 (88.5%)	
Male	36 (21.3%)	
Female	133 (78.7%)	
Age <45 years	55 (32.5%)	
Age ≥45 years	114 (67.5%)	
No	22 (11.5%)	

*Mean ($\bar{x} \pm 2$ SD) ** Median (Min–Max)

3.1. Difference in hyperviscosity between healthy subjects and patients with hypercholesterolemia

According to the chi-squared test results, the healthy subjects had normal cholesterol levels and had no risk factors for increased blood viscosity (Table 3). By contrast, 88 patients with hypercholesterolemia had hyperviscosity.

Table 3. Chi-squared test results for healthy subjects and patients with hypercholesterolemia

		Viscosity		p value
		Normal n	High n	
Cholesterol	Normal	40	0	<0.001
	High	10	88	
	Total	50	88	

3.2. Relationship between hypercholesterolemia and hyperviscosity among patients at Posbindu

The analysis illustrated that the data for cholesterol levels were normally distributed ($p = 0.2$), whereas the distribution of data for blood viscosity was abnormal ($p = 0.009$). According to Pearson's correlation analysis of cholesterol levels and blood viscosity, the relationship between cholesterol levels and blood viscosity was insignificant ($p = 0.103$). Figure 1 presents the results of Pearson's correlation analysis.

The chi-squared test further indicate that hypercholesterolemia was insignificantly associated with blood viscosity ($p = 0.559$, Table 4).

Table 4. Chi-squared analysis of the association between hypercholesterolemia and hyperviscosity

		Viscosity		p value
		Normal n	High n	
Cholesterol	Normal	12	81	0.559
	High	10	88	
	Total	22	169	

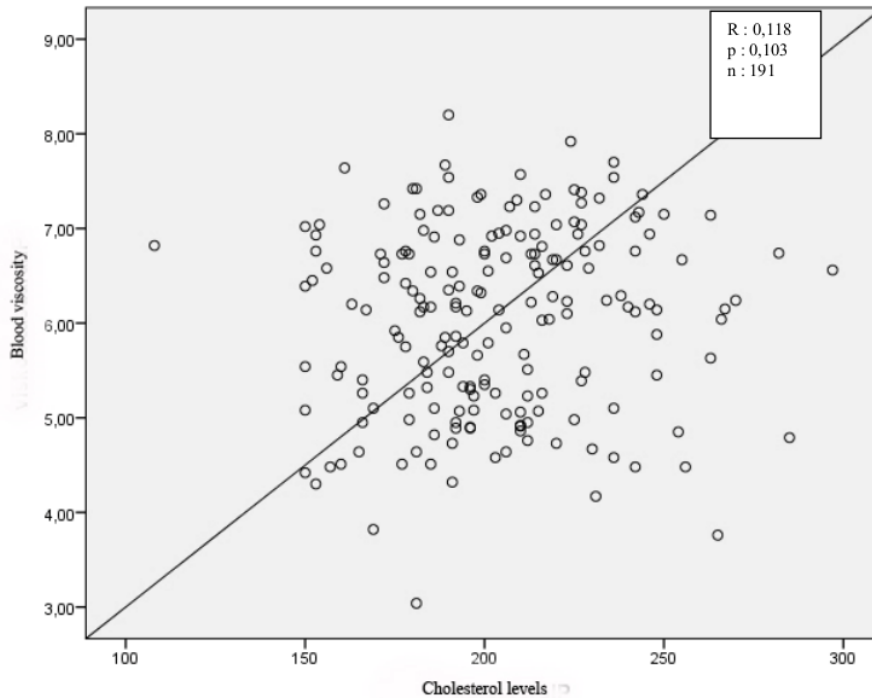


Figure 1. Correlation between cholesterol and blood viscosity

4. Discussion

According to NCEP, cholesterol levels exceeding 200 mg/dL necessitate follow-up and medical treatment. Hypercholesterolemia is a risk factor for stroke because cholesterol can form atherosclerotic plaques, which can restrict blood flow, thus reducing blood vessel diameter and leading to reduced perfusion to tissues, including the brain [9]. Our study data shows that a large portion of patients at Posbindu are at increased risk of stroke.

Indonesia has an abnormally high prevalence of high cholesterol levels at 35.9%, with hypercholesterolemia being more common in females than in males. These data are in accordance with the results of our study, in which hypercholesterolemia was more prevalent among females than among males. Furthermore, the prevalence of hypercholesterolemia was higher at Posbindu than in the rest of the country. This finding could be attributed to the fact that most patients at Posbindu are older than 45 years old.

In our study population, nearly three-fourths of patients older than 45 years old exhibited hypercholesterolemia. Therefore, this age may be linked to increased risk of cardiovascular disease in patients with hypercholesterolemia owing to the increased prevalence of atherosclerosis.

According to a study by Rasyid et al. [5], blood viscosity can affect blood flow, including slower blood flow to the brain, thereby increasing the incidence of stroke. Consequently, most of the patients at Posbindu had elevated risks of stroke. Given its ease of use, the Digital Microcapillary device can be quickly employed to identify subjects with hyperviscosity, thus permitting early treatment to prevent stroke.

The current study found an insignificant relationship between cholesterol levels and blood viscosity, which contradicts the results of Machida et al. [10]. The researchers argued that LDL-C can stimulate erythrocyte aggregation, thus leading to extremely slow blood flow in vessels and increasing blood viscosity. The difference between the current study and that by

Machida et al. [5] is the inclusion of a control group of patients without hypercholesterolemia. However, the control patients may have factors other than hypercholesterolemia that lead to increased blood viscosity, such as diabetes mellitus, hyperuricemia, obesity, hypertension, and smoking habits. These factors might explain why most patients in the control group exhibited hyperviscosity without hypercholesterolemia. This hypothesis is supported by the significant difference in the risk of hyperviscosity between patients with hypercholesterolemia and healthy controls without risk factors for hyperviscosity.

5. Conclusion

A significant difference in the risk of blood viscosity was observed between healthy controls and patients with hypercholesterolemia. However, elevated cholesterol levels were not linked to an increased risk of hyperviscosity. This finding may be due to the presence of other risk factors in patients in the control group, who have normal cholesterol levels. Furthermore, the study confirmed the utility of Digital Microcapillary[®] as a tool for measuring blood viscosity in primary health facilities because of its simple examination procedure and instant results.

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