Metabolic Syndrome Predicts Poor Outcome in Acute Ischemic Stroke Patients After Endovascular Thrombectomy

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Background and Aims: The metabolic syndrome (MetS) is believed to contribute to a higher probability of developing cardiovascular diseases. This study aimed to investigate whether MetS could predict the prognosis in ischemic stroke patients after endovascular thrombectomy (EVT).

Methods: Between January 2016 and September 2019, patients treated with EVT due to large vessel occlusions in anterior circulation were prospectively recruited. MetS was defined using the International Diabetes Federation criteria after admission. The primary outcome was a 3-month poor outcome (modified Rankin scale score of 3–6). Secondary outcomes included symptomatic intracranial hemorrhage (sICH) and mortality at 3 months. Multivariable logistic regression models were used to assess the relationship between MetS and clinical outcomes.

Results: A total of 248 patients were enrolled (mean age, 66.7 years; 37.5% female) and 114 (46.0%) met with the MetS criteria. The median National Institutes of Health Stroke Scale score was 15.0. There were 131 (52.8%) patients achieving the poor outcome at 3 months, among which 26 (10.5%) patients developed sICH. The mortality at 3 months was 19.0% (47/248). In multivariable analysis, MetS was significantly correlated to poor outcome (odds ratio [OR], 2.48; 95% confidence interval [CI], 1.29–4.78, P = 0.014). The risk for poor outcome was positively associated with the increased number of MetS components (OR 1.78; 95% CI 1.39–2.35, P = 0.001). No significant findings were found in the association of MetS with sICH and mortality.

Conclusion: Our data demonstrated that MetS was associated with poor prognosis in acute ischemic patients treated with EVT.

Keywords: metabolic syndrome, ischemic stroke, endovascular thrombectomy, prognosis

Introduction

Stroke has been ranked as the first leading cause of major disability and mortality in China.1 Endovascular thrombectomy (EVT) has profoundly changed the landscape of acute stroke therapy in large vessel occlusions of the anterior circulation.2–4 This early identification of the patient’s prognosis is of vital importance for further improving the benefit of EVT.

The metabolic syndrome (MetS) is a highly prevalent constellation of vascular risk factors, including insulin resistance, central obesity, elevated blood pressure, and dyslipidemia.5 The epidemiological investigation demonstrated the prevalence of MetS has reached approximately 60% of the elderly Chinese population and it is
projected to increase considerably. Moreover, data from the Guangdong Nutrition and Health Survey estimate that a total of 4.0 million residents aged 20 years or above have the MetS in southern China. Inflammatory state and coagulation system activation accompanied by MetS may confer higher risks for ischemic events. Guidelines for the prevention of stroke showed that MetS could predict cardiovascular disease including coronary heart disease and stroke, leading to increased mortality. MetS has been also reported to be associated with functional outcomes and refractoriness to intravenous thrombolysis in acute ischemic stroke patients. To date, there remains a paucity of data from a prospective cohort examining the relationship between MetS and prognosis in ischemic stroke patients treated with EVT. We, therefore, performed this prospective study to investigate whether MetS could predict the functional outcome at 90 days in ischemic stroke patients after EVT treatment.

**Methods**

**Study Design and Participants**

We prospectively recruited participants with EVT admitted to Mianyang Central Hospital between January 2016 and September 2019. The participants were screened consecutively based on the inclusion criteria: (1) acute ischemic stroke with occlusions of the internal carotid artery (ICA) or middle cerebral artery (MCA) confirmed by computed tomographic angiography, magnetic resonance angiography, or digital subtracted angiography; (2) aged ≥ 18 years; (3) pre-stroke modified Rankin Scale (mRS) score ≤ 2. Patients with severe renal disease and hepatic disease, cardiac insufficiency, tumor, and autoimmune disease were excluded. This study was approved by the ethics committee of Mianyang Central Hospital. The study was conducted under the declaration of Helsinki. Informed consent was obtained from participants or legal representatives. Several ischemic stroke patients admitted to hospital with severe neurological deficits, as such as disturbance of consciousness. Therefore, the informed consents were obtained from their legal representatives.

**Data Collection**

We collected patient’s demographic characteristics, traditional risk factors, baseline clinical data, imaging data, and procedure-related characteristics. The baseline stroke severity was assessed by trained neurologists using the National Institutes of Health Stroke Scale (NIHSS).

Ischemic stroke subtype was classified based on the trial of ORG 10,172 in Acute Stroke Treatment classification. The Alberta Stroke Program Early Computed Tomography Score (ASPECTS) was used to evaluate the extent of preoperative early cerebral ischemia. The collateral circulation status was evaluated using the American Society of Interventional and Therapeutic Neuroradiology/Society of Interventional Radiology (ASITN/SIR) and defined ASITN/SIR ≥ 2 as a good collateral circulation. Successful vascular recanalization was defined as the modified Thrombolysis in Cerebral Infarction scale 2b/3. Symptomatic intracranial hemorrhage (sICH) was diagnosed according to Heidelberg Bleeding Classification.

**Definition of MetS**

MetS was defined according to the International Diabetes Federation criteria. Individuals were considered to have MetS if they had central obesity (waist circumference ≥ 90 cm for Asian men or ≥ 80 cm for Asian women) plus any 2 of 4 additional components. These 4 risk components are as follows: (1) triglyceride (TG) ≥ 1.70 mmol/L; (2) Decreased HDL-cholesterol < 1.03 mmol/L in male and < 1.29 mmol/L in female (or specific treatment for these lipid abnormalities); (3) elevated blood pressure: systolic blood pressure ≥ 130 mmHg, or diastolic blood pressure ≥ 85 mmHg, or use for antihypertensive drugs; (4) hyperglycemia: fasting plasma glucose ≥ 5.6 mmol/L or previously diagnosed type 2 diabetes.

**Clinical Outcomes**

The 90-day functional outcomes after stroke were evaluated using mRS by outpatient service, the medical information provided by the rehabilitation hospital, and the telephone interview. The primary outcome was the unfavorable functional outcome (mRS of 3–6). Secondary outcomes included sICH with 72 hours and mortality at 3 months.

**Statistical Analysis**

Continuous variables were presented as mean (SD, standard deviation) and median (interquartile range) and categorical variables as number (percentage). Differences in baseline characteristics between groups were analyzed using independent sample t-tests, and Mann–Whitney U-tests for continuous variables, and the chi-square test or fisher’s exact test for categorical variables, as appropriate. Binary logistic regression analysis with 2 models was performed to estimate the risk of 3-month unfavorable
Table 1 Comparison of Baseline Data in Patients with and Without MetS

| Variables                                      | All Patients (n = 248) | With MetS (n = 114) | Without MetS (n = 134) | P value |
|------------------------------------------------|------------------------|---------------------|------------------------|---------|
| Demographic characteristics                    |                        |                     |                        |         |
| Age, years                                      | 66.7 ± 13.0            | 68.8 ± 13.2         | 64.9 ± 12.7            | 0.018   |
| Female, n (%)                                   | 93 (37.5)              | 60 (52.6)           | 33 (24.6)              | 0.001   |
| Vascular risk factors, n (%)                   |                        |                     |                        |         |
| Hypertension                                   | 150 (60.5)             | 71 (62.3)           | 79 (59.0)              | 0.285   |
| Diabetes mellitus                              | 64 (25.8)              | 37 (32.5)           | 27 (20.1)              | 0.027   |
| Hyperlipidemia                                  | 25 (10.1)              | 12 (10.5)           | 13 (9.7)               | 0.830   |
| Atrial fibrillation                            | 101 (40.7)             | 44 (38.6)           | 57 (42.5)              | 0.396   |
| Coronary heart disease                         | 32 (12.9)              | 14 (12.3)           | 18 (13.4)              | 0.787   |
| Current smoker                                 | 81 (32.7)              | 37 (32.5)           | 44 (32.8)              | 0.949   |
| Current drinker                                | 50 (20.2)              | 19 (16.7)           | 31 (23.1)              | 0.207   |
| Family history of stroke                       | 19 (7.7)               | 11 (9.6)            | 8 (6.0)                | 0.278   |
| Medication history                             |                        |                     |                        |         |
| Antiplatelet drugs                              | 78 (31.5)              | 37 (32.5)           | 41 (30.6)              | 0.753   |
| Statin                                         | 67 (27.0)              | 35 (30.7)           | 32 (23.9)              | 0.228   |
| Antihypertensive drugs                         | 79 (31.9)              | 42 (36.8)           | 37 (27.6)              | 0.120   |
| Clinical data                                  |                        |                     |                        |         |
| Waist circumference, cm                        | 86.5 ± 5.4             | 89.4 ± 4.2          | 84.0 ± 5.2             | 0.001   |
| Systolic blood pressure, mmHg                  | 154.8 ± 23.8           | 164.5 ± 19.5        | 146.7 ± 24.1           | 0.001   |
| Diastolic blood pressure, mmHg                 | 79.9 ± 12.9            | 83.2 ± 14.2         | 77.1 ± 11.0            | 0.001   |
| Time from onset to treatment, min              | 220.5 (177.0, 265.0)   | 235.0 (176.0, 270.0)| 218.0 (199.0, 250.0)  | 0.653   |
| Time from puncture to recanalization, min      | 62.5 (43.5, 77.0)      | 56.0 (43.0, 75.0)   | 65.0 (45.0, 84.5)      | 0.153   |
| Baseline NIHSS, score                          | 15.0 (11.0, 20.0)      | 16.0 (13.0, 20.0)   | 14.0 (11.0, 18.0)      | 0.047   |
| Baseline ASPECTS, score                        | 9.0 (9.0, 10.0)        | 10.0 (9.0, 10.0)    | 9.0 (9.0, 10.0)        | 0.241   |
| Prior IVT, n (%)                               | 168 (67.7)             | 82 (71.9)           | 86 (64.2)              | 0.193   |
| Good collateral, n (%)                         | 175 (70.6)             | 80 (70.2)           | 95 (70.9)              | 0.901   |
| Total passes of stent retriever                | 2.0 (1.0, 2.0)         | 1.5 (1.0, 2.0)      | 1.0 (1.0, 2.0)         | 0.140   |
| Successful recanalization, n (%)               | 181 (73.0)             | 84 (73.7)           | 97 (72.7)              | 0.819   |
| Vascular occlusion site, n (%)                 |                        |                     |                        |         |
| ICA                                            | 95 (38.3)              | 46 (40.4)           | 49 (36.6)              | 0.777   |
| MCA-M1                                         | 138 (55.6)             | 63 (55.3)           | 75 (56.0)              |         |
| MCA-M2                                         | 15 (6.0)               | 6 (5.3)             | 9 (6.7)                |         |
| Stroke etiology, n (%)                         |                        |                     |                        |         |
| Atherosclerotic                                | 119 (48.0)             | 56 (49.1)           | 63 (47.0)              | 0.031   |
| Cardioembolic                                  | 106 (42.7)             | 42 (36.8)           | 64 (47.8)              |         |
| Others                                         | 23 (9.3)               | 16 (14.0)           | 7 (5.2)                |         |
| Procedural modes, n (%)                        |                        |                     |                        |         |
| Stent retriever only                           | 238 (96.0)             | 110 (96.5)          | 128 (95.5)             | 0.699   |
| Stent retriever with implantation of stent     | 10 (4.0)               | 4 (3.5)             | 6 (4.5)                |         |
| Clinical outcomes, n (%)                       |                        |                     |                        |         |
| Poor outcome at 3-months                       | 131 (52.8)             | 72 (63.2)           | 59 (44.0)              | 0.003   |
| Mortality at 3-months                          | 47 (19.0)              | 25 (21.9)           | 22 (16.4)              | 0.270   |
| siCH                                           | 26 (10.5)              | 11 (9.6)            | 15 (11.2)              | 0.692   |
| Laboratory data                                |                        |                     |                        |         |
| Total cholesterol, mmol/L                     | 4.1 ± 1.1              | 4.1 ± 1.1           | 4.1 ± 1.0              | 0.772   |
| Triglyceride, mmol/L                           | 1.6 (1.3, 2.1)         | 1.7 (1.4, 2.3)      | 1.5 (1.2, 1.9)         | 0.004   |
| Low density lipoprotein, mmol/L                | 3.0 (2.6, 3.5)         | 3.3 (2.6, 3.7)      | 2.8 (2.5, 3.4)         | 0.033   |

(Continued)
outcome by calculating odds ratios (OR) and 95% confidence intervals (CI). Model 1 was adjusted for age and gender. Model 2 included the factors in model 1 as well as variables with \( P < 0.1 \) in univariate analysis (including atrial fibrillation, onset to treatment time, puncture to recanalization, baseline NIHSS score, baseline ASPECTS, prior IVT, collateral circulation status, total passes of stent retriever, successful recanalization, vascular occlusion site, and Hs-CRP levels). We also used the ordinal logistic regression analysis to estimate an effect of MetS across the entire range of the mRS score. All \( P \) values were 2 tailed, and a significance level of 0.05 was used. Statistical analysis was performed using SPSS 24.0 (IBM, Chicago, IL, USA).

**Results**

A total of 248 patients (mean age, 66.7 years; 37.5% female) were included with large vessel occlusions in the anterior circulation treated by EVT. Demographics, clinical, and radiological characteristics, as well as clinical outcomes in the study cohort, are summarized in Table 1. Median onset to treatment time was 220.5 minutes. The median NIHSS was 15 (IQR 11–20) at baseline and the median ASPECTS was 10 (IQR 9–10). Vascular occlusion site was as follows: MCA-M1 138 (55.6%), MCA-M2 15 (6.0%) and ICA 95 (38.3%), sICH was diagnosed in 26 patients (10.5%) within 72 hours after EVT treatment. MetS was present in 46.0% of the participants. As compared with subjects without MetS, patients with MetS were more likely to be female and older, and had a higher prevalence of diabetes mellitus and atherosclerotic stroke, and had a higher level of waist circumference, blood pressure, baseline NIHSS score, blood glucose and, Hs-CRP. There were 131 patients (52.8%) who developed an unfavorable functional outcome (mRS 3–6). The overall mortality was 47 (19.0%) at 90 days after EVT. Unfavorable functional outcome was more prevalent in patients with MetS than in patients without it (63.2% versus 44.0%; \( P = 0.003 \)). No significant findings were found in association of MetS with sICH (9.6% versus 11.2%; \( P = 0.692 \)) and mortality (21.9% versus 16.4%; \( P = 0.270 \)) at 3 months.

Comparison of baseline data in patients with and without 3-month poor outcome is showed in Table 2. In univariate analysis, the prevalence of atrial fibrillation in patients with unfavorable outcome was higher (48.1% versus 32.5%; \( P = 0.009 \)). Baseline systolic blood pressure was higher in patients with unfavorable outcome (median 158 versus 150; \( P = 0.012 \)). Patients with 3-month poor outcome had lower baseline ASPECT scores (median, 8.0 versus 9.0; \( P = 0.001 \) and higher baseline NIHSS scores (median, 16 versus 14; \( P = 0.001 \)). Prior IVT was less prevalent in patients with poor outcome (61.8% versus 74.4%; \( P = 0.035 \)). Unfavorable outcome was associated with longer delay from symptom onset to treatment (median, 240 versus 220 minutes; \( P = 0.001 \)), and longer puncture to recanalization (median, 65 versus 55 minutes; \( P = 0.035 \)). Moreover, unfavorable outcome lowered successful recanalization ratio (54.2% versus 94.0%; \( P = 0.001 \)).

In univariate logistic analysis, MetS (OR, 2.18; 95% CI, 1.31–3.63; \( P = 0.003 \)) increased numbers of MetS components (OR, 1.89; 95% CI, 1.46–2.44, \( P = 0.001 \)), low HDL-C (OR, 3.13; 95% CI, 1.83–5.36; \( P = 0.001 \)), elevated blood pressure (OR, 2.79; 95% CI, 1.48–5.26; \( P = 0.002 \)), and elevated blood glucose (OR, 2.05; 95% CI, 1.04–4.06; \( P = 0.038 \)) were associated with 3-month unfavorable outcome after EVT (Table 3). After controlled for age, gender, atrial fibrillation, onset to treatment time, puncture to recanalization, baseline NIHSS score, baseline ASPECTS, prior IVT, collateral circulation status, total passes of stent retriever, recanalization, vascular occlusion site, and Hs-CRP levels, this associations remained significant.

Table 1

| Variables                  | All Patients (n = 248) | With MetS (n = 114) | Without MetS (n = 134) | \( P \) value |
|----------------------------|------------------------|---------------------|------------------------|--------------|
| High density lipoprotein, mmol/L | 1.2 ± 0.2              | 1.1 ± 0.2            | 1.2 ± 0.2              | 0.886        |
| Blood glucose level, mmol/L     | 8.2 ± 3.1              | 8.6 ± 3.5            | 7.8 ± 2.7              | 0.036        |
| Hs-CRP, mg/L                 | 1.8 (1.3, 2.6)         | 2.0 (1.2, 3.0)       | 1.5 (1.2, 2.3)         | 0.018        |

Abbreviations: ASPECTS, the Alberta Stroke Program Early Computed Tomography Score; Hs-CRP, hyper-sensitive C-reactive protein; ICA, internal carotid artery; IVT, intravenous thrombolysis; MetS, metabolic syndrome; MCA, middle cerebral artery; NIHSS, National Institute of Health Stroke Scale; sICH, symptomatic intracranial hemorrhage.
Table 2 Comparison of Baseline Data in Patients with and Without 3-Month Poor Outcome

| Variables                                | Unfavorable Outcome (n = 131) | Favorable Outcome (n = 117) | P value |
|-------------------------------------------|-------------------------------|----------------------------|---------|
| Demographic characteristics              |                               |                            |         |
| Age, years                                | 66.5 ± 13.6                   | 66.9 ± 12.3                | 0.792   |
| Female, n (%)                             | 57 (43.5)                     | 36 (30.8)                  | 0.039   |
| Vascular risk factors, n (%)              |                               |                            |         |
| Hypertension                              | 80 (61.1)                     | 70 (59.8)                  | 0.842   |
| Diabetes mellitus                         | 38 (29.0)                     | 26 (22.2)                  | 0.233   |
| Hyperlipidemia                            | 11 (8.4)                      | 14 (12.0)                  | 0.351   |
| Atrial fibrillation                       | 63 (48.1)                     | 38 (32.5)                  | 0.009   |
| Coronary heart disease                    | 17 (13.0)                     | 15 (12.8)                  | 0.971   |
| Clinical data                             |                               |                            |         |
| Waist circumference, cm                   | 86.7 ± 5.2                    | 86.3 ± 5.8                 | 0.545   |
| Systolic blood pressure, mmHg             | 158.4 ± 23.1                  | 150.8 ± 24.1               | 0.012   |
| Diastolic blood pressure, mmHg            | 80.7 ± 12.6                   | 78.9 ± 13.2                | 0.289   |
| Time from onset to treatment, min         | 240.0 (215.0, 283.0)          | 202.0 (176.0, 245.0)       | 0.001   |
| Time from puncture to recanalization, min | 65.0 (48.0, 84.0)             | 55.0 (43.0, 73.0)          | 0.001   |
| Baseline NIHSS, score                     | 16.0 (12.0, 20.0)             | 14.0 (9.0, 17.0)           | 0.001   |
| Baseline ASPECTS, score                   | 9.0 (8.0, 10.0)               | 10.0 (9.0, 10.0)           | 0.001   |
| Prior IVT, n (%)                          | 81 (61.8)                     | 87 (74.4)                  | 0.035   |
| Good collateral, n (%)                    | 65 (49.6)                     | 110 (94.0)                 | 0.001   |
| Total passes of stent retriever           | 2.0 (1.0, 2.0)                | 1.0 (1.0, 2.0)             | 0.004   |
| Successful recanalization, n (%)          | 71 (54.2)                     | 110 (94.0)                 | 0.001   |
| sICH, n (%)                               | 25 (19.1)                     | 1 (0.9)                    | 0.001   |
| Vascular occlusion site, n (%)            |                               |                            |         |
| ICA                                       | 59 (45.0)                     | 36 (30.8)                  | 0.036   |
| MCA-MI                                    | 67 (51.1)                     | 71 (60.7)                  |         |
| MCA-M2                                    | 5 (3.8)                       | 10 (8.5)                   |         |
| Stroke etiology, n (%)                    |                               |                            |         |
| Atherosclerotic                           | 54 (41.2)                     | 65 (55.6)                  | 0.074   |
| Cardioembolic                             | 64 (48.9)                     | 42 (35.9)                  |         |
| Others                                    | 13 (9.9)                      | 10 (8.5)                   |         |
| Procedural modes, n (%)                   |                               |                            | 0.855   |
| Stent retriever only                      | 126 (96.2)                    | 112 (95.7)                 |         |
| Stent retriever with implantation of stent| 5 (3.8)                       | 5 (4.3)                    |         |
| MetS                                      |                               |                            |         |
| Numbers of MetS components                | 3.0 (3.0, 4.0)                | 2.0 (2.0, 3.0)             | 0.001   |
| Elevated waist circumference             | 71 (54.2)                     | 49 (41.9)                  | 0.053   |
| Elevated triglyceride                     | 59 (45.0)                     | 48 (41.0)                  | 0.524   |
| Decreased high density lipoprotein        | 68 (51.9)                     | 30 (25.6)                  | 0.001   |
| Elevated blood pressure                   | 113 (86.3)                    | 81 (69.2)                  | 0.001   |
| Elevated blood glucose                    | 115 (87.8)                    | 91 (77.8)                  | 0.036   |
| Laboratory data                           |                               |                            |         |
| Total cholesterol, mmol/L                | 4.0 ± 1.1                     | 4.2 ± 1.0                  | 0.318   |
| Triglyceride, mmol/L                      | 1.7 (1.2, 2.2)                | 1.6 (1.3, 1.9)             | 0.473   |
| Low density lipoprotein, mmol/L           | 2.8 (2.5, 3.7)                | 3.2 (2.6, 3.4)             | 0.621   |
| High density lipoprotein, mmol/L          | 1.2 ± 0.2                     | 1.2 ± 0.2                  | 0.158   |
| Blood glucose level, mmol/L              | 8.3 ± 3.1                     | 8.0 ± 3.2                  | 0.424   |
| Hs-CRP, mg/L                              | 2.1 (1.3, 3.0)                | 1.6 (1.2, 2.2)             | 0.014   |

Abbreviations: ASPECTS, the Alberta Stroke Program Early Computed Tomography Score; Hs-CRP, hyper-sensitive C-reactive protein; ICA, internal carotid artery; IVT, intravenous thrombolysis; MetS, metabolic syndrome; MCA, middle cerebral artery; NIHSS, National Institute of Health Stroke Scale; sICH, symptomatic intracranial hemorrhage.
odds ratio of ordinal logistic regression analysis illustrated that patients with MetS have increased mRS scores (OR, 1.82; 95% CI, 1.16–2.82; \(P = 0.009\)).

**Discussion**

In this prospective study, we observed that MetS occurred in 46.0% of patients. MetS was associated with an increased risk of unfavorable functional outcome at 90 days in ischemic stroke treated with EVT. No significant findings were found in the association of MetS with sICH and mortality at 3 months.

MetS is a growing public health problem worldwide. Findings from the third National Health and Nutrition Examination Survey reported the prevalence of MetS was approximately 40% in adults in the United States. A longitudinal study performing in China showed that the 5-year cumulative incidence of MetS was 10.8% in 2007 to 2012. Most researches on MetS with cardiovascular disease have been restricted to stroke prevention rather than prognosis. Our study extended the current knowledge about the detrimental effect of MetS in ischemic stroke as it unveiled a significant association between MetS and poor prognosis in EVT patients. The mechanisms underlying the detrimental effect of MetS on the stroke prognosis after EVT are not well defined, but several explanations may account for this phenomenon. MetS has been reported to be associated with a proinflammatory state, platelet activation, impairments in endogenous fibrinolytic capacity, and endothelial dysfunction, all of which may amplify neuron damage.

| Variables                        | Crude Model | \(P\) value | Model 1  | \(P\) value | Model 2  | \(P\) value |
|----------------------------------|-------------|-------------|----------|-------------|----------|-------------|
| MetS                             | 2.18 (1.31–3.63) | 0.003       | 2.04 (1.19–3.49) | 0.009       | 2.48 (1.29–4.78) | 0.014       |
| Numbers of MetS components       | 1.89 (1.46–2.44) | 0.001       | 1.89 (1.42–2.50) | 0.001       | 1.72 (1.34–2.38) | 0.001       |
| Elevated waist circumference     | 1.64 (0.99–2.72) | 0.067       | 0.99 (0.97–1.02) | 0.445       | 1.85 (0.94–3.62) | 0.069       |
| Elevated triglyceride            | 1.18 (0.71–1.95) | 0.524       | 1.20 (0.72–2.01) | 0.488       | 1.21 (0.76–1.93) | 0.379       |
| Decreased high density lipoprotein | 3.13 (1.83–5.36) | 0.001       | 3.26 (1.72–6.17) | 0.001       | 3.75 (1.79–6.94) | 0.001       |
| Elevated blood pressure          | 2.79 (1.48–5.26) | 0.002       | 2.73 (1.43–5.21) | 0.002       | 4.55 (1.69–9.22) | 0.001       |
| Elevated blood glucose           | 2.05 (1.04–4.06) | 0.038       | 2.01 (1.01–4.03) | 0.046       | 3.04 (1.12–7.77) | 0.028       |

**Notes:** Crude model did not adjust for any variables; Model 1 adjusted for age and sex; Model 2 adjusted for age, sex, atrial fibrillation, onset to reperfusion, baseline National Institute of Health Stroke Scale score, baseline Alberta Stroke Program Early Computed Tomography Score, prior intravenous thrombolysis, collateral circulation status, total passes of stent retriever, successful recanalization, vascular occlusion site, stroke etiology, and hyper-sensitive C-reactive protein levels.

**Abbreviations:** CI, confidence interval; MetS, metabolic syndrome; OR, odds ratio.
hamper arterial recanalization and induce vascular re-
occlusion of EVT treatment.8,22 The mortality ratio in
this study was slightly higher in patients with MetS than
those without it (21.9% versus 16.4%). However, the
difference did not reach statistical significance (P = 0.270).
Atherosclerosis may challenge the passage of the
retriever devices to the targeting lesions. Repeated throm-
bectomy may cause intima injury and may be related to
a higher risk for sICH.23 As MetS have been implicated in
the pathophysiology of atherosclerosis,24 we, therefore,
hypothesized that the MetS might be associated with
sICH. However, we also did not find a significant associ-
bation between MetS and sICH rates. This discrepancy prob-
ably was due to the small sample size. Further studies with
large sample size are needed to assess this association.

Obesity, defining based on either waist circumference
or body mass index, is a fundamental component of MetS.
The role of obesity in the prognosis of stroke has been
questioned of debate. A post hoc analysis of the MR
CLEAN trial demonstrated that a shift toward a better
functional outcome with higher body mass index, and
mortality was inversely related to body mass index;25
while some other studies showed no significant favorable
effect, or negative effect of obesity on outcome after
recanalization treatment.26,27 Similarly, our present study
did not find a significant association between increased
waist circumference and clinical outcomes after EVT.
This discrepancy might be due to the differences in study
populations and study methods, especially in the definition
of obesity. On the other hand, our data confirmed the
adverse effect of hyperglycemia on functional outcome in
stroke patients after revascularization therapy. It can cause
intracellular acidosis and mitochondrial dysfunction and
enhance the generation of reactive oxygen species and
extracellular glutamate, which might induce the exaggera-
tion of neuronal damage and disruption of blood-brain
barrier.28–30 These results highlighted the need for further
randomized controlled trials to determine whether the
modulation of blood glucose within an appropriate range
could improve functional outcomes in ischemic stroke
treated with EVT.

The present study has some limitations. First, the study
was performed in one stroke center with 248 patients
treated with EVT, which limited the generalizability of
our results to other populations. Second, the definition of
MetS varies among different studies.10–12 However, the
definition in our study has been widely used in the Asian
population. Third, stress hyperglycemia occurs in
a relatively high proportion of acute stroke patients.
Therefore, it is possible that the blood glucose used for
defining MetS in the present study does not accurately
reflect pre-stroke metabolic status. Finally, some potential
confounders were not available in this study, such as non-
HDL cholesterol, blood pressure variability, and chronic
kidney disease. Our results should be cautiously inter-
preted and replicated in a larger series of patients.

Despite these limitations, the strengths of our study
include using standardized research methods, prospective
design, and recruiting a homogeneous population of EVT
patients, all of which makes this group appropriate for
examining the relationship between MetS and clinical out-
comes. The present study is the first attempt to detect the
effects of MetS and its components on the prognosis of
patients with EVT. Importantly, as a practical consequence
of this observation, the diagnosis of MetS may allow
a prior identification of a subgroup of patients who are
candidates for a more or less postprocedural intensive
management.

In conclusion, our study showed that MetS is asso-
ciated with an increased risk of poor outcome at 90 days
in patients with acute ischemic stroke due to large vessel
occlusion of the anterior circulation and treated with EVT.
Further studies with large patient groups and other popula-
tions are needed to investigate this effect comprehensively.
Potential pathophysiological mechanisms and therapeutic
considerations also remain to be determined.

Data Sharing Statement
The data that support the findings of this study are avail-
able on request from the corresponding author.

Disclosure
The authors report no funding and no conflicts of interest
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