



Original Research

Hemoglobin decline within 24 h post-mechanical thrombectomy as an indicator of poor clinical outcomes

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ABSTRACT

Background: Mechanical thrombectomy (MT) for acute large vessel occlusion (LVO) significantly improves patient prognosis. However, despite successful recanalization achieved through MT, some patients still have unfavorable outcomes. Although anemia in the context of ischemic stroke is recognized as a detrimental prognostic factor, its impact on patients undergoing MT remains inconclusive. Post-MT anemia is frequently a target of intervention, but its prevention is of greater importance. We investigated the extent of hemoglobin (Hb) reduction after MT for acute LVO, its impact on prognosis, and potential preventive strategies.

Methods: The study included 102 patients who underwent MT between January 2016 and December 2022. Hb levels were monitored from admission until day 10 post-MT. We collected data on age, sex, weight, cause of ischemic stroke, location of vessel occlusion, and details regarding MT. The administration of recombinant tissue plasminogen activator, pre-stroke antithrombotic therapy, National Institutes of Health Stroke Scale (NIHSS) score, and presence of chronic kidney disease or chronic heart failure were also recorded. The modified Rankin Scale (mRS) score was assessed on admission and at 3 months follow-up. Factors associated with mRS scores of 3–6 at 3 months were identified.

Results: The highest Hb decrease was noted from admission to 24 h post-MT, with the median Hb level reaching its lowest point on day 4. Poor prognosis was associated with mRS score on admission (odds ratio [OR], 6.94; 95% confidence interval [CI], 1.28–37.60), NIHSS score (OR, 1.14; 95% CI, 1.04–1.25), modified thrombolysis in cerebral infarction 2c–3 recanalization (OR, 0.16; 95% CI, 0.03–0.73), and Hb decrease 24 h post-MT (OR, 2.17; 95% CI, 1.07–4.43). Hb decrease 24 h post-MT was significantly associated with more than two device passes (*p*-value, 0.037).

Conclusions: A decrease in Hb 24 h post-MT was associated with a negative prognosis, with a decrease in Hb being linked to more than two device passes. Efforts should be directed toward optimizing the first-pass effect in MT to enhance procedural efficacy and clinical outcomes.

1. Introduction

Mechanical thrombectomy (MT) for acute large vessel occlusion (LVO) significantly improves patient prognosis. However, despite successful recanalization with MT, some patients experience poor outcomes [1]. Identifying prognostic factors beyond recanalization and optimizing them during the perioperative period may contribute to improved clinical outcomes in patients undergoing MT [2–4].

Anemia is present in approximately 20% of patients with acute

ischemic stroke upon admission [5]. Anemia associated with cerebral infarction has been widely recognized as a poor prognostic factor [6–8]. Previous studies have suggested that baseline anemia and its progression following hospital admission may be associated with poorer outcomes in patients undergoing MT [9–12], although the findings remain inconsistent. Moreover, limited attention has been given to the development of targeted strategies for managing anemia following MT. Although post-MT anemia is often managed with interventions, prevention would be a more effective approach.

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To address this gap, we analyzed the post-MT hemoglobin (Hb) dynamics to determine whether the extent of Hb reduction and the lowest Hb levels are associated with patient prognosis. Additionally, we investigated the factors contributing to Hb decline following MT.

2. Methods

2.1. Ethical statements

This study was approved by the Institutional Review Board of Shimane University Hospital (approval no: 20230221-3). Individual data collected during routine clinical practice were anonymized to eliminate any risk to patient privacy. The Ethics Approval Committee waived the requirement for obtaining informed consent and implemented an opt-out policy. Our study adhered to the ethical principles outlined in the Declaration of Helsinki, ensuring participant confidentiality and conducting research with integrity and respect for the rights of the individuals involved.

2.2. Case collection

This retrospective single-center cohort study enrolled 122 patients who underwent MT at the Shimane University Hospital between January 2016 and December 2022. Seven patients with posterior communicating artery occlusion, anterior cerebral artery occlusion, or spontaneous opening, who only underwent percutaneous transluminal angioplasty, or who required retreatment within 24 h were excluded. Of the remaining 115 patients, three with missing data about Hb on admission were also excluded. After excluding patients with a modified Rankin Scale (mRS) score of 4 or 5 on admission, 102 patients were

finally selected (Fig. 1).

2.3. Data collection

Data on the Hb levels from admission to 10 days post-MT were obtained from the medical records of 102 patients included in our analysis. Additionally, we collected patients' demographic and clinical data, including age, sex, and weight, and documented the underlying causes of ischemic stroke, such as cardioembolism, intracranial atherosclerosis, and others. The location of vessel occlusion was identified as the internal carotid artery (ICA), middle cerebral artery (MCA), basilar artery (BA), or tandem lesions of ICA and MCA. The National Institutes of Health Stroke Scale (NIHSS) score and brain natriuretic peptide (BNP) levels on admission were recorded. Data on the use of recombinant tissue plasminogen activator (rt-PA) and pre-stroke antithrombotic medication were also collected. Additionally, the presence of chronic kidney disease (CKD) and chronic heart failure (CHF) was documented. CKD was defined as an estimated glomerular filtration rate below 60, whereas CHF was defined as a BNP level exceeding 100 on admission. The method of MT was categorized as stent retriever (SR) alone [13], contact aspiration (CA) alone [14], or combined SR and CA [15]. The modified thrombolysis in cerebral infarction (mTICI) score, puncture-to-recanalization (PTR) time, and total number of device passes were obtained. The presence of puncture site bleeding and intracranial hemorrhagic complications, and perioperative infusion volume were recorded. The mRS score was assessed both on admission and 3 months post-MT.

2.4. MT procedure

All procedures were performed via the catheterization through the

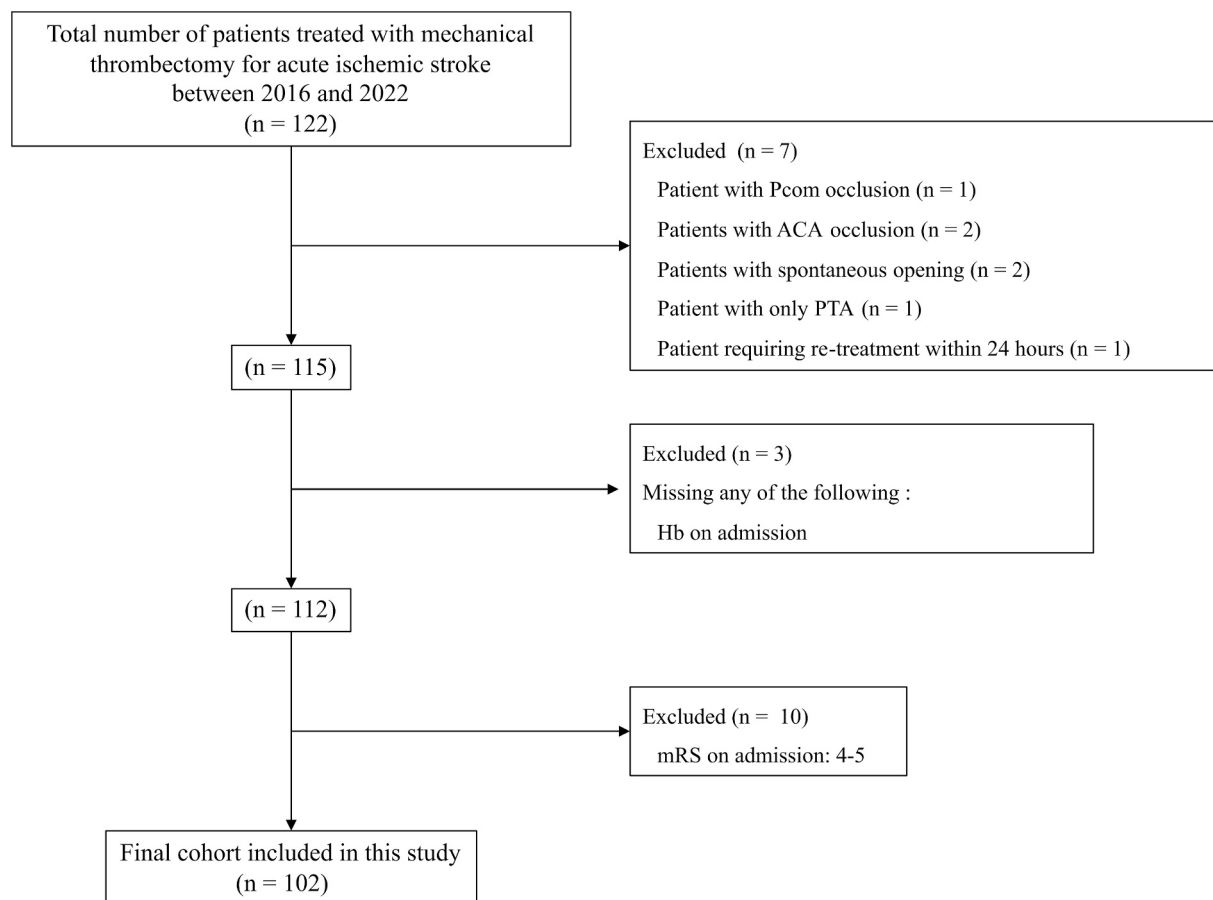


Fig. 1. Flowchart showing the participant selection process. ACA: anterior cerebral artery, Hb: hemoglobin, mRS: modified Rankin scale; Pcom: posterior communicating artery, PTA: percutaneous transluminal angioplasty.

femoral artery. The selection of MT devices approved in Japan was left to the discretion of the operator. Balloon-guiding catheters were routinely employed. MT techniques included SR alone, CA alone, or combined SR and CA, selected based on the operator's preference. All patients underwent MT under local anesthesia, with supplementary conscious sedation administered as needed. Recanalization outcomes following MT were evaluated using the mTICI scale. The rt-PA was administered when clinically indicated. Hemostasis at the arterial puncture site was consistently achieved using either mechanical artery compression or vascular closure devices, followed by the application of sustained pressure dressing and enforced bed rest extending until the first postoperative day. A head computed tomography scan was conducted immediately following MT and repeated the subsequent day to evaluate for intracranial hemorrhagic complications.

2.5. Statistical analyses

Categorical variables were compared using the Fisher's exact probability test. Continuous variables with normal distributions were analyzed using the Student's *t*-test, whereas those with non-normal distributions were analyzed using the Mann-Whitney *U* test. Univariable analysis was performed to identify the factors associated with mRS scores of 3–6 at 3 months post-MT, with a *p*-value of <0.05 indicating significance. Multivariable logistic regression analysis was performed to examine the factors affecting the 3-month mRS score, calculating odds ratios (ORs) and 95 % confidence intervals (CIs). The variables with a *p*-value of <0.05 in the univariable analysis were considered in the multivariable analysis. Furthermore, univariable analysis was performed to determine the factors related to Hb decrease 24 h post-MT. The variance inflation factors (VIFs) for each independent variable were determined as part of the sensitivity analysis. All statistical analyses were conducted using JMP® Pro version 17 software.

3. Results

The highest decrease in Hb levels was observed from admission to 24 h post-MT, with the lowest median Hb level observed on day 4 (Fig. 2).

This study included 102 patients (men: 57.8 %), with a median age of 76 years (interquartile range: 71.0 %–86.3 %). At 3 months post-MT, 27 patients (26.5 %) had an mRS score of 0–2. The primary cause of ischemic stroke was cardioembolism (71.6 %), followed by intracranial atherosclerosis (19.6 %), and other causes (8.8 %). Approximately 30.4 %, 54.9 %, and 9.8 % of the patients showed occlusions in the ICA, MCA, and BA, respectively, whereas 4.9 % developed tandem lesions in the ICA and MCA. The median NIHSS score was 17 (interquartile range: 11–24). The rt-PA and pre-stroke antithrombotic medications were administered in 43.1 % and 35.3 % of patients, respectively. CKD and CHF were detected upon admission in 49.0 % and 63.9 % of the patients, respectively. The median Hb levels were 13.1 g/dL (interquartile range: 11.8–14.3 g/dL) on admission, 11.4 g/dL (interquartile range: 10.3–12.7 g/dL) 24 h post-MT, and 10.5 g/dL (interquartile range: 9.7–12.0 g/dL) 4 days post-MT. Meanwhile, the median levels of Hb decrease were 1.4 g/dL (interquartile range: 0.7–2.1 g/dL) 24 h post-MT and 2.1 g/dL (interquartile range: 1.4–3.0 g/dL) 4 days post-MT (Table 1).

SR alone, CA alone, and combined SR and CA were performed in 17.6 %, 11.8 %, and 70.6 % of the patients, respectively. The mTICI scale 2c–3 recanalization rate was 52.9 %. The median PTR time was 50.5 min (interquartile range: 34.8–83.3 min). The average number of device passes was 1.9. Puncture site bleeding and intracranial hemorrhagic complications occurred in 11.8 % and 24.2 % of cases, respectively. The median perioperative infusion volume was 388 mL (interquartile range: 240–538 mL) (Table 2).

Age, mRS score on admission, NIHSS score on admission, presence of CHF, Hb decrease 24 h post-MT, mTICI scale 2c–3, PTR time, and ≥ 2 device passes were significantly associated with 3-month mRS scores of 3–6 in the univariable analysis (Table 3). In the multivariable analysis,

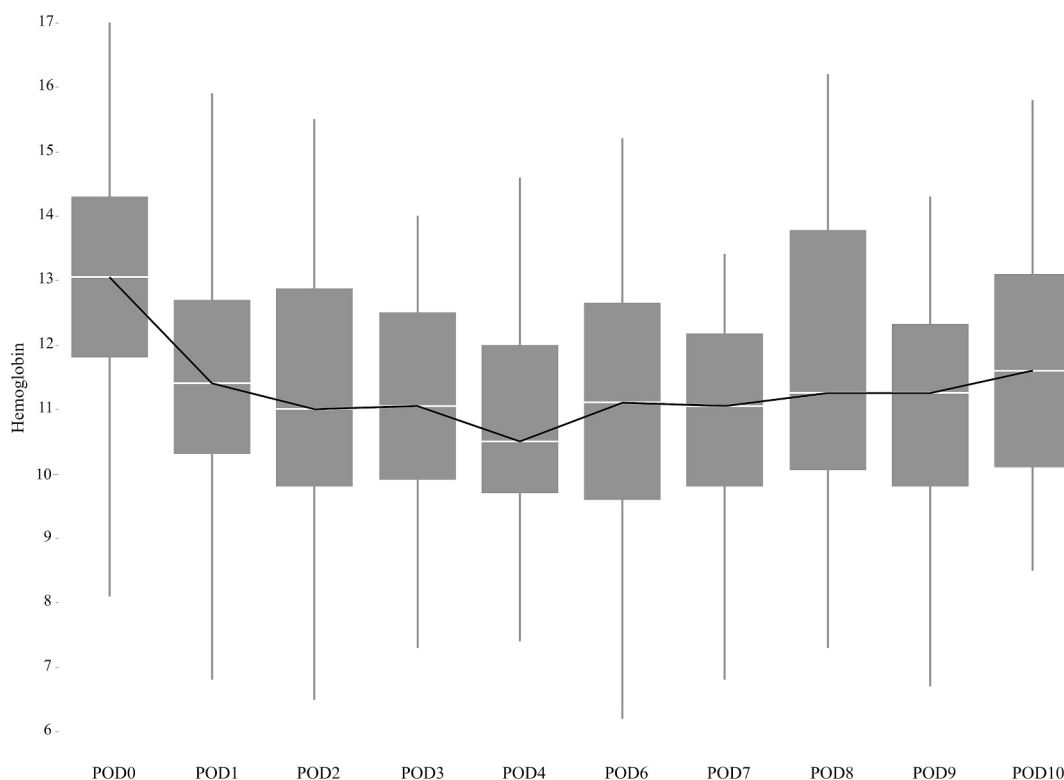


Fig. 2. Changes in Hb levels from admission to 10 days post-MT. The Hb decrease was greatest from admission to 24 h post-MT, and the median Hb level was the lowest on day 4 post-MT. Hb: hemoglobin, MT: mechanical thrombectomy, POD: postoperative day.

Table 1
Baseline characteristics of study participants.

Number	Total patients (n = 102)
Age, median (IQR), year	76 (71.0–86.3)
Sex, male (%)	59 (57.8 %)
Weight, median (IQR), kg	52.1 (46.4–61.6)
mRS score on admission	
0 (%)	66 (64.7 %)
1 (%)	19 (18.6 %)
2 (%)	8 (7.8 %)
3 (%)	9 (8.8 %)
mRS score at 3 months post-MT	
0 (%)	6 (5.9 %)
1 (%)	9 (8.8 %)
2 (%)	12 (11.8 %)
3 (%)	20 (19.6 %)
4 (%)	27 (26.5 %)
5 (%)	18 (17.6 %)
6 (%)	10 (9.8 %)
Cause of ischemic stroke	
Cardioembolism (%)	73 (71.6 %)
Intracranial atherosclerosis (%)	20 (19.6 %)
Other (%)	9 (8.8 %)
Location of vessel occlusion	
Internal cerebral artery (%)	31 (30.4 %)
Middle cerebral artery (%)	56 (54.9 %)
Basilar artery (%)	10 (9.8 %)
Tandem lesions (%)	5 (4.9 %)
NIHSS score on admission, median (IQR)	17 (11–24)
Presence of rt-PA (%)	44 (43.1 %)
Pre-stroke antithrombotic medication (%)	36 (35.3 %)
Presence of chronic kidney disease (%)	50 (49.0 %)
Presence of chronic heart failure (%)	62 (63.9 %)
Hb, median (IQR), g/dL	
Hb levels on admission	13.1 (11.8–14.3)
Hb levels 24 h post-MT	11.4 (10.3–12.7)
Hb levels 4 days post-MT	10.5 (9.7–12.0)
Hb decrease 24 h post-MT	1.4 (0.7–2.1)
Hb decrease 4 days post-MT	2.1 (1.4–3.0)

Hb: hemoglobin; IQR: interquartile range; mRS: modified Rankin Scale; MT: mechanical thrombectomy; NIHSS: National Institutes of Health Stroke Scale; rt-PA: recombinant tissue plasminogen activator; SD: standard deviation

Table 2
Baseline characteristics of the mechanical thrombectomy methods used in the study.

Number	Total patients (n = 102)
Method of MT	
Stent retriever alone (%)	18 (17.6 %)
Contact aspiration alone (%)	12 (11.8 %)
Combined stent retriever and aspiration (%)	72 (70.6 %)
mTICI scale	
0 (%)	1 (1.0 %)
1 (%)	7 (6.9 %)
2a (%)	8 (7.8 %)
2b (%)	32 (31.4 %)
2c (%)	9 (8.8 %)
3 (%)	45 (44.1 %)
PTR time, median (IQR), min	50.5 (34.8–83.3)
Total number of device passes, mean (SD), times	1.9 (\pm 1.2)
Puncture site bleeding (%)	12 (11.8 %)
Intracranial hemorrhagic complication	
Intracerebral hemorrhage (%)	14 (13.7 %)
Subarachnoid hemorrhage (%)	11 (10.8 %)
Perioperative infusion volume, median (IQR), mL	388 (240–538)

IQR: interquartile range; MT: mechanical thrombectomy; mTICI: modified thrombolysis in cerebral infarction; PTR: Puncture-to-recanalization; SD: standard deviation.

the 3-month mRS scores of 3–6 were associated with the mRS score on admission (OR, 6.94; 95 % CI, 1.28–37.60), NIHSS score on admission (OR, 1.14; 95 % CI, 1.04–1.25), Hb decrease 24 h post-MT (OR, 2.17; 95 % CI, 1.07–4.43), and mTICI scale 2c–3 (OR, 0.16; 95 % CI, 0.03–0.73)

(Table 3).

The univariable analysis revealed that two or more device passes were significantly associated with Hb decrease 24 h post-MT (p -value, 0.037). Hemorrhagic complications related to MT, including access site bleeding and intracranial hemorrhage, were not significantly associated with Hb decrease 24 h post-MT. Moreover, perioperative infusion volume was likewise not associated with Hb decline (Table 4). Sensitivity analysis demonstrated that the VIF for all parameters remained below 3, indicating a minimal probability of multicollinearity.

4. Discussion

The study aimed to identify the anemia index with the most significant prognostic effect on patients with LVO undergoing MT. We observed that the decrease in Hb levels was the highest from admission to 24 h post-MT, with the lowest median Hb level observed on day 4. The Hb decrease 24 h post-MT was associated with poorer prognosis. Additionally, this decrease in Hb levels 24 h post-MT correlated with the occurrence of ≥ 2 device passes.

In previous studies examining anemia in patients undergoing MT for LVO, the prognostic factors related to anemia varied: anemia upon admission [12,16,17], Hb levels within 24 h [11], and Hb nadir within 5 days post-MT [10]. Our findings suggest that a reduction in Hb levels within 24 h following MT is a significant prognostic factor. Cerebral oxygen delivery is influenced by cerebral blood flow, Hb levels, and arterial oxygen saturation levels [12]. Brain oxygenation can be maintained even when Hb decreases to approximately 8 g/dL in healthy individuals [18]; however, this may not be the case in patients who experience stroke, as cerebral autoregulation is often compromised. Despite reperfusion being achieved through MT for LVO, impaired cerebral autoregulation persists [18]. Furthermore, anemia may have a significant impact on the extensive penumbra resulting from LVO [19]. Additionally, variations in the development of collateral circulation among patients make it challenging to directly correlate absolute Hb values with prognosis. Although the effect of anemia on stroke outcomes has been extensively investigated, the effectiveness of and criteria for blood transfusion remain inconclusive [20]. This uncertainty may be partly owing to the influence of various factors beyond anemia, such as the extent of the penumbra, the degree of collateral vascular development, pneumonia, urinary tract infections, heart failure, and diabetes, on stroke prognosis. Therefore, the management of stroke-related anemia during the perioperative phase should prioritize preventing post-treatment Hb decrease, rather than focus solely on the presence of anemia on admission or treatment through blood transfusion. Various methods for preventing post-treatment Hb loss should be explored.

In our study, the number of device passes correlated with an Hb decrease within 24 h post-MT, with patients requiring only one pass experiencing a smaller decrease. Given that MT inherently involves some degree of blood loss, an increased number of device passes likely exacerbated blood loss and contributed to the progression of anemia. The utilization of a balloon guide catheter has been shown to potentially enhance the first-pass effect [21] and should be prioritized when catheter navigation is feasible. The combined techniques (stent retrievers with aspiration) do not improve neuroprognosis or recanalization rates but demonstrate a better first-pass effect [22], which may help reduce postoperative anemia. In our study, the lack of increased first-pass success in the use of combined techniques may be attributed to the inclusion of patients utilizing older aspiration catheter models. Moreover, the aspiration catheter should be selected with the largest feasible diameter, considering vessel caliber and distal accessibility, to maximize suction efficacy, which is crucial for enhancing the first-pass effect [23]. Additionally, preoperative hyperdense signs on head computed tomography imaging [24] and susceptibility vessel signs on magnetic resonance imaging [25] can aid in thrombus localization and adjustment of the stent and suction catheter position for an optimal first pass. Hemodilution with replacement fluid may contribute to Hb reduction [26]. In

Table 3
Factors associated with the 3-month mRS scores of 3–6.

Factor	Univariable analysis			Multivariable analysis	
	mRS 0–2 n = 27	mRS 3–6 n = 75	p-value	Odds ratios (95 % CI)	p-value
Age, median (IQR), year	74 (70–81)	77 (72–88)	0.022*	1.02 (0.94–1.12)	0.615
Sex, male (%)	19 (70.4 %)	40 (53.3 %)	0.087		
mRS score on admission			0.008*	6.94 (1.28–37.60)	0.025*
0 (%)	24 (88.9 %)	42 (56.0 %)			
1 (%)	3 (11.1 %)	16 (21.3 %)			
2 (%)	0 (0 %)	8 (10.7 %)			
3 (%)	0 (0 %)	9 (12.0 %)			
Cause of ischemic stroke			0.239		
Cardioembolism (%)	19 (67.9 %)	54 (73.0 %)			
Intracranial atherosclerosis (%)	8 (28.6 %)	12 (16.2 %)			
Other (%)	1 (3.6 %)	8 (10.8 %)			
Location of vessel occlusion			0.165		
Internal cerebral artery (%)	4 (14.3 %)	27 (36.5 %)			
Middle cerebral artery (%)	18 (64.3 %)	38 (51.4 %)			
Basilar artery (%)	4 (14.3 %)	6 (8.1 %)			
Tandem lesions (%)	2 (7.1 %)	3 (4.1 %)			
Baseline NIHSS score, median (IQR)	13 (9–18)	19 (12–25)	0.012*	1.14 (1.04–1.25)	0.005*
Presence of rt-PA (%)	16 (57.1 %)	28 (37.8 %)	0.079		
Pre-stroke antithrombotic medication (%)	9 (32.1 %)	27 (36.5 %)	0.682		
Presence of chronic kidney disease (%)	14 (50.0 %)	36 (48.7 %)	0.903		
Presence of chronic heart failure (%)	12 (46.2 %)	50 (70.4 %)	0.028*	2.44 (0.56–10.63)	0.237
Hb, median (IQR), g/dL					
Hb levels on admission	13.3 (11.7–13.9)	13.0 (11.8–14.3)	0.642		
Hb levels 4 days post-MT	11.5 (9.9–12.7)	10.4 (9.7–11.6)	0.162		
Hb decrease 24 h post-MT	0.5 (0.1–1.6)	1.6 (1.1–2.2)	0.002*	2.17 (1.07–4.43)	0.003*
Method of MT			0.471		
Stent retriever alone (%)	4 (14.8 %)	14 (18.7 %)			
Contact aspiration alone (%)	5 (18.5 %)	7 (9.3 %)			
Combined (%)	18 (66.7 %)	54 (72.0 %)			
mTICI scale 2c-3 (%)	22 (78.6 %)	32 (43.2 %)	0.001*	0.16 (0.03–0.73)	0.002*
PTR time, median (IQR), min	39 (30–55)	66 (37–95)	0.009*	1.01 (0.98–1.05)	0.461
Total number of device passes					
More than two times (%)	9 (32.1 %)	43 (58.1 %)	0.019*	6.11 (0.98–38.27)	0.053
Addition of PTA (%)	5 (17.9 %)	8 (10.8 %)	0.341		
Intracranial hemorrhagic complication (%)	3 (12.0 %)	22 (88.0 %)	0.059		

Hb: hemoglobin; IQR: interquartile range; mRS: modified Rankin Scale; MT: mechanical thrombectomy; mTICI: modified thrombolysis in cerebral infarction; NIHSS: National Institutes of Health Stroke Scale; PTA: percutaneous transluminal angioplasty; PTR: puncture-to-recanalization; rt-PA: recombinant tissue plasminogen activator; SD: standard deviation

Table 4
Factors associated with hemoglobin decline within 24 h.

Factor	Univariable analysis	
	p-value	VIF
Age	0.834	2.24
Sex	0.870	1.65
Weight	0.681	1.70
Cause of ischemic stroke	0.949	1.98
Location of vessel occlusion	0.830	1.62
Presence of rt-PA	0.792	1.35
Pre-stroke antithrombotic medication	0.442	1.14
Presence of chronic kidney disease	0.991	1.28
Presence of chronic heart failure	0.849	1.85
Method of MT	0.701	2.96
PTR time	0.070	1.84
Total number of device passes		
More than two times	0.037*	1.71
Puncture site bleeding	0.756	1.35
Intracranial hemorrhagic complication	0.777	1.27
Perioperative infusion volume	0.089	1.24

MT: mechanical thrombectomy; PTR: puncture-to-recanalization; rt-PA: recombinant tissue plasminogen activator; VIF: variance inflation factor.

contrast, in our study, we found no significant association between perioperative infusion volume and Hb decrease 24 h post-MT. However, it is important to acknowledge that the volume of heparinized saline administered via pressurized infusion bags during MT was not quantitatively assessed in this study, potentially leading to an underestimation of the total infused fluid volume. Furthermore, preventing anemia due to

hemodilution remains challenging, as the appropriate fluid volume varies among patients. Hemorrhage at the vascular access site may also represent a contributory factor to Hb decrease post-MT. Compared to the radial artery approach outcome, femoral artery access combined with heparin anticoagulation has been associated with a higher incidence of major bleeding events [27]. However, in our study, access site hemorrhage did not demonstrate a significant correlation with Hb decrease following MT. This outcome may be attributed to the standardized application of hemostatic measures at the puncture site, including mechanical compression of the femoral artery or utilization of vascular closure devices, followed by sustained pressure dressing, and enforced bed rest extending through the first postoperative day. As a result, even when bleeding at the access site occurred, it was limited to minor subcutaneous hematomas in this study. Additionally, intracranial hemorrhagic complications post-MT may also influence hemoglobin decline [28]. Nevertheless, in our cohort, the occurrence of such complications was not associated with a significant decrease in hemoglobin levels. The lack of complications was likely owing to the localized nature of all subarachnoid hemorrhages and the predominantly minor extent of intracerebral hemorrhages, none of which required surgical hematoma evacuation.

5. Conclusions

A reduction in Hb levels at 24 h post-MT was associated with a poorer prognosis, with a greater Hb decline observed in patients requiring more than two device passes. Optimizing the first-pass effect in MT should be prioritized to improve procedural efficacy and clinical

outcomes.

6. Limitations

This study has some limitations. First, its single-center study design and small sample size may limit statistical power. Second, the underlying cause of anemia was not determined, and potential confounding factors may have been present. Third, the effects of hemodilution resulting from the infusion of heparinized normal saline during MT and variations in MT techniques were not adjusted. Fourth, other adverse prognostic factors in patients who underwent MT for LVO may not have been considered in this study.

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CRediT authorship contribution statement

Masahiro Uchimura: Writing – original draft, Visualization, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Tomohiro Yamasaki:** Writing – review & editing, Formal analysis, Data curation. **Mizuki Kambara:** Writing – review & editing, Formal analysis, Data curation. **Tsutomu Yoshikane:** Writing – review & editing, Formal analysis, Data curation. **Tomomi Kimiwada:** Writing – review & editing, Supervision, Formal analysis, Data curation. **Kentaro Hayashi:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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None.

Data availability statement

The corresponding author may share anonymized data from the present study upon request from a qualified researcher. Additionally, data can be obtained upon request following the Institutional Review Board review committee.

References

- Goyal M, Menon BK, van Zwam WH, Dippel DW, Mitchell PJ, Demchuk AM, et al. Endovascular thrombectomy after large-vessel ischaemic stroke: a meta-analysis of individual patient data from five randomised trials. *Lancet* 2016;387:1723–31. [https://doi.org/10.1016/S0140-6736\(16\)00163-X](https://doi.org/10.1016/S0140-6736(16)00163-X).
- Jadhav AP, Molyneaux BJ, Hill MD, Jovin TG. Care of the post-thrombectomy patient. *Stroke* 2018;49:2801–7. <https://doi.org/10.1161/STROKEAHA.117.020273>.
- Krishnan R, Mays W, Eljovich L. Complications of mechanical thrombectomy in acute ischemic stroke. *Neurology* 2021;97:S115–25. <https://doi.org/10.1212/WNL.00000000000012803>.
- Simonsen CZ, Bösel J, Rasmussen M. Periprocedural management during stroke thrombectomy. *Neurology* 2021;97:S105–14. <https://doi.org/10.1212/WNL.00000000000012798>.
- Li Z, Zhou T, Li Y, Chen P, Chen L. Anemia increases the mortality risk in patients with stroke: a meta-analysis of cohort studies. *Sci Rep* 2016;6:26636. <https://doi.org/10.1038/srep26636>.
- Barlas RS, Honney K, Loke YK, McCall SJ, Bettencourt-Silva JH, Clark AB, et al. Impact of hemoglobin levels and anemia on mortality in acute stroke: analysis of UK regional registry data, systematic review, and meta-analysis. *J Am Heart Assoc* 2016;5:e003019. <https://doi.org/10.1161/JAHA.115.003019>.
- Khan MF, Shamael I, Zaman Q, Mahmood A, Siddiqui M. Association of anemia with stroke severity in acute ischemic stroke patients. *Cureus* 2018;10:e2870.
- Heo J, Youk TM, Seo KD. Anemia is a risk factor for the development of ischemic stroke and post-stroke mortality. *J Clin Med* 2021;10:2556. <https://doi.org/10.3390/jcm10122556>.
- Nisar T, Lebioda K, Shaulov S, Shapouran S, Abu-Hadid O, Tofade T, et al. Interplay between anemia parameters and collateral status in patients who undergo mechanical thrombectomy. *J Clin Neurosci* 2022;104:34–41. <https://doi.org/10.1016/j.jocn.2022.07.021>.
- Nisar T, Shapouran S, Abu-Hadid O, Shaulov S, Tofade T, Patel J, et al. Association of anemia with functional outcomes in patients with mechanical thrombectomy. *Clin Neurol Neurosurg* 2021;211:107028. <https://doi.org/10.1016/j.clineuro.2021.107028>.
- Inui R, Koge J, Tanaka K, Yoshimoto T, Shiozawa M, Abe S, et al. Detrimental effect of anemia after mechanical thrombectomy on functional outcome in patients with ischemic stroke. *Front Neurol* 2023;14:1299891. <https://doi.org/10.3389/fneur.2023.1299891>.
- Akpınar CK, Gurkas E, Aytac E. Moderate to severe anemia is associated with poor functional outcome in acute stroke patients treated with mechanical thrombectomy. *Interv Neurol* 2018;7:12–8. <https://doi.org/10.1159/000480642>.
- Nguyen TN, Malisch T, Castonguay AC, Gupta R, Sun CH, Martin CO, et al. Balloon guide catheter improves revascularization and clinical outcomes with the solitaire device: analysis of the North American solitaire acute stroke registry. *Stroke* 2014;45:141–5. <https://doi.org/10.1161/STROKEAHA.113.002407>.
- Turk AS, Spiotta A, Frei D, Mocco J, Baxter B, Fiorella D, et al. Initial clinical experience with the ADAPT technique: a direct aspiration first pass technique for stroke thrombectomy. *J Neurointerv Surg* 2018;10:i20–5. <https://doi.org/10.1136/neurintsurg-2013-010713>.
- Massari F, Henninger N, Lozano JD, Patel A, Kuhn AL, Howk M, et al. ARTS (aspiration-retriever technique for stroke): initial clinical experience. *Interv Neuroradiol* 2016;22:325–32. <https://doi.org/10.1177/1591019916632369>.
- Pienimäki JP, Protto S, Hakomäki E, Jolma P, Sillanpää N. Anemia predicts poor clinical outcome in mechanical thrombectomy patients with fair or good collateral circulation. *Cerebrovasc Dis Extra* 2020;10:139–47. <https://doi.org/10.1159/000510228>.
- Fujiwara S, Sakai N, Imamura H, Ohara N, Tanaka K, Yamagami H, et al. Association between anemic status on admission and clinical outcomes of acute large vessel occlusion. *J Neurol Sci* 2022;440:120343. <https://doi.org/10.1016/j.jns.2022.120343>.
- Huang WY, Chen IC, Meng L, Weng WC, Peng TI. The influence of anemia on clinical presentation and outcome of patients with first-ever atherosclerosis-related ischemic stroke. *J Clin Neurosci* 2009;16:645–9. <https://doi.org/10.1016/j.jocn.2008.08.014>.
- Hsiao KY, Hsiao CT, Lin LJ, Shiao CJ, Chen IC. Severe anemia associated with transient ischemic attacks involving vertebrobasilar circulation. *Am J Emerg Med* 2008;26(382):e3–4. <https://doi.org/10.1016/j.ajem.2007.05.028>.
- Desai A, Oh D, Rao EM, Sahoo S, Mahajan UV, Labak CM, et al. Impact of anemia on acute ischemic stroke outcomes: a systematic review of the literature. *PLoS One* 2023;18:e0280025. <https://doi.org/10.1371/journal.pone.0280025>.
- Bai X, Zhang X, Wang J, Zhang Y, Dmytriw AA, Wang T, et al. Factors influencing recanalization after mechanical thrombectomy with first-pass effect for acute ischemic stroke: a systematic review and meta-analysis. *Front Neurol* 2021;12:628523. <https://doi.org/10.3389/fneur.2021.628523>.
- Di Maria F, Kyheng M, Consoli A, Desilles JP, Gory B, Richard S, et al. Identifying the predictors of first-pass effect and its influence on clinical outcome in the setting of endovascular thrombectomy for acute ischemic stroke: results from a multicentric prospective registry. *Int J Stroke* 2021;16:20–8. <https://doi.org/10.1177/1747493020923051>.
- Pérez-García C, Maegerlein C, Rosati S, Rütger C, Gómez-Escalonilla C, Zimmer C, et al. Impact of aspiration catheter size on first-pass effect in the combined use of contact aspiration and stent retriever technique. *Stroke Vasc Neurol* 2021;6:553–60. <https://doi.org/10.1136/svn-2020-000833>.
- Gharaibeh K, Aladamat N, Samara M, Mierzwa AT, Ali A, Zaidi S, et al. Hyperdense sign as a predictor for successful recanalization and clinical outcome in acute ischemic stroke: a systematic review and meta-analysis. *Interv Neuroradiol* 2024. <https://doi.org/10.1177/15910199241235431>. 15910199241235431.
- Kanamoto T, Tateishi Y, Yamashita K, Furuta K, Torimura D, Tomita Y, et al. Impact of width of susceptibility vessel sign on recanalization following endovascular therapy. *J Neurol Sci* 2023;446:120583. <https://doi.org/10.1016/j.jns.2023.120583>.
- Bellwald S, Balasubramaniam R, Nagler M, Burri MS, Fischer SDA, Hakim A, et al. Association of anemia and hemoglobin decrease during acute stroke treatment with infarct growth and clinical outcome. *PLoS One* 2018;13:e0203535. <https://doi.org/10.1371/journal.pone.0203535>.
- Bagai J, Little B, Banerjee S. Association between arterial access site and anticoagulation strategy on major bleeding and mortality: a historical cohort analysis in the veteran population. *Cardiovasc Revasc Med* 2018;19:95–101. <https://doi.org/10.1016/j.carrev.2017.06.005>.
- Roh DJ, Poyraz FC, Mao E, Shen Q, Kansara V, Cottarelli A, et al. Anemia from inflammation after intracerebral hemorrhage and relationships with outcome. *J Am Heart Assoc* 2024;13:e035524. <https://doi.org/10.1161/JAHA.124.035524>.