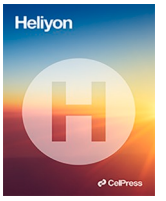
Heliyon 10 (2024) e26854

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

Risk factors for hemorrhage in patients with long-term aspirin therapy undergoing emergency external ventricular drainage/ intracranial pressure probe placement

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ARTICLE INFO

Keywords:
Aspirin
Thromboelastography
Platelet inhibition rate
External ventricular drainage
Intracranial pressure
Hemorrhage

ABSTRACT

Background: Studies have been inconclusive on the risk for hemorrhage in patients with a history of aspirin use who underwent emergency external ventricular drainage (EVD)/intracranial pressure (ICP) probe placement. The aim of this study was to explore hemorrhage-related risk factors in order to reduce the risk for hemorrhage in these patients.

Methods: Between July 2014 and July 2020, patients were retrospectively divided into EVD/ICP-related hemorrhage and non-hemorrhage groups. The collected data included age, gender, major diagnosis, medical history, imaging examinations, conventional coagulation test data, thromboelastography with platelet mapping (TEG-PM), surgical procedures and discharge conditions.

Results: In total 94 patients, 21 in the hemorrhage group (15 males, 6 females) and 73 in the non-hemorrhage group (52 males, 21 females) were included. The majority of hemorrhages were recorded in EVD patients (19/21; 90.5%). Platelet AA pathway inhibition rate of ≥75% (sensitivity: 79.45% specificity: 52.38%) ($P = 0.014$) and SBP ≥125 mmHg ($P = 0.006$) were significantly related to hemorrhage. When the platelet AA pathway inhibition rate was ≥75% and the during-procedure SBP was ≥125 mmHg, the hemorrhage rate was significantly higher (83.3%) than with SBP <125 mmHg (6.7%) ($P < 0.001$). When the inhibition rate was <75%, there were no significant differences in the hemorrhage rates between the during-procedure SBP ≥125 mmHg group (17.2%) and the SBP <125 mmHg group (13.2%) ($P > 0.05$). Multivariate logistic regression analysis revealed that a platelet AA pathway inhibition rate ≥75% (OR = 5.183, 95% CI: 1.683–15.960) and during-procedure SBP ≥125 mmHg (OR = 4.609, 95% CI: 1.466–14.484) were independent risk factors for EVD/ICP-related hemorrhage.

Conclusion: Patients with long-term aspirin therapy, a platelet AA pathway inhibition rate ≥75% and during-procedure SBP ≥125 mmHg had a significantly higher risk of hemorrhage, which could be reduced by adjusting the SBP to <125 mmHg.

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https://doi.org/10.1016/j.heliyon.2024.e26854
Received 16 December 2023; Received in revised form 21 February 2024; Accepted 21 February 2024
Available online 28 February 2024

1. Introduction

As an anti-platelet drug, aspirin is widely used for the prevention and treatment of cardiovascular and cerebrovascular diseases [1]. The Expert Consensus on the Use of Aspirin in Primary Prevention of Cardiovascular Diseases in China provided recommendations for the use of aspirin as a primary drug to prevent atherosclerotic cardiovascular diseases in the Chinese population [2]. Therefore, the use of low-dose aspirin for the prevention of cardiovascular diseases is quite common and its antithrombotic effect by inhibiting platelet aggregation significantly reduces the risk of death associated with cerebrovascular accidents [3–5]. However, surgical intervention preceding any medical therapy is indicated for patients who develop acute increased intracranial pressure due to traumatic brain injury (TBI), spontaneous intracerebral hemorrhage (sICH) or massive cerebral infarction (MCI) [6]. However, aspirin induced inhibition of platelet function does not recover immediately after its withdrawal [7], therefore diminished coagulation may increase the risk of hemorrhage and re-hemorrhage after surgery [8,9].

The conventional coagulation test does not accurately reflect platelet dysfunction caused by aspirin and cannot provide an accurate and effective reference for the risk of hemorrhage during emergency external ventricular drainage (EVD)/intracranial pressure (ICP) probe placement in patients with a history of long-term aspirin therapy [10]. In contrast, thrombelastography with platelet mapping (TEG-PM) can provide comprehensive information on coagulation, fibrinolysis and platelet function by simulating platelet aggregation, coagulation and fibrinolysis [11,12]. Combined with conventional coagulation test data, TEG-PM can reflect the physical coagulation function more accurately and effectively and plays an important role in platelet function assessment and treatment decision making in patients using aspirin.

Existing studies have been inconclusive on the risk of hemorrhage in patients with a history of aspirin use who underwent emergency EVD/ICP probe placement [13]. The aims of the present study were to evaluate the risk of hemorrhage in patients using aspirin therapy who underwent emergency EVD/ICP probe placement, by combining TEG-PM with conventional coagulation test data. Related risk factors were also explored in order to improve the safety of the procedure and reduce the incidence of hemorrhagic complications.

2. Methods

2.1. Patients

2.1.1. Study population

A total of 94 patients who received long-term aspirin therapy and emergency EVD/ICP probe placement in the neurosurgery department of Tangdu Hospital from July 2014 to July 2020 were included in the study. Patients were divided into hemorrhage and non-hemorrhage groups according to whether the EVD/ICP procedures caused hemorrhage or not.

The study was approved by the Biological and Medical Ethics Committee of Tangdu Hospital (No. TDLL-KY-202011-01) and all patients provided signed informed consent before receiving treatment.

2.1.2. Inclusion and exclusion criteria

The inclusion criteria were [1]: patients >18 years old [2]; a clear history of aspirin use before admission [3]; patients who received the TEG-PM test after admission [4]; mainly diagnosed as having TBI, sICH or MCI; and [5] patients who received emergency EVD/ICP probe placement. The exclusion criteria were [1]: hemorrhage caused by aneurysm, arteriovenous malformation or moyamoya disease [2]; patients with idiopathic thrombocytopenic purpura or hemophilia [3]; severe liver and renal insufficiency or vital organ failure; and [4] incomplete imaging examination data.

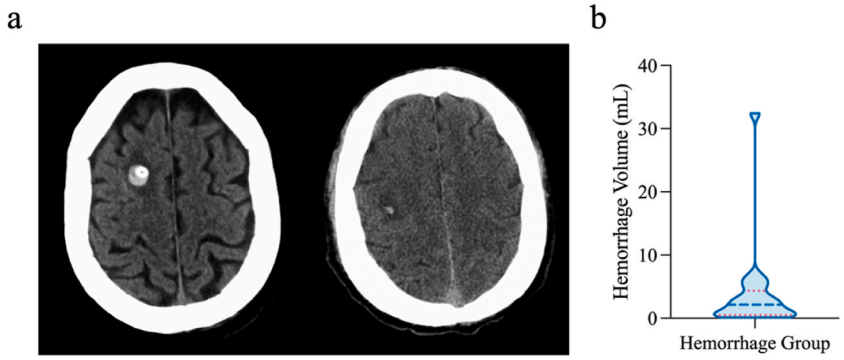

Fig. 1. Representative CT images of hemorrhages caused by EVD/ICP probe placement a) CT images of examples of hemorrhage caused by EVD placement (left) and ICP probe placement (right); b) violin diagram of hemorrhage volumes in the hemorrhage group showing the hemorrhage volume ranged from 0.10 mL to 32.40 mL (average 3.71 ± 6.89 mL).

2.2. Assessment indicators and measurements

2.2.1. TEG-PM

TEG-PM was carried out by the blood transfusion department of Tangdu Hospital using a TEG-PM analyzer (Hemoscope model 5000, USA). For patients with a history of anticoagulant therapy, TEG-PM was performed on admission. The blood sample was extracted and transferred to the blood transfusion department within half an hour, and TEG-PM data were available after approximately an hour of testing. The measurements included the inhibition rate of the AA pathway and the R, K, Angle, MA, CI and LY30 values.

2.2.2. Hemorrhage and blood loss

The CT data of the patients included the admission time, pre-intervention, intervention and after drainage/probe removal periods. By comparing the images at these specific time points, the origin of bleeding was determined and hemorrhage and blood loss in the puncture passage assessed (Fig. 1a).

Blood loss was calculated using the multi-field formula:

$$\mathrm{V\ (blood\ loss, mL)} = \mathrm{A\ (cm)} \times \mathrm{B\ (cm)} \times \mathrm{C\ (cm)} \times 1/2.$$

A, the longest diameter of the hematoma at the level of the maximum hematoma area; B, the longest diameter perpendicular to the longest diameter at the level of maximum hematoma area; C, the multiplied number of layers with hematoma on the CT image (Fig. 1a).

2.2.3. Surgical procedure

All procedures were performed by qualified and experienced neurosurgeons. The entire procedure lasted approximately 30 min, and blood pressure was monitored during the procedure using a noninvasive blood pressure cuff with an interval of 5 min.

2.2.4. EVD placement

The majority of EVD placements were performed through the frontal region. The entry point was located 2 cm in front of the coronal joint, 3 cm from the midline. After skin preparation, disinfection and anesthesia, the scalp was cut and a small opening made in the skull using a cranial drill. An incision was made in the dura and the trajectory was in the mid pupillary line and halfway between the tragus and lateral canthus. An EVD catheter was inserted to a depth of 5–7 cm. The proximal catheter was then tunneled subcutaneously through a separate posterior stab incision and secured to the scalp.

2.2.5. ICP probe placement

The ICP monitoring system was calibrated before placement. The entry point was located 2 cm in front of the coronal joint, 3 cm from the midline. After skin preparation, disinfection and anesthesia, the scalp was cut and a small opening made in the skull using a cranial drill. An incision was made in the dura and the ICP probe was carefully inserted into the brain parenchyma to a depth of approximately 2 cm. Then, the proximal ICP probe was secured and connected to the intracranial pressure detector.

2.3. Outcomes

The risk factors of patients in the EVD/ICP-related hemorrhage group was evaluated to analyze various parameters including medical history, imaging examination results, conventional coagulation test data, TEG-PM data, and surgical procedures in the EVD/ICP-related hemorrhage group.

2.4. Statistical analysis

SPSS ver. 26.0 statistical software was used for data analysis. Measurement data are expressed as the mean ± standard deviation (SD). An independent sample *t*-test was used to look for differences between two groups of data with normal distributions, and for data with a non-normal distribution a non-parametric test was employed. Counting data are given as frequencies and percentages. A chi-squared test was used for comparison between groups and univariate and multivariate logistic regression analyses were conducted in order to identify variables predictive for hemorrhage. The optimal cut-off points based on ROC accuracy were then applied to test accuracy in predicting these indicators. A *P*-value <0.05 was considered to be a statistically significant finding.

3. Results

3.1. Comparison of baseline data between hemorrhage and non-hemorrhage groups

Among the patients hospitalized in the neurosurgery department of Tangdu Hospital from July 2014 to July 2020, 94 patients were included for retrospective analyses, with 21 in the hemorrhage group (15 males and 6 females) and 73 in the non-hemorrhage group (52 males and 21 females). Among the 21 patients in the hemorrhage group, the maximum hemorrhage volume was 32.40 mL, the minimum 0.10 mL and the average 3.71 ± 6.89 mL (Fig. 1b). There were no statistically significant differences between the two groups

with regard to age, sex, admission Glasgow Coma Scale (GCS), major diagnosis, or the medical history (Table 1).

3.2. Comparison of conventional coagulation test data and TEG-PM data between the hemorrhage and non-hemorrhage groups

The hemorrhage rate of patients in the group with a platelet AA pathway inhibition rate ≥75% was significantly higher than in the group with an inhibition rate <75% ($P = 0.014$) (Table 2). The cut-off value of platelet AA pathway inhibition rate is 75.60%, with a sensitivity of 79.45% and specificity of 52.38%. The area under the ROC curve, along with a 95% confidence interval, is shown on Supplementary Fig. 1a. There were no statistically significant differences in other coagulation parameters between the two groups.

3.3. Comparison of peri-procedural conditions of patients in the hemorrhage and non-hemorrhage groups

The hemorrhage rate in 94 patients who received long-term aspirin and emergency EVD/ICP probe placement was 22.3%. In the hemorrhage group, 20 of 21 patients hemorrhage volumes ranged from 0.01 mL to 6.81 mL (2.27 ± 2.07 mL), while a large hemorrhage (32.40 mL) occurred in 1 patient. None of the hemorrhages caused significant clinical symptoms.

Since it is not possible to determine the specific impact of systolic blood pressure at a particular moment during surgery on the risk of hemorrhage, we utilized the average intraoperative systolic blood pressure as a parameter to reflect the overall status of systolic blood pressure during the procedure. There were statistically significant differences in during-procedure SBP and hemorrhage rates caused by different implants between the two groups (Table 3). In the hemorrhage group, the during-procedure SBP was significantly higher than that in the non-hemorrhage group ($P = 0.019$). 71.4% of the patients in the hemorrhage group had during-procedure SBP ≥125 mmHg and 64.4% in the non-hemorrhage group had during-procedure SBP <125 mmHg ($P = 0.006$). The cut-off value of SBP is 124.5, with a sensitivity of 0.75 and specificity of 0.66. The area under the ROC curve, along with a 95% confidence interval, is shown on Supplementary Fig. 1b. The hemorrhage rate caused by EVD catheter placement (20.2%) was significantly higher than that caused by ICP probe placement (2.1%) ($P < 0.001$). There were no statistically significant differences between the two groups in placement sites, and during-procedure diastolic blood pressure (DBP).

3.4. Comparison of discharge conditions between hemorrhage and non-hemorrhage groups

There were no statistically significant differences for in-hospital mortality, discharge GCS, tracheotomy rates, length of ICU stay, total length of stay, and total hospitalization costs between the two groups (Table 4).

3.5. The influence of during-procedure SBP on the hemorrhage rate under different platelet AA pathway inhibition rates

When the platelet AA pathway inhibition rate was ≥75%, the hemorrhage rate of the during-procedure SBP ≥125 mmHg group (83.3%) was significantly higher than that of the SBP <125 mmHg group (6.7%) ($P < 0.001$) (Table 5). When the inhibition rate was <75%, there were no significant differences in the hemorrhage rates between the during-procedure SBP ≥125 mmHg group (17.2%) and the SBP <125 mmHg group (13.2%) ($P > 0.05$).

3.6. Logistic regression analysis results

Univariate logistic regression analysis showed that a platelet AA pathway inhibition rate ≥75% (OR = 3.919, 95% CI: 1.413–10.870) and during-procedure SBP ≥125 mmHg (OR = 4.128, 95% CI: 1.415–12.041) significantly increased the risk of EVD/ICP-related hemorrhage (Table 6). The results of multivariate logistic regression analysis showed that a platelet AA pathway inhibition

Table 1
Baseline data of the hemorrhage and non-hemorrhage groups.

	Total	Hemorrhage group (n = 21)	Non-hemorrhage group (n = 73)	T/X^2	*P*-value
Age (years)	62.44 (9.05)	62.38 (8.95)	62.45 (9.14)	−0.320	0.975
Gender (Male)	67 (71.3)	15 (71.4)	52 (71.2)	–	0.986
Admission GCS	8 [6,10]	9 [7,12]	8 [6,10]	1.450	0.156
Major diagnosis					
ICH	75 (79.8)	19 (90.5)	56 (76.7)		0.226
TBI	15 (16.0)	1 (4.8)	14 (19.2)	2.528	
MCI	4 (4.3)	1 (4.8)	3 (4.1)		
Medical history					
Hypertension	79 (84.0)	16 (76.2)	63 (86.3)	1.243	0.265
Cerebral infarction	21 (22.3)	7 (33.3)	14 (19.2)	1.883	0.170
Cerebral hemorrhage	8 (8.5)	0 (0.0)	8 (11.0)	2.515	0.113
Coronary heart disease	21 (22.3)	6 (28.6)	15 (20.5)	0.605	0.437
Diabetes	18 (19.1)	4 (19.0)	14 (19.2)	–	0.989
Operation history	25 (26.6)	4 (19.0)	21 (28.8)	0.789	0.374

Data are expressed as numbers and percentages or as the mean ± SD.
Abbreviations: GCS, Glasgow Coma Scale; ICH, intracerebral hemorrhage; MCI, massive cerebral infarction; TBI, traumatic brain injury.

Table 2
Conventional coagulation test data and TEG-PM indicators in the hemorrhage and non-hemorrhage groups.

	Hemorrhage group (n = 21)	Non-hemorrhage group (n = 73)	*P*-value
Conventional coagulation test data (mean ± SD, median IQR)			
Platelet count ($\times 10^9$/L)	191.76 (70.48)	186.22 (99.70)	0.813
PT (sec)	11.40 (10.05, 11.90)	11.50 (10.80, 12.20)	0.834
PTA (%)	92.80 (84.70, 99.50)	96.20 (86.45, 104.65)	0.430
INR	1.02 (0.95, 1.11)	0.98 (0.93, 1.05)	0.234
APTT (sec)	23.20 (19.75, 28.75)	22.30 (19.90, 25.65)	0.502
Fib (g/L)	2.78 (2.37, 3.97)	2.97 (2.39, 3.42)	0.931
TT (sec)	16.90 (15.90, 18.05)	16.40 (15.55, 17.70)	0.416
FDP (μg/mL)	5.07 (2.90, 15.09)	5.74 (3.10, 25.06)	0.435
DD (μg/mL)	1.14 (0.84, 4.26)	1.91 (1.08, 5.47)	0.222
TEG-PM data (median IQR)			
R (min)	3.60 (3.10, 4.20)	3.30 (2.90, 3.80)	0.432
K (min)	1.50 (1.25, 1.70)	1.50 (1.20, 1.90)	0.978
α Angle (deg)	69.30 (67.85, 72.70)	69.50 (65.40, 72.70)	0.946
MA (mm)	62.00 (60.05, 66.70)	62.60 (58.15, 66.15)	0.895
CI	2.20 (1.35, 3.15)	2.30 (1.00, 3.20)	0.938
Platelet AA pathway inhibition rate (%)			
<75 (n = 67)	10/21 (47.6)	57/73 (78.1)	0.014
≥75 (n = 27)	11/21 (52.4)	17/73 (23.3)	

Abbreviations: AA, arachidonic acid; APTT, activated partial thromboplastin time; CI, clotting index; DD, d-dimer; Fib, fibrinogen; TT, thrombin time; FDP, fibrinogen degradation product; INR, international normalized ratio; MA, maximum amplitude; PT, prothrombin time; PTA, prothrombin activity; TEG-PM, thromboelastography with platelet mapping.

Table 3
Peri-procedural conditions of patients in the hemorrhage and non-hemorrhage groups.

	Hemorrhage group [n = 21 (%)]	Non-hemorrhage group [n = 73 (%)]	*P*-value
Placement site			
Operating room	17 (81.0)	63 (86.3)	0.544
Bedside	4 (19.0)	10 (13.7)	
During-procedure BP			
SBP (mmHg)	128.55 (13.07)	120.20 (13.95)	0.019
<125 (n = 53)	6 (28.6)	47 (64.4)	0.006
≥125 (n = 41)	15 (71.4)	26 (35.6)	
During-procedure DBP (mmHg)	74.38 (8.08)	70.61 (9.62)	0.113
Hemorrhage caused by different implants			
EVD-related hemorrhage	19 (90.5)	–	<0.001
ICP-related hemorrhage	2 (9.5)	–	

Data are expressed as numbers and percentages or as the mean ± SD.
Abbreviations: BP, blood pressure; DBP, diastolic blood pressure; EVD, external ventricular drainage; ICP, intracranial pressure; SBP, systolic blood pressure.

Table 4
Comparisons of the severity of the patient's condition during their hospital stay, the effectiveness of treatment, and the total hospitalization cost between the hemorrhage and non-hemorrhage groups.

	Hemorrhage group	Non-hemorrhage group	*P*-value
In-hospital deaths	3 (14.3)	16 (21.9)	0.443
Discharge GCS	12 (8, 13.5)	11 [7,14]	0.419
Tracheotomy	11 (52.4)	27 (37.0)	0.205
Length of ICU stay (days)	5 [4,10]	6 (3, 9.5)	0.845
Total length of stay (days)	13 (8.5, 17)	12 (7, 17.75)	0.504
Total hospitalization costs (yuan)	114,357.95 (43,590.10)	112,476.64 (44,013.93)	0.863

Data are expressed as numbers and percentages, median and interquartile range or as the mean ± SD.
Abbreviations: GCS, Glasgow Coma Scale; ICU, intensive care unit.

rate ≥75% (OR = 5.183, 95% CI: 1.683–15.960) and during-procedure SBP ≥125 mmHg (OR = 4.609, 95% CI: 1.466–14.484) were independent risk factors for EVD/ICP-related hemorrhage.

4. Discussion

As an anti-platelet drug, aspirin is widely used for the prevention and treatment of cardiovascular and cerebrovascular diseases.

Table 5
The influence of during-procedure SBP on hemorrhage rates under different platelet AA pathway inhibition rates.

Platelet AA pathway inhibition rate (%)	During-procedure SBP (mmHg)				*P*-value
	<125 (n = 53)		≥125 (n = 41)		
	No. of patients n (%)	No. of hemorrhages n (%)	No. of patients n (%)	No. of hemorrhages n (%)	
<75	38 (40.4)	5 (13.2)	29 (30.9)	5 (17.2)	>0.05
≥75	15 (16.0)	1 (6.7)	12 (12.8)	10 (83.3)	<0.001
P-value		0.662		<0.001	

Abbreviations: AA, arachidonic acid; SBP, systolic blood pressure.

Evidence-based medicine has shown that aspirin can significantly reduce the incidence and mortality of ischemic stroke and has become a routine drug for primary and secondary prevention of this condition [1]. The mechanism of action is acetylation of cyclooxygenase and inhibition thromboxane synthesis [22,23]. Due to the special mechanism of action of aspirin, the conventional coagulation test cannot accurately reflect platelet dysfunction caused by aspirin [10], so it cannot provide an accurate and effective reference for the assessment of risk of hemorrhage caused by aspirin. TEG-PM can provide comprehensive information on coagulation, fibrinolysis and platelet function by simulating platelet aggregation, coagulation and fibrinolysis (Fig. 2). The efficacy of most anti-coagulant medications can be analyzed by using one or a combination of parameters in the thromboelastography test (Table 7). Combined with conventional coagulation test data, it can reflect the body's coagulation function more accurately and effectively and plays an important role in platelet function assessment and treatment decision making in patients using aspirin. Due to the different drug sensitivities of individual patients to aspirin, the antiplatelet effects of the same dose varies in different patients [24,25]. Therefore, when performing emergency surgical operations or procedures, the efficacy level of drugs should be evaluated according to the inhibition rate of the platelet AA pathway, facilitate the formulation of a treatment plan. Some studies have suggested that a preoperative history of aspirin use is a risk factor for hemorrhage during surgical procedures [17–19], while others suggested that aspirin use was not associated with a risk of hemorrhage [20,21]. In general, patients with a history of aspirin use and a high inhibition rate should undergo anticoagulant reversal prior to invasive procedures to reduce the potential risk of hemorrhage [26]. However, there is still no clear consensus on the safety of invasive operations or procedures in brain parenchyma without sufficient time and conditions to reverse anticoagulation in critically ill neurosurgical patients.

According to the literature, the hemorrhage rate of EVD-related hemorrhage varies from 1% to 41% [14–16] and a meta-analysis found that the hemorrhage rate of EVD-related hemorrhage was 12.1% [15]. In this study, among the 94 patients who received long-term aspirin therapy and emergency EVD/ICP probe placement, 21 (22.3%) had hemorrhages, but none of the hemorrhages caused significant clinical symptoms. Further analysis suggested that a platelet AA pathway inhibition rate ≥75% and during-procedure SBP ≥125 mmHg were independent risk factors for EVD/ICP-related hemorrhage. when the platelet AA pathway inhibition rate was ≥75%, the hemorrhage rate of during-procedure SBP ≥125 mmHg group was significantly higher than in the SBP <125 mmHg group, but when the inhibition rate was <75%, there was no significant difference in hemorrhage rates between the groups of during-procedure SBP ≥125 mmHg and <125 mmHg. For patients with high AA pathway inhibition rate and requiring emergency surgery, studies have suggested that emergency platelet transfusion may be an effective method to reduce the risk of hemorrhage [27]. However, a randomized, open-label, phase 3 trial found that emergency platelet transfusion did not reduce the risk of hemorrhage [28], conclusions that need to be confirmed by further research. Our results suggest that for such patients, the risk of EVD/ICP-related hemorrhage is relatively low by keeping the SBP below 125 mmHg during the surgical procedure.

We also found that the risk of hemorrhage caused by ICP probe placement was significantly lower than that of the EVD catheter. The EVD catheter is required to be placed in the deep ventricle of the brain, with the location of the tube being deep and its diameter relatively thick. The occupying effect of the catheter may have caused a temporary local pressure increase, resulting in puncture passage hemorrhage. In addition, due to the influence of the surgeon's technical proficiency and the patients' intracranial condition, the ventricular puncture may not be initially be successful. It has been reported that repeated puncture attempts are also one of the risk factors for hemorrhage during EVD placement [29]. The risk of hemorrhage caused by ICP probe placement has been reported to be lower than that for an EVD catheter due to its small diameter, shallow placement (2 cm under the cortex) and no requirement to adjust its position multiple times.

Table 6
Risk factors for hemorrhage.

	No. of patients n (%)	No. of hemorrhages n (%)	Multivariate logistic regression analysis		
			P-value	OR	95% CI
Platelet AA pathway inhibition rate (%)					
<75	67 (71.3)	10 (47.6)	REF.	–	–
≥75	27 (28.7)	11 (52.4)	0.004	5.183	(1.683–15.960)
During-procedure SBP (mmHg)					
<125	53 (56.4)	6 (28.6)	REF.	–	–
≥125	41 (43.6)	15 (71.4)	0.009	4.609	(1.466–14.484)

Abbreviations: AA, arachidonic acid; CI, confidence interval; OR, odds ratio; REF, reference; SBP, systolic blood pressure.

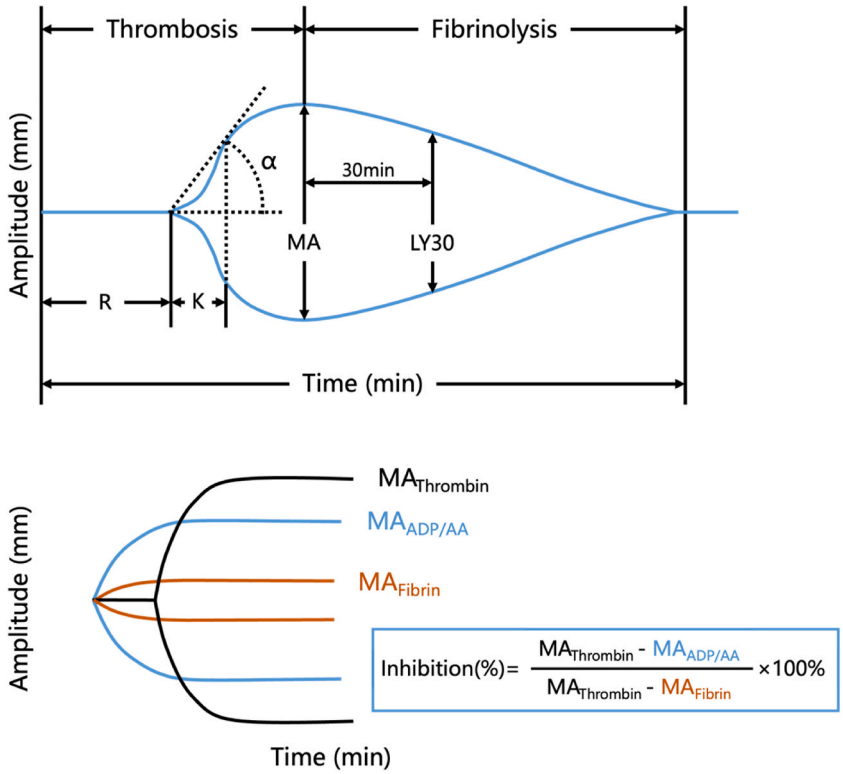

Fig. 2. TEG-PM schematic. Abbreviations: TEG-PM, thromboelastography with platelet mapping; R, reaction time; K, clot formation time; α, alpha angle; MA, maximum amplitude; LY30, lysis index at 30 min.

Table 7
Thromboelastography Interpretation.

TEG	Description	Normal	Abnormality: Cause	Treatment
R value	Time from start to 2 mm amplitude	5–10 min	↑clotting factor deficiencies, anti-coagulants ↓hypercoagulable states	Fresh frozen plasma
K value	Time from 2 mm to 20mm amplitude	1–3 min	↑hypofibrinogenemia	Cryoprecipitate
α-angle	Angle of tangent line from 2 mm to 20mm	53–72°	↓hypofibrinogenemia	Cryoprecipitate
MA	Amplitude measured at peak clot strength	50–70 mm	↓thrombocytopenia, platelet dysfunction	Platelets, DDAVP
LY30	Percent loss of amplitude at 30min after MA	0–8%	↑enzymatic or mechanical hyperfibrinolysis	Tranexamic acid

Abbreviations: TEG, thromboelastography; MA, maximum amplitude; LY30, lysis index at 30 min.

Between the hemorrhage and non-hemorrhage groups, there was no statistically significant difference in discharge conditions, suggesting that even if hemorrhage occurred, it had no significant impact on in-hospital mortality, discharge GCS, tracheotomy rate, length of stay or the cost of hospitalization. In this study, the average hemorrhage volume in the hemorrhage group was 3.71 ± 6.89 mL, and the median was 2.15 mL, suggesting that even if the EVD/ICP probe placement did cause hemorrhage, the degree of hemorrhage was usually small and did not affect the survival and prognosis of patients [15,29]. In only one patient, a large hemorrhage of 32.40 mL occurred due to EVD placement. This patient had a platelet AA pathway inhibition rate of 100% and a during-procedure SBP of 127.67 mmHg. The hemorrhage, which was adjacent to the cortex, was likely caused by injury to the blood vessels on the brain surface during the procedure. However, since the hemorrhage mainly affected non-critical functional areas and the EVD allowed for adjustable intracranial pressure, it did not lead to significant neurological dysfunction, and no further surgical intervention was needed. This highlights the importance of avoiding critical functional areas within the brain when planning the puncture pathway.

5. Limitations of the study

The study had several limitations. First, due to the retrospective nature of the study, the possibility of selection bias cannot be excluded. Second, potential methodological limitations may have affected the research results. Third, it was a single center study with a small sample size and multi-center randomized controlled trials are needed to verify the universal applicability of the results.

6. Conclusions

When emergency EVD/ICP probe placement is performed on patients taking long-term aspirin therapy, an inhibition rate of the platelet AA pathway ≥75% and SBP ≥125 mmHg during the procedure were associated with a higher risk of hemorrhage. The risk of hemorrhage caused by EVD catheter placement was higher than for an ICP probe. SBP should be controlled below 125 mmHg during the procedure to reduce the risk of hemorrhage.

Sources of funding

This study was funded by the National Natural Science Foundation of China (No: 81,630,027).

Ethics declarations

This study was reviewed and approved by the Biological and Medical Ethics Committee of Tangdu Hospital, with the approval number: TDLL-KY-202011-01.

All procedures performed in studies involving human patients were conducted in accordance with the ethical standards of the institutional and/or national research committee, and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Data availability statement

The datasets obtained and analyzed during the current study are available from the corresponding author on reasonable request.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Fei Gao: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Shunnan Ge:** Writing – review & editing, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Wenxing Cui:** Writing – review & editing, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jingya Zhao:** Software, Resources, Methodology, Investigation, Formal analysis, Data curation. **Yang Yang:** Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation. **Wei Guo:** Validation, Resources, Formal analysis, Data curation. **Hao Bai:** Validation, Resources, Investigation, Data curation. **Bao Wang:** Resources, Methodology, Formal analysis, Data curation. **Chen Yang:** Visualization, Validation, Resources, Data curation. **Shijie Mu:** Resources, Methodology, Formal analysis, Data curation. **Liang Wang:** Validation, Supervision, Resources, Methodology. **Tianzhi Zhao:** Validation, Supervision, Resources, Investigation. **Yan Qu:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization. **Yaning Cai:** Writing – review & editing, Validation, Supervision, Software, Resources, Project administration, Methodology, Formal analysis, Data curation, Conceptualization.

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.

Acknowledgments

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e26854.

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