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Not all head injured patients on antiplatelet drugs need platelets: Integrating platelet reactivity testing into platelet transfusion guidelines☆,☆☆

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ABSTRACT

Introduction: Antiplatelet medication use continues to rise in an aging population, and these agents can have a deleterious effect for patients with traumatic intracranial hemorrhage (tICH). The purpose of the current investigation is to assess the safety and efficacy of using platelet reactivity testing (PRT) to direct platelet transfusion for tICH patients.
Patients and Methods: A Level I trauma center adopted a targeted platelet transfusion guideline using PRT to determine whether platelets were inhibited by an antiplatelet medication (aspirin or P2Y12 inhibitors). Non-inhibited patients were monitored without platelet transfusion, regardless of severity of the head injury. The guideline was analyzed retrospectively to evaluate patient outcomes during the study period (June 2014–December 2016). All patients sustained blunt tICH and received a PRT for known or suspected antiplatelet medication use. Differences were assessed with Kruskal-Wallis and Fisher's Exact tests.
Results: 166 patients met study inclusion criteria. PRT results indicated that 48 patients (29%) were not inhibited by an antiplatelet medication, and 92% of those patients (n = 44) were spared platelet transfusion. Seven percent (n = 11) of all patients had a clinically significant progression of the head bleed, but this did not differ by inhibition or transfusion status. Implementation of this guideline reduced platelet transfusions by an estimated 30–50% and associated healthcare costs by 42%.
Conclusions: A targeted platelet transfusion guideline using PRT reduced platelet usage for patients with tICH. If appropriately tested, results suggest that not all tICH patients taking or suspected of taking antiplatelet drugs need platelet transfusion. Platelet reactivity testing can significantly reduce healthcare costs and resource usage.

Introduction

Traumatic intracranial hemorrhage (tICH) is a well-described problem with significant associated morbidity and mortality, particularly for older adults. Patients taking antiplatelet medications are at increased risk for tICH [1], and it is increasingly common for older adults to be prescribed these medications for a host of medical conditions, including coronary artery disease (CAD), stroke, transient ischemic attack, and peripheral artery disease [2–5]. Patients who present to a trauma center with tICH are often unable to provide a reliable medical history or list of medications [2], and the prevalence of aspirin therapy is particularly difficult to ascertain because patients regularly take this medication without prescription or indication.

There is no standard protocol or high-quality evidence to guide reversal of patients taking antiplatelet agents [6–12]. One extreme is to empirically transfuse every tICH patient taking an antiplatelet agent based on the premise that transfusing uninhibited platelets may limit hemorrhage progression or decrease mortality [5,8,13].

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For patients with non-traumatic intracerebral hemorrhages, studies have found that platelet transfusion can reduce hemorrhage recurrence, hemorrhage volume, and mortality [14,15].

An alternative is to not transfuse at all or to limit platelet transfusions to patients undergoing neurosurgical procedures. Evidence is mixed if platelet transfusion influences tICH progression; in several studies, transfusion did not alter rates of progression [16–18]. Extensive experience with antiplatelet therapy has also failed to demonstrate a uniform response to antiplatelet agents. Approximately 30% of patients may not receive the intended antiplatelet effect of the medications [3,8,18,19].

Platelet reactivity testing (PRT) has emerged from the fields of cardiology, neurology, and vascular surgery to assess risk for thromboembolic events during surgery [3,19]. Several medical societies, including the Neurocritical Care Society in conjunction with the Society of Critical Care Medicine, have strongly recommended that PRT should guide platelet transfusions [8,20,21]. We are aware of only two published studies that report transfusion guidelines using PRT. Bachelani et al. used PRT to ascertain aspirin history and guide transfusion for inhibited tICH patients, but they do not report outcomes for non-inhibited patients who were not transfused [2]. Bansal et al. used PRT to determine clopidogrel history, however this was a small study of patients with minor injury and only four patients sustained a tICH [3].

The purpose of this study is to investigate clinical outcomes when using platelet reactivity testing to direct platelet transfusion for tICH patients. We hypothesized that a guideline using PRT results will reduce platelet usage but will not be associated with increased morbidity or mortality. Additionally, we sought to determine the effect of the guideline on healthcare costs and resource utilization.

Patients and methods

Study design

We conducted an observational study at a Level 1 trauma center in the Midwest. The hospital serves a medium-sized city, as well as rural areas in a 100 mile radius of the hospital. An anticoagulation and antiplatelet reversal guideline was initiated in June 2014 to standardize blood product usage and guide transfusion decisions for traumatically injured patients taking an anticoagulation or antiplatelet medication at the time of injury. A portion of the guideline is illustrated in Fig. 1. As it pertains to antiplatelet medication, the guideline specified that all trauma patients were screened for antiplatelet therapy, including aspirin or P2Y12 inhibitors (clopidogrel, ticagrelor, prasugrel, cangrelor, ticlopidine). This screening occurred through patient and family report and review of medical history. If antiplatelet medication use was confirmed, or if there was reasonable suspicion based on medical or surgical history (e.g. CAD, carotid disease, vascular disease), a platelet reactivity test (PRT) was ordered.

The PRT was obtained using the VerifyNow system (Accriva Diagnostics, San Diego, CA), which measures platelet reactivity via light transmission aggregometry in whole blood samples to ascertain if platelets are inhibited [22,23]. The P2Y12 assay measured reactivity of P2Y12 receptors and platelet aggregation was recorded as P2Y12 Reaction Units (PRU); this will be referred to as the PRU Test. The Aspirin assay measured arachidonic acid induced aggregation and platelet aggregation was recorded as Aspirin Reaction Units (ARU); this will be referred to as the ARU Test. PRT results were available within 15 (PRU) or 35 (ARU) minutes. Values were reported to the physician via the electronic medical record (EMR).

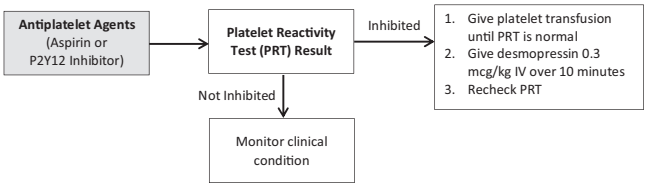

Fig. 1. Oral Anticoagulation Emergent Guideline for Patient with Major Intracranial Hemorrhage Taking Antiplatelet Agent.

Clinical cutoffs for aspirin and P2Y12 inhibition were derived from the manufacturer: uninhibited (PRU $\geq$ 208 or ARU $\geq$ 550) or inhibited (PRU < 208 or ARU < 550) [22,23]. Platelet transfusion was initiated for inhibited patients who sustained a tICH, as diagnosed by head CT scan. Treatment included transfusion of 6 units or 1 pack of platelets and administration of intravenous 0.3 mcg/kg desmopressin (DDAVP). After platelet transfusion, the PRT was repeated and subsequent transfusions were directed by those results. Transfusion continued until the patient was no longer inhibited or follow-up head CT scan showed stability, generally discontinued after one or two rounds of treatment.

Patient sample

We identified tICH all patients for whom PRT was ordered during the study period (June 2014-December 2016). Study inclusion criteria were: age 18 years or older; PRT after arrival or after tICH was identified on CT scan within 12 h of hospital arrival; and blunt head injury (abbreviated injury score {AIS} head $\geq$ 2). Patients were excluded if they had a penetrating injury to the head, minor head injury (AIS head = 1), Do Not Resuscitate (DNR) order prior to hospital arrival that limited care in the Emergency Department (ED), died in the ED, or received platelets as part of the massive transfusion protocol. If there were multiple encounters for a single patient during the study period, only the first encounter was analyzed.

The EMR was reviewed for data not included in the trauma registry. A standardized data abstraction form was used, and charts were reviewed by two sets of abstractors. Medical record data were abstracted by two physicians and pharmacy data were abstracted by the trauma pharmacist and pharmacy students. Twenty-percent of records were randomly assigned for dual review to assess interrater reliability (IRR); medical record abstraction achieved IRR = 94% and pharmacy abstraction achieved IRR = 95%. Ethical approval for the study was obtained from the hospital's Institutional Review Board. Because data were collected retrospectively, the requirement of informed consent was waived.

Study variables

Demographic variables were abstracted from the trauma registry. Injured body regions and ISS were calculated from AIS 2005 Update 2008, with head AIS $\geq$ 4 denoting a severe or critical tICH. Antiplatelet and anticoagulation medications were derived from chart abstraction. Pharmacy students reviewed the EMR using the History & Physical (H&P), prior medication history, or medication reconciliation notes. Students were blinded to PRT results during their initial review. After data entry, the trauma pharmacist reviewed cases where discrepancies were noted between PRT results and medication abstraction. The pharmacist reviewed all available information and made a clinical judgment about antiplatelet medication use. Pharmacy review did not utilize any documentation from prior or subsequent hospital encounters.

Several clinical values were obtained. Dates, times, and values of initial and subsequent PRTs were noted, and patients were categorized as inhibited or not inhibited based on the initial

results. PRT time was when the specimen was received in the lab for testing. We also abstracted the dates and times for initiation of platelet transfusion and administration of DDAVP.

The primary outcome was clinically significant worsening or progression of the tICH. In the initial review of the chart, it was noted if there was any radiology report that mentioned clinically significant change, expansion, progression, worsening, or new bleed, regardless of whether it was immediate or delayed. For any patient with a noted progression, the trauma surgeon on the study reviewed clinical documentation to determine if there was an association between progression noted on CT and neurological deterioration. A clinically significant worsening is noted if there was a radiological and clinical change in neurological status. If a patient had a neurosurgical procedure/evacuation before the follow-up head CT scan, the patient was not considered to have a clinically significant worsening unless it occurred post-operatively. A bleed was not considered a progression if radiology or neurosurgical notes indicated expected, clinically-irrelevant radiographic changes and there was not a change in clinical status. Other patient outcomes included mortality, hospital length of stay, and ICU days.

To determine healthcare costs and savings, we used cost estimates from the literature [24–26], manufacturer, and study hospital. Depending on regional and vendor variation, there is a maximum charge of $11,000 as a one-time cost to purchase the PRT machine to run both assays. The cost of each PRT also varies, but we estimated $100 per test. A conservative estimate of $2000 per unit of transfused platelets included costs of storing, processing, and preparing platelets, as well as administration charges for nursing and transfusion supplies. We computed healthcare costs and platelet usage for our protocol, removing instances of noncompliance as to not inflate savings that occurred because of failure to transfuse patients per protocol. This was compared to estimated healthcare costs and platelet usage without the guideline, which assumed that in the absence of PRT every tICH patient would have been transfused 1 or 2 units of platelets [6,7].

Statistical procedures

Analyses were performed with IBM SPSS Basic Statistics for Windows, v20.0 (IBM Corp, Armonk, NY, 2011). Descriptive statistics were examined and reported for continuous data as medians and interquartile ranges (IQR); categorical data were reported as counts and percentages. Because some data were not normally distributed and sample sizes were unequal across phases, nonparametric methods were used. Differences between medians were assessed using Kruskal-Wallis test by ranks and differences between nominal variables were assessed using two-tailed Fisher's Exact tests. Associations between variables were assessed with Spearman correlation coefficients with two-tailed tests of significance.

Results

There were 439 patients with tICH during the study period, and 166 patients received PRT and met study inclusion criteria (see Fig. 2). Fourteen patients received only the PRU Test, 117 received only the ARU Test, and 35 patients received both tests. Table 1 shows the characteristics of the sample as a whole; Tables 2 and 3 show the results for the PRU Test and ARU Test, respectively.

Overall, 29% (n = 48) of patients were found to be non-inhibited by an antiplatelet medication (see Table 1), and 50% of these patients (n = 24) were determined to be taking a P2Y12 inhibitor, aspirin, or both at the time of injury. In contrast, 93% of inhibited were determined to be taking one or both antiplatelet agents. There were no significant differences between groups in sex, age, or ISS, and approximately 40% of patients in each group sustained a severe or critical tICH.

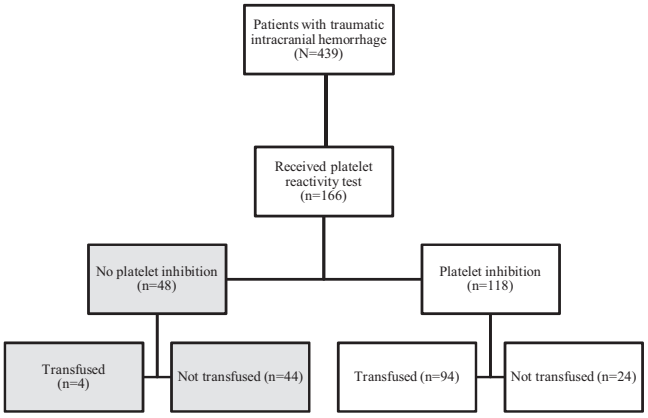

Fig. 2. Study sample, June 2014–December 2016.

There were no statistically significant differences between inhibited and non-inhibited patients for ICU days, hospital length of stay, mortality, or clinically significant worsening of tICH. Worsening tICH was not correlated with platelet transfusion ($r_s = 0.07$, $p = .34$), DDAVP administration ($r_s = -0.02$, $p = .81$), or home medication ($r_s = 0.07$, $p = .38$) but was correlated with having a severe or critical tICH ($r_s = .23$, $p = .004$).

PRU and ARU test results

Thirty percent (n = 49) of patients received a PRU Test (see Table 2), and 38% of non-inhibited patients and 79% of inhibited patients were determined to be taking a P2Y12 inhibitor as a home medication. The average PRU for patients taking only a P2Y12 inhibitor was 190 (IQR: 145, 265) and the average PRU for patients taking both a P2Y12 inhibitor and aspirin was 180 (IQR: 137, 239). For the 28 inhibited patients transfused at least 1 unit of platelets, median length of time between initiating the PRU Test and starting platelet transfusion was 2.2 h (IQR: 0.2, 4.1 h). There were no significant differences between inhibited and non-inhibited patients for age, ISS, length of stay, ICU days, mortality, or worsening of the tICH.

As shown in Table 3, 152 patients (92%) received an ARU Test. Forty-three percent of non-inhibited patients and 90% of inhibited patients were determined to be taking aspirin at the time of injury. The average ARU for patients taking only aspirin was 456 (IQR: 428, 521) and the average ARU for patients taking aspirin and a P2Y12 inhibitor was 430 (IQR: 398, 502). For the 87 inhibited patients transfused at least 1 unit of platelets, median length of time between initiating the ARU Test and beginning platelet transfusion was 3.1 h (IQR: 1.9, 5.0 h). There were no significant differences between inhibited and non-inhibited patients for ISS, length of stay, ICU days, mortality, or worsening of the tICH.

Guideline compliance

Guideline compliance for the study period was 83%. Four non-inhibited patients were transfused prior to obtaining initial PRT results. In contrast, 24 inhibited patients were not transfused due to misinterpretation of the guideline or test results (75%), contraindication to transfusion (14%), or delayed presentation from injury (11%). Compliance with the guideline improved over time and exceeded 95% in the last year (2016) of the study period.

Progression of tICH

Radiographic progression of tICH did not differ by inhibition or transfusion status. Eight percent (n = 4) of non-inhibited patients

Table 1
Patients with traumatic intracranial hemorrhage (tICH) by inhibition status (N = 166).

	Not Inhibited N = 48	Inhibited N = 118	p-value
Male, n (%)	26 (54%)	61 (52%)	.86
Age, median (IQR)	69 (57, 86)	79 (67, 84)	.08
Mechanism of injury equal to fall, n (%)	34 (71%)	102 (86%)	.03
Severe or critical head bleed, n (%)	19 (40%)	48 (41%)	.99
ISS, median (IQR)	14 (9, 22)	14 (9, 21)	.51
Polytraumatic injury, n (%)	20 (42%)	19 (16%)	.001
Operative procedure in first 24 hours, n (%)	8 (17%)	10 (9%)	.17
Neurosurgical procedure	4 (50%)	7 (70%)	–
Orthopedic or vascular procedure	4 (50%)	3 (30%)	–
Antiplatelet therapy home medication, n (%)*	24 (50%)	110 (93%)	<.001
P2Y12 inhibitor only	4 (17%)	8 (7%)*	–
Aspirin only	18 (75%)	84 (76%)*	–
P2Y12 and aspirin	2 (8%)	18 (16%)*	–
Other anticoagulation home medication, n (%)	1 (2%)	16 (14%)	.03
Received platelet transfusion, n (%)	4 (8%)	94 (80%)	<.001
Received DDAVP, n (%)	2 (4%)	64 (54%)	<.001
ICU days, median (IQR)	3 (2, 4)	3 (2, 4)	.45
Hospital length of stay, median (IQR)	5 (3, 7)	4 (2, 7)	.38
Mortality, n (%)	6 (13%)	10 (9%)	.40
Clinically significant worsening of tICH, n (%)	4 (8%)	7 (6%)	.73

* Total does not add up to 100% due to rounding.

Table 2
Patients with traumatic intracranial hemorrhage (tICH) who received the P2Y12 (PRU) Test, by inhibition status (N = 49).

	Not Inhibited N = 16	Inhibited N = 33	p-value
Male, n (%)	9 (56%)	26 (79%)	.18
Age, median (IQR)	83 (62, 87)	76 (66, 83)	.81
Mechanism of injury equal to fall, n (%)	11 (69%)	26 (79%)	.49
Severe or critical head bleed, n (%)	9 (56%)	16 (49%)	.76
ISS, median (IQR)	17 (11, 23)	17 (9, 25)	.98
Polytraumatic injury, n (%)	7 (44%)	6 (18%)	.09
Operative procedure in first 24 hours, n (%)	1 (6%)	5 (15%)	.65
Neurosurgical procedure	1 (100%)	4 (80%)	–
Orthopedic or vascular procedure	–	1 (20%)	–
P2Y12 inhibitor home medication, n (%)	6 (38%)	26 (79%)	.009
Other anticoagulation home medication, n (%)	0 (0%)	3 (9%)	.54
Received platelet transfusion, n (%)	2 (13%)	28 (85%)	<.001
Received DDAVP, n (%)	2 (13%)	20 (61%)	.002
ICU days, median (IQR)	3 (2, 7)	3 (2, 6)	.91
Hospital length of stay, median (IQR)	4 (3, 6)	6 (2, 9)	.43
Mortality, n (%)	3 (19%)	3 (9%)	.38
Clinically significant worsening of tICH, n (%)	1 (6%)	3 (9%)	.99

Table 3
Patients with traumatic intracranial hemorrhage (tICH) who received the Aspirin (ARU) Test, by inhibition status (N = 152).

	Not Inhibited N = 42	Inhibited N = 110	p-value
Male, n (%)	23 (55%)	56 (51%)	.72
Age, median (IQR)	64 (56, 82)	79 (67, 85)	.005
Mechanism of injury equal to fall, n (%)	28 (67%)	94 (86%)	.01
Severe or critical head bleed, n (%)	17 (41%)	44 (40%)	.99
ISS, median (IQR)	15 (9, 24)	12 (9, 20)	.27
Polytraumatic injury, n (%)	19 (45%)	17 (15%)	<.001
Operative procedure in first 24 hours, n (%)	8 (19%)	9 (8%)	.08
Neurosurgical procedure	4 (50%)	7 (78%)	–
Orthopedic or vascular procedure	4 (50%)	2 (22%)	–
Aspirin home medication, n (%)	18 (43%)	99 (90%)	<.001
Other anticoagulation home medication, n (%)	1 (2%)	15 (14%)	.07
Received platelet transfusion, n (%)	4 (10%)	87 (79%)	<.001
Received DDAVP, n (%)	1 (2%)	61 (56%)	<.001
ICU days, median (IQR)	3 (2, 5)	3 (2, 4)	.28
Hospital length of stay, median (IQR)	5 (3, 7)	4 (2, 7)	.13
Mortality, n (%)	6 (14%)	9 (8%)	.36
Clinically significant worsening of tICH, n (%)	4 (10%)	6 (6%)	.46

had a clinically significant progression of the tICH; 2 of these patients received platelet transfusion (guideline deviation) and 2 were nonsurgical candidates for whom end-of-life measures were elected. Six percent (n = 7) of inhibited patients had a clinically significant progression of the tICH; 6 of these patients were transfused platelets but did not improve and 1 patient was not transfused due to misinterpretation of the test result early in the study period (guideline noncompliance).

Reductions in healthcare costs and platelets

Table 4 provides detailed information on platelet usage and healthcare costs. After removing guideline noncompliance, results indicate that one-third of patients (44 of 138) were uninhibited and did not receive platelet transfusion. After accounting for costs associated with conducting the tests and administering platelets, eliminating transfusion for 44 patients resulted in at least a 22% reduction in transfusion-associated healthcare costs over 2.5 years, when compared to standard practice where every patient would have been transfused one unit of platelets. When compared to standard practice of transfusing two units of platelets to every patient, we estimate that the guideline resulted in a 42% reduction in costs, equivalent to approximately $230,000.

Discussion

When a patient is injured, it is imperative to have rapid and reliable ways to assess risks and make clinical decisions, especially in the context of traumatic intracranial hemorrhage. Antiplatelet medication use is increasingly prevalent, but it remains controversial what, if anything, should be done to reverse these medications after injury. In the present study, platelet reactivity testing was used to ascertain platelet inhibition status for patients taking or suspected of taking antiplatelet medications. More than one-quarter of patients were uninhibited by an antiplatelet medication and platelet transfusion was avoided for 93% of those patients. Transfusing only inhibited tICH patients reduced healthcare associated costs and conserved platelet resources. If appropriately tested, findings suggest that not all head injured patients taking or suspected of antiplatelet medications need platelet transfusion.

While the Neurocritical Care Society cautions against platelet transfusion for tICH patients who will not undergo a neurosurgical procedure [8], it is difficult to put this recommendation into practice in the absence of objective, reliable evidence. For patients with tICH, many practitioners will err on the side of caution and will initiate platelet transfusion until there is radiographic evidence of stability of the bleed. Results from the present study, however, indicate that platelet transfusion can be safely avoided for patients with normal platelet reactivity. PRT is a quick and objective way to guide platelet transfusion, sparing those where suspicion of taking antiplatelet medications turns out to be unfounded and those for whom antiplatelet medication was not having the expected effect on platelet function.

Most importantly, using PRT to direct transfusion decisions was not associated with worsening prognosis or other adverse outcomes. Approximately 7% of patients in the study had a clinically significant progression of the tICH, but this did not differ by inhibition or transfusion status. Results are consistent with the literature that progression is a common phenomenon, especially for patients with severe bleeds [27–29].

While our intent was to evaluate the safety of the guideline in avoiding transfusion for uninhibited tICH patients, guideline noncompliance generates a broader question: do inhibited patients need platelet transfusion? The present study was not designed to investigate this recommendation, but 24 inhibited patients were not transfused per the guideline and only one patient had a clinically significant progression of the tICH. Further investigation is merited.

Because PRT assays are specific to P2Y12 inhibitors and aspirin, test results can serve as a proxy for antiplatelet medication use. Medication reconciliation can be challenging, and aspirin is particularly difficult to reconcile because it is available over-the-counter and may not be in hospital or pharmacy records. For the handful of inhibited patients where an antiplatelet medication was not discovered during chart review, we suspect they were likely taking an agent and the PRT results were more valid than chart review. Conversely, there were also patients for whom home antiplatelet medication was confirmed but the PRT was non-therapeutic. Patients with normal platelet reactivity would not benefit from transfusion, even if they are taking an antiplatelet medication prior to injury, and transfusion may be avoided in this population.

Given the increased use of elastography as a point-of-care test during trauma resuscitation [30,31], it deserves mention that the study hospital has rotational thromboelastometry (ROTEM) but does not use it to direct platelet transfusion in this guideline. First, the test does not provide a single numeric result to use as a clinical decision trigger. Results are reported as ranges and require interpretation of many data points, whereas PRT can be interpreted more easily because it provides a single numeric result. In addition, elastography does not look at platelet function based on drug effect, whereas the ARU and PRU Tests are specific to aspirin and P2Y12 inhibitors, respectively. Finally, traditional thrombelastography (TEG, not available at the study hospital) does have a platelet mapping function, but it is not FDA-approved for P2Y12 inhibitors and some studies (e.g [32,33].) have shown this assay has limitations in detecting inhibition.

Table 4
Heathcare costs and platelet usage (N = 138).[a]

	Without Guideline		With Guideline	
	N	Dollars	N	Dollars
Platelet reactivity testing (PRT) machine	–	–	1	$11,000
1st P2Y12 PRT	–	–	42	$4200
1st Aspirin PRT	–	–	125	$12,500
1st Unit Platelet Transfusion	138	$276,000	94	$188,000
2nd P2Y12 PRT	–	–	19	$1,900
2nd Aspirin PRT	–	–	65	$6,500
2nd Unit Platelet Transfusion	138	$276,000	34	$68,000
3rd P2Y12 PRT	–	–	6	$600
3rd Aspirin PRT	–	–	26	$2,600
3rd Unit Platelet Transfusion	–	–	12	$24,000
Total	**$552,000**		**$319,300**	

[a] Removed 4 non-inhibited patients who were transfused and 24 inhibited patients who were not transfused.

Limitations

This study has several limitations. First, results are from a single center and data were collected retrospectively. As with any retrospective study, unmeasured confounding variables and characteristics of the study hospital may affect the outcomes. Second, progression or worsening of hemorrhage was based on radiology interpretation from head CT scans. These reads were made in real-time for clinical decision making, not for research purposes. At the time of the study, the radiology reports at the study hospital did not include a Marshall or Rotterdam classification score. Third, there is no objective way to determine if the platelet dysfunction is caused by the antiplatelet medication or due to the trauma itself. Our protocol makes no distinction: any patient with abnormal platelet reactivity is considered an at-risk patient and receives platelet transfusion,

regardless of the cause of the dysfunction. Finally, while we used a robust and systematic process for medication reconciliation, it is difficult to ascertain medication history retrospectively. It is possible that patients were incorrectly categorized for home medication use, especially for aspirin use.

Conclusions

A targeted platelet transfusion guideline reduced transfusion rates and platelet usage for patients with tICH. Platelet reactivity testing was used to determine which patients did not require platelet transfusion, which significantly reduced healthcare costs and resource utilization at a major trauma center.

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