Impact of a multidisciplinary workflow on safety and management of patients with heparin-induced thrombocytopenia

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Purpose. Heparin-induced thrombocytopenia (HIT) is a serious complication of heparin administration. Management strategies are complex and include discontinuing heparin products, initiating alternative anticoagulants, interpreting laboratory test results, documenting heparin allergies, and providing patient education. Medication error reports and a retrospective review conducted at an academic medical center revealed an opportunity for a quality improvement initiative and led to the creation of a multidisciplinary workflow for the management of HIT. In a pre-post study, the impact of the multidisciplinary workflow on the safety and management of HIT was evaluated.

Methods. The preimplementation group consisted of adult patients tested for suspected HIT from April 4, 2014, through May 31, 2016; the postimplementation group consisted of adult patients tested from November 1, 2016, through October 31, 2018. The primary outcome was the incidence of heparin product administration while HIT testing was ongoing. The secondary outcome was the rate of appropriate heparin allergy documentation.

Results. The incidence of heparin product administration while HIT testing results were pending was significantly reduced, from 54.2% to 20.0% ($P < 0.001$), after workflow implementation. The rate of appropriate heparin allergy documentation significantly increased, from 95.0% to 100% ($P < 0.001$).

Conclusion. Implementation of a multidisciplinary workflow for the management of HIT significantly reduced the incidence of heparin administration while testing was ongoing and improved the rate of appropriate heparin allergy documentation.

Keywords: anticoagulants, documentation, heparin, quality improvement, thrombocytopenia

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A high percentage of hospitalized patients receive heparin-containing products.¹ Heparin-induced thrombocytopenia (HIT), a rare but serious complication of heparin administration, is variously estimated to occur in less than 0.1% to as many as 7% of exposed patients.² The diagnosis pathway for HIT is complex, involving diagnostic testing that can take several days to result. Both the American Society of Hematology (ASH) and American College of Chest Physicians (ACCP)

published guidelines highlighting the standard of care for HIT.^{2,3} When the disorder is suspected, a clinical score (the 4Ts score) is calculated to determine the pretest probability of HIT. A low 4Ts score (≤ 3) indicates HIT is unlikely, and testing is not recommended in most situations. If there is uncertainty regarding the 4Ts score, testing may still be considered.² If an intermediate or high 4Ts score (≥ 4) is calculated, heparin should be discontinued and a nonheparin anticoagulant

initiated. An immunoassay to detect antibodies against the heparin/platelet factor 4 (PF4) complex is performed; if the result is positive, a functional assay is completed to confirm the diagnosis of HIT. Laboratory samples collected for functional assays must be heparin free, as contamination can lead to false-negative results.⁴ If the functional assay is negative, HIT is unlikely and no further testing is recommended. If the functional assay is positive, HIT is likely.^{2,3} Upon diagnosis of HIT, clinicians must document a heparin allergy and educate patients to prevent future exposure to heparin. Although professional guidelines provide management recommendations, practices may still vary by institution, with implications for patient safety and cost.

Patient safety implications.

Guidelines recommend cessation of heparin therapy once the diagnosis of HIT is suspected.^{2,3} The proportion of patients who continue to receive heparin with ongoing HIT testing is not well described. Ritchie et al⁵ published their experience with implementing a hemostatic and antithrombotic stewardship program. In their pre-post study, they found high rates of continued heparin administration (79.9%) despite ongoing testing for HIT. The majority (60.6%) of patients continued on heparin were at low risk for HIT, with a calculated 4Ts score of 0 to 3. Heparin was continued in 18.1% of intermediate-risk (4Ts score of 4-5) and 1.2% of high-risk (4Ts score of 6-8) patients. No significant reduction in the incidence of continued heparin administration was noted after implementation of their program. As continued heparin administration can lead to increased risks of thrombosis, limb amputation, and death in HIT-positive patients, efforts to reduce administration during testing could have a positive impact on patient safety and outcomes.^{2,3}

Cost implications. Other researchers have described costs associated with variations in HIT testing practices. Passero and Xavier⁶ retrospectively reviewed patients undergoing HIT testing within their

KEY POINTS

- Heparin-induced thrombocytopenia (HIT) is a serious complication of heparin administration.
- Management of HIT is complex and requires completion of multiple steps to ensure patient safety.
- A multidisciplinary management approach has a positive impact on the care of patients evaluated for HIT.

institution over 1 year. They found that a high percentage (73.8%) of patients with a low 4Ts score (0-3) underwent testing. They estimated that potential cost savings that could be achieved by avoiding testing and by avoiding alternative anticoagulant use were \$33,360 and \$100,750, respectively. Lastly, McMahon et al⁷ retrospectively evaluated appropriate heparin allergy documentation in the electronic health record (EHR) in HIT-negative patients over an 8-year period. Of the 100 HIT-negative patients evaluated, 68 (68%) had a heparin allergy documented in their EHR a median of 7.5 years after initial testing was performed. Although cost data were not provided, the investigators described 68 subsequent hospitalizations in this group, during which the patients received alternative anticoagulants in consideration of their documented heparin allergy.

Results of these studies demonstrate the impact variations in practice can have on safety and costs in patients undergoing HIT testing. Standardized practices that are generalizable to other institutions are needed to improve these outcomes.

At the institution where the quality improvement project described here was conducted, voluntary and anonymous medication error reports had described patients continuing to receive heparin while HIT testing was ongoing.

A retrospective review validated this safety concern and demonstrated that a large percentage of patients continued to receive heparin despite ongoing HIT testing and that documentation of heparin allergy was often inaccurate (as determined via review of final HIT testing results). Given the potential consequences of continued heparin administration and inappropriate allergy documentation, we initiated a quality improvement project. Our primary objectives were to reduce the incidence of heparin administration to patients with suspected HIT and improve appropriate heparin allergy documentation once HIT testing is finalized. Our secondary objective was to modify our workflow through use of quality improvement methods to optimize compliance and reduce unnecessary HIT testing. This descriptive report highlights the impact of the initiative and our experiences implementing a multidisciplinary workflow for the management of HIT.

Methods

Multidisciplinary workflow planning and implementation. After reviewing the voluntary, anonymous medication error reports and retrospective analysis, an interdisciplinary project group convened to develop institution-specific HIT guidelines and a standardized workflow. The project group included physicians (hematology and hematopathology specialists), pharmacists (critical care, hematology, and cardiology specialists), nurses (cardiology and surgery specialists), the medication safety officer, the pharmacy information system development pharmacist, and laboratory staff.

Once the guidelines and workflow were finalized, team members presented workflow education to clinicians (physicians and advanced practice providers), pharmacists, and laboratory staff. Additionally, educational memos describing the workflow were distributed to nurses.

Multidisciplinary workflow overview and modifications. *Pre-implementation workflow.* Prior to implementation of the new workflow,

clinicians were required to order HIT laboratory tests individually and were not provided guidance on recommended testing based on total 4Ts score. Available in-house testing included an immunoassay, an immunoglobulin G-specific enzyme-linked immunosorbent assay (ELISA) to detect heparin/PF4 antibodies (Lifecodes PF4 IgG Kit, Immucor, Inc., Norcross, GA) (normal optical density range, <0.4); and a functional assay, a heparin-induced platelet aggregation assay performed by aggregometry (Chrono-log Model 700, Chrono-log Corp., Havertown, PA). The heparin/PF4 antibody ELISA was performed on Mondays, Wednesdays, and Fridays, and the platelet aggregation assay was performed on Thursdays. A serotonin-release assay (SRA) (Versiti, Inc.; Milwaukee, WI) was available as a send-out test and resulted in approximately 1 week. Alternative anticoagulants (argatroban and fondaparinux) were also ordered separately. Decentralized clinical pharmacists reviewed alternative anticoagulant orders for clinical appropriateness. No process to notify other team members that HIT testing was ongoing existed. Further, there was no process to ensure final test results were reviewed, heparin allergies were appropriately updated, or patient education was completed.

Postimplementation workflow. The workflow was implemented on November 1, 2016 (Figure 1). Components of the workflow targeted specific steps of the medication-use process, including the ordering, reviewing, administration, and monitoring phases.⁸

For the ordering phase, we created HIT management order panels in the EHR (Epic Systems Corporation, Verona, WI) that were named according to the alternative anticoagulant being prescribed and total 4Ts score. Order panels allow for medications and clinical orders that are commonly prescribed together to be grouped on the same screen during order entry. Per our institutional guidelines, clinicians may order a heparin/PF4 antibody ELISA for patients with a low 4Ts

score. This decision was made during the planning phase after results published by Linkins et al⁹ demonstrated that the pretest probability of HIT was 1.9% in patients with low 4Ts scores. A combination of a low 4Ts score and negative heparin/PF4 antibody ELISA reduced this probability to 0%. The heparin/PF4 antibody ELISA and platelet aggregation are recommended for patients with intermediate or high 4Ts score. The SRA is recommended when in-house testing leads to indeterminate results (ie, a positive result on the heparin/PF4 antibody ELISA and a negative platelet aggregation test result or vice versa). Each order panel contained appropriate laboratory testing combinations (a heparin/PF4 antibody ELISA only for patients with a low 4Ts score; a heparin/PF4 antibody ELISA and platelet aggregation assay for those with an intermediate or high 4Ts score), alternative anticoagulants, a pharmacist consult order, and nursing precaution orders (described below). The SRA was not included in the order panels. However, it could be ordered separately by clinicians. Additionally, the default time for collection of samples for laboratory testing was specified as 8 hours after order placement in an effort to ensure a heparin-free sample was processed. The 8-hour window was selected with the assumption that heparin would be discontinued at the time of order placement, thereby providing an appropriate washout period before sample collection.

For the reviewing phase of the medication-use process, the decentralized clinical pharmacist continued to review alternative anticoagulant orders for clinical appropriateness. A pharmacist consult order was placed through the order panel, which prompted the pharmacists to review all active orders for heparin-containing products and recommend discontinuation. Pharmacists also placed in the EHR a temporary notation of heparin allergy along with a reaction comment: "HIT testing pending (last updated: MM/DD/YY)." Placement of this allergy notation was key in notifying

other team members that HIT testing was ongoing. If a provider ordered or a nurse scanned a heparin-containing product, an alert notifying them of the temporary notation of allergic status would appear. Pharmacists also placed in the EHR a consult note that included the 4Ts score that was calculated with the clinician and alternative anticoagulant recommendations.

For the administration phase, nurses received precaution orders, which were placed through the order panel. These orders prompted nurses to place a sign at the bedside as a visual reminder to avoid heparin administration. These orders also advised nurses to use normal saline flushes in preference to heparin for all central venous access devices.

For the monitoring phase, we focused on improving follow-up on HIT testing once finalized. We created a partnership between our coagulation laboratory and pharmacy resident on-call program by which laboratory staff paged the on-call pharmacy resident when HIT testing was finalized (such notification was provided only if testing included platelet aggregation). The on-call pharmacy resident worked with the decentralized clinical pharmacist to develop a pharmacotherapy plan. The decentralized clinical pharmacist was responsible for following up on "heparin/PF4 antibody ELISA only" testing results through use of pharmacy sign-out documentation in the EHR. The pharmacist deleted or updated the temporary notation of heparin allergy and placed a final consult note summarizing treatment recommendations in the EHR. Furthermore, we designated a HIT stewardship pharmacist to review and follow up on results for discharged patients. Lastly, we formed a partnership between nursing personnel and pharmacists to provide education for newly diagnosed patients, during which an allergy card and handout were provided.

Patients with a previous history of HIT and a documented allergy at the time of admission were managed using a separate workflow in which only nursing precaution orders were placed.

Figure 1. Postimplementation multidisciplinary workflow for management of heparin-induced thrombocytopenia (HIT). EHR indicates electronic health record.

Plan-do-study-act (PDSA) assessments were conducted, and the workflow was modified accordingly to improve compliance (Figure 2). PDSA cycle 1 revealed that clinicians

were rarely using the order panels. Additionally, clinicians were accessing the order panels to order alternative anticoagulants for patients with a history of HIT and inadvertently ordering

HIT testing. Modifications included updating the order panel names to improve visibility, rearranging components in the order panel, and adding a method to order alternative

Figure 2. Implementation barriers and corrective EHR modifications performed in each plan-do-study-act cycle during the postimplementation period. EHR indicates electronic health record; HIT, heparin-induced thrombocytopenia.

Cycle	Barriers	EHR Modifications
1 November 2016-January 2017	<ul style="list-style-type: none"> • Low utilization of order panels • Inadvertent HIT laboratory testing orders 	<ul style="list-style-type: none"> • Updated order panel name • Reorganized order panel • Add back alternative anticoagulant order
2 February 2017-May 2017	<ul style="list-style-type: none"> • Continued low utilization of order panels 	<ul style="list-style-type: none"> • Removed HIT laboratory testing orders outside of order panels
3 June 2017-October 2017	<ul style="list-style-type: none"> • HIT laboratory testing inadvertently added back 	<ul style="list-style-type: none"> • Removed HIT laboratory testing orders • Created process to ensure deletion
4 November 2017-May 2018	<ul style="list-style-type: none"> • Clinician workarounds identified 	<ul style="list-style-type: none"> • Created branched order panel structure • Reorganized order panel

anticoagulants outside of the order panels for previously diagnosed patients. PDSA cycle 2 demonstrated continued low utilization of the order panels. At this time, clinicians were able to order HIT testing outside of the order panels. To overcome this work-around, the option of ordering HIT testing outside of the order panels was removed from the EHR. During PDSA cycle 3, it was identified that the removed HIT testing ordering option had been inadvertently restored in the EHR. This option was again removed, and a process to ensure permanent deletion was created. During PDSA cycle 4, it was identified that clinicians were unselecting the pharmacist consult and nursing precaution order in the order panel. Therefore, text describing the purpose of these orders was added. Lastly, a new feature was implemented to allow us to create a branched order panel that incorporated decision support questions to facilitate appropriate ordering.

Multidisciplinary workflow evaluation. We conducted a single-center pre- and postimplementation study of our multidisciplinary workflow. All patients 18 years of age or older who were hospitalized and underwent HIT testing (heparin/PF4 antibody ELISA, platelet aggregation, or SRA) during the study period were included. Patients

were excluded if they had a history of HIT along with an EHR-documented heparin allergy at the time of admission, as a different workflow was followed in such cases. The preimplementation group included patients tested during the period April 4, 2014, through May 31, 2016; the postimplementation group consisted of patients tested from November 1, 2016, through October 31, 2018. Preimplementation data were collected retrospectively from the EHR. Postimplementation data were collected prospectively from the EHR after patient discharge. The following data points were collected for both groups: age, sex, ethnicity/race, HIT testing combinations performed and results, acuity at the time of HIT testing, diagnosis of HIT or HIT complicated by thrombosis (HITT) (defined as new thrombosis or extension of existing thrombosis identified via imaging studies at the time of or after collection of HIT testing samples), the date and time the first HIT testing sample was collected and the date and time that HIT testing with the ordered test combination was finalized, heparin (unfractionated heparin or enoxaparin) administration over the HIT testing timeframe, date and time of death (as necessary), and heparin allergy documentation. Additionally, compliance

rates for each workflow step and documented 4Ts score from the clinical pharmacist consult note were collected for the postimplementation group. The study was approved by the institutional review board.

The incidence of heparin administration was determined by (1) reviewing the date and time the first HIT testing sample was collected and the date and time the final HIT test was finalized and (2) screening for heparin administration during this timeframe. Every HIT laboratory test combination ordered over the study period was included in the analysis, including duplicate tests from the same and subsequent admissions. We evaluated heparin administration rates (from the date of sample collection to the date all testing was finalized) for patients with HIT testing ongoing, patients with testing that yielded positive results, and those with indeterminate results. Patients included in the positive and indeterminate groups were also included in the ongoing group. Testing was considered positive if the heparin/PF4 antibody ELISA was positive (as indicated by an optical density of ≥ 0.4) and platelet aggregation was positive or if the SRA was positive. Testing results were considered indeterminate when the heparin/PF4 antibody ELISA

alone was positive or the heparin/PF4 antibody ELISA or platelet aggregation assay had contradicting results (eg, the heparin/PF4 antibody ELISA was positive and the platelet aggregation assay was negative) and the SRA was not performed. Final diagnosis of HIT was determined by the clinician based on clinical assessment and laboratory testing results.

The percentage of patients with appropriate heparin allergy documentation once HIT testing was finalized was determined by reviewing the final diagnoses designated by the clinician and comparing heparin allergy documentation. All patients tested over the pre- and postimplementation periods were included in this analysis except for those who expired before testing was finalized.

Workflow compliance was assessed by evaluating completion of the following steps: 4Ts score documentation, temporary allergy documentation, initial profile review performed by pharmacist (allergy documented by pharmacist or initial consult note written), nursing precaution orders placed, follow-up profile review performed by pharmacist (allergy status updated by pharmacist or follow-up consult note written), and on-call pharmacy resident documentation (excluding testing that did not include a platelet aggregation assay). Compliance with the complete bundle was also collected and included all steps described above, which was defined a priori.

The impact of the workflow on unnecessary laboratory testing was assessed by comparing the number of duplicate HIT test combinations performed for the same patient in the pre- and postimplementation periods. Additionally, we determined the number of samples that met heparin-free criteria in the postimplementation group.

Statistical analysis. Data were analyzed using means and standard deviations for continuous variables and proportions for categorical variables. Continuous variables were compared

using the Student *t* test and categorical variables using χ^2 or Fisher's exact test. An α of <0.05 was considered significant. All analyses were performed using SPSS, version 26 (IBM Corporation, Armonk, NY). It was determined a priori that the workflow would be modified based on PDSA cycle data every 3 to 5 months and that postimplementation data would be collected for 2 years after implementation; therefore, a sample size calculation was not performed.

Results

The preimplementation group included 517 patients, who underwent a total of 590 HIT laboratory test combinations (an average of 2.3 tests per patient), and the postimplementation group included 339 patients, who underwent 350 HIT laboratory test combinations (an average of 1.9 tests per patient). Baseline demographics were not significantly different between groups. A significantly higher percentage of testing combinations consisted of the heparin/PF4 antibody ELISA only ($P < 0.001$) or the heparin/PF4 antibody ELISA plus the platelet aggregation assay and SRA ($P = 0.004$) in the postimplementation group. Additionally, a significantly lower percentage of testing combinations consisted of the heparin/PF4 antibody ELISA plus the platelet aggregation assay in the postimplementation group ($P < 0.001$) (Table 1).

Heparin product administration rates. A total of 590 and 350 HIT laboratory test combinations were performed in the pre- and postimplementation groups, respectively. The incidence of heparin administration while HIT testing was ongoing was significantly higher in the preimplementation vs postimplementation group (54.2% vs 20.0%, $P < 0.001$) (Table 2). We further evaluated patients in whom test results subsequently returned positive or indeterminate. Although reduced, heparin administration rates among HIT-positive patients were not significantly different in the pre- and postimplementation groups (8.7%

and 16.6%, respectively; $P = 0.464$). Among the HIT-positive patients continued on heparin during testing, HIT was diagnosed in 1 of 6 patients in the preimplementation group and 1 of 2 patients in the postimplementation group. The rate of heparin administration was significantly lower among HIT-indeterminate patients (54.5% vs 0%, $P = 0.043$). For patients continued on heparin during testing in the postimplementation group ($n = 70$), 35.7% were continued on a prophylactic dose, 34.3% were continued on a treatment dose, and 30% received heparin flushes.

Appropriate allergy documentation. After excluding those who expired before testing was finalized, there were 465 and 316 patients in the pre- and postimplementation groups, respectively. The percentage of patients with appropriate heparin allergy documentation once HIT testing was finalized significantly improved in the postimplementation group (to 100%, as compared with 95% in the preimplementation group; $P < 0.001$) (Table 3). This improvement was primarily driven by correct allergy documentation in the records of HIT-negative patients. Two patients with diagnosed HIT in the preimplementation group did not have a heparin allergy documented in the EHR.

Multidisciplinary workflow compliance by PDSA cycle. A total of 350 HIT laboratory test combinations performed in the postimplementation group were included in this analysis. Workflow compliance by PDSA cycle is described in Table 4. Compliance rates for each workflow step significantly improved from PDSA cycle 1 to cycle 5, with the exception of on-call pharmacy resident documentation. Pharmacy resident documentation rates were lowest in PDSA cycles that included the first 4 months of a new residency academic year (July-October). Interventions were rarely required by the HIT stewardship pharmacist, occurring in approximately 5% of the postimplementation population. The

Table 1. Baseline Demographics and HIT Testing Performed, by Study Group

Characteristic or Variable	Preimplementation Group (n = 517)	Postimplementation Group (n = 339)	P Value
Age, mean (SD), y	57.5 (15.3)	58.4 (15.2)	0.378
Male, No. (%)	267 (51.6)	167 (49.3)	0.495
Ethnicity/race, No. (%)			0.315
Caucasian	289 (55.9)	193 (56.9)	
African American	160 (30.9)	109 (32.2)	
Other	47 (9.1)	31 (9.1)	
Hispanic	21 (4.1)	6 (1.8)	
No. of HIT test combinations completed ^a	590	350	
Heparin/PF4 ELISA only, no. (%)	31 (5.3)	88 (25.1)	<0.001
Negative	28 (90.3)	87 (98.9)	
Positive	0	0	
Indeterminate	3 (9.7)	1 (1.1)	
Heparin/PF4 ELISA + aggregation, No. (%)	524 (88.8)	219 (62.6)	<0.001
Negative	485 (92.6)	195 (89.0)	
Positive	31 (5.9)	19 (8.7)	
Indeterminate	8 (1.5)	5 (2.3)	
Heparin/PF4 ELISA + aggregation + SRA, No. (%)	31 (5.3)	37 (10.5)	0.004
Negative	26 (83.9)	34 (91.9)	
Positive	5 (16.1)	3 (8.1)	
Indeterminate	0	0	
Heparin/PF4 ELISA + SRA, No. (%)	0	3 (0.9)	0.051
Negative	0	2 (66.7)	
Positive	0	1 (33.3)	
Indeterminate	0	0	
Aggregation only, No. (%)	4 (0.6)	3 (0.9)	0.716
Negative	4 (100.0)	3 (100.0)	
Positive	0	0	
Indeterminate	0	0	
Acuity at time of testing, No. (%)			0.245
Intensive care unit	309 (52.4)	197 (56.3)	
Step-down or floor unit	281 (47.6)	153 (43.7)	
Diagnosis of HIT, No. (%)	11 (2.1)	6 (1.8)	0.806
Diagnosis of HITT, No. (%)	17 (3.3)	17 (5.0)	0.215

Abbreviations: ELISA, enzyme-linked immunosorbent assay; HIT, heparin-induced thrombocytopenia; HITT, heparin-induced thrombocytopenia with thrombosis; PF4, platelet factor 4; SRA, serotonin release assay.

^aIncludes duplicate tests in same patient during same and/or subsequent admission.

Table 2. Heparin Administration by HIT Testing Status

Testing Status	Preimplementation Group (n = 590)	Postimplementation Group (n = 350)	P Value
HIT testing ongoing	320 (54.2)	70 (20.0)	<0.001
HIT testing positive	6/36 (16.6)	2/23 (8.7)	0.464
HIT testing indeterminate	6/11 (54.5)	0/6 (0)	0.043

Abbreviation: HIT, heparin-induced thrombocytopenia.

^aAll data are number (percentage) or fraction (percentage) of documented laboratory test combinations (denoted by n).

Table 3. Appropriate Heparin Allergy Documentation After Testing Finalization, by Study Group^a

	Preimplementation Group (n = 464) ^b	Postimplementation Group (n = 316)	P Value
Correct documentation	441 (95.0)	316 (100)	<0.001
HIT diagnosis confirmed	26/28 (92.9)	23/23 (100)	0.495
HIT diagnosis ruled out	413/433 (95.4)	290/290 (100)	<0.001
Test results indeterminate	2/3 (66.7)	3/3 (100)	>0.99

Abbreviation: HIT, heparin-induced thrombocytopenia.

^aData are number (percentage) or fraction (percentage) of patients.

^bExcludes patients who expired prior to finalization of testing results.

most common intervention was reviewing patients discharged prior to finalization of testing.

Most effective multidisciplinary workflow component. We assessed which initial step prior to testing finalization was the most effective in preventing heparin administration (Table 5). Administration occurred least frequently when a temporary notation of heparin allergy was placed in the EHR (the corresponding heparin administration rate was 9.2%). The second most effective step was pharmacist initial profile review (9.6% heparin administration rate). There were higher heparin administration rates for patients with a documented intermediate 4Ts score (18.2% heparin administration rate) or high 4Ts score (12.9% heparin administration rate) compared to those with a documented low 4Ts score (3.4% heparin administration rate).

Minimizing unnecessary laboratory testing. In the preimplementation group 73 duplicate test combinations were identified, of which 61 (83.6%)

were obtained during the same hospitalization and 12 (16.4%) were obtained during a subsequent hospitalization. The postimplementation group included 11 duplicate test combinations, of which 9 (81.8%) were obtained during the same hospitalization and 2 (18.2%) were obtained during a subsequent hospitalization. There was a significantly higher percentage of duplicate laboratory test combinations in the pre- vs postimplementation group (12.4% vs 3.1%, $P < 0.001$). Finally, high rates of heparin-free sample collection in the postimplementation group were sustained between PCDA cycles 1 (75%) and 5 (82.9%) ($P = 0.300$).

Discussion

In our single-center pre-post study, a multidisciplinary workflow for the management of HIT significantly reduced the incidence of heparin administration while testing was ongoing. Although not statistically significant, the results indicated that the workflow reduced heparin administration

rates in patients later deemed HIT-positive, which is the group at highest risk for morbidity and mortality with continued heparin exposure.^{2,3} The workflow also significantly improved appropriate heparin allergy documentation once testing was finalized. Additionally, PDSA cycles with workflow modifications facilitated improvement of compliance. Placement in the EHR of a temporary notation of heparin allergy was the most effective step in preventing heparin administration. Our study was, to our knowledge, the first to document a positive impact on heparin administration rates while HIT testing was ongoing, as well as appropriate heparin allergy documentation.

Our results are consistent with previous literature that describes the impact of protocol implementation for patients undergoing HIT testing. Ritchie et al⁵ published their experience with implementing a hemostatic and antithrombotic stewardship program. They described high rates of heparin administration (79.9%) in patients undergoing HIT testing. They were unable to achieve a significantly reduced postimplementation administration rate, but antithrombotic stewardship significantly reduced the duration of alternative anticoagulant use (from 6.64 days to 5.17 days, $P = 0.01$) and the number of heparin/PF4 antibody ELISA tests obtained per patient (from 1.31 to 1.16). Similarly, we were able to reduce the number of duplicate test combinations performed in our postimplementation group. We suspect this reduction was due to improved communication among the healthcare team while testing was ongoing and close follow-up once testing was finalized. In contrast to the findings of Ritchie et al,⁵ we were able to more effectively reduce heparin administration rates in patients undergoing HIT testing. Many of our interventions focused on identifying patients at the time orders for HIT testing were placed rather than when an alternative anticoagulant was ordered; this may have allowed us to recommend heparin discontinuation sooner in the

Table 4. Multidisciplinary Workflow Compliance Overall and by PDSA Cycle^a

Workflow Component	All Patients (n = 350)	PDSA 1 Nov 2016- Jan 2017 (n = 68)	PDSA 2 Feb-May 2017 (n = 55)	PDSA 3 Jun-Oct 2017 (n = 70)	PDSA 4 Nov 2017- May 2018 (n = 87)	PDSA 5 Jun-Oct 2018 (n = 70)	P Value ^d
4Ts score documented	177 (50.6)	22 (32.4)	25 (45.5)	33 (47.1)	46 (52.9)	51 (72.9)	<0.001
Low score (0–3)	58 (32.8)	5 (22.7)	8 (32.0)	17 (51.5)	11 (23.9)	17 (33.3)	0.418
Intermediate score (4–5)	88 (49.7)	11 (50.0)	14 (56.0)	12 (36.4)	25 (54.3)	26 (51.0)	>0.99
High score (6–8)	31 (17.5)	6 (27.3)	3 (12.0)	4 (12.1)	10 (21.7)	8 (15.7)	0.332
Temporary notation of heparin allergy in EHR	250 (71.4)	38 (55.9)	31 (56.4)	50 (71.4)	68 (78.2)	63 (90.0)	<0.001
Initial profile review by pharmacist	239 (68.3)	38 (55.9)	28 (50.9)	45 (64.3)	66 (75.9)	62 (88.6)	<0.001
Nursing heparin precautions ordered	213 (60.9)	19 (27.9)	26 (47.3)	35 (50.0)	70 (80.5)	63 (90.0)	<0.001
Follow-up profile review by pharmacist	223 (63.7)	36 (52.9)	32 (58.2)	42 (60.0)	60 (69.0)	53 (75.7)	<0.001
On-call pharmacy resident documentation ^b	135/259 (52.1)	30/57 (52.6)	29/48 (60.4)	20/43 (46.5)	31/58 (53.4)	25/53 (47.2)	0.703
Compliance with complete bundle ^c	77 (22.0)	5 (7.4)	13 (23.6)	12 (17.1)	20 (23.0)	27 (38.6)	<0.001

Abbreviations: EHR, electronic health record; PDSA, plan-do-study-act cycle.

^aAll data are number (percentage) or fraction (percentage) of patients.^bDenominators are numbers of patients who underwent platelet aggregation testing.^cCompliance with all 6 bundle components; if testing did not include platelet aggregation testing, on-call pharmacy resident documentation was excluded from analysis.^dFor comparison of PDSA 1 and PDSA 5.

diagnostic algorithm. Many (60.6%) of the patients continued on heparin in the study of Ritchie et al⁵ had a low 4Ts score, possibly demonstrating low risk of continued heparin administration. Although HIT testing is not recommended in this population per ASH and ACCP guidelines,^{2,3} we argue that if a clinician's suspicion for HIT is still high enough despite a low 4Ts score to perform laboratory testing, heparin should be discontinued. As previously discussed, collection of a heparin-free laboratory sample is essential to ensure accuracy of functional testing, as contamination can lead to false-negative results.⁴ Additionally, Linkins et al⁹ performed a prospective cohort study and demonstrated that 1.9% of patients had diagnosed HIT despite a low 4Ts score. Lastly, the interobserver reliability of the 4Ts score when performed by clinicians without HIT expertise has been previously questioned.¹⁰ Varying results among clinicians may lead to a missed diagnosis of HIT, which could contribute to significant morbidity and mortality if heparin is continued while HIT testing is performed. Interestingly, we demonstrated lower rates of continued heparin administration in patients with a documented low 4Ts score compared to those with an intermediate or high 4Ts score. These results demonstrate that both stewardship programs and workflows can reduce the number of HIT tests ordered per patient, but a workflow may be more effective in reducing heparin administration while HIT testing is ongoing.

Our results are also comparable to previous literature that highlighted the impact of multidisciplinary partnerships when managing patients undergoing HIT testing. Burnett et al¹¹ implemented a collaborative practice between laboratory staff and a pharmacist-led anticoagulation service. Their workflow required calculation of a 4Ts score by a pharmacist when HIT testing was ordered. The pharmacist recommended discontinuation of testing or an alternative anticoagulant. Those investigators demonstrated a

Table 5. Heparin Administration by Workflow Component Completion

Completed Workflow Component	Patients With Component Completed, <i>n</i>	Heparin Administered, No. (%)
4Ts score documented	177	21 (11.9)
Low score documented	58	2 (3.4)
Intermediate score documented	88	16 (18.2)
High score documented	31	4 (12.9)
Temporary notation of heparin allergy in EHR	250	23 (9.2)
Initial profile review by pharmacist	239	23 (9.6)
Nursing precautions ordered	213	23 (10.8)
All bundle components	77	10 (13.0)

Abbreviation: EHR, electronic health record.

significant reduction in the percentage of inappropriate HIT tests processed in a postimplementation group (72.2% vs 52.4%; $P = 0.004$). Additionally, 4Ts score documentation was missing in only 12% of patients in their postimplementation group. Similarly, we demonstrated the benefits of a laboratory and pharmacy collaboration by significantly improving appropriate allergy documentation once testing was finalized. We also similarly demonstrated improvement in 4Ts score documentation, with the records of only 27.1% of our PDSA 5 population missing this information. These results demonstrate the positive impact of multidisciplinary partnerships on managing patients undergoing HIT testing. Through collaboration, inappropriate testing can be minimized and both 4Ts score documentation and appropriate allergy documentation improve.

Our study had a number of limitations to consider. First, it was a single-center study. As such, the workflow was tailored to our institution, and not all steps may be applicable to other institutions; however, components of our workflow can be implemented as permitted by available resources. We demonstrated that temporary EHR

notation of heparin allergy was the most effective step in preventing heparin administration, which could be generalizable. Second, the investigators were aware of group assignments when adjudicating outcomes. However, outcomes were collected by reviewing EHR documentation after patient discharge, so knowledge of group designation was unlikely to affect outcomes. Third, a difference in preimplementation and postimplementation timeframes (26 and 24 months, respectively) could have led to imbalances in our populations; however, given the lack of seasonality of HIT testing and the considerable numbers of patients included in both groups, we do not believe the difference influenced our results. Lastly, our institutional guidelines and workflow were created prior to the publication of the 2018 ASH guidelines on HIT management.² However, data collection concluded prior to publication, minimizing the risk of results confounding due to practice changes.

Conclusions

Implementation of a multidisciplinary workflow significantly reduced the incidence of heparin administration while HIT testing was ongoing and significantly improved appropriate

allergy documentation once testing was finalized. The use of PDSA methodology allowed us to successfully implement a complex workflow and modify the process to improve compliance. Although our workflow incorporated a multidisciplinary group, other institutions could implement the most impactful steps identified. Future directions include further refining the workflow through additional PDSA cycles, creating a streamlined workflow that can be implemented across the health system, evaluating and refining our HIT testing recommendations based on total 4Ts score, and targeting clinical outcomes such as development of thrombosis due to continued heparin administration and length of stay. Further studies are needed to continue improving the safety and cost-effectiveness of managing patients with suspected HIT.

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Disclosures

The authors have declared no potential conflicts of interest.

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Additional information

The project described in this article was awarded the 2017 ASHP Foundation Award for Excellence in Medication Safety. Authors presented a webinar during the Medication Safety Best Practices Educational Series

representing this work titled “Putting Together the Puzzle: Multidisciplinary Approach to Improving Patient Safety,” which is available for continuing-education credit.

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