






## ORIGINAL ARTICLE

# Improving preprocedure antithrombotic management: Implementation and sustainment of a best practice alert and pharmacist referral process

Henry Han MD<sup>1</sup>  | Grace Chung BA, MPH<sup>2</sup> | Emily Sippola BA<sup>3</sup> | Wilson Chen PharmD<sup>4</sup> | Spencer Morgan BS<sup>3</sup> | Elizabeth Renner PharmD<sup>5</sup> | Allison Ruff MD<sup>6</sup>  | Anne Sales PhD, RN<sup>3</sup>  | Jacob Kurlander MD, MSc<sup>7</sup>  | Geoffrey D. Barnes MD, MSc<sup>3</sup> 

<sup>1</sup>Department of Cardiovascular and Internal Medicine, University of Michigan, Ann Arbor, MI, USA

<sup>2</sup>Department of Cardiovascular Medicine and University of Michigan School of Public Health, Ann Arbor, MI, USA

<sup>3</sup>Department of Cardiovascular Medicine, University Of Michigan, Ann Arbor, MI, USA

<sup>4</sup>Department of Cardiovascular Medicine and University of Michigan School of Pharmacy, Ann Arbor, MI, USA

<sup>5</sup>Department of Pharmacy, University of Michigan, Ann Arbor, MI, USA

<sup>6</sup>Department of Internal Medicine, University of Michigan, Ann Arbor, MI, USA

<sup>7</sup>Department of Gastroenterology, University of Michigan, Ann Arbor, MI, USA

## Correspondence

Henry Han, 1500 E. Medical Center Dr., 2381 Cardiovascular Center, Ann Arbor, MI 48109, USA.  
Email: hehan@med.umich.edu

## Funding information

This study was funded by the National Heart, Lung, and Blood Institute under grant K01HL13592.

**Handling Editor:** Lana Castellucci

## Abstract

**Background:** Electronic medical record-based interventions such as best practice alerts, or reminders, have been proposed to improve evidence-based medication prescribing. Formal implementation evaluation including long-term sustainment are not commonly reported. Preprocedural medication management is often a complex issue for patients taking antithrombotic medications.

**Methods:** We implemented a best practice alert (BPA) that recommended referral to an anticoagulation clinic before outpatient elective gastrointestinal (GI) endoscopies. Eligible patients were taking an oral anticoagulant (warfarin or direct oral anticoagulant [DOAC]) and/or antiplatelet medications. Patients referred to the anticoagulation clinic were compared to those managed by the ordering provider. Outcomes assessed included guideline-adherent drug management before endoscopy, documentation of a medication management plan, guideline-adherent rates of bridging for high-risk patients taking warfarin, and evaluation for sustained use of BPA.

**Results:** Eighty percent of patients (553/691) were referred to the anticoagulation clinic during the initial 13-month study period. Most referrals came from gastroenterologists (397/553; 71.8%) followed by primary care providers (127/554; 22.9%). Patients referred had improved rates of guideline-adherent medication management compared to those who were not referred (97.4% vs 91.0%;  $P = .001$ ). Documentation of medication plan was significantly higher in the referred group (99.1% vs 59.4%;  $P \leq .001$ ). There were no differences in rates of appropriate bridging for patients taking warfarin. Implementation of the BPA also resulted in sustained, consistent use over an additional 18 months following the initial study period.

**Conclusion:** Implementation of a BPA before elective outpatient GI endoscopies was associated with improved rates of guideline-adherent medication management

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

© 2021 The Authors. *Research and Practice in Thrombosis and Haemostasis* published by Wiley Periodicals LLC on behalf of International Society on Thrombosis and Haemostasis (ISTH).

and documented management plan, while streamlining preprocedural medication management.

**KEYWORDS**

anticoagulation, anticoagulation clinic, endoscopy, pharmacist, preprocedure management, quality improvement

**Essentials**

- Preprocedural management of antithrombotic medications is complex.
- Implementing a referral process to an anticoagulation clinic improved medication management.
- The referral assisted with management of all oral anticoagulants and antiplatelet medications.
- Documentation of the preprocedure plan was improved with the referral process.
- Use of this referral process was sustained across >2 years following implementation.

## 1 | INTRODUCTION

Variation in medication prescribing is a common and complex quality of care delivery challenge. This is particularly true for clinical scenarios with robust evidence on how best to safely and effectively use medication therapy to reduce disease morbidity and/or mortality. Examples include underuse of lipid-lowering statin therapies in patients with known cardiovascular disease,<sup>1,2</sup> underuse of aldosterone antagonists in heart failure,<sup>3-5</sup> and overuse of antibiotics for patients with acute respiratory infections.<sup>6</sup> Electronic medical record (EMR) interventions have been proposed to reduce variation and improve quality of medication prescribing. While some have demonstrated improvement in evidence-based prescribing,<sup>7</sup> others have failed to achieve their goals.<sup>8,9</sup> And few have been evaluated for multiyear sustained usage.

Antithrombotic medications, including anticoagulants, such as warfarin, apixaban, rivaroxaban, and dabigatran, and antiplatelet agents, such as clopidogrel, prasugrel, and ticagrelor, are commonly used to prevent thrombotic complications in patients with a variety of medical conditions, including atrial fibrillation, venous thromboembolism, coronary artery disease, peripheral arterial disease, and mechanical heart valves. Despite their proven efficacy, they also pose significant risk of bleeding, especially during an invasive procedure. Coordinating preprocedure management of chronic antithrombotic medications often presents a clinical challenge for both patients and clinicians. Additionally, clinical decision making varies greatly between different clinicians and specialists and frequently does not follow evidence-based management.<sup>10</sup> Mismanagement of antithrombotic medications places patients at increased risk of potentially life-threatening bleeding and/or thromboembolic complications (blood clots). It also leads to last-minute procedural cancellations as well as patient and clinician dissatisfaction.<sup>11</sup>

We used gastrointestinal (GI) endoscopy procedures as an exemplary case study to test an EMR-based intervention. Specifically, we developed and implemented an automated EMR best practice alert (BPA), or reminder, and referral process to a dedicated

anticoagulation clinic for patients taking chronic antithrombotic medications before their elective outpatient GI endoscopy procedures. We evaluated key implementation process outcomes, guideline-adherent medication management, and sustained usage of this EMR-based alert and referral process.

## 2 | METHODS

### 2.1 | Implementation process

A new BPA and anticoagulation clinic referral process was implemented within our EMR system (Epic) starting in November 2017 as a pilot in one gastroenterology clinic and one primary care clinic in a single health care system in a Midwestern state in the United States.<sup>12</sup> It was gradually expanded over the subsequent 5 months until it was implemented system-wide in April 2018. This BPA (Figure S1) is triggered when an outpatient elective GI endoscopy procedure is ordered in the EMR for a patient listed as taking an oral anticoagulant or an antiplatelet medication (other than aspirin). The BPA recommends referral for preprocedural antithrombotic medication management by a clinical pharmacist within the health system's anticoagulation clinic. The ordering physician has the option to accept or decline the referral. If a referral is made to the anticoagulation clinic, a clinical pharmacist reviews the medical record, including date of procedure, type of antithrombotic medication, and comorbidities to assess for optimal preprocedure management. Preprocedure management, including if and when to stop the antithrombotic medication and the need for any short-acting "bridging" heparin anticoagulant, is determined using institutional guidelines (Tables S1 and S2). These institutional guidelines were adapted from national society guidelines and endorsed by clinical leaders within the health system. This plan is documented within the EMR, and a copy is sent to the ordering provider/primary care physician, cardiologist, and/or gastroenterologist for review. If the patient does not fall clearly within guideline management for issues such as thrombotic risk

assessment, bleed risk assessment, or necessity of “bridging” heparin, then the pharmacists will reach out to the physicians or providers for input and consensus on best management strategy. Plans are reviewed and created typically more than 1 to 2 weeks before the procedure date to allow for sufficient time for changes to antithrombotic cessation plan if necessary.

An additional 0.6 full-time equivalent (FTE) pharmacist was added to help with increased workload. Pharmacists received instructions using health system–approved guidelines in addition to relying on their general pharmacotherapy training.

## 2.2 | Patient selection

Eligible patients were at least 18 years old and taking either an anticoagulant medication (warfarin, apixaban, rivaroxaban, or dabigatran) or an antiplatelet agent (clopidogrel, prasugrel, or ticagrelor) who were also ordered for outpatient elective GI endoscopy. Patients were taken from a study period between November 1, 2017, and December 31, 2018. Relevant diagnoses of atrial fibrillation, venous thromboembolism, coronary artery disease, peripheral arterial disease, and mechanical heart valve were included in this study. Patients were excluded from the study if they were not taking an anticoagulant or antiplatelet medication before the GI endoscopic procedure, if they needed inpatient or urgent/emergent endoscopy, or if they were taking only aspirin. For the full list of exclusion criteria, please see the supplemental appendix.

## 2.3 | Process outcomes

The primary process outcome is the effect of the BPA on appropriate guideline-adherent medication management, where the key independent variable is whether the patient was referred or not. Appropriateness was defined as correct drug discontinuation date—typically 7 days before the procedure for prasugrel; 5 days before the procedure for warfarin, clopidogrel, and ticagrelor; and 2 days before the procedure for apixaban, rivaroxaban, and dabigatran—and whether short-acting bridging heparin was required in accordance with institutional periprocedural medication management guidelines (Tables S1 and S2). The secondary outcome was documentation of a medication management plan within the EMR before endoscopy. We also explored sustainment of this implementation effort by assessing the number and proportion of BPAs that resulted in anticoagulation clinic referrals between November 2017 and June 2020, >2.5 years after the BPA was introduced.

## 2.4 | Referral pattern outcomes

We evaluated the association between patient-, provider-, and procedure-level characteristics and referral patterns to

anticoagulation clinic. Patient factors of interest included diagnosis for antithrombotic therapy, type of antithrombotic medication taken, age, sex, type of procedure, concurrent use of aspirin, and prior endoscopic procedures as documented in EMR. Provider-level characteristics included specialty of referring provider (defined as cardiology, gastroenterology, primary care, or other), and whether previous encounter with this BPA showed an increased pattern of referral from those same providers. Procedure-level characteristics include the duration of time (days) between the start of BPA implementation (November 2017) and the actual date of endoscopy.

## 2.5 | Sustainment analysis

To assess the sustainment of our implementation effort, the frequency of BPAs and percentage that resulted in anticoagulation clinic referral were assessed both in the primary study period (November 2017 to December 2018) and for an additional 18 months (through June 2020).

## 2.6 | Statistical analysis

We used the Pearson chi-squared test to examine differences in referral to an anticoagulation clinic according to patient-, provider-, and procedure-level characteristics. A multilevel logistic regression model was constructed including all predictors that were significant in bivariate logistic regression analyses (diagnosis and type of medication at the patient level, specialty at the provider level). The multilevel model accounted for clustering at the provider level using provider identifier as a random effects variable. Trend analysis was performed for the outcomes of appropriate preprocedure medication discontinuation and documentation over the study period using multilevel logistic regression. Bivariate analyses were conducted to compare the anticoagulation management outcome measures of patients who did and did not get referral after the BPA for documentation of preprocedure management plan in chart, appropriate drug discontinuation before endoscopy, and appropriate bridging. All statistical analyses were performed using Stata/SE16.0 (StataCorp, College Station, TX, USA).

A waiver of informed consent was approved by the institutional review board for this project given the retrospective nature of the data collection.

## 3 | RESULTS

### 3.1 | Patient-level characteristics

During the primary study period (November 2017 to December 2018), the BPA resulted in referral of 553 of 691 cases (80.0%) to the anticoagulation clinic for management of antithrombotic medications before

**TABLE 1** Association between patient-, provider-, and procedure-level characteristics and referral to anticoagulation clinic

Characteristics	Was referral placed?		P value
	No N (%)	Yes N (%)	
Total	138 (20.0)	553 (80.0)	
<b>Patient-level</b>			
Age, y			
Median (IQR)	69 (63–76)	68 (61–75)	
20–39	1 (0.7)	11 (2.0)	.43
40–59	22 (15.9)	114 (20.6)	
60–79	96 (69.6)	357 (64.6)	
80–99	19 (13.8)	71 (12.8)	
Sex			
Male	86 (62.8)	318 (57.7)	.28
Female	51 (37.2)	233 (42.3)	
Diagnosis			
AF	49 (36.3)	173 (31.6)	.06
VTE	28 (20.7)	184 (33.6)	
CAD	51 (37.8)	165 (30.1)	
PAD	5 (3.7)	21 (3.8)	
Mechanical valve	2 (1.5)	5 (0.9)	
Type of medication			
VKA	36 (27.1)	184 (34.7)	.10
DOAC	58 (43.6)	233 (43.9)	
P2Y12 antiplatelet	39 (29.3)	114 (21.5)	
Concurrent use of aspirin			
No	103 (74.6)	397 (71.8)	.50
Yes	35 (25.4)	156 (28.2)	
Prior endoscopy			
No	122 (88.4)	486 (87.9)	.87
Yes	16 (11.6)	67 (12.1)	
<b>Provider-level</b>			
Specialty			
Anticoagulation	3 (25.0)	9 (75.0)	<.001
Cardiology	4 (66.7)	2 (33.3)	
GI	83 (17.3)	397 (82.7)	
PCP	28 (18.1)	127 (81.9)	
Other	20 (52.6)	18 (3.3)	
Total number of BPA firing			
Median (IQR)	2 (1–5)	2 (1–5)	
1	58 (42.0)	172 (31.1)	.03
2–4	37 (26.8)	218 (39.4)	
5–8	22 (15.9)	87 (15.7)	
≥9	21 (15.2)	76 (13.7)	
<b>Procedure-level</b>			
Type of procedure			

**TABLE 1** (Continued)

Characteristics	Was referral placed?		P value
	No N (%)	Yes N (%)	
Colonoscopy/ flexible sigmoidoscopy	73 (52.9)	267 (48.6)	.36
EGD	65 (47.1)	283 (51.5)	
Duration (in days) between BPA implementation on November 15, 2017, and endoscopy date			
Median (IQR)	265 (195–335)	282 (210–349)	
30–100	5 (3.6)	18 (3.3)	.16
101–160	12 (8.7)	56 (10.1)	
161–220	33 (23.9)	79 (14.3)	
221–280	28 (20.3)	123 (22.2)	
281–340	27 (19.6)	117 (21.2)	
341–410	33 (23.9)	160 (28.9)	
Duration (in months) between VTE event date and endoscopy date*			
<3	2 (1.5)	2 (0.4)	0.30
3–12	2 (1.5)	11 (2.0)	
>12	134 (97.1)	540 (97.7)	

Abbreviations: AF, atrial fibrillation; BPA, best practice alert; CAD, coronary artery disease; DOAC, direct oral anticoagulant; EGD, esophagogastroduodenoscopy; GI, gastrointestinal; IQR, interquartile range; PAD, peripheral artery disease; PCP, primary care physician; VKA, vitamin K antagonist; VTE, venous thromboembolism.

\*Among patients with VTE only.

outpatient GI endoscopy. Baseline patient-level characteristics are represented in Table 1. There were no significant differences between patients who were referred or not with regard to age, sex, concurrent use of aspirin, type of medication, and diagnosis.

### 3.2 | Provider-level characteristics

Of all the ordering providers, most anticoagulation clinic referrals were placed by gastroenterologists (397/553; 71.8%) and primary care providers (127/553; 22.9%). Among all gastroenterologist-placed endoscopy orders, 82.7% were referred to an anticoagulation clinic (397/480 orders). Among primary care provider-placed orders, 81.9% were referred to an anticoagulation clinic (127/155 orders). Providers who received BPAs on multiple patient interactions (2–4 alerts firing) during the study period were more likely to place a referral than those who saw the BPA only once.

### 3.3 | Procedure-level characteristics

As shown in Table 1, referral patterns were similar between different GI endoscopic procedure types of colonoscopy/flexible

(Continues)

sigmoidoscopy and esophagogastroduodenoscopy. Likewise, the interval between a more recent venous thromboembolic event and the endoscopy date did not significantly influence referral to anticoagulation clinic.

### 3.4 | Post-BPAs

Guideline-adherent medication discontinuation pre-procedure was more common in the patient referred to the anticoagulation clinic than those not referred (97.4% vs 91.0%;  $P = .001$ ; Table 2). Patients referred to the anticoagulation clinic were more likely to have documentation of their preprocedure medication management plan than those not referred (99.1% vs 59.4%;  $P < .001$ ). Both findings persisted in the multivariable logistic regression analyses (Table S3). Despite a numerical difference in the percent of patients receiving appropriate bridging management before endoscopy in the referral and nonreferral groups, this did not meet statistical significance (Table 2).

Post-BPA implementation, there was no observed difference over time in the rates of guideline-adherent drug discontinuation and the proportion of patients with appropriate documentation between January and December 2018 ( $P_{\text{trend}} > .50$  for both; Figure 1).

### 3.5 | Sustained use of BPA and referral

Both the total number of BPA fires and proportion of those BPAs leading to an anticoagulation clinic referral were sustained over a >2.5-year period after initial implementation in November 2017 (Figure 2). There was a notable decline in case numbers in April and May 2020 related to the coronavirus disease 2019 pandemic and intentional roll-back of elective outpatient endoscopies.

**TABLE 2** Association between referral to anticoagulation clinic and anticoagulation management outcomes

	Was referral placed?		Total	P value
	No N (%)	Yes N (%)		
Documentation of preprocedure management plan in chart				
No	56 (40.6)	5 (0.9)	61 (8.8)	<.001
Yes	82 (59.4)	548 (99.1)	630 (91.2)	
Total	138 (100.0)	553 (100.0)	691 (100.0)	
Appropriate drug discontinuation prior to endoscopy				
No	12 (9.0)	14 (2.6)	26 (3.9)	.001
Yes	121 (91.0)	517 (97.4)	638 (96.1)	
Total	133 (100.0)	531 (100.0)	664 (100.0)	
Appropriate bridging				
No	2 (50.0)	5 (27.8)	7 (31.8)	.39
Yes	2 (50.0)	13 (72.2)	15 (68.2)	
Total	4 (100.0)	18 (100.0)	22 (100.0)	

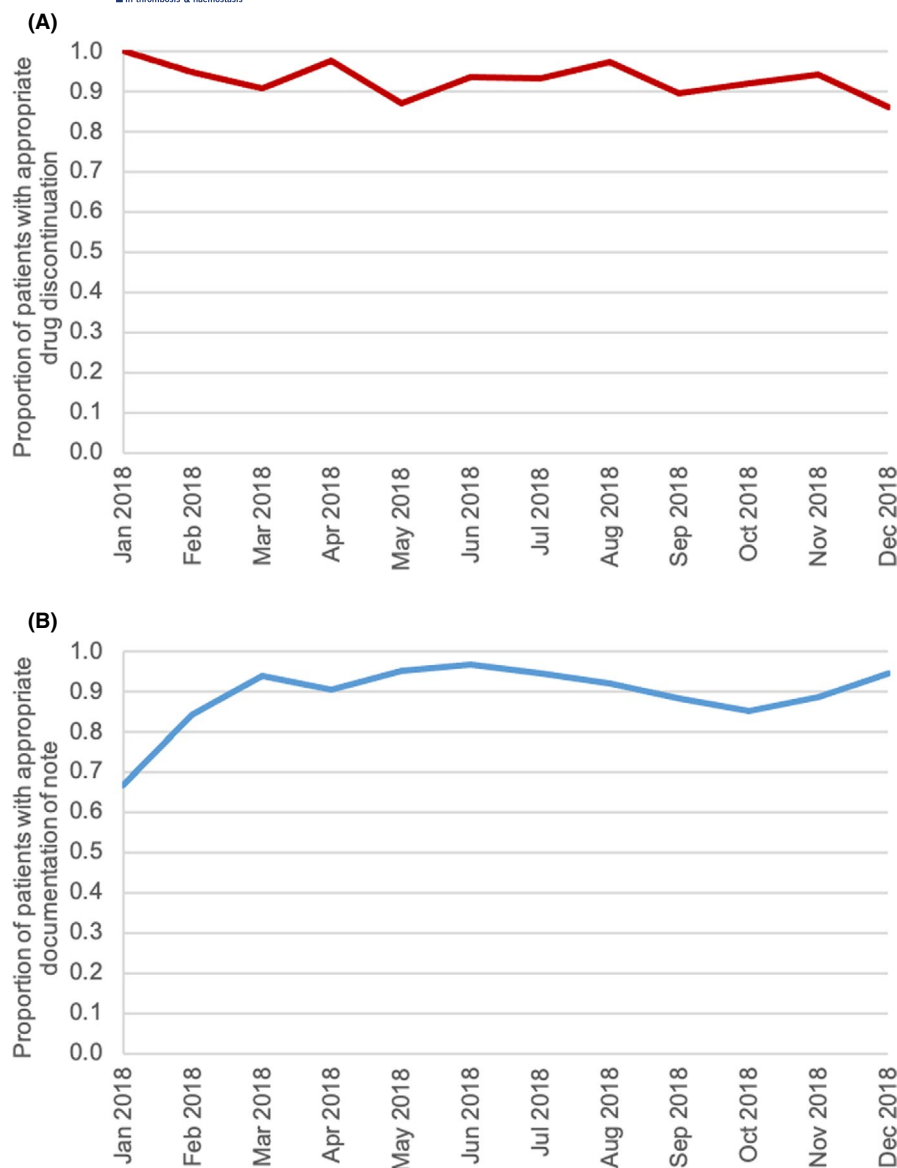
## 4 | DISCUSSION

We successfully implemented a system-wide BPA recommending anticoagulation clinic referral before elective GI endoscopy procedure for patients taking antithrombotic medications. Use of the referral process was high and sustained for >2.5 years. Implementation of the BPA and pharmacists' referral process improved preprocedure anticoagulation management and documentation, reducing variation in care.

Our study found that implementation of a BPA and anticoagulation clinic referral was associated with improved rates of guideline-adherent antithrombotic medication management. This demonstrates a successful expansion of the traditional role that anticoagulation clinics serve.<sup>13</sup> While these clinics typically have focused on making necessary monthly dose adjustments for warfarin-treated patients,<sup>14</sup> many clinics have begun offering expanded care for patients taking DOAC medications (eg, apixaban, rivaroxaban, dabigatran) and preprocedural drug management.<sup>15</sup> Recently, Spencer and colleagues<sup>16</sup> reported on their anticoagulation clinic's perioperative medication management program. Similar to the process described above, they helped to manage both warfarin and DOAC medications using evidence-based guidelines. However, unlike our program, they did not manage nonaspirin antiplatelet medications. While all antiplatelet agents are viewed as "blood thinners" to many patients and clinicians, the nuances of safe preprocedure management are complex and differ both by drug class and individual medication. Therefore, use of dedicated pharmacist experts applying evidence-based protocols is a highly effective implementation strategy for ensuring high-quality management of high-risk medications during the preprocedure period.

Two design features may have been associated with widespread and persistent use of the BPA. First, the BPA and referral process were designed to reduce the overall workload on the referring clinician. This was done by supporting collaborative work (referring clinician and anticoagulation pharmacists), fitting the alert into the referring clinician's work flow, and including actionable tools within the alert.<sup>17</sup> This incentivized clinicians to accept the BPA referral, as they no longer had to coordinate between different specialists and communicate with the patient regarding preprocedure medication management—the anticoagulation clinic managed those activities. Competent medication management resulted in trust in the anticoagulation clinic pharmacists and their evidence-based recommendations. Previous studies have demonstrated that streamlining workflow, such as for prenatal maternal vaccination and uncontrolled hypertension within outpatient visits, resulted in improved patient-associated outcomes.<sup>18,19</sup>

Second, the BPA design included the principle "make the *right* thing to do the *easy* thing to do." By automatically alerting clinicians at the time an endoscopy was ordered and preselecting the option for referral, the clinicians only had to "accept" the referral offer on the BPA for the process to begin. If they wanted to decline the referral, they had to use a few extra "clicks." In this way, the path of least resistance encouraged use of the anticoagulation clinic pharmacists and



**FIGURE 1** (A) Proportion of appropriate preprocedural antithrombotic drug discontinuation after implementation of best practice alert. (B) Proportion of appropriate documentation of drug plan after best practice alert implementation

increased the likelihood of evidence-based medication management. This has been previously shown to be an effective method in inpatient tobacco counseling with “opting out” as the default for an automatic BPA, for both patient-level outcomes and hospital-level performance measures.<sup>20</sup> These design principles likely contributed both to the broad adoption of this care pathway and to its sustained use for nearly 2 years.

While this BPA used GI endoscopy as the exemplary case for implementation, this system could be expanded to include other outpatient elective procedures as well, such as lumbar puncture, thoracentesis, and elective cardiac procedures. In the United States, nearly two-thirds of anticoagulation clinics already use pharmacists and would be ideally positioned to provide preprocedure antithrombotic medication management if the appropriate guidelines and protocols were enacted.<sup>15</sup> Furthermore, other clinics that have explored this preprocedure management process have found it to be feasible.<sup>21</sup> As described previously, a diverse group of stakeholders

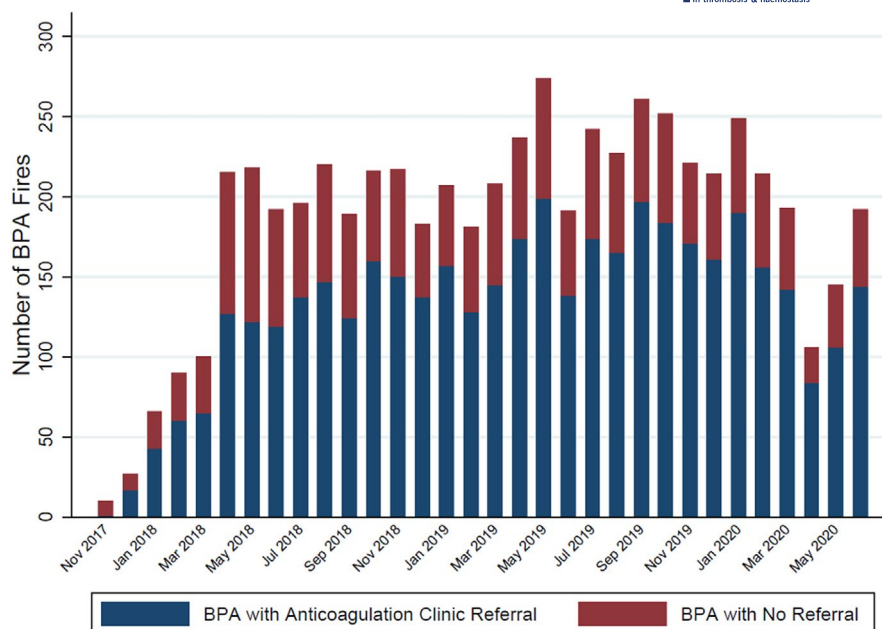
was intimately involved in the development and pilot of this process.<sup>12</sup> While our system did require additional FTE pharmacist effort to handle the additional volume, we have previously shown that fewer cancellations resulting from this referral and review process would result in significant cost savings to the hospital system and would more than cover the additional costs.<sup>12</sup>

## 5 | LIMITATIONS

First, implementation of this BPA was done at a single academic university health center, so outcomes may not be generalizable to other health centers. Additionally, we used our institutional guidelines for periprocedural antithrombotic medication management rather than national guidelines (ie, American Society for Gastrointestinal Endoscopy, American College of Cardiology) because national guidelines have some discrepancies on which patients are considered high



**FIGURE 2** Best practice alert (BPA) use and anticoagulation clinic referral over time



risk for thrombosis and require bridging anticoagulation. Furthermore, we excluded patients with intermediate thrombotic risk in the evaluation of bridging appropriateness since a decision either in favor of or against bridging can be justified by guidelines as an evidence-based practice. Rates of preimplementation anticoagulation clinic use for preprocedure medication management are not available but likely would be small given that most patients using DOAC and antiplatelet medications were not routinely followed by the anticoagulation clinic. Finally, while we are able to report on robust implementation and process outcomes, we are unable to report on clinical adverse event rates associated with the BPA and referral process.

## 6 | CONCLUSION

Implementation of a BPA recommending referral to an anticoagulation clinic before elective GI endoscopic procedures in patients taking antithrombotic medications was associated with improved rates of documented medication management plan within the EMR as well as improved rates of guideline-adherent medication management. Furthermore, this referral process streamlined preprocedural antithrombotic medication management and showed consistent, sustained adoption over >2 years' time.

### AUTHOR CONTRIBUTIONS

HH and GB contributed equally to the writing of this manuscript. HH, WC, and SM contributed to data collection. HH, GB, and GC contributed to data analysis. All authors contributed to manuscript review and revisions.

### RELATIONSHIP DISCLOSURE

GB discloses consulting fees from Pfizer/Bristol-Myers Squibb, Janssen, AMAG Pharmaceuticals, and Acelis Connected Health. All other authors declare no conflicts of interest.

### ORCID

Henry Han  <https://orcid.org/0000-0003-4911-1070>

### TWITTER

Allison Ruff  @AlliLRuff

Anne Sales  @AnneSales4

Jacob Kurlander  @Jekurlander

Geoffrey D. Barnes  @GBarnesMD

### REFERENCES

1. McBride CL, Akeroyd JM, Ramsey DJ, et al. Statin prescription rates and their facility-level variation in patients with peripheral artery disease and ischemic cerebrovascular disease: insights from the Department of Veterans Affairs. *Vasc Med*. 2018;23(3):232-240. <https://doi.org/10.1177/1358863X18758914>
2. Tran HV, Waring ME, McManus DD, et al. Underuse of effective cardiac medications among women, middle-aged adults, and racial/ethnic minorities with coronary artery disease (from the National Health and Nutrition Examination Survey 2005 to 2014). *Am J Cardiol*. 2017;120:1223-1229.
3. Savarese G, Carrero J-J, Pitt B, et al. Factors associated with underuse of mineralocorticoid receptor antagonists in heart failure with reduced ejection fraction: an analysis of 11 215 patients from the Swedish Heart Failure Registry. *Eur J Heart Fail*. 2018;20:1326-1334.
4. Ferreira JP, Rossignol P, Machu J-L, et al. Mineralocorticoid receptor antagonist pattern of use in heart failure with reduced ejection fraction: findings from BIOSTAT-CHF. *Eur J Heart Fail*. 2017;19:1284-1293.
5. Thorvaldsen T, Benson L, Dahlström U, Edner M, Lund LH. Use of evidence-based therapy and survival in heart failure in Sweden 2003-2012. *Eur J Heart Fail*. 2016;18:503-511.
6. Havers FP, Hicks LA, Chung JR, et al. Outpatient antibiotic prescribing for acute respiratory infections during influenza seasons. *JAMA Netw Open*. 2018;1:e180243.
7. Lau BD, Haut ER. Practices to prevent venous thromboembolism: a brief review. *BMJ Qual Saf*. 2014;23:187-195.
8. Edrees H, Amato MG, Wong A, Seger DL, Bates DW. High-priority drug-drug interaction clinical decision support overrides in a newly

- implemented commercial computerized provider order-entry system: override appropriateness and adverse drug events. *J Am Med Inform Assoc.* 2020;27:893-900.
9. Holmgren AJ, Co Z, Newmark L, Danforth M, Classen D, Bates D. Assessing the safety of electronic health records: a national longitudinal study of medication-related decision support. *BMJ Qual Saf.* 2020;29:52-59.
  10. Barnes GD, Kurlander J, Haymart B, Kaatz S, Saini S, Froehlich JB. Bridging anticoagulation before colonoscopy: results of a multispecialty clinician survey. *JAMA Cardiol.* 2016;1:1076-1077.
  11. Acosta J, Graves C, Spranger E, Kurlander J, Sales AE, Barnes GD. Periprocedural antithrombotic management from a patient perspective: a qualitative analysis. *Am J Med.* 2019;132:525-529.
  12. Barnes GD, Spranger E, Sippola E, et al. Assessment of a best practice alert and referral process for preprocedure antithrombotic medication management for patients undergoing gastrointestinal endoscopic procedures. *JAMA Netw Open.* 2020;3:e1920548.
  13. Barnes GD, Nallamothu BK, Sales AE, Froehlich JB. Reimagining anticoagulation clinics in the era of direct oral anticoagulants. *Circ Cardiovasc Qual Outcomes.* 2016;9:182-185.
  14. Witt DM, Sadler MA, Shanahan RL, Mazzoli G, Tillman DJ. Effect of a centralized clinical pharmacy anticoagulation service on the outcomes of anticoagulation therapy. *Chest.* 2005;127:1515-1522.
  15. Barnes GD, Kline-Rogers E, Graves C, et al. Structure and function of anticoagulation clinics in the United States: an AC forum membership survey. *J Thromb Thrombolysis.* 2018;46:7-11.
  16. Spencer NH, Sardo LA, Cordell JP, Douketis JD. Structure and function of a perioperative anticoagulation management clinic. *Thromb Res.* 2019;182:167-174.
  17. Marcilly R, Ammenwerth E, Roehrer E, Niès J, Beuscart-Zéphir M-C. Evidence-based usability design principles for medication alerting systems. *BMC Med Inform Decis Mak.* 2018;18:69.
  18. Morgan JL, Baggari SR, Chung W, Ritch J, McIntire DD, Sheffield JS. Association of a best-practice alert and prenatal administration with tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis vaccination rates. *Obstet Gynecol.* 2015;126:333-337.
  19. Swedlund M, Norton D, Birstler J, Chen G, Cruz L, Hanrahan L. Effectiveness of a best practice alerts at improving hypertension control. *Am J Hypertens.* 2019;32:70-76.
  20. Herbst N, Wiener RS, Helm ED, et al. Effectiveness of an opt-out electronic health record-based tobacco treatment consult service at an urban safety net hospital. *Chest.* 2020;158:1734-1741.
  21. Barnes GD, Acosta J, Kurlander JE, Sales AE. Using health systems engineering approaches to prepare for tailoring of implementation interventions. *J Gen Intern Med.* 2021;36:178-185.

## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

**How to cite this article:** Han H, Chung G, Sippola E, et al. Improving preprocedure antithrombotic management: Implementation and sustainment of a best practice alert and pharmacist referral process. *Res Pract Thromb Haemost.* 2021;5:e12558. <https://doi.org/10.1002/rth2.12558>