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Implementation of the Management of Anticoagulation in the Periprocedural Period App Into an Electronic Health Record: A Prospective Cohort Study

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Abstract

Appropriate perioperative management of patients on chronic oral anticoagulation (OAC)—including warfarin and the direct oral anticoagulants—is a poorly defined yet important clinical issue with potentially severe consequences in the postoperative period. We sought to prospectively evaluate the effect of the Management of Anticoagulation in the Periprocedural Period (MAPPP) mobile app as a clinical decision tool in the management of patients on chronic OAC undergoing elective procedures or surgeries. Between January 1, 2018, and January 31, 2019, 642 patients treated in our health system were included. Eligible patients met the following criteria: age >18 years old, creatinine clearance $\geq$15 mL/min, and on chronic OAC with adequate information regarding baseline characteristics. Our study outcome was patient's emergency department (ED) visits within 30 days postprocedure. The MAPPP app was integrated into the electronic health record (EHR), and the end user was free to accept or decline recommended evidence-based perioperative anticoagulation management guidance. Analysis revealed that acceptance was more common in younger patients ($P = .0137$), patients on oral anticoagulants other than warfarin ($P < .0001$), and patients undergoing increased bleeding risk procedures ($P = .0068$). Acceptance of the MAPPP app recommendation was significantly associated with fewer ED visits (acceptance group: 4.0% vs rejection group: 8.3%, $P = .0205$). Logistic regression showed that intervention acceptance and female gender were significantly associated with fewer—while age $\geq$80 with more—30-day ED visits. Our findings indicate that newer technologies, such as the MAPPP app, integrated into clinical EHR workflow, can significantly augment evidence-based perioperative anticoagulation management and potentially result in a reduction of adverse outcomes.

Keywords

MAPPP, anticoagulation, electronic health record, adverse drug event, emergency visits, perioperative, health informatics technology, warfarin, direct oral anticoagulants

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Introduction

The periprocedural management of patients receiving chronic oral anticoagulants (OACs) such as vitamin K antagonists like warfarin and direct oral anticoagulants (DOACs) represents an important dilemma for practicing physicians and affects at least 250 000 patients/year in North America.[1-3] Annually, 1 out of every 6 patients on chronic OAC with atrial fibrillation (AF) require an elective surgical procedure and periprocedural anticoagulation interruption.[4-6] The management of patients on chronic OAC during the periprocedural period is complicated by the conflicting risks of procedure-related bleeding or thrombosis associated with patient-related factors or interruption of anticoagulant therapy, respectively. Previously, the Greater Cincinnati/Northern Kentucky Stroke Study has shown that 5.2% of the 2197 first-ever or recurrent strokes occur after withdrawal of anticoagulant or antiplatelet therapy, and 47.4% of discontinuation events occur in the periprocedural period. The authors suggested the need for more careful clinical decision approaches for the management of anticoagulation/antiplatelet medications in the periprocedural period.[7]

The US Department of Health and Human Services' National Action Plan for Adverse Drug Event Prevention (ADE Action Plan) outlined opportunities to prevent anticoagulant-related ADEs through innovations in the areas of surveillance, use of evidence-based prevention tools, and utilization of health informatics technology (HIT).[8] In addition, according to the ADE Action Plan, the likelihood for an ADE increases during transitions of care, such as elective surgical procedures that commonly interrupt the routine patient management process. Health informatics technology includes mobile and web-based health apps that augment the decision-making and facilitate appropriate management of chronic diseases.[9] In 2013, the New York State Anticoagulation Coalition guided the development of the Management of Anticoagulation in the Periprocedural Period (MAPPP) mobile app in order to facilitate clinician awareness and clinical decision support of the most current guidelines of the periprocedural management of patients on chronic OAC, including warfarin and DOACs. The MAPPP app utilizes a 3 × 3 matrix to classify patients according to patient-related thromboembolic risk (low, moderate, or high) and periprocedural bleeding risk (minimal, low, or high). The resulting output includes evidence-based recommendations regarding periprocedural anticoagulation interruption and timing, heparin bridging, and indicated laboratory monitoring, as well as timing and dosing scheme of postoperative anticoagulant reinitiation.[10]

Our prospective cohort study evaluated the implementation of the MAPPP app as a clinical decision support tool in the periprocedural management of patients on chronic OAC (warfarin and DOACs) undergoing elective invasive procedures. The primary intervention was the integration of MAPPP app into active clinical decision support (CDS) within the electronic health record (EHR) of our health system. Targeted application users included nurse practitioners responsible for presurgical testing and physicians ordering surgical procedures. The primary objective of the present study was to ascertain if use of the MAPPP app resulted in fewer post-procedural emergency department (ED) visits.

Methods

Study Design

An overview of the MAPPP app design and recommendations based on a 3 × 3 matrix of procedural bleed risk (minimal, low, and high) and patient-related thromboembolic risk (low, moderate, high) is shown in Supplementary Figure. The MAPPP app was integrated in our health system's Sunrise EHR (Allscripts) by using REDCap, an electronic data capture tool.

Health care practitioners' participation in the project required education and support for the MAPPP app through our institution's online learning module and a live continuing medical education program. The end user was free to follow or decline recommended evidence-based guidance, and 2 distinct cohorts were created based on the acceptance or rejection of MAPPP app recommendations by health care providers. Eligible patients met the following criteria: age >18 years old, creatinine clearance ≥15 mL/min (patients undergoing dialysis were excluded), on chronic OAC treatment (warfarin, dabigatran, rivaroxaban, or apixaban), and adequate information regarding grouping (acceptance or rejection group), date of surgery, age, gender, weight, procedural bleeding risk, patient thromboembolic risk, and medical record number (to identify follow-up data in the EHR system). As per the MAPPP app recommendations, procedural bleeding risk was classified as "minimal," "low," and "high," and patient-related thromboembolic risk was classified as "low," "medium," or "high." In addition, classification of patients included antiplatelet medication use in the form of aspirin or clopidogrel. This study was reviewed and approved by the institutional review board at Northwell Health.

Study Data and Outcomes

The primary outcome for the study was emergency department visits within 30 days of the procedure (yes/no at the patient level) identified using billing data. Baseline patient characteristics (age, gender, weight) and clinical parameters (creatinine, creatinine clearance, anticoagulation medication, antiplatelet medication, procedural bleeding risk, patient-related thromboembolic risk) were extracted from the EHR. Data collection was facilitated through REDCap, both manually and through direct REDCap acquisition of EHR structured fields.

Statistical Analysis

Data analysis was performed to compare patients' demographics, the utilization of anticoagulant and antiplatelet medications, procedural bleeding and patient thromboembolic risk, and 30-day postoperative ED visits. Bivariate analyses compared the acceptance and rejection groups as well as the with or without 30-day ED visit groups. Continuous variables were

Table 1. Patient Characteristics and Outcomes (N = 642).

Patient characteristics	Mean (SD)	n (%)
Age category		
20-64		149 (23.2%)
65-79		288 (44.9%)
80+		205 (31.9%)
Gender		
Male		369 (57.5%)
Female		273 (42.5%)
Weight (kg)	86.7 (24.1)	615
Creatinine (mg/dL)	1.23 (1.27)	628
Creatinine clearance (mL/min)	76.4 (42.7)	605
Anticoagulation medication		
Warfarin		232 (36.1%)
Dabigatran		35 (5.5%)
Rivaroxaban		156 (24.3%)
Apixaban		219 (34.1%)
Antiplatelet medication		
Aspirin		
Yes		106 (16.5%)
No		536 (83.5%)
Clopidogrel		
Yes		25 (3.9%)
No		617 (96.1%)
Procedure bleeding risk		
Minimal		41 (6.4%)
Low		268 (41.7%)
High		333 (51.9%)
Patient's thromboembolic risk		
Low		276 (43%)
Medium		261 (40.7%)
High		105 (16.4%)
Intervention group		
Acceptance		353 (55.0%)
Rejection		289 (45.0%)

compared with pooled *t* tests, and categorical variables were compared with χ^2 tests. Logistic regression was performed to further analyze the association between baseline or clinical parameters and primary outcome. Statistical analyses were conducted using SAS Version 9.4 (SAS Institute Inc). A *P* value of <.05 was considered statistically significant.

Results

Patient Population

The study sample consisted of 642 patients receiving chronic OAC treatment who underwent elective procedures or surgeries from January 1, 2018, through January 31, 2019. Overall, patients had a mean age of 72.6 ± 12.6 years, mean weight of 86.7 ± 24.1 kg, and mean creatinine of 1.23 mg/dL and were predominantly male (n = 369 [57.5%]; Table 1). In total, 76.8% of patients were older than 65 years. Warfarin (36.1%) and apixaban (34.1%) were the most commonly used OAC medications, and antiplatelet agents (aspirin, clopidogrel) were used in less than 25% of the population sample. Approximately half of the cohort underwent high bleeding risk procedures or surgeries (51.9%), and 16.4% were considered at high thromboembolic risk. The intervention recommendation was accepted in 353 patients (55.0%) and rejected in 289 patients (45.0%).

Study Outcomes

Intervention acceptance. Acceptance and rejection groups differed significantly in terms of mean age (71.4 vs 74.1 years, P = .068), mean weight (88.9 vs 84.0 kg, P = .0118), and mean creatinine clearance (80.8 vs 71.0 ml/min, P = .0040). Acceptance was more commonly observed for patients aged 20-64 (P = .0137), patients on anticoagulant medications other than warfarin (P < .0001), and in patients undergoing procedures or surgeries with high bleeding risk (P = .0068). Creatinine level, gender, clopidogrel prescription, and thromboembolic risk were similar between the acceptance and rejection groups.

Postoperative ED Visit

Overall, 38 (5.9%) of patients had at least 1 ED visit within 30 days of the surgery. Acceptance of MAPPP app recommendation was significantly associated with fewer ED visits (acceptance group: 4.0% vs rejection group: 8.3%, P = .0205; Table 2). In contrast, male gender (P = .0154) and age ≥80 years (P = .0269) were associated with more ED visits (Table 3). Mean age, mean weight, creatinine, creatinine clearance, procedural bleeding risk, patient-related thromboembolic risk, and anticoagulation and antiplatelet medication usage were similar between patients who went to the ED and those who did not.

In the logistic regression model, intervention acceptance (odds ratio [OR]: 0.497, 95% CI: 0.249-0.992) and female gender (OR: 0.401, 95% CI: 0.185-0.869) were significantly associated with fewer 30-day ED visits, while advanced age (age ≥80, OR: 2.116, 95% CI: 1.083-4.137) was associated with more ED visits (Table 4). The overall predictive ability of the model had a concordance index (c-index) of 0.681.

Discussion

Our prospective study evaluated the integration of the MAPPP app as a CDS tool in the management of patients on chronic OAC undergoing elective invasive procedures or surgeries. Although the acceptance group and rejection group cohorts differed in terms of kidney function, age, weight, medication profile, and procedural bleeding risk, the acceptance group had significantly fewer postoperative ED visits within 30 days. Regression analysis revealed that intervention acceptance of the MAPPP app recommendations (in addition to female sex) was significantly associated with fewer ED visits and advanced age (≥ 80 years) was associated with more ED visits.

The 30-day postoperative period, utilized in our study, has been classically used in the evaluation of postoperative mortality and hospitalization.[11-14] The primary outcome of post-procedural ED visits represents an important health care economic burden and an outcome associated with the quality of treatment.[15-17] Theoretically, interventions that improve the

Table 2. Intervention Group Characteristics and Outcomes (N = 642).[a,b]

Patient characteristics	Acceptance (n = 353)	Rejection (n = 289)	P value
Age category			**.0137**
20-64	96 (64.4%)	53 (35.6%)	
65-79	157 (54.5%)	131 (45.5%)	
80+	100 (48.8%)	105 (51.2%)	
Gender			.7614
Male	201 (54.5%)	168 (45.5%)	
Female	152 (55.7%)	121 (44.3%)	
Weight (kg)	88.9 (25.4)	84.0 (22.2)	**.0118**
Creatinine (mg/dL)	1.27 (1.63)	1.18 (0.56)	.3610
Creatinine clearance (mL/min)	80.8 (46.5)	71.0 (36.8)	**.0040**
Anticoagulation medication			**<.0001**
Warfarin	96 (41.4%)	136 (58.6%)	
Dabigatran	18 (51.4%)	17 (48.6%)	
Rivaroxaban	92 (59.0%)	64 (41.0%)	
Apixaban	147 (67.1%)	72 (32.9%)	
Warfarin			**<.0001**
Yes	96 (41.4%)	136 (58.6%)	
No	257 (62.3%)	153 (37.3%)	
Antiplatelet medication			
Aspirin			**.0473**
Yes	49 (46.2%)	57 (53.8%)	
No	304 (56.7%)	232 (43.3%)	
Clopidogrel			.1245
Yes	10 (40.0%)	15 (60.0%)	
No	343 (55.6%)	274 (44.4%)	
Procedure bleeding risk			**.0068**
Minimal	14 (34.1%)	27 (65.9%)	
Low	142 (53%)	126 (47%)	
High	197 (59.2%)	136 (40.8%)	
Patient's thromboembolic risk			.8586
Low	155 (56.2 %)	121 (43.8 %)	
Medium	142 (54.4 %)	119 (45.6 %)	
High	56 (53.3%)	49 (46.7 %)	
Outcome (30 days after surgery)			
ED visit			**.0205**
Yes	14 (4.0%)	24 (8.3%)	
No	339 (96.0%)	265 (91.7%)	

Abbreviation: ED, emergency department.
[a]A *P* value of <.05 was considered statistically significant.
[b]Values are mean (SD) or n (%).

Table 3. Patient characteristics Versus ED Visit in 30 Days (N = 642).[a]

Patient characteristics	ED visit (n = 38)	No visit (n = 604)	P value
Age category			**.0269**
20-64	9 (6.0%)	140 (94%)	
65-79	10 (3.5%)	278 (96.5%)	
80+	19 (9.3%)	186 (90.7%)	
Gender			**.0154**
Male	29 (7.9%)	340 (92.1%)	
Female	9 (3.3%)	264 (96.7%)	
Weight	82.4 (21.0)	86.9 (24.2)	.2616
Creatinine	1.18 (0.59)	1.23 (1.30)	.7978
Creatinine clearance	71.6 (33.9)	76.7 (43.2)	.4825
Anticoagulation medication			.1220
Warfarin	18 (7.8%)	214 (92.2%)	
Dabigatran	1 (2.9%)	34 (97.1%)	
Rivaroxaban	12 (7.7%)	144 (92.3%)	
Apixaban	7 (3.2%)	212 (96.8%)	
Warfarin			.1373
Yes	18 (7.8%)	214 (92.2%)	
No	20 (4.9%)	390 (95.1%)	
Antiplatelet medication			
Aspirin			.4369
Yes	8 (7.6%)	98 (92.4%)	
No	30 (5.6%)	506 (94.4%)	
Clopidogrel			.6529
Yes	2 (8.0%)	23 (92.0%)	
No	36 (5.8%)	581 (94.2%)	
Procedure bleeding risk			.5420
Minimal	1 (2.4%)	40 (97.6%)	
Low	18 (6.7%)	250 (93.3%)	
High	19 (5.7%)	314 (94.3%)	
Patient's thromboembolic risk			.7312
Low	14 (5.1%)	262 (94.9%)	
Medium	17 (6.5%)	244 (93.5%)	
High	7 (6.7%)	98 (93.3%)	

[a]A *P* value of <.05 was considered statistically significant.

Table 4. Logistic Regression Results of 30-Day ED Visit on Patient Characteristics (N = 642).[a,b]

Patient characteristics	MLE	OR (95% CI)	P value
Intervention acceptance	−0.699	0.497 (0.249-0.992)	**.0473**
Age 80+	0.750	2.116 (1.083-4.137)	**.0284**
Female gender	−0.914	0.401 (0.185-0.869)	**.0206**
High bleeding risk	−0.050	0.951 (0.481-1.883)	.8861
High thromboembolic risk	0.144	1.155 (0.477-2.793)	.7499
Aspirin	0.109	1.115 (0.486-2.555)	.7972

Abbreviations: MLE, maximal likelihood estimation; OR, odds ratio.
[a]A *P* value of <.05 was considered statistically significant.
[b]C-index = 0.681.

quality of care should result in a decreased ADE incidence and reduced ED visits and formed the basis of our hypothesis that the MAPPP app would be effective in reducing ED visits during the 30-day postprocedural period. Emergency department visits were decreased by approximately 50% in the acceptance group versus the rejection group (4.0% vs 8.3%, P = .0205). Previously, the MAPPP mobile app version in 2016 was associated with a 20% relative reduction in the 30-day postoperative ADE rate, although the observed effect could not be attributed directly to the app.[10]

Perioperative management of patients on chronic OAC in elective periprocedural settings continues to be a complex issue, as DOACs have emerged as alternative agents to warfarin with increased use in the treatment of patients with AF and with established thromboembolic disease.[18] Although the temporary perioperative interruption of DOACs has been associated with low rates of perioperative thrombotic events, the lack of awareness of appropriate management options may lead to severe postoperative complications.[2,19] Despite the

evidence-based benefit of DOACs in the treatment of thromboembolism and AF, physicians and nurse practitioners involved in the management of anticoagulation are not always familiar with the most recent advances and recommendations.[10] Our study's acceptance group had better renal function (creatinine clearance: 80.8 vs 71.0 mL/min, P = .0040) compared to the rejection group. In addition, acceptance of MAPPP app recommendations was higher in patients receiving OAC medications other than warfarin (P < .0001). These findings suggest that MAPPP app end users preferred to follow their clinical judgment, instead of the most current guidelines in patients on chronic OAC with impaired renal function (increased ADE risk) and in patients receiving warfarin, which has been in the market for many years and with which health care providers are very familiar. Nonfamiliarity regarding emerging data about the safety and efficacy of DOACs in periprocedural settings may have played a role in greater adherence to the evidence-based recommendations for periprocedural DOAC management as incorporated into the MAPPP app.

The usual distribution of guidelines through hard or electronic copies is a passive user-dependent education process. In contrast, mobile and web-based apps have been shown to be effective CDS and guideline dissemination tools.[10,20,21] The MAPPP app development has been previously described and its objective was to reduce the rate of anticoagulant-associated ADEs.[10] Benefits include broad dissemination, remote updates according to newer guidelines, and tracking of utilization. Notably, the American College of Cardiology (ManageAnticoag app) and University of Michigan (MAQI2 Anticoagulation Toolkit) have developed apps similar to the MAPPP app in order to facilitate appropriate periprocedural anticoagulation management.[22,23] The EHR-integrated CDS tools have been assessed in a variety of settings with patients receiving anticoagulant medications. Ahuja et al developed a CDS tool to provide evidence-based dosing and increase the safety of DOACs in hospitalized patients. User adherence to CDS recommendations was high (75-87%), and noncompliance/lower dosing was mainly attributed to impaired renal function, history of bleeding, and perceived patients' vulnerability.[24] A recent systematic review assessed the EHR interventions that could potentially improve the safety of inpatient anticoagulation. Only 5 of 27 studies evaluated the CDS tool impact in terms of morbidity, mortality, and hospital readmissions.[25]

Our study provides further evidence on the value of integrating the MAPPP app into additional hospital EHRs and measuring outcomes as part of patient safety goals. The perioperative management of anticoagulation is included as a new Improvement Activity in the Medicare Quality Payment program and additionally is a new requirement for Joint Commission National Patient Safety Goals (NPSG.03.05.01) for the Hospital Accreditation Program. We anticipate an increase in MAPPP app utilization and EHR integration due to recent recognition by the Joint Commission 2019 National Patient Safety Goals, which recommended education and approved protocols for the initiation and maintenance of anticoagulation regimens, including the during periprocedural period.[26]

Several limitations to our study should be acknowledged. The MAPPP app generalizability is limited by the population characteristics (adult patients with creatinine clearance $\geq$15 mL/min) and the ability of the EHR to incorporate MAPPP in the form of a fully Substitutable Medical Applications and Reusable Technologies on Fast Healthcare Interoperability Resources (SMART on FHIR) application. Further, our app was designed with the ability to use the latest SMART on FHIR technology to allow seamless and rapid interaction with EHRs, but the health systems were not ready for this level of integration. Another limitation of our study is its relatively small sample size and the possibility of hidden confounders between the acceptance and rejection groups, which could potentially affect the study power and identification of any association between primary outcome and investigated variables.

Conclusion

Integration of a CDS tool for the management of patients on chronic OAC undergoing elective procedures or surgeries—the MAPPP app—into an EHR was associated with a significantly lower rate of ED visits during the 30-day postoperative period. The MAPPP app as part of HIT is a promising evidence-based CDS tool that can augment clinical management and has the potential to decrease anticoagulation-related adverse outcomes.

Authors' Note

All authors contributed equally to this work. All authors read and approved the final manuscript. A.C.S., J.C., A.M., and J.J.W. conceptualized or designed the work. J.C., S.J., A.M., and M.Q. collected data. A.C.S., J.J.W., M.Q., S.A., D.G., D.I., and R.J.H. analyzed data and contributed in interpretation. A.C.S., J.J.W., A.M., J.C., and D.G. drafted the article. A.C.S., J.J.W., and D.G. critically revised the article. All authors gave final approval of the version to be published.

Declaration of Conflicting Interests

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