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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 ≥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 ≥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 52% 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 postprocedural 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%) | 288 (44.9%) |
| 65-79                   | 205 (31.9%) | 273 (42.5%) |
| **Gender**              |           |       |
| Male                    | 369 (57.5%) | 615 |
| Female                  | 232 (36.1%) | 628 |
| **Weight (kg)**         | 86.7 (24.1) | 605 |
| **Creatinine (mg/dL)**  | 1.23 (1.27) | 628 |
| **Creatinine clearance (mL/min)** | 76.4 (42.7) | 615 |
| **Anticoagulation medication** | | |
| Warfarin                | 232 (36.1%) | 615 |
| Dabigatran              | 35 (5.5%) | 615 |
| Rivaroxaban             | 156 (24.3%) | 615 |
| Apixaban                | 219 (34.1%) | 615 |
| **Antiplatelet medication** | | |
| Yes                     | 106 (16.5%) | 615 |
| No                      | 536 (83.5%) | 615 |
| **Procedure bleeding risk** | | |
| Minimal                 | 41 (6.4%) | 615 |
| Low                     | 268 (41.7%) | 615 |
| High                    | 333 (51.9%) | 615 |
| **Patient’s thromboembolic risk** | | |
| Low                     | 276 (43%) | 615 |
| Medium                  | 261 (40.7%) | 615 |
| High                    | 105 (16.4%) | 615 |
| **Intervention group**  | | |
| Acceptance              | 353 (55.0%) | 615 |
| Rejection               | 289 (45.0%) | 615 |

compared with pooled t tests, and categorical variables were compared with χ² 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: 0.185-0.869) was 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 30-day ED visits, while advanced age (age ≥80, OR: 2.116, 95% CI: 1.083-4.137) 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
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

### Table 2. Intervention Group Characteristics and Outcomes (N = 642)\(^a,b\)

| Patient characteristics | Acceptance (n = 353) | Rejection (n = 289) | P value |
|-------------------------|---------------------|-------------------|---------|
| Age category            |                     |                   |         |
| 20-64                   | 96 (64.4%)          | 53 (35.6%)        | .0137   |
| 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 |

### 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            |                  |                   |         |
| 20-64                   | 9 (6.0%)         | 140 (94%)         | .0269   |
| 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 (kg)             | 82.4 (21.0)      | 86.9 (24.2)       | .2616   |
| Creatinine (mg/dL)      | 1.18 (0.59)      | 1.23 (1.30)       | .7978   |
| Creatinine clearance (mL/min) | 71.6 (33.9) | 76.7 (43.2) | .4825 |

### 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 |

Abbreviation: ED, emergency department.
\(^a\)A P value of <.05 was considered statistically significant.
\(^b\)Values are mean (SD) or n (%).
A recent systematic review assessed the EHR interfunction, history of bleeding, and perceived patients’ vulnerability/lower dosing was mainly attributed to 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. The MAPPP app development has been previously described and its objective was to reduce the rate of anticoagulant-associated ADEs. 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. 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. 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.

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 peroperative 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.

Several limitations to our study should be acknowledged. The MAPPP app generalizability is limited by the population characteristics (adult patients with creatinine clearance ≥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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**References**

1. Douketis JD, Spyropoulos AC, Spencer FA, et al. Perioperative management of antithrombotic therapy: antithrombotic therapy and prevention of thrombosis, 9th ed: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines. Chest. 2012;141(2 suppl):e326S-e350S. doi:10.1378/chest.11-2298

2. Douketis JD, Spyropoulos AC, Duncan J, et al. Perioperative management of patients with atrial fibrillation receiving a direct oral anticoagulant. *JAMA Intern Med.* 2019;179(11):1469-1478. doi:10.1001/jamainternmed.2019.2431

3. Spyropoulos AC, Badri AA, Sherwood MW, Douketis JD. Periprocedural management of patients receiving a vitamin K antagonist or a direct oral anticoagulant requiring an elective procedure or surgery. *J Thromb Haemost.* 2016;14(5):875-885. doi:10.1111/jth.13305

4. Healey JS, Ezekowitz J, Douketis J, et al. Periprocedural bleeding and thromboembolic events with dabigatran compared with warfarin: results from the randomized evaluation of long-term anticoagulation therapy (RE-LY) randomized trial. *Circulation.* 2012;126(3):343-348. doi:10.1161/CIRCULATIONAHA.111.090464

5. Garcia D, Alexander JH, Wallentin L, et al. Management and clinical outcomes in patients treated with apixaban vs warfarin undergoing procedures. *Blood.* 2014;124(25):3692-3698. doi:10.1182/blood-2014-08-595496

6. Douketis JD, Spyropoulos AC, Kaatz S, et al. Perioperative bridging anticoagulation in patients with atrial fibrillation. *N Engl J Med.* 2015;373(9):823-833. doi:10.1056/NEJMoai15-1035

7. Broderick JP, Bonomo JB, Kissela BM, et al. Withdrawal of antithrombotic agents and its impact on ischemic stroke occurrence. *Stroke J Cereb Circ.* 2011;42(9):2509-2514. doi:10.1161/STROKEAHA.110.611905

8. US Department of Health and Human Services, *Office of Disease Prevention and Health Promotion.* National Action Plan for Adverse Drug Event Prevention. 190; 2014.

9. Stephan LS, Almeida ED, Guimarães RB, et al. Oral anticoagulation in atrial fibrillation: development and evaluation of a mobile health application to support shared decision-making. *Arg Bras Cardiol.* 2018;110(1):7-15. doi:10.5935/abc.20170181

10. Spyropoulos AC, Myrka A, Triller DM, et al. Uptake and utilization of the Management of Anticoagulation in the Periprocedural Period app: longitudinal analysis. *JMIR MHealth UHealth.* 2018;6(12):e11090. doi:10.2196/11090

11. Schiergens TS, Dörsch M, Mittermeier L, et al. Thirty-day mortality leads to underestimation of postoperative death after liver resection: a novel method to define the acute postoperative period. *Surgery.* 2015;158(6):1530-1537. doi:10.1016/j.surg.2015.07.019

12. Stefani LC, Gamermann PW, Backof A, et al. Perioperative mortality related to anesthesia within 48 h and up to 30 days following surgery: a retrospective cohort study of 11,562 anesthetic procedures. *J Clin Anesth.* 2018;49:79-86. doi:10.1016/j.jcana.2018.06.025

13. Virani S, Michaelson JS, Hutter MM, et al. Morbidity and mortality after liver resection: results of the patient safety in surgery study. *J Am Coll Surg.* 2007;204(6):1284-1292. doi:10.1016/j.jamcollsurg.2007.02.067

14. Myles PS. More than just morbidity and mortality—quality of recovery and long-term functional recovery after surgery. *Anaesthesia.* 2020;75(S1):e143-e150. doi:10.1111/anae.14786

15. Mull HI, Rosen AK, Charns MP, et al. Emergency department use after outpatient surgery among dually enrolled VA and Medicare patients. *Qual Manag Health Care.* 2019;28(4):191-199. doi:10.1097/QMH.0000000000000225

16. Khanna A, Fedrigon D, Monga M, Gao T, Schold J, Abouassaly R. Postoperative emergency department visits after urinary stone surgery: variation based on surgical modality. *J Endourol.* 2019;34(1):93-98. doi:10.1089/end.2019.0399

17. Ross TD, Dvorani H, Saksin R, Khoshbin A, Atrey A, Warb SE. Temporal trends and predictors of thirty-day readmissions and emergency department visits following total knee arthroplasty in Ontario between 2003 and 2016. *J Arthroplasty.* 2019;35(2):364-370. doi:10.1016/j.arth.2019.09.015

18. Barnes GD, Lucas E, Alexander GC, Goldberger ZD. National trends in ambulatory oral anticoagulant use. *Am J Med.* 2015;128(12):1300-1305.e2. doi:10.1016/j.amjmed.2015.05.044

19. Shaw JR, Woodfine JD, Douketis J, Schulman S, Carrier M. Perioperative interruption of direct oral anticoagulants in patients with atrial fibrillation: a systematic review and meta-analysis. *Res Pract Thromb Haemost.* 2018;2(2):282-290. doi:10.1002/rth2.12076

20. Carter J, Sandall J, Shennan AH, Tribe RM. Mobile phone apps for clinical decision support in pregnancy: a scoping review. *BMC Med Inform Decis Mak.* 2019;19(1):219. doi:10.1186/s12911-019-0954-1

21. Paradis M, Stiell I, Atkinson KM, et al. Acceptability of a mobile clinical decision tool among emergency department clinicians: development and evaluation of the Ottawa rules app. *JMIR MHealth UHealth.* 2018;6(6):e10263. doi:10.2196/10263

22. MAQI2Anticoagulation Toolkit App. *Michigan Anticoagulation Quality Improvement Initiative.* 2015. http://anticoagulation toolkit.org. Accessed February 20, 2020. Updated December 3, 2019.

23. ManageAnticoag App. *American College of Cardiology.* 2017. https://www.acc.org/tools-and-practice-support/mobile-resources/features/manageanticoag. Accessed February 20, 2020. Updated June, 2018.

24. Ahuja T, Raco V, Papadopoulos J, Green D. Antithrombotic stewardship: assessing use of computerized clinical decision support tools to enhance safe prescribing of direct oral anticoagulants in
hospitalized patients. *J Patient Saf*. 2018. doi:10.1097/PTS.0000000000000535

25. Austin J, Barras M, Sullivan C. Interventions designed to improve the safety and quality of therapeutic anticoagulation in an inpatient electronic medical record. *Int J Med Inform*. 2020 March;135:104066. doi:10.1016/j.ijmedinf.2019.104066.

26. National Patient Safety Goals. 2003. https://www.jointcommission.org/standards/national-patient-safety-goals Accessed January 12, 2020. Updated July 1, 2020.