TITLE PAGE

Project Title: Improving Safe Use of Direct Oral Anticoagulants: A Population Health Approach
Principal Investigator: Geoffrey Douglas Barnes, BS, MD, MS
Team members: Michael Dorsch, PharmD, MS, Co-Investigator Michael Lanham, MD, Co-Investigator Anne Sales, PhD, RN, Co-Investigator Jeremy Sussman, MD, MSc, Co-Investigator Patrick Spoutz, PharmD, Consultant Arthur Allen, PharmD, Consultant Josh Errickson, PhD, Statistician
Recipient Organization: Regents of the University of Michigan, 503 Thompson Street, Ann Arbor, MI 48109
Project/Grant Period: 4/1/20 – 3/31/24 (includes 1 no-cost extension year)
Federal project officer: Deborah Perfetto, transferred to Farzana Samad
Acknowledgment of Agency Support: This research was supported in part by award R18 HS026874 from the Agency for Healthcare Research and Quality. The authors are solely responsible for this document's contents, findings, and conclusions, which do not necessarily represent the views of AHRQ. Readers should not interpret any statement in this report as an official position of AHRQ or of HHS.
Grant Award Number: R18 HS 026874

ABSTRACT

Purpose: To evaluate the implementation of the DOAC Dashboard within the Veterans Health Administration (VHA) and assess its expansion into four new health systems, using quantitative and qualitative analyses.

Scope: The project incorporated the nationwide implementation experience within the VHA to inform the deployment of the DOAC Dashboard in additional health systems, aiming to enhance the safety of DOAC prescribing across diverse healthcare settings.

Methods: The study employed the RE-AIM framework for quantitative evaluation of Dashboard usage data and conducted qualitative interviews with system users. The qualitative data was examined using the Consolidated Framework for Implementation Research and the Technology Acceptance Models to explore determinants of implementation success.

Results: The quantitative analysis revealed that, of 164 VHA sites, 150 adopted the Dashboard between August 2016 and June 2020, with the number of users increasing from an average of 2.4 to 7.5 per site. Over the course of the study, 84% of sites maintained moderate to high usage levels. In the non-VHA sites, pharmacist recommendations from the Dashboard were accepted by clinicians 88% of the time. Half of the sites adopting the Dashboard reduced the percentage of patients with off-label DOAC prescription errors. The qualitative analysis from 45 stakeholder interviews (32 VHA and 13 non-VHA) identified five key determinants for successful implementation: clinician authority, clinician self-identity, documentation needs, staffing, and system integration. These insights were instrumental in understanding the variations in acceptance and utilization between the VHA and non-VHA sites, particularly in relation to IT support and clinician autonomy.

Key Words: anticoagulants, clinical decision support, population health, implementation science, medication error

PURPOSE

Our primary goal was to improve the safety of DOAC prescribing through the implementation of a DOAC Dashboard in two diverse healthcare contexts (Veterans Health Administration [VHA] and Michigan Anticoagulation Quality Improvement Initiative [MAQI^2]). We proposed to achieve this goal through three specific research aims:

1) Evaluate the effectiveness, implementation successes, and limitations of the DOAC Dashboard for safe DOAC prescribing within the national VHA system.

   We measured the reach, effectiveness, adoption, implementation, and maintenance (RE-AIM) of the VHA DOAC Dashboard using both patient-level and provider-/facility-level measures. By linking data from the VHA DOAC Dashboard to the VHA Clinical Data Warehouse, we were able to identify high- and low-user centers, individual patient and prescriber characteristics, DOAC dosing errors, and DOAC adverse event rates (bleeding and thrombotic events).

2) Identify and compare barriers and facilitators for the use of a DOAC population health tool within fully integrated and traditional health systems.

   We interviewed high-, moderate-, and low-/non-utilizing VHA sites as well as stakeholders within MAQI^2 sites to identify specific barriers/facilitators to using the DOAC Dashboard. These interviews were informed by the Consolidated Framework for Implementation Research (CFIR), which incorporates both organizational and individual-level determinants of implementation, and the Technology Acceptance Model (TAM).

3) Explore the implementation and evaluation of a DOAC Dashboard for safe DOAC management within MAQI^2.

   Informed by the design and implementation of the VHA DOAC Dashboard, we adapted and implemented a DOAC Dashboard at four diverse MAQI^2 health systems. We evaluated this implementation using the RE-AIM framework. After implementation at each site, we also performed qualitative interviews (as in Aim 2) to assess the acceptability of this care model.

SCOPE

Background and Context

Many anticoagulants are high-risk medications and are commonly prescribed inappropriately. For more than five decades, warfarin was the only available oral anticoagulant. Since 2010, four new direct oral anticoagulants (DOACs) have been introduced into the market. All are approved by the U.S. Food and Drug Administration (FDA) for the prevention of stroke in non-valvular atrial fibrillation (AF) and to prevent or treat venous thromboembolism (VTE). The DOACs require a different management approach than warfarin. Specifically, (1) there is no routine laboratory test available to monitor drug levels; (2) unlike warfarin, each drug is excreted in part through the kidneys; (3) different drug-drug interactions impact DOAC dosing and safe use compared to warfarin; and (4) dosing of DOAC medications is different for each indication (AF, VTE, and coronary/peripheral artery disease). In fact, multiple studies have identified that as many as 1 in 7 patients have inappropriate DOAC prescriptions.

When DOACs are used inappropriately (over-dosing, under-dosing, and dosing based on the wrong indication), patients are at markedly increased risk for costly and potentially deadly bleeding and thrombotic/stroke complications.

Anticoagulation clinic staff are rarely utilized for DOAC-treated patients. Many warfarin-treated patients are managed by anticoagulation clinics due to the drug's complex pharmacokinetics and the need for frequent laboratory-guided dose adjustment. These clinics are staffed by pharmacists and nurses with expertise in thrombotic disorders and anticoagulation. The Veterans Health Administration (VHA) has been a national leader in the use of anticoagulation clinics. Anticoagulation clinics are also common outside the VHA and may improve the safe use of warfarin. Given the robust network of anticoagulation clinics managing warfarin-treated patients, we previously suggested that all DOAC-treated patients should be managed similarly. However, without the burden of frequent laboratory tests or dose adjustment, most prescribers do not routinely refer DOAC-treated patients to anticoagulation clinics.

Could there be an anticoagulation stewardship model that will make DOAC use safer but less burdensome than anticoagulation clinic referral for all DOAC-treated patients? Instead of directly referring individual patients to the anticoagulation clinic, the clinic staff can leverage data currently residing in the electronic health record (EHR) to identify patients from across their health system with potentially inappropriate DOAC prescriptions.

Traditional approaches (e.g., education and alerts) are unlikely to improve safe DOAC prescribing. Provider education is unlikely to solve this significant quality gap because of the large number of uncommon but important risks. These include (1) a variety of drug-drug interactions to both common and rare drugs; (2) different adjustments for renal function for each different drug, all of which use the Cockcroft-Gault creatinine clearance rather than the estimated glomerular filtration rate; and (3) the nuanced differences in dosing for AF and VTE for each DOAC medication. In addition to intentionally under-dosing patients at high-risk for bleeding, these errors are often unintentional and can lead to both under- and over-dosing of DOAC medications. EHR alerts and dosing guidance might encourage appropriate dosing. However, alert fatigue has led many health systems to either deactivate EHR drug alerts or display only the highest-risk alerts. Additionally, many of the DOAC dosing issues may develop after the initial prescription (e.g., progressive renal function decline, failure to change VTE lead-in dosing for apixaban or rivaroxaban after 7 or 21 days, respectively). Therefore, an EHR-based alert targeted at a prescribing provider is unlikely to be highly effective.

Population health tools offer an efficient and innovative anticoagulation stewardship approach to safe DOAC management. Population health tools, such as dashboards, leverage the power of the EHR to identify patients within a large population (e.g., an entire health system) who match certain criteria (e.g., being prescribed an oral anticoagulant) and then screen for any potential red flags (e.g., inappropriate dosing for a given renal function). Though not able to address all components of high-quality medication use, these tools address one critical component (appropriate dosing) in an efficient manner. Such tools are currently being used for population-based management of patients with diabetes. However, integration into clinical workflow and responsiveness to user feedback remain major obstacles to implementation and broad dissemination.

Setting

Veterans Health Administration (VHA)

VHA is the largest single, fully integrated healthcare system in the country. VHA has been a national leader in the use of anticoagulation clinics staffed by pharmacy specialists to ensure high-quality anticoagulation care. However, with the introduction of DOAC therapy, each VHA hospital or health system independently determined how best to manage these cases. Some systems required that all patients on DOACs be referred to the anticoagulation clinics. Others allowed clinicians to prescribe DOACs independently but made the anticoagulation clinic available for consultation as needed. In response to the rapid growth of DOAC use and concerns about appropriate dosing, practicing VHA pharmacists developed a population health tool (DOAC Dashboard) to assist anticoagulation pharmacists in DOAC management. The tool identifies every VHA patient nationally who is prescribed a DOAC and screens for a pre-defined set of alerts. These alerts, developed by a national VHA consensus panel of pharmacists and thrombosis/anticoagulation experts, include FDA-recommended dosing by indication and renal function as well as potentially dangerous drug-drug interactions. The tool, which refreshes daily, allows a pharmacist to click on an individual patient record, review the details of their DOAC prescribing and reason for an alert, and then indicate if they want to take an action (e.g., change the dose, alert another provider, or clear the alert). Any action made is recorded in the DOAC Dashboard and will suppress future alerts until new information appears (e.g., a new prescription or new laboratory test). The DOAC Dashboard was made available to all VHA pharmacists in 2016. More than 150 providers are regular Dashboard users.

Michigan Anticoagulation Quality Improvement Initiative (MAQI^2)

The second setting included four large, diverse health systems that participate in the Michigan Anticoagulation Quality Improvement Initiative (MAQI^2) collaborative. After beginning to enter warfarin-treated patients into the MAQI^2 registry in 2009, these four systems self-selected to enter DOAC-treated patients beginning in 2016. Each of these health systems has a functioning anticoagulation clinic and uses the Epic™ EHR. The MAQI^2 registry includes randomly selected patients newly initiating DOAC therapy and follows them as long as they remain on anticoagulation. DOAC-treated patients are identified from across each health system, but most are not managed by the anticoagulation clinic. All data in the MAQI^2-DOAC registry are manually abstracted into pre-defined electronic data forms from the EHR by trained abstractors with regular data audits to ensure accuracy. The current MAQI^2-DOAC registry represents only a small, random sample of the total DOAC population at each of the participating health systems. For example, there were more than 14,000 patients taking DOAC medications with one or more visits at the University of Michigan (one of the MAQI^2 sites) in 2017. These systems collectively employ more than 50 FTE pharmacists and nurses to assist with warfarin and DOAC management.

Participants

This project included two key populations. First, we enrolled patients prescribed DOAC medications within VHA nationally and the four participating MAQI^2 centers. These patients were included in several quantitative analyses.

The second population includes clinicians (nurses, pharmacists, physicians) involved in frontline anticoagulation care within VHA and MAQI^2. These clinicians were included in qualitative semi-structured interviews.

Incidence and prevalence

Within the VHA nationally, there were 211,837 patients taking DOAC medications between 2014-2017. These include 6,018 (3%) women, 23,605 (11%) Black patients, and 6,359 (3%) Hispanic patients. The mean age was 71.1 years (standard deviation 11.2). Use of apixaban (824,332 fills) and rivaroxaban (772,530 fills) was most common between 2014 and 2017. DOACs were used for atrial fibrillation (66.5%) and venous thromboembolism (17.3%) most commonly.

Within MAQI, we identified 72,730 DOAC-treated patients across the four participating sites in 2023.

METHODS

Design, Data Sources, and Measures

The DOAC Dashboard study was reviewed and approved or deemed "not regulated" by the University of Michigan (HUM00162234 and HUM0021922) and VHA Ann Arbor Institutional Review Boards (IRB-2018-1101).

The study design and outcome measures include both quantitative and qualitative analyses in both the VHA and MAQI^2 settings.

The data sources for quantitative evaluation include the VHA clinical data warehouse, VHA Pharmacy Benefits Management system, the MAQI^2 DOAC registry, and the MAQI^2 DOAC Dashboard database. The data sources for qualitative evaluation include semi-structured interviews with key anticoagulation stakeholders (clinical pharmacists, nurses, physicians) within VHA and MAQI^2.

Quantitative evaluation of the current VHA DOAC Dashboard followed the RE-AIM framework (Front Pub Health 2019;7:1-9), which includes Reach, Effectiveness, Adoption, Implementation, and Maintenance (Table 1).

Table 1: RE-AIM framework definitions

RE-AIM Component	Domain	Brief definition
Reach	Dashboard use	Number of sites with at least one login per month
Effectiveness	Patient impact	Proportion of off-label prescriptions per month
Adoption	Dashboard use	Number of sites with moderate to high use per month
Implementation	Patient impact	Number of patients with prescription change following Dashboard notification
Maintenance	Dashboard use	Number of sites with moderate to high use for 6 months

The reach, adoption and maintenance data is associated with the use of the Dashboard by pharmacists and other staff, while the implementation and effectiveness data is associated with the patients whose data appears on the Dashboard.

For Reach, Adoption and Maintenance, we received data from the VHA Pharmacy Benefits Management Center for Medication Safety (MedSAFE) regarding the provider-level usage of the DOAC Dashboard. The dataset included information about the time and date of each login to the DOAC Dashboard throughout our study period, from August 2016 to June 2020.

Each login was recorded with the username of the person who had accessed the DOAC Dashboard, from which we were able to obtain the site code and Veterans Integrated Services Network. We aggregated the data by month and site to calculate Reach, Adoption, and Maintenance throughout our study period.

We calculated summary statistics by looking at Reach, Adoption, and Maintenance for each month that we had login data. We also defined four phases of implementation and adoption:

- Pilot Phase: (August 2016 through March 2017) During this initial phase, only a few initial sites had access to the VHA DOAC Dashboard.
- Growth Phase: (April 2017 to December 2017.) Once the pilot sites gained experience with the DOAC Dashboard, the Dashboard use grew by word-of-mouth among clinical pharmacists within VHA. However, there was no formal, VHA-wide implementation of the DOAC Dashboard.
- Full-Use Phase: (January 2018 through December 2018.) The VHA DOAC Dashboard was formally available to all VHA sites nationwide. They were encouraged to use this tool by the development team via socialization events, webinars, and one-on-one coaching.
- Maintenance Phase: (January 2019 through June 2020—the end of study period). After all sites had potential access to the DOAC Dashboard for 1 year through the "full-use" phase, the "Maintenance Phase" signified the extent to which institutions maintained use of the DOAC Dashboard.

For **Reach**, we looked at the total number of sites per month of our 164 total VHA sites with at least one login to the Dashboard.

For **adoption**, we categorized usage of the Dashboard into 3 categories: low (1 unique day with a login per month), moderate (2-5 unique days with at least 1 login per month), and high (6+ unique days with at least 1 login per month). We considered "adoption" as sites with "moderate" or "high" usage of the Dashboard for each month. The denominator in our calculation for "adoption" was the total number of sites that had accessed the Dashboard in that month or any previous month. For additional details on adoption, we looked at the average number of unique users at each site per month and the average number of days with at least one login per month.

We defined **maintenance** as sites that had kept up sustained moderate/high usage of the DOAC Dashboard for the previous 6+ months, of the total number of sites that could have reached "maintenance" in that month (i.e., the total number of sites that had accessed the Dashboard at least once per month for that month and each of the previous 6 months).

With regard to effectiveness (primary study outcome) and implementation, we used data from the Veterans Health Affairs to identify all patients prescribed DOACs for atrial fibrillation or venous thromboembolism between August 2015 and December 2019. Sites were grouped based on the timing of moderate-high usage of the DOAC Dashboard.

Effectiveness was defined in two ways: (1) as the monthly rate of off-label DOAC prescribing and (2) as the rate of clinical adverse events (bleeding, composite of stroke or venous thromboembolism [VTE]).

Implementation was evaluated as the percentage of patients with an off-label DOAC dosing prescription who had a change in their prescription within 7 days. This differed slightly from our pre-planned analysis, as we were unable to obtain access to DOAC Dashboard flag-specific data.

Any change in the medication, dosage, or frequency of administration was considered a change in the prescription, to assess the implementation outcome.

Statistical Methods

To assess for changes in site-level monthly off-label DOAC prescribing based on the timing when each site achieved moderate-high DOAC Dashboard use, we constructed a linear regression model that included an interaction between time (measured by month), the timing of when the site achieved moderate-high DOAC Dashboard use (defined above), and a pre-post Dashboard use. The model was fit at the group-month level without adjustment for patient-level characteristics, given an ecological analytic approach. The slope and change in slope of DOAC Dashboard use across each implementation time group was estimated from the model using marginal effects estimation. Statistical significance was set with a p value of <0.05.

Qualitative Evaluation of Implementation Barriers

Method: Initial qualitative analysis

Settings and participants

This project gathered interview data from providers in two healthcare contexts.

The first was the VHA health systems. We interviewed pharmacists, pharmacy technicians, and clinic managers who work in ambulatory anticoagulation clinics. We also interviewed the programmer who developed the VHA DOAC Dashboard. Clinic managers identified and invited participants through e-mail communication.

The second setting included four distinct health systems that participate in MAQI^2. The participants from this setting came from a wider variety of professional backgrounds, including physician champions and medical directors, nurses and pharmacists who work in ambulatory anticoagulation clinics, and anticoagulation clinic managers.

In this phase of qualitative investigation, an important distinction between these two contexts is that the VHA sites all had access to the DOAC Dashboard (and most were experienced users) at the time of the interviews, but the MAQI^2 sites had not yet implemented their Dashboard.

Data collection

Our semi-structured interview guides (both for VHA and MAQI^2) were developed using pre-specified constructs from the Consolidated Framework for Implementation Research (CFIR) in addition to the Technology Acceptance Model (TAM) framework (Impl Sci 2007;2:42 and J Biomed Inform 2010;43:159-172). Our implementation team reviewed sample interview questions from cfirguide.org and published literature using TAM. Questions that were anticipated to be relevant to this project were adapted. The overall interview guide was then tested with two preliminary interviewees, and edits were made to improve flow and clarity. VHA sites were selected based on their level of DOAC Dashboard use (high, moderate, low/none). We also selected key VHA sites where DOAC Dashboard use had changed significantly between 2017 and 2019 (e.g., high-to-low) to assess what specific determinants influenced the change in usage. All four MAQI^2 sites who currently manage DOAC patients (but were not yet using the Dashboard) were interviewed. We identified participants at each site (VHA and MAQI^2) by asking managers to identify key front-line clinical staff.

All participants provided verbal consent to participate and for the interviews to be recorded. Recordings were transcribed and anonymized by removing participant and site names. The interviewees collected notes during and after each interview, following the rapid qualitative analysis approach.

Rapid qualitative analysis

We undertook a rapid qualitative analytic approach that incorporated elements of a template analysis by using pre-existing codes from CFIR and TAM. The three qualitative researchers reviewed notes taken during the interviews as well as the transcribed interviews to identify relevant themes. These were done using both pre-defined codes related to individual CFIR and TAM constructs as well as any newly emergent themes from the interviews.

Method: Determinants of Dashboard implementation success at VHA.

Using the same data set of interview transcripts, we used a comparative multiple case study design with the goal of analyzing the patterns across different VHA clinical sites in order to produce more generalizable knowledge about whether and how available resources and implementation climate change across implementation phases specifically for technological interventions in healthcare settings. (This study was approved by the institutional review board of the Ann Arbor VHA Healthcare System.)

Qualitative data coding

We used the qualitative analysis software MAXQDA to re-code and analyze the existing interview data. Data coding and analysis were guided by the VHA Quality Enhancement Research Initiative (QUERI) Roadmap and the CFIR.

We coded participants' responses regarding their implementation efforts prior to the adoption of the DOAC Population Management Dashboard as the *pre-implementation* phase, including the process of identifying problems and potential solutions to optimize anticoagulation management, engaging stakeholders, and assessing organizational capacity prior to implementing the Dashboard. Participants' responses would be coded as the *implementation* phase if they discussed how the Dashboard was first introduced to their clinics and the process of learning the new tool, activating the implementation teams, getting technical and adaptive support, and cleaning the backlog of notifications in the early phase of using the DOAC Population Management Dashboard. We coded participants' statements as the *sustainment* phase if they were related to whether and how the Dashboard has been embedded and become routine practice in their clinical settings as well as their ongoing evaluation and reflection regarding the impact of the Dashboard on their anticoagulation practice.

When we coded interview data using the CFIR, we focused on two specific CFIR codes in the inner setting domain: *available resources* and *implementation climate*. In the initial stage of coding, we discovered that certain elements of available resources mentioned by participants were closely related to other CFIR constructs, such as *champions* and *leadership engagement*. Consequently, to capture this relationship, we expanded the definition of available resources to encompass the support provided by champions, leaders, and other stakeholders involved in the implementation process. When examining the CFIR code of *implementation climate*, we also included the six sub-constructs of implementation climate: tension for change, compatibility, relative priority, organizational incentives and rewards, goals and feedback, and learning climate.

Rating with CFIR constructs

Once coding was complete, we examined the intersection between the three implementation phases (pre-implementation, implementation, and sustainment) and the CFIR codes *available resources* and *implementation climate*. We reviewed the coded segments from the interview data and created a document containing all summary statements, plus supporting quotes for each interview.

Interview segments with the two CFIR codes were rated with a 5-point bipolar scale (−2 to +2) to reflect the valence (positive or negative) and magnitude of changes in *available resources* and i*mplementation climate* over the course of implementation.

Thematic analysis

After the rating process was complete, we used a graph to visualize the way that *available resources* and *implementation climate* change from implementation to sustainment phases for each site. We categorized sites based on the direction of change in the two CFIR constructs across phases. We also conducted a qualitative thematic analysis across three groups, as specified in the results, to identify the key resources that affected the implementation climate at different phases and examine how available resources and implementation climate interacted with each other during these phases.

Method: Determinants of Dashboard implementation success at MAQI² sites

Setting and Participants

Following the Dashboard implementation at the MAQI² sites, we conducted additional semi-structured interviews with anticoagulation professionals working in three regional health systems (n=4 sites), all of whom had implemented DOAC Dashboard within their Epic EHR system (Epic Systems Corporation). These sites had all previously participated in the interviews that were conducted before the implementation of the DOAC Dashboard in their health systems.

The participants interviewed were a purposeful sample of clinical pharmacists and nurses involved in patient monitoring and care in anticoagulation clinics. These individuals' experiences using the Dashboard reflect the commonality and diversity in the implementation of this population management tool across health systems. All participants provided verbal consent for participation and recording; each transcription was deidentified per an institutional review board–approved protocol.

Data Collection

Semi-structured interviews, with a focus on clinicians' empowerment over their workflow as well as their work on and within the DOAC Dashboard, took place from August to September 2022. The interviews were conducted via Zoom (Zoom Technologies), audio recorded, and transcribed.

Thematic Analysis

The research team used the method of content analysis to analyze their data. The transcripts were coded for the five key determinants of implementation success from our previous research (Implement Sci Commun 2022;3:10. https://doi.org/10.1186/s43058-022-00262-w): (1) clinician authority and autonomy; (2) communication, documentation, and administrative needs; (3) work scheduling and staffing; (4) integration with existing information systems; and (5) clinician self-identity

and job satisfaction. Expanded definitions of each determinant are available in our related publication (JMIR Hum Factors 2023;10:e49025. https://doi.org/10.2196/49025).

Each segment was coded for any applicable determinants present, so a single segment may be coded as containing multiple relevant determinants. Each coded segment was also scored as containing sentiments that reflected positively regarding the presence of the determinant or reflected negatively regarding the absence of the determinant.

To better understand the subcomponents of individual clinician authority, we examined the co-occurrence of that determinant with the other four determinants. We aggregated segments that contained both individual clinical authority and one other determinant and reviewed the aggregated segments for thematic patterns.

Interventions

No interventions were performed as a part of this study. Instead, the study evaluated the implementation efforts already being conducted within the VHA and MAQI^2 systems.

Limitations

First, the study population was, by design, limited to users of the DOAC Dashboard. This limited our study population to the VHA health system and four Michigan institutions in the MAQI^2 consortium. We recognize that VHA data may not be representative of other populations or health system delivery. Additionally, because of the small number of MAQI^2 institutions using the Dashboard, the MAQI^2 data ares limited in power and may not represent other populations or health systems.

Second, our data are also limited by the specific time frame during which data collection occurred. It should be noted that data collection was disrupted by the impact of the COVID pandemic in 2020.

Third, we were limited by the granularity of the data available to us. Because of inherent limitations on our data access as well as technical limitations in data processing and EHR data accuracy, we were not able to conduct analyses with covariates of certain patient-level factors from the VHA and MAQI^2 clinical data.

RESULTS

Principal Findings and Outcomes

We identified four domains of principal findings and outcomes: (1) Quantitative VHA findings regarding provider Dashboard use (Reach, Adoption, and Maintenance), (2) Quantitative VHA findings regarding patient outcomes (effectiveness and implementation), (3) Qualitative stakeholder findings from VHA (with pre-implementation MAQI^2), and (4) Quantitative post-implementation findings from MAQI^2.

Quantitative VHA Outcomes

We analyzed the national VHA data using the RE-AIM implementation evaluation framework. Key findings are summarized below:

Reach: Implementation of the VHA Dashboard began with five VHA sites in August 2016 with access to the tool. Pilot sites averaged 413 patients per site in the first month after implementation. By June 2020, 150 of 164 VHA sites (90.3%) used the Dashboard and averaged 1875 patients per site managed using

the Dashboard. Nationwide, 258,820 patients were prescribed DOAC medications at VHA sites using the DOAC Dashboard by June 2020.

Adoption: Moderate or high adoption, defined as at least one login on at least 2 separate days of the month, across the VHA centers remained low during the early phase (August 2016 to March 2017). At the start of the early phase, 3/5 (60%) sites with Dashboard access had moderate or high adoption, but two sites used the DOAC Dashboard fewer than 2 days per month. By the end of the early phase, 7/10 (70%) of sites with DOAC Dashboard access had moderate or high adoption. There was a rapid increase in the number of sites during the growth phase (April 2017 to December 2017), and adoption remained constant. At the start of the growth phase, 9/13 (69.2%) sites with DOAC Dashboard access had moderate or high adoption; by the end of the growth phase, 48/67 (71.6%) sites with DOAC Dashboard access had moderate or high adoption. During the full-use phase (January 2018 to December 2018), there was an increase in adoption nationwide. Moderate or high adoption of the DOAC Dashboard remained stable from the start (105/128; 82%) to the end (105/130; 82%) of the full-use phase. In the maintenance phase (January 2019 to June 2020) of adoption, there was another increase in moderate or high adoption and the number of VHA sites that had access to the Dashboard (120/130; 92.3% at the start and 142/150; 94.7% at the end).

During the early phase, the average number of unique users per site increased from 2.24 (SD 1.94) to 2.3 (SD 1.49) by the end. During the growth phase, the average number of unique users per site increased from 3.23 (SD 2.83) at the start to 3.34 (SD 4.09) at the end. During the full-use phase, the average number of unique users per site increased from 4.02 (SD 3.98) at the start to 4.84 (SD 4.24) at the end. During the maintenance phase of adoption, the average number of unique users per site increased from 6.13 (SD 5.13) at the start to 7.53 (SD 6.18) at the end.

Maintenance: Over the course of each adoption phase, the number and proportion of VHA sites in maintenance increased. At the end of the growth phase, 50% (18/36); full-use phase, 53.9% (69/128); and maintenance phase, 84% (126/150) of VHA sites continued use of the DOAC Dashboard for 6 months.

Effectiveness: Across 123 VHA sites, the mean site-level percent of patients with off-label DOAC prescribing each month ranged between 6.8% in December 2019 and 8.6% in January 2016. Across all sites, the mean off-label monthly DOAC dosing prescription rate declined from 8.7% (1.2%) to 7.6% (1.2%) from pre- and post-implementation. In the linear regression model, all four groups had a decline in the trend line of off-label DOAC dosing prescriptions from before to after achieving moderate-high DOAC Dashboard use. However, that change was statistically significant for the group that started on or before April 2017 (change of slope = -0.111, 95% CI -0.064 to -0.159, $p<0.001$) and for the group that started between May and December 2017 (change of slope = -0.04, 95% CI -0.004 to -0.083, $p=0.031$). The latter two groups had declines in the regression line slope that were significant only at the 10% level (change of slope = -0.042, 95% CI -0.092 to 0.008, $p=0.099$ and change of slope = 0.08, 95% CI -0.169 to 0.005, $p=0.064$).

Mean (standard deviation) rates of bleeding overall were 3.0 (0.5) per 100 patient-years before and 2.9 (0.4) per 100 patient-years after implementation. Over the study period, the group that adopted the DOAC Dashboard at a moderate-high level at the earliest time period (April 2017 or earlier) had slightly less of a downward trend of bleeding events after adoption at a moderate-high level (change of slope = 0.033, 95% CI 0.00 – 0.067, $p=0.049$).

The second group (May-December 2017) had a statistically significant decline in the slope of bleeding events (change in slope = -0.037, 95% CI -0.064 – 0.009, p=0.010) while the third (January-June 2018) and fourth groups (July 2018 or later) had non-significant declines in the slope (change in slope = -0.009, 95% CI -0.045 – 0.026, p=0.600 and change in slope = -0.012, 95% CI -0.073 – 0.049, p=0.701, respectively).

Mean (standard deviation) composite rates of VTE and stroke overall were 2.7 (0.2) per 100 patient-years before and 2.2 (0.3) per 100 patient-years after implementation. Over the study period, all four groups had a reduction in the composite rate of VTE or stroke (Figure 3). The change was smallest for the earliest adopting group (change in slope = -0.013, 95% CI -0.025 to -0.002, p=0.018) and largest for the latest adopting group (change in slope = -0.443, 95% CI -0.065 to -0.024, p<0.001). The second and third adopting groups had similar changes (change in slope = -0.026, 95% CI -0.035 to -0.017, p<0.001 and change in slope = -0.025, 95% CI -0.037 to -0.013, p<0.001, respectively).

Implementation Fidelity: To assess the fidelity in the DOAC Dashboard use at the site level, we assessed the percentage of patients with an off-label DOAC prescription that had a change to their prescription within 7 days. There was no meaningful difference in the rate of off-label DOAC use based on the site-level timing of DOAC Dashboard adoption. In regression analysis, there was no statistically significant change in the rate of flags resolved within 7 days from before to after DOAC Dashboard adoption.

Qualitative Stakeholder Findings

We interviewed 45 interviewees (32 in VHA, 13 in MAQI[2]) of key stakeholders (anticoagulation clinic nurses, pharmacists, and leaders). Interviews took place at 22 VHA sites. Interviews lasted an average of 38 min (range 22-61 min).

Five key determinants of implementation success were identified during rapid qualitative analysis of the VHA transcripts. These were (1) clinician authority and autonomy; (2) clinician self-identity and job satisfaction; (3) documentation, communication, and administrative needs; (4) staffing and work schedule; and (5) technology integration.

Clinician authority and autonomy were commonly identified determinants of implementation success at VHA sites. Specifically, staff expressed a strong desire to control their own workflow and identify ways for the DOAC Dashboard to fit into their pre-existing workflow.

Stakeholder interviewees also expressed concerns about the level of autonomy they would have for making guideline-recommended DOAC dose changes when the DOAC Dashboard alerted them to an unsafe prescription. This was particularly troubling for some pharmacists when they had to alert a prescribing clinician rather than make the change themselves. Once they were aware of a DOAC dosing error, they found a lack of autonomy limited their ability to enact meaningful changes if the prescribing clinician did not promptly respond to their messages. They noted that, without the knowledge of a DOAC prescribing error identified by the DOAC Dashboard, they would not feel an obligation to “fix” the prescribing error. Importantly, the issue around autonomy was not a direct result of the DOAC Dashboard but rather the variation in practice authority and autonomy given to pharmacists or nurses across the USA.

Clinician self-identity and job satisfaction were closely linked to how robustly they integrated the DOAC Dashboard into their practice.

Some pharmacists expressed a concern that the computer is replacing their clinical judgment or justification for their work. Furthermore, many VHA pharmacists who were used to seeing patients face to face feared the loss of direct patient care if they no longer had scheduled visits and instead relied only on the DOAC Dashboard to identify potential dosing errors. Documentation and work performance barriers were commonly cited by many VHA stakeholder interviewees. These include difficulties communicating with primary care providers and specialists both within and outside the VHA health system, a problem that is not unique to the DOAC Dashboard itself and often requires additional staff time to complete. They also expressed concern that staff performance measures may not include DOAC Dashboard work if there is not sufficient documentation to account for the time spent reviewing charts and communicating with other clinicians or the patient.

Having sufficient staff and scheduled time to work with the DOAC Dashboard was a common determinant of implementation success. Stakeholder interviewees who felt the DOAC Dashboard was highly successful tended to describe a workflow that included dedicated staff and time to review the Dashboard and make clinically appropriate changes. This included interviewees at sites that developed pure "Dashboard clinics," days in which the pharmacists would work primarily on addressing flags.

This would allow them to extend the length between visits for patients who did not have flags. In distinction, stakeholder interviewees who expressed difficulty using the Dashboard often worked at sites where the DOAC Dashboard was added to the existing workflow. This was particularly true when sites first began using the DOAC Dashboard because of the large number of alerts they encountered. Over time, this number was reduced, and interviewees reported a manageable "steady state." Last, additional concerns about integration with existing information systems were cited by some VHA interviewees. Two major areas were highlighted, including uncertainty around the accuracy of the tool and the speed with which it loads and can be used. Some pharmacists expressed a lack of trust in the Dashboard, finding it not always accurate and missing individual patients for whom the Dashboard did not show an alert.

This was seen as a barrier for clinicians used to reviewing every patient that they followed on a regular basis.

Quantitative MAQI² Outcomes

Our first analysis explored the implementation outcomes from one center (Michigan Medicine) and their use of the DOAC Dashboard over a 4-month period.

In total, 10,912 patients were identified by the DOAC Dashboard at the initiation of the program. In total, 5038 alerts were triggered. Of those, 668 (13%) were critical, 3337 (66%) were possible critical, and 1033 (21%) were for-your-information alerts for potential VTE prophylaxis dosing. Pharmacists addressed 1796 alerts during the study period. Pharmacists addressed 762 critical alerts and 1034 possibly critical alerts. The majority of critical alerts were inappropriate dosing, 379 (50%). Overall, 62 (8%) critical alerts addressed were due to significant DDI. Of the 762 critical alerts, 291 (38%) required pharmacist intervention. The overwhelming majority of proposed interventions (256, 88%) were accepted by patients' primary anticoagulation prescribing clinician and were implemented. Critical alerts and possible critical alerts not requiring intervention were resolved by entering or editing information within the EHR. On average, the student pharmacist was able to resolve about 20 alerts per 8-hour period. In total, 197 alerts were resolved by a student pharmacist between August and November 2022.

On average, the nursing team was able to resolve approximately 60 alerts per 8-hour period. Overall, 2663 alerts were resolved by the nursing team between April 2021 and November 2022.

Our second analysis explored the number of patients on DOACs and the actions taken by anticoagulation clinic staff at the four participating MAQI^2 centers using the DOAC Dashboard.

The total number of DOAC-prescribed patients at each site increased by an average (95% CI) of 821 (-1 to 1654), with DOAC-treated populations at each site ranging from 5000 to 32,000 by the 4th quarter of 2023. The percentage of patients with off-label DOAC prescribing per quarter ranges between 6% and 13%. Two of the four groups had a statistically significant reduction in the percentage of patients with off-label DOAC prescribing during the 2 years following implementation (-0.25%/quarter, 95% CI -0.16% to -0.33%, and -0.19%/quarter, 95% CI -0.02% to -0.37%). To demonstrate implementation maintenance, the sites were able to sustain a stable number of alerts resolved after the first 6-9 months of implementation.

Discussion

Our analysis of a population health approach to safe DOAC prescribing incorporated both quantitative and qualitative methods across multiple organizations and contexts. However, key findings were largely consistent and demonstrated benefits for patients and health systems.

First our quantitative analysis of the VHA DOAC Dashboard found broad nation-wide adoption over a 4-year period. This broad adoption was associated with a statistically significant reduction in off-label DOAC use in several of the VHA DOAC Dashboard adoption groups. Most importantly, there was a statistically significant reduction in the composite rate of VTE and stroke after sites began using the VHA DOAC Dashboard regularly. However, no reduction was seen in bleeding rates following VHA DOAC Dashboard use.

Second, our quantitative analysis of the MAQI^2 DOAC Dashboard also found patient-level benefits across four centers in Michigan. Specifically, the percentage of patients with off-label DOAC prescriptions declined quarter-by-quarter, with two of the four centers achieving statistically significant reductions. In a more in-depth analysis at one MAQI^2 center, pharmacists were able to address 1796 alerts over a 4-month period, mostly related to incorrect dosing. After initial pharmacist review, 38% were recommended for a clinical prescription change and 88% of those recommended changes were adopted by the prescribing clinicians.

Third, our qualitative analysis of key stakeholders in both VHA and MAQI^2 centers identified several key determinants of successful DOAC Dashboard implementation. These include the degree of clinician authority and autonomy; a clinician's self-identify and level of job satisfaction; barriers related to documentation, communication, and administrative needs; level of staffing and work schedules; and degree of technological integration between different systems. New health systems looking to implement similar population health dashboards for medication safety must address these important determinants to maximize successful implementation.

Conclusions

A population health approach to ensuring medication safety through pharmacist use of a DOAC Dashboard is associated with improved evidence-based DOAC prescribing, reductions in adverse thromboembolic events, and a high level of prescriber update of pharmacist recommendations.

To achieve these patient and population-level benefits, implementation teams need to carefully address pharmacist authority and autonomy while ensuring the clinicians using the DOAC Dashboard maintain a high level of self-identity and job satisfaction related to the use of a dashboard. The findings from this study provide critical evidence in support of this novel and impactful anticoagulation stewardship model of care in the outpatient clinical space.

Significance and Implications

Given the rapid growth in anticoagulation use, particularly DOACs, there is a need to design care anticoagulation stewardship delivery models that efficiently and sustainably ensure safe and effective DOAC prescribing. Unlike warfarin and other vitamin K antagonists that require frequent laboratory monitoring and one-on-one interactions with clinical staff, DOACs are prescribed by a wide variety of clinicians without frequent laboratory monitoring or health system touch-points. Furthermore, the high level of off-label DOAC use (estimated up to 20%) is associated with increased risk of bleeding, thrombosis, hospitalization, and all-cause mortality. Finally, DOACs are leading contributors of adverse drug events leading to emergency department visits.

To address these issues, various anticoagulation stewardship efforts have been developed and implemented that aim to improve the safe use of DOAC medications. A population health approach leveraging clinical pharmacists is a promising anticoagulation stewardship intervention that aims to improve safe use of DOACs and reduce adverse drug events. This study provided critical evidence that demonstrates successful implementation of a population health dashboard focused on DOAC use in several different health systems and contexts. More importantly, it demonstrated the improved clinical outcomes that patients and health systems may anticipate if they implement a population health model of care for DOAC-treatment patients.

Publications

1. Feng Y, Pai C-W, Seiler K, Barnes GD. Inappropriate Prescription of Direct Oral Anticoagulant Starter Packs. Am J Med 2021;134:370-373.e1. https://doi.org/10.1016/j.amjmed.2020.06.045.
2. Barnes GD, Sippola E, Dorsch M, Errickson J, Lanham M, Allen A, et al. Applying population health approaches to improve safe anticoagulant use in the outpatient setting: the DOAC Dashboard multi-cohort implementation evaluation study protocol. Implement Sci IS 2020;15:83. https://doi.org/10.1186/s13012-020-01044-5.
3. Al Rowily A, Jalal Z, Price MJ, Abutaleb MH, Almodiaemgh H, Al Ammari M, et al. Prevalence, contributory factors and severity of medication errors associated with direct-acting oral anticoagulants in adult patients: a systematic review and meta-analysis. Eur J Clin Pharmacol 2022;78:623–45. https://doi.org/10.1007/s00228-021-03212-y.
4. Barnes GD, Sippola E, Ranusch A, Takamine L, Lanham M, Dorsch M, et al. Implementing an electronic health record dashboard for safe anticoagulant management: learning from qualitative interviews with existing and potential users to develop an implementation process. Implement Sci Commun 2022;3:10. https://doi.org/10.1186/s43058-022-00262-w.
5. Dorsch MP, Chen CS, Allen AL, Sales AE, Seagull FJ, Spoutz P, et al. Nationwide Implementation of a Population Management Dashboard for Monitoring Direct Oral Anticoagulants: Insights From the Veterans Affairs Health System. Circ Cardiovasc Qual Outcomes 2022:e009256. https://doi.org/10.1161/CIRCOUTCOMES.122.009256.

6. Ranusch A, Lin Y-J, Dorsch MP, Allen AL, Spoutz P, Seagull FJ, et al. Role of Individual Clinician Authority in the Implementation of Informatics Tools for Population-Based Medication Management: Qualitative Semistructured Interview Study. JMIR Hum Factors 2023;10:e49025. https://doi.org/10.2196/49025.
7. Lin Y-J, Ranusch A, Seagull FJ, Sussman JB, Barnes GD. Dynamic interplay between available resources and implementation climate across phases of implementation: a qualitative study of a VA national population health tool. Implement Sci Commun 2023;4:74. https://doi.org/10.1186/s43058-023-00460-0.
8. Herron GC, DeCamillo D, Kong X, Haymart B, Kaatz S, Ellsworth S, Ali MA, Giuliano C, Froehlich JB, Barnes GD.. Timing of Off-Label Dosing of Direct Oral Anticoagulants in Three Large Health Systems. Thromb Haemost. PMID: 39009007 HTTPS://doi.org/10.1055/a-2365-8681

Papers in preparation

Barnes GD, Chen C, Holleman R, Errickson J, Seagull FJ, Dorsch MP, Allen AL, Spoutz P. Pharmacist Use of a Population Management Dashboard for Safe Anticoagulant Prescribing: Evaluation of a Nation-wide Implementation Effort. (Under review)

REFERENCES

1. Levy JH, Spyropoulos AC, Samama CM, Douketis J. Direct Oral Anticoagulants: New Drugs and New Concepts. JACC Cardiovasc Interv 2014;7:1333-51.
2. Barra ME, Fanikos J, Connors JM, Sylvester KW, Piazza G, Goldhaber SZ. Evaluation of Dose-Reduced Direct Oral Anticoagulant Therapy. Am J Med 2016;129:1198-204.
3. Steinberg BA, Shrader P, Thomas L, et al. Off-Label Dosing of Non-Vitamin K Antagonist Oral Anticoagulants and Adverse Outcomes: The ORBIT-AF II Registry. J Am Coll Cardiol 2016;68:2597-604.
4. Trujillo-Santos J, Di Micco P, Dentali F, et al. Real-life treatment of venous thromboembolism with direct oral anticoagulants: The influence of recommended dosing and regimens. Thromb Haemost 2017;117:382-9.
5. Basaran O, Filiz Basaran N, Cekic EG, et al. PRescriptiOn PattERns of Oral Anticoagulants in Nonvalvular Atrial Fibrillation (PROPER study). Clin Appl Thromb Hemost 2017;23:384-91.
6. 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.
7. Garrison SR, Allan GM. Do specialty anticoagulation clinics really outperform primary care at INR management? J Thromb Thrombolysis 2014;38:420-1.
8. McGuinn TL, Scherr S. Anticoagulation clinic versus a traditional warfarin management model. Nurse Pract 2014;39:40-6.
9. Stoudenmire LG, DeRemer CE, Elewa H. Telephone versus office-based management of warfarin: impact on international normalized ratios and outcomes. Int J Hematol 2014;100:119-24.
10. Entezari-Maleki T, Dousti S, Hamishehkar H, Gholami K. A systematic review on comparing 2 common models for management of warfarin therapy; pharmacist-led service versus usual medical care. J Clin Pharmacol 2016;56:24-38.
11. Manzoor BS, Cheng WH, Lee JC, Uppuluri EM, Nutescu EA. Quality of Pharmacist-Managed Anticoagulation Therapy in Long-Term Ambulatory Settings: A Systematic Review. Ann Pharmacother 2017;51:1122-37.

12. Barnes GD, Nallamothu BK, Sales AE, Froehlich JB. Reimagining Anticoagulation Clinics in the Era of Direct Oral Anticoagulants. Circ Cardiovasc Qual Outcomes 2016;9:182-5.
13. Barnes GD, Acosta J, Graves C, et al. Barriers to integrating direct oral anticoagulants into anticoagulation clinic care: A mixed-methods study. Res Pract Thromb Haemost 2019;3:79-84.
14. Cockcroft DW, Gault MH. Prediction of creatinine clearance from serum creatinine. Nephron 1976;16:31-41.
15. Stevens LA, Schmid CH, Greene T, et al. Comparative performance of the CKD Epidemiology Collaboration (CKD-EPI) and the Modification of Diet in Renal Disease (MDRD) Study equations for estimating GFR levels above 60 mL/min/1.73 m2. Am J Kidney Dis 2010;56:486-95.
16. Carli D, Fahrni G, Bonnabry P, Lovis C. Quality of Decision Support in Computerized Provider Order Entry: Systematic Literature Review. JMIR Med Inform 2018;6:e3.
17. Backman R, Bayliss S, Moore D, Litchfield I. Clinical reminder alert fatigue in healthcare: a systematic literature review protocol using qualitative evidence. Syst Rev 2017;6:255.
18. Minhas AS, Jiang Q, Gu X, et al. Renal function in atrial fibrillation patients switched from warfarin to a direct oral anticoagulant. J Thromb Thrombolysis 2016;42:566-72.
19. Becattini C, Giustozzi M, Ranalli MG, et al. Variation of renal function over time is associated with major bleeding in patients treated with direct oral anticoagulants for atrial fibrillation. J Thromb Haemost 2018;16:833-41.
20. Valencia D, Spoutz P, Stoppi J, et al. Impact of a Direct Oral Anticoagulant Population Management Tool on Anticoagulation Therapy Monitoring in Clinical Practice. Ann Pharmacother 2019:1060028019835843.
21. Eggleston EM, Klompas M. Rational use of electronic health records for diabetes population management. Curr Diab Rep 2014;14:479.
22. U.S. Department of Health and Human Services OoDPaHP. National Action Plan for Adverse Drug Event Prevention. National Action Plan for Adverse Drug Event Prevention2014.
23. Glasgow RE, Vogt TM, Boles SM. Evaluating the public health impact of health promotion interventions: the RE-AIM framework. Am J Public Health 1999;89:1322-7.
24. Flottorp SA, Oxman AD, Krause J, et al. A checklist for identifying determinants of practice: a systematic review and synthesis of frameworks and taxonomies of factors that prevent or enable improvements in healthcare professional practice. Implement Sci 2013;8:35.
25. Michie S, Johnston M, Abraham C, et al. Making psychological theory useful for implementing evidence based practice: a consensus approach. Qual Saf Health Care 2005;14:26-33.
26. Damschroder LJ, Lowery JC. Evaluation of a large-scale weight management program using the consolidated framework for implementation research (CFIR). Implement Sci 2013;8:51.
27. Holden RJ, Karsh BT. The technology acceptance model: its past and its future in health care. J Biomed Inform 2010;43:159-72.
28. Markovitz AA, Holleman RG, Hofer TP, Kerr EA, Klamerus ML, Sussman JB. Effects of Guideline and Formulary Changes on Statin Prescribing in the Veterans Affairs. Health Serv Res 2017;52:1996-2017.
29. Barnes GD, Li Y, Gu X, et al. Periprocedural Bridging Anticoagulation: Measuring the Impact of a Clinical Trial on Care Delivery. Am J Med 2018.
30. Somers M-A, Zhu P, Jacob R, Bloom H. The Validity and Precision of the Comparative Interrupted Time Series Design and the Difference-in-Difference Design in Educational Evaluation. MDRC Working Paper on Research Methodology: MDRC; 2013.

31. Dimick JB, Ryan AM. Methods for evaluating changes in health care policy: the difference-indifferences approach. JAMA 2014;312:2401-2.
32. Kaatz S, Ahmad D, Spyropoulos AC, Schulman S, Subcommittee on Control of A. Definition of clinically relevant non-major bleeding in studies of anticoagulants in atrial fibrillation and venous thromboembolic disease in non-surgical patients: communication from the SSC of the ISTH. J Thromb Haemost 2015;13:2119-26.
33. Schulman S, Kearon C. Definition of major bleeding in clinical investigations of antihemostatic medicinal products in non-surgical patients. J Thromb Haemost 2005;3:692-4.
34. Jasuja GK, Reisman JI, Miller DR, et al. Identifying major hemorrhage with automated data: results of the veterans affairs study to improve anticoagulation (VARIA). Thromb Res 2013;131:31-6.
35. Brooks J, McCluskey S, Turley E, King N. The Utility of Template Analysis in Qualitative Psychology Research. Qual Res Psychol 2015;12:202-22.
36. Michie S, Johnston M, Francis J, Hardeman W, Eccles M. From Theory to Intervention: Mapping Theoretically Derived Behavioural Determinants to Behaviour Change Techniques. Applied Psychology 2008;57:660-80.
37. Powell BJ, Waltz TJ, Chinman MJ, et al. A refined compilation of implementation strategies: results from the Expert Recommendations for Implementing Change (ERIC) project. Implement Sci 2015;10:21.
38. Kawamoto K, Houlihan CA, Balas EA, Lobach DF. Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. BMJ 2005;330:765.