

THE PRESENT AND FUTURE

STATE-OF-THE-ART REVIEW

Practical Management of Anticoagulation in Patients With Atrial Fibrillation



Richard J. Kovacs, MD,* Greg C. Flaker, MD,† Sherry J. Saxonhouse, MD,‡ John U. Doherty, MD,§
Kim K. Birtcher, PHARM.D, MS,|| Adam Cuker, MD, MS,¶ Bruce L. Davidson, MD, MPH,# Robert P. Giugliano, MD, SM, **
Christopher B. Granger, MD,†† Amir K. Jaffer, MD, MBA,†† Bella H. Mehta, PHARM.D, §§ Edith Nutescu, PHARM.D, MS,|||
Kim A. Williams, MD††

ABSTRACT

Anticoagulation for atrial fibrillation has become more complex due to the introduction of new anticoagulant agents, the number and kinds of patients requiring therapy, and the interactions of those patients in the matrix of care. The management of anticoagulation has become a "team sport" involving multiple specialties in multiple sites of care. The American College of Cardiology, through the College's Anticoagulation Initiative, convened a roundtable of experts from multiple specialties to discuss topics important to the management of patients requiring anticoagulation and to make expert recommendations on issues such as the initiation and interruption of anticoagulation, quality of anticoagulation care, management of major and minor bleeding, and treatment of special populations. The attendees continued to work toward consensus on these topics, and present the key findings of this roundtable in a state-of-the-art review focusing on the practical aspects of anticoagulation care for the patient with atrial fibrillation. (J Am Coll Cardiol 2015;65:1340–60) © 2015 by the American College of Cardiology Foundation.

From the *Krannert Institute of Cardiology, Indiana University School of Medicine, Indianapolis, Indiana; †Wes and Simone Chair of Cardiovascular Research, University of Missouri School of Medicine, Columbia, Missouri; ‡Sanger Heart and Vascular Institute, Carolinas Health Care System, Charlotte, North Carolina; §Jefferson Heart Institute, Thomas Jefferson University, Philadelphia, Pennsylvania; ||University of Houston College of Pharmacy, Houston, Texas; ¶Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania; #Division of Pulmonary and Critical Care Medicine, University of Washington School of Medicine, Seattle, Washington; **Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts; ††Cardiac Care Unit, Duke University Medical Center, Durham, North Carolina; ‡‡Rush University Medical Center, Chicago, Illinois; §§Ohio State University College of Pharmacy, Columbus, Ohio; and the |||Center for Pharmacoepidemiology and Pharmacoeconomic Research, University of Illinois at Chicago College of Pharmacy/Antithrombosis Center, University of Illinois at Chicago Hospital and Health Sciences System, Chicago, Illinois. Boehringer Ingelheim and Janssen Pharmaceuticals provided funding to the American College of Cardiology for the Anticoagulation Initiative. Dr. Kovacs is a Trustee of the American College of Cardiology. Dr. Flaker is a consultant for Boehringer Ingelheim, Bristol-Myers Squibb, Daiichi Sankyo, Janssen, Pfizer, and Sanofi; and is a member of the American College of Cardiology. Drs. Saxonhouse, Doherty, Birtcher, and Williams are members of the American College of Cardiology Anticoagulation Initiative. Dr. Williams is Vice-President of the American College of Cardiology. Dr. Cuker is a consultant for Baxter, Bayer, CSL Behring, Bracco, and Genzyme; has served on an advisory panel for Daiichi Sankyo and Genzyme; has received research grants from Diagnostica Stago and T2 Biosystems; and is a member of the American College of Physicians and the American Society of Hematology. Dr. Davidson is a consultant and attended advisory boards for Bayer, Daiichi Sankyo, and Janssen. Dr. Giugliano is a consultant for Bristol-Myers Squibb, Daiichi-Sankyo, Johnson & Johnson, Merck, and Pfizer; has received research funding from Daiichi-Sankyo and Merck; is a coinvestigator in clinical trials for GlaxoSmithKline and Johnson & Johnson; and is a member of the American College of Cardiology Anticoagulation Initiative. Dr. Granger is a consultant for Boehringer Ingelheim, Bristol-Myers Squibb, Daiichi Sankyo, GlaxoSmithKline, Janssen, Pfizer, and Sanofi; has received research funding from Bayer, Boehringer Ingelheim, Bristol-Myers Squibb, Daiichi Sankyo, GlaxoSmithKline, Janssen, Merck, Pfizer, and Sanofi; has been a consultant for Hoffmann-La Roche, Medtronic, Eli Lilly, Takeda, The Medicines Company, AstraZeneca, Ross Medical Corporation, Salix Pharmaceuticals, Gilead, Amgen; and is a member of the American College of Cardiology Anticoagulation Initiative. Dr. Jaffer is a consultant for and has received honoraria and travel reimbursement from Boehringer-Ingelheim, CSL Behring, Janssen, Bristol-Myers Squibb, Daiichi Sankyo, Pfizer, and University Health Consortium; is a board member of the Society of Preoperative Assessment and Quality Improvement; has received a research grant from the National Institutes of Health; and is a member of the Society of Hospital Medicine. Dr. Mehta had investments in Pfizer; and has a relationship with AmerisourceBergen, Cardinal Health, and the American Pharmacists Association Foundation. Dr. Nutescu is a consultant for Abbott, CSL Behring, Daiichi Sankyo, Janssen, and The Medicines Company;



In September 2013, following a series of pivotal trials and drug approvals, the American College of Cardiology (ACC) convened a roundtable discussion at the Heart House to address clinical issues regarding oral anticoagulant alternatives to warfarin in patients with nonvalvular atrial fibrillation (AF). The meeting included representatives of specialty societies, the U.S. Food and Drug Administration (FDA), industry, and patient advocates (Online Appendix 1). Discussions covered 4 general topics:

1. Initiation and interruption of anticoagulant therapy;
2. Quality, cost, and team-based management of anticoagulation;
3. Management of bleeding and emergency care; and
4. Complex disease states and special populations.

The discussion was supplemented with focused reviews of the English language published data in PubMed to November, 2014, that pertained to the roundtable themes.

Data from the ACC's PINNACLE Registry showed large variations in the percentage of appropriate anticoagulation for AF even before the introduction of direct-acting oral anticoagulants (DOACs) (1). Management of anticoagulation crosses the bounds of specialty and type of practice (Central Illustration). This review attempts to provide practical consensus recommendations as well as to point out gaps in knowledge and areas of future inquiry.

ASSESSING THE BENEFITS AND RISKS OF ORAL ANTICOAGULANT AGENTS

Oral anticoagulant therapy (OACT) reduces stroke risk in patients with nonvalvular AF. Patients with valvular AF and those with prosthetic mechanical heart valves or significant (moderate to severe) mitral stenosis were excluded from clinical trials, and therefore, this document will not suggest changes in their management. Patients with nonvalvular AF (paroxysmal, persistent, or permanent) with or without symptoms are all considered for OACT on the basis of their individual risk profile.

The 2014 AF guidelines recommend the use of the CHA₂DS₂-VASC (Congestive heart failure or left ventricular dysfunction; Hypertension; Age ≥ 75 years; Diabetes mellitus; Stroke, transient ischemic attack, or thromboembolism; Vascular disease; Age 65 to

74 years; Sex category) scoring system (Table 1) (2) instead of CHADS₂ (Congestive heart failure, Hypertension, Age ≥ 75 years, Diabetes mellitus, Stroke or transient ischemic attack) (3), because it increases the number of patients who meet criteria for anticoagulation therapy while more accurately identifying truly low-risk patients. Many patients (women, those age 65 to 75 years, and patients with vascular disease) are redistributed from the low- to higher-risk categories (3).

Several bleeding risk scores are available, including HAS-BLED (Hypertension, Abnormal renal or liver function, Stroke, Bleeding, Labile INR, Elderly, Drugs and alcohol) and ATRIA (Anticoagulation And Risk Factors In Atrial Fibrillation) (4,5), which may identify patients at higher risk of bleeding; however, more information is needed on their clinical utility (2). Tools, such as the Anticoag-Evaluator and the Stroke Prevention in Atrial Fibrillation Risk Tool, are available at the point of care to estimate the risk of stroke and benefits of anticoagulation therapy in patients with AF (6,7).

CLINICAL TRIALS COMPARING DOACs WITH VITAMIN K ANTAGONISTS

There are 2 classes of DOACs: factor Xa (FXa) inhibitors, such as rivaroxaban, apixaban and edoxaban; and direct thrombin inhibitors, such as dabigatran. Table 2 highlights selected trials comparing the safety and efficacy of DOACs to adjusted-dose warfarin with target international normalized ratio (INR) of 2 to 3.

These trials have limitations, including non-inferiority study designs and relatively short treatment follow-up. The median time in therapeutic range (TTR) for warfarin patients was $\leq 69\%$ in each of the trials; the results may have been different if the patients had achieved a greater percentage of TTR. Limited guidance is provided concerning the potential advantage of using DOACs in patients taking warfarin with TTR $> 75\%$. When data from the trials are combined, DOACs appear to reduce stroke, intracranial hemorrhage (ICH), and overall mortality compared with warfarin, with similar major bleeding risks. However, gastrointestinal bleeding appears increased with rivaroxaban, edoxaban 60 mg, and dabigatran when compared with warfarin (8).

ABBREVIATIONS AND ACRONYMS

ACS	= acute coronary syndrome(s)
AF	= atrial fibrillation
DOAC	= direct-acting oral anticoagulant
DAPT	= dual antiplatelet therapy
FFP	= fresh frozen plasma
ICH	= intracranial hemorrhage
INR	= international normalized ratio
OACT	= oral anticoagulant therapy
TTR	= time in therapeutic range
VKA	= Vitamin K antagonist

has received grant support from Janssen (to institution) and the National Institutes of Health; and has a relationship with the American College of Clinical Pharmacy, the National Blood Clot Alliance, and the Anticoagulation Forum.

Manuscript received November 27, 2014; revised manuscript received January 21, 2015, accepted January 29, 2015.

CENTRAL ILLUSTRATION Complex Interactions Surrounding the Anticoagulation Patient
1 Initiation of OAC to reduce stroke risk in patients with AF

- The CHA₂DS₂-VASc scoring system helps clinicians determine stroke risk and to choose oral anticoagulation (OAC) therapy
- OAC therapy options: New direct oral anticoagulants (DOAC) or vitamin K antagonists (VKA). The most commonly used VKA is warfarin
- Drug interactions should also be considered when prescribing



Risk factor	Points
C Congestive heart failure (or left ventricular systolic dysfunction)	1
H Hypertension (blood pressure consistently above 140/90 mmHg)	1
A ₂ Age ≥ 75 years	2
D Diabetes Mellitus	1
S ₂ Prior Stroke or TIA or thromboembolism	2
V Vascular disease (peripheral artery disease, MI, aortic plaque)	1
A Age 65-74 years	1
Sc Sex category (i.e. female sex)	1
Total score	Anticoagulation therapy options
0 (low stroke risk)	No antithrombotic therapy (or aspirin 75-325 mg daily)
1 (moderate)	Either DOAC or warfarin at an international normalized ratio (INR) of 2.0-3.0
≥ 2 (high)	Either DOAC or warfarin at INR 2.0-3.0

2 Quality, cost and team-based management


- Patients taking OACs will require baseline and periodic lab monitoring to determine dose
- Coordinating care through anticoagulation clinics improves patient outcomes and reduces costs. Anticoagulation clinics need financial support from healthcare systems to be able to exist

3 Management of bleeding and emergency care


Even with coordinated care, bleeding complications can occur. Minor bleeding may predict major bleeding and may lead to stoppage of effective OAC therapy. Major bleeding is associated with higher mortality.

There are specific recommendations for managing these scenarios:

- Bleeding onset
- Major bleeding
- Clinically relevant non-major bleeding
- Minor bleeding or elevated INR values
- After bleeding

4 Management of complex disease


Patients with AF requiring anticoagulation therapy often have comorbid conditions

There are specific recommendations for OAC use for these patients:

- Recent coronary stent and new onset AF
- Established AF, on OACs, requiring elective stenting
- Established AF, on OACs, who develop acute coronary syndrome
- Established AF, on OACs, with medically managed coronary disease
- Patients with stenting >1 month ago with a bare metal stent, or >6 months ago with a drug eluting stent, who develop AF
- Cerebral vascular disease and AF
- Previously on OACs, presenting with acute Ischemic stroke
- Ischemic stroke treated with vitamin K antagonist – convalescent phase
- Hemorrhagic stroke, on OACs
- Significant carotid stenosis and AF
- Peripheral artery disease and AF
- Mechanical heart valves and needing cardiac surgery
- Cardioversion
- AF ablation

Kovacs, R.J. et al. J Am Coll Cardiol. 2015; 65(13):1340-60.

New drugs, such as the direct-acting oral anticoagulants (DOACs), are tested for safety and efficacy in clinical trials involving specific patient populations with rigorous inclusion and exclusion criteria. Labels with prescribing instructions are written on the basis of those trial data and data from a limited number of supporting trials using specific patient samples to test a limited number of drug interactions and a few select special patient populations. Once approved for use, these drugs are introduced into a much more complex system of care. Patients taking DOACs move between hospital care and outpatient care and interact with many health care workers in a complex system. Patients taking DOACs have multiple comorbidities and take DOACs for long periods of time. Coordination of care is of the utmost importance to provide safe and effective management of oral anticoagulation in the modern health care environment. AF = atrial fibrillation; INR = international normalized ratio; MI = myocardial infarction; OAC = oral anticoagulants; TIA = transient ischemic attack; VKA = vitamin K antagonist.

THE RIGHT DRUG FOR THE RIGHT PATIENT

Appropriate drug selection depends on approved indications, patient characteristics, concomitant medications, clinician and patient preference, and cost. Therapy with well-managed warfarin and with high TTR is appropriate for certain patients. Several reports quantify the relationship between TTR and major clinical outcomes in patients with AF (9,10). Patients with TTR $<58\%$ despite adequate warfarin

dosing adjustment may benefit from a DOAC (11). Clinical trials have also shown lower risks of ICH with DOACs when compared with warfarin.

Individual response to warfarin varies with age, sex, body mass index, concomitant medicines, certain foods, and genotype. Warfarin has a relatively narrow therapeutic index. Overdosing can result in bleeding; underdosing can result in thrombosis. Patients treated with warfarin should have an INR determined at least weekly during initiation of

TABLE 1 The 2009 Birmingham Schema Expressed as a Point-Based Scoring System, With the Acronym CHA ₂ DS ₂ -VASc	
Risk Factor	Score
Congestive heart failure or left ventricular dysfunction	1
Hypertension	1
Age ≥ 75 yrs	2
Diabetes mellitus	1
Stroke, transient ischemic attack, or thromboembolism	2
Vascular disease (prior myocardial infarction, peripheral artery disease, or aortic plaque)	1
Age 65–74 yrs	1
Sex category (i.e., female)	1
Maximum total points	9

Reprinted with permission from Lip et al. (106).

therapy and regular ongoing monitoring when INR is stable and within range. Genetics influence vitamin K antagonist (VKA) response; however, genetic testing to predict VKA response has not been widely adopted, nor has it been shown to be of value in randomized trials (12,13). Home monitoring of VKA therapy is reasonable in selected patients

(14), including those who have difficult access to laboratory services. Many insurance plans, including Medicare, cover the cost of a device and once-weekly use of test strips. Several nationwide VKA home management services accept commercial and Medicare health insurance (15).

The DOACs' mechanism of action, dosing information, drug interactions, and recommended monitoring schedules are listed in **Table 3**. Although DOACs are more expensive than warfarin, advantages for some patients include a lack of dietary limitations, fewer drug interactions, and elimination of INR testing.

Patients taking OACs require baseline and periodic laboratory monitoring (16). DOAC dosing is sensitive to changes in renal function. A summary of dosing changes relative to renal function can be found in **Table 3**. Although many laboratories report renal function as the estimated glomerular filtration rate, renal function should be estimated using the Cockcroft-Gault equation $[(140 - \text{age}) \times \text{weight} (\text{in kg}) \times 0.85 \text{ if female}]/[72 \times \text{creatinine} (\text{in mg/dL})]$ to determine the appropriate DOAC dose.

TABLE 2 Summary of Selected DOACs Clinical Trials

	RE-LY (33) (N = 18,113) (3 arms)*	ROCKET-AF (34) (N = 14,264)	ARISTOTLE (35) (N = 18,201)	ENGAGE AF-TIMI 48 (36) (N = 21,105) (3 arms)†
Drug, dose	Dabigatran, 150 mg bid	Rivaroxaban, 20 mg daily	Apixaban, 5 mg bid	Edoxaban, 60/30 mg daily
Adjusted dose?	No	Yes, at randomization only: 15 mg daily if CrCl 30–49 mL/min	Yes, at randomization only: 2.5 mg bid if 2 of: age ≥ 80 yrs, weight < 60 kg, SCr ≥ 1.5 mg/dL	Yes, at randomization and during study: both doses halved if any 1 of the following: CrCl 30–50 mL/min, weight ≤ 60 kg, use of verapamil, quinidine, or dronedarone
Design	Randomized open-label	Randomized double-blind, double-dummy	Randomized double-blind, double-dummy	Randomized double-blind, double-dummy
Mean age, yrs	71.5	73	70	72
Prior stroke/ transient ischemic attack/systemic embolism	20%	55%	19%	28%
Mean CHADS ₂	2.2	3.5	2.1	2.8
Warfarin-naïve	50.4%	37.6%	43%	41%
Comparator warfarin INR 2–3	67% TTR (median)	58% TTR (median)	66% TTR (median)	68% (median)
Comparator Warfarin INR 2–3	64% TTR (mean)	55% TTR (mean)	62% TTR (mean)	65% (mean)
Outcome, RR (95% CI)				
Stroke/systemic embolism	0.66 (0.53–0.82)	0.88 (0.75–1.03)	0.79 (0.66–0.95)	0.88 (0.75–1.03)
Ischemic stroke	0.76 (0.60–0.98)	0.94 (0.75–1.17)	0.92 (0.74–1.13)	1.00 (0.83–1.19)
Hemorrhagic stroke	0.26 (0.14–0.49)	0.59 (0.37–0.93)	0.51 (0.35–0.75)	0.54 (0.38–0.77)
Major bleeding	0.93 (0.81–1.07)	1.04 (0.90–1.20)	0.69 (0.60–0.80)	0.80 (0.71–0.91)
Intracranial hemorrhage	0.40 (0.27–0.60)	0.67 (0.47–0.93)	0.42 (0.30–0.58)	0.47 (0.34–0.63)
Gastrointestinal bleeding	1.50 (1.19–1.89)	1.39 (1.19–1.61)	0.89 (0.70–1.15)	1.23 (1.02–1.50)
Cardiovascular mortality	0.85 (0.72–0.99)	0.89 (0.73–1.10)	0.89 (0.76–1.04)	0.86 (0.77–0.97)
All-cause mortality	0.88 (0.77–1.00)	0.85 (0.70–1.02)	0.89 (0.80–0.998)	0.92 (0.83–1.01)

Estimate creatinine clearance (CrCl) using Cockcroft-Gault formula: $[(140 - \text{age}) \times \text{weight} (\text{in kg}) \times 0.85 \text{ if female}]/(72 \times \text{creatinine} [\text{in mg/dL}])$. *Results are shown for dabigatran 150 mg bid. †Results are shown for edoxaban 60 mg daily.

CHADS₂ = Congestive heart failure, Hypertension, Age ≥ 75 years, Diabetes mellitus, Stroke or transient ischemic attack; CI = confidence interval; CrCl = creatinine clearance; DOAC = direct-acting oral anticoagulant; INR = international normalized ratio; RR = risk ratio; SCr = serum creatinine; TTR = time in therapeutic range.

Patients with severe renal impairment were excluded from the large phase III trials evaluating DOACs, and therefore, warfarin remains the treatment of choice for AF patients with severe renal impairment or end-stage renal disease (2). However, the FDA has approved apixaban in patients with end-stage renal disease on hemodialysis on the basis of pharmacokinetic modeling data.

DRUG INTERACTIONS

Drug interactions should be considered when prescribing any OACT (Tables 3 and 4). All patients should be instructed to alert the clinician prescribing the OACT any time changes in other medications are made (Table 5). Warfarin has many food and drug interactions (17), although some are not well

TABLE 3 FDA-Approved Direct Acting Oral Anticoagulants for Nonvalvular Atrial Fibrillation*

	Dabigatran (Pradaxa) (107)	Rivaroxaban (Xarelto) (108)	Apixaban (Eliquis) (109)	Edoxaban (Savaysa) (24)
Mechanism of action	Direct thrombin inhibitor	Factor Xa inhibitor	Factor Xa inhibitor	Factor Xa inhibitor
Dosing for nonvalvular AF†	150 mg twice daily	20 mg daily with evening meal	5 mg twice daily	If CrCl‡ >50 ml/min to ≤95 ml/min: 60 mg daily
Dosing considerations for nonvalvular AF with renal adjustments	If CrCl‡ is 15–30 ml/min: 75 mg twice daily If CrCl <15 ml/min: avoid use	If CrCl‡ is 15–50 ml/min: 15 mg daily with evening meal	If the patient has at least 2 of the following: - Age ≥80 years old - Weight ≤60 kg - SCr ≥1.5 mg/dL: 2.5 mg twice daily	If CrCl‡ >95 ml/min: do not use; may have an increased risk of ischemic stroke as compared with warfarin If CrCl‡ 15–50 ml/min: 30 mg daily
Dosing considerations for nonvalvular AF with hepatic adjustments	Administration in patients with moderate hepatic impairment (Child-Pugh B) showed no evidence of change in exposure or pharmacodynamics	Avoid use in patients with Child-Pugh B and C hepatic impairment or with any degree of hepatic impairment associated with coagulopathy	Mild hepatic impairment: no dose adjustment needed Moderate hepatic impairment: no dosing recommendation available Severe hepatic impairment: avoid use	Avoid use in patients with Child-Pugh B and C hepatic impairment
Drug interactions	Avoid concomitant use with P-gp inducers (e.g., rifampin). P-gp inhibitors and impaired renal function can lead to increased exposure to dabigatran: avoid concomitant use with severe renal impairment (<30 ml/min); for moderate renal impairment reduce dose to 75 mg twice daily when used concomitantly with dronedarone or systemic ketoconazole	Avoid concomitant use with strong dual inhibitors of CYP3A4 and P-gp (e.g., ketoconazole, ritonavir, erythromycin) or reduce apixaban dose Avoid concomitant use with strong dual inducers of CYP3A4 and P-gp (e.g., rifampin, phenytoin, carbamazepine) Avoid concomitant use with other anticoagulants	Avoid concomitant use with strong dual inhibitors of CYP3A4 and P-gp (e.g., ketoconazole, ritonavir, erythromycin) or reduce apixaban dose Avoid concomitant use with strong dual inducers of CYP3A4 and P-gp (e.g., rifampin, phenytoin, carbamazepine) Concomitant use with antiplatelet agents, fibrinolytic agents, heparin, aspirin, and chronic NSAID increases bleeding risk	Avoid concomitant use with P-gp inducers (e.g., rifampin)
Major adverse effects	Dyspepsia, bleeding	Bleeding	Bleeding	Bleeding
Monitoring§	Baseline laboratory assessment: hemoglobin/hematocrit, liver function, renal function, PT/INR At every visit: adherence, signs/symptoms of bleeding or thromboembolism, side effects, concomitant medications (including over-the-counter) Annual laboratory assessment: hemoglobin/hematocrit, renal function, liver function If CrCl 30–60 ml/min, >75 years of age, or fragile: renal function q 6 months If CrCl 15–30 ml/min: renal function q 3 months If condition changes that might affect anticoagulation therapy: check renal and/or liver function			

*Other indications for these agents are not included in this table. Refer to the prescribing information for complete information. †May need to adjust dose or avoid on the basis of concomitant medications. ‡Estimate creatinine clearance (CrCl) using Cockcroft-Gault formula: $([140 - \text{age}] \times \text{weight} [\text{in kg}] \times 0.85 \text{ if female}) / (72 \times \text{creatinine} [\text{in mg/dL}])$. §Adapted from Heidbuchel et al. (16).

AF = atrial fibrillation; CrCl = creatinine clearance; CYP3A4 = cytochrome P450 3A4; INR = international normalized ratio; NSAID = nonsteroidal anti-inflammatory drug; P-gp = P-glycoprotein; PT = prothrombin time.

TABLE 4 Selected Drug Interactions With Direct Acting Oral Anticoagulants*

	Mechanism of Drug Interaction	Dabigatran (Pradaxa) (107)	Rivaroxaban (Xarelto) (108)	Apixaban (Eliquis) (109)	Edoxaban (Savaysa) (24)
Carbamazepine	Strong inducer of CYP3A4 and P-gp	Avoid use	Avoid use	Avoid use	No specific recommendations
Clarithromycin	Strong inhibition of CYP3A4 and P-gp	No adjustment needed	No adjustment needed	Reduce dose from 5 mg twice daily to 2.5 mg twice daily If on 2.5 mg twice daily, discontinue apixaban	No specific recommendations
Dronedarone	P-gp inhibitor	With CrCl 30–50 mL/min, reduce dose to 75 mg twice daily	No specific recommendations	No specific recommendations	No adjustment needed
Itraconazole	Strong inhibition of CYP3A4 and P-gp	No adjustment needed	Avoid use	Reduce dose from 5 mg twice daily to 2.5 mg twice daily If on 2.5 mg twice daily, discontinue apixaban	No specific recommendations
Ketoconazole	Strong inhibition of CYP3A4 and P-gp	With CrCl 30–50 mL/min, reduce dose to 75 mg twice daily	Avoid use	Reduce dose from 5 mg twice daily to 2.5 mg twice daily If on 2.5 mg twice daily, discontinue apixaban	No specific recommendations
Phenytoin	Strong inducer of CYP3A4 and P-gp	Avoid use	Avoid use	Avoid use	No specific recommendations
Rifampin	Strong inducer of CYP3A4 and P-gp	Avoid use	Avoid use	Avoid use	Avoid use
Ritonavir	Strong inhibition of CYP3A4 and P-gp	No adjustment needed	Avoid use	Reduce dose from 5 mg twice daily to 2.5 mg twice daily If on 2.5 mg twice daily, discontinue apixaban	No specific recommendations
St. John's wort	Strong inducer of CYP3A4 and P-gp	Avoid use	Avoid use	Avoid use	No specific recommendations

*This is not a comprehensive list of all drug interactions. Please refer to individual medication manufacturer prescribing information for complete information. Estimate creatinine clearance (CrCl) using Cockcroft-Gault formula: $([140 - \text{age}] \times \text{weight [in kg]} \times 0.85 \text{ if female}) / (72 \times \text{creatinine [in mg/dL]})$.

Abbreviations as in Table 3.

documented. Nonprescription medications (e.g., acetaminophen, fish oil, herbal supplements, and grapefruit juice) can potentiate the effect of VKAs (18–21).

DOACs are also subject to drug interactions. Rivaroxaban and apixaban interact with drugs that are strong cytochrome P450 3A4 inhibitors or inducers and are impacted by the efflux transporter P-glycoprotein (22). Rifampin, a P-glycoprotein inducer, should not be used with edoxaban or dabigatran. Medications that inhibit the P-glycoprotein system increase dabigatran and edoxaban plasma concentrations. Concomitant use of quinidine, dronedarone, or verapamil with edoxaban significantly increases edoxaban exposure (23). Although the dose of edoxaban was reduced by 50% in patients taking concomitant verapamil, quinidine, or dronedarone in ENGAGE AF-TIMI 48 (Effective Anticoagulation with Factor Xa Next Generation in Atrial Fibrillation-Thrombolysis In Myocardial Infarction 48), the FDA does not recommend dose reduction in patients who are taking concomitant P-gp inhibitors (24). Patients taking antiretroviral therapy, cyclosporine, azole antifungals, and macrolides were excluded from ENGAGE AF-TIMI 48, and the use of these agents in patients taking DOACs should be avoided as they increase edoxaban concentrations.

INTERRUPTION OF DRUG THERAPY

Short-term interruption of OACT is safe for most low-risk invasive procedures. Management of OACT should be individualized for patients at higher thromboembolic risk who are undergoing high-risk procedures. Procedures that pose a high risk of bleeding include intracranial, intraspinal, retroperitoneal, or intrathoracic surgery. Intraocular procedures and neuraxial anesthesia may present risks to patients with even minor bleeding. Bridging with a parenteral agent (e.g., unfractionated heparin or low-molecular-weight heparin) is common, but the data on prevention of embolic events are limited, and the rate of bleeding is significantly increased (25). The decision to bridge must balance the risk of an embolic event against the risk of bleeding (26).

TRANSITIONING BETWEEN ANTICOAGULANT AGENTS

The INR monitoring is needed when transitioning patients from VKA to a DOAC to avoid over-anticoagulation. INR targets when switching from warfarin to a DOAC are summarized in Table 4. If

TABLE 5 Transitioning Between Anticoagulants and Interruption of Therapy*

Conversion	Apixaban (Eliquis) (109)	Rivaroxaban (Xarelto) (108)	Dabigatran (Pradaxa) (107)	Edoxaban (Savaysa) (24)
From warfarin to DOAC	Stop warfarin and start apixaban when INR <2	Stop warfarin and start rivaroxaban when INR <3 (108)	Stop warfarin, start dabigatran when INR <2	Stop warfarin and start edoxaban when INR ≤2.5
From DOAC to warfarin†	Stop apixaban and start warfarin and parenteral anticoagulant when next dose of apixaban would be due; discontinue parenteral agent when INR in therapeutic range	Stop rivaroxaban and start warfarin and parenteral anticoagulant when next dose of rivaroxaban would be due; discontinue parenteral agent when INR in therapeutic range	If CrCl ≥50 mL/min, start warfarin 3 days before stopping dabigatran If CrCl 30–50 mL/min, start warfarin 2 days before stopping dabigatran If CrCl 15–30 mL/min, start warfarin 1 day before stopping dabigatran If CrCl <15 mL/min, no available recommendation	Oral option: reduce edoxaban dose by 50% and start warfarin; check INR at least weekly and just prior to edoxaban dose. When INR ≥2, discontinue edoxaban. Parenteral option: stop edoxaban; start parenteral anticoagulant and warfarin at time the next dose of edoxaban would be due. When INR ≥2, discontinue edoxaban.
From parenteral agent to DOAC	Discontinue parenteral agent; start apixaban at the time the next dose of parenteral agent would be due	LMWH: discontinue LMWH; start rivaroxaban 0–2 h before next scheduled evening dose of LMWH and omit administration of LMWH Unfractionated heparin intravenous infusion: initiate rivaroxaban when discontinuing heparin infusion	LMWH: discontinue LMWH; start dabigatran 0–2 h before the time the next dose of LMWH would be due. Unfractionated heparin intravenous infusion: initiate dabigatran when discontinuing heparin infusion	LMWH: discontinue LMWH; start edoxaban at the time the next dose of LMWH would be due. Unfractionated heparin intravenous infusion: initiate edoxaban 4 h after discontinuing heparin infusion
From DOAC to parenteral anticoagulant	Discontinue apixaban; start parenteral agent at the time the next dose of apixaban would be due	Discontinue rivaroxaban; start parenteral agent at the time the next dose of rivaroxaban would be due	If CrCl ≥30 mL/min; discontinue dabigatran; start parenteral agent 12 h after last dabigatran dose If CrCl <30 mL/min; discontinue dabigatran; start parenteral agent 24 h after last dabigatran dose	Discontinue edoxaban; start parenteral agent at the time the next dose of edoxaban would be due
From DOAC to DOAC	Discontinue apixaban; start DOAC at the time the next dose of apixaban would be due	Discontinue rivaroxaban; start DOAC at the time the next dose of rivaroxaban would be due	No information available; consider patient specific characteristics (e.g., renal function, risk of bleeding or stroke)	Discontinue edoxaban; start DOAC at the time the next dose of edoxaban would be due
Temporary interruption of DOAC for surgery and other invasive procedures	Moderate-High-Risk Bleeding: discontinue at least 48 h prior to surgery or invasive procedure Low-Risk Bleeding: Discontinue at least 24 h prior to surgery or invasive procedure	Discontinue at least 24 h prior to surgery or invasive procedure	If CrCl ≥50 mL/min: discontinue at least 1–2 days prior to surgery or invasive procedure If CrCl <50 mL/min: Discontinue at least 3–5 days prior to surgery or invasive procedure	Discontinue at least 24 h prior to surgery or invasive procedure

*Refer to the prescribing information for complete information. †DOACs can affect INR, so INR monitoring during conversion from DOAC to warfarin is not clinically useful. Estimate creatinine clearance (CrCl) using Cockcroft-Gault formula: $([140 - \text{age}] \times \text{weight} [\text{in kg}] \times 0.85 \text{ if female}) / (72 \times \text{creatinine} [\text{in mg/dL}])$.

DOAC = direct-acting oral anticoagulant; other abbreviations as in Table 3.

switching from a DOAC to VKA, bridging with a short-acting parenteral agent or a lower dose of the DOAC may be needed. INR should be at least twice weekly, and VKA dose should be adjusted using a reliable algorithm until the INR reaches 2.0 to avoid excess bleeding or thrombotic events (27). When transitioning from parenteral agents to DOACs, the DOACs can be initiated up to 2 h before the next dose of the parenteral agent or when stopping the intravenous (IV) infusion. For those patients transitioning from FXa inhibitors to parenteral agents, the parenteral agents can be started at the intended time for the

next dose of FXa inhibitor. When converting from dabigatran to a parenteral agent, the starting time is dependent on the patient's creatinine clearance (Table 5).

LONG-TERM MANAGEMENT OF OACT

National guidelines and regulatory agencies endorse coordinated-care anticoagulation management models to maximize patient outcomes (14,28–31). Despite data showing that coordinating care through anticoagulation clinics (ACs) improves

patient outcomes and reduces costs when compared with usual medical care (14,28,29), only 30% to 40% of patients taking VKAs are managed in an AC (32).

The scope of AC services should include management of DOACs (32). Therapy with both DOACs and VKAs requires continual patient education (Table 6), evaluation for drug interactions, and periodic laboratory monitoring (Table 3), all of which could be coordinated through institutional protocols or through ACs that facilitate initiation, compliance, transition between agents, and interruption for procedures.

MANAGEMENT OF BLEEDING AND EMERGENCY CARE

Even with the best coordinated care, bleeding complications will occur. Clinical trials comparing VKA with DOACs for stroke prevention in AF have shown an annual rate of major bleeding ranging from 2.1% to 3.6% of patients. Fatal bleeding occurs in up to 0.5% (33-36). Major bleeding is associated with higher mortality. In an analysis of 5 phase III clinical trials, 30-day mortality after a major bleeding episode was 13% with warfarin and 9% with dabigatran (37).

Minor bleeding may predict major bleeding (5,38) and may lead to discontinuation of effective anti-coagulation therapy, underscoring the importance of both preventing and effectively managing bleeding episodes. With VKA therapy, regular monitoring and appropriate dose adjustment will improve anti-coagulation quality and reduce bleeding. For DOACs, adjustment of dose on the basis of renal function is crucial. With both VKA and DOACs, avoidance of concomitant aspirin and other antiplatelet agents, including long-acting NSAIDs, whenever possible, is important.

BLEEDING DEFINITIONS

Bleeding severity in outpatient trials of anti-coagulation was defined by the International Society on Thrombosis and Haemostasis (39) and has been revised (40). For this review, those definitions have been modified to enhance their clinical relevance (Figure 1).

GENERAL ASSESSMENT OF THE BLEEDING PATIENT RECEIVING OACT

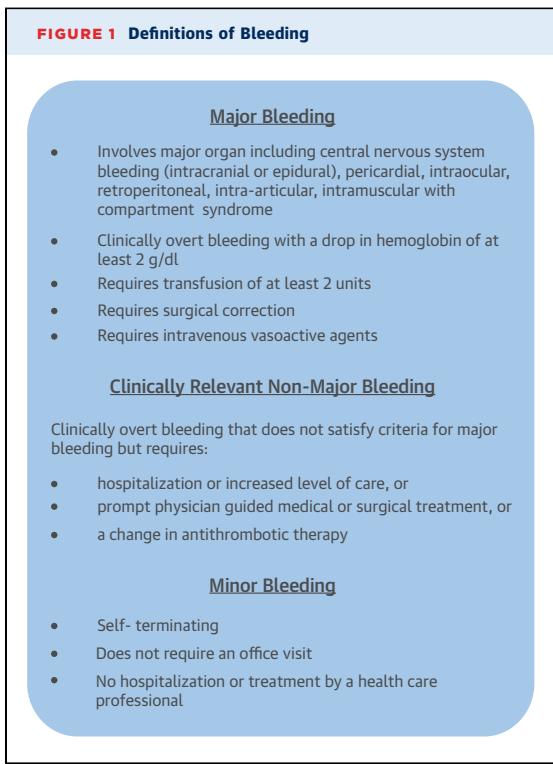
Management of the bleeding patient taking an anti-coagulant is outlined in Figure 2. Basic assessment includes determination of the site, onset, and volume

TABLE 6 Education Topics for Oral Anticoagulants

VKA and DOACs	
Anticoagulation basics	Reason for anticoagulation How medication reduces AF complications Generic, trade names Onset, duration of action Duration of therapy Reversibility Storage
Adherence	When to take doses What to do if a dose is missed Do not run out of this medication; consequence of nonadherence Consequence of taking too much Common signs and symptoms of clot; what to do if they occur
Risk and benefits	Common signs and symptoms of bleeding; what to do if they occur Need for birth control in women of childbearing age Precautionary measures to minimize risk of trauma or bleeding
Preventative care	Potential drug interactions; which providers to notify when medication regimen changes Alcohol Aspirin NSAIDs Self-care Accessing health care
	Avoid/limit alcohol intake Avoid unless clearly indicated Avoid or minimize use Common adverse effects, allergic reactions Which providers to notify of anticoagulant use Which providers to notify when dental, surgical, or invasive procedures are scheduled Carrying identification (medication bracelet or necklace, wallet card)
General laboratory monitoring	Frequency, what will be checked
Dabigatran Only	
Adherence	Swallow whole, do not break, crush, or open capsule. Take with full glass of water.
Storage	Keep in original container; do not put in pillbox (do not discard desiccant)
Self-care	May increase GI upset; discuss with clinician if bothersome.
Rivaroxaban Only	Take with food (evening meal)
VKA Only	
Diet	Influence of dietary vitamin K, need for consistency
INR monitoring	Meaning, significance, target Frequency

GI = gastrointestinal; VKA = vitamin K antagonist; other abbreviations as in Tables 3 and 5.

of bleeding, and whether bleeding is ongoing. The time of last ingestion of the anticoagulant is especially important with DOACs. Concomitant medications should be reviewed (Table 3). An assessment of comorbid conditions and evidence of cardiac decompensation should be done. Laboratory assessment includes a complete blood count with platelet count, prothrombin time (PT) and activated partial thromboplastin time (aPTT), serum electrolytes, and renal and hepatic function.



LABORATORY MONITORING OF ANTICOAGULATION

VKA-TREATED PATIENTS. The PT/INR is essential to the assessment of the VKA-treated patient with bleeding. Invasive procedures to define and correct the bleeding source are often delayed until the INR is reduced. The type and amount of reversal agent is often determined on the basis of the degree of PT prolongation, although there are few data correlating clinical outcomes with the initial INR level and few data correlating clinical improvement with the use of reversal agents.

DOAC-TREATED PATIENTS. Figure 3 summarizes the potential use of coagulation assays in the assessment of the bleeding patient taking a DOAC (41). A prolonged aPTT indicates an anticoagulant effect of dabigatran, and a prolonged PT indicates an anticoagulant effect of the FXa inhibitors. However, elevated plasma levels of dabigatran and FXa inhibitors may occur with normal aPTT or PT values, making them less useful in the assessment of the bleeding patient. Different PT and aPTT reagents vary widely in their sensitivity to the DOACs.

Furthermore, there may be some danger in relying on conventional parameters to define reversal therapy in a bleeding patient receiving a DOAC. For example, an aPTT of $>2.5 \times$ control suggests a supratherapeutic dabigatran concentration (42). A reversal agent may take several hours to reach the patient

after ordering. Because the half-life of dabigatran is relatively short, by the time a reversal agent is administered, the reversal drug dose may be excessive, resulting in clotting. This highlights 1 of the difficulties in the design of clinical trials to assess reversal agents (43).

The dilute thrombin time, a functional test of the effect of thrombin on fibrin formation, provides a reasonable estimate of dabigatran concentration across a wide range of drug levels (42), and is commercially available (Hemoclot HYPHEN BioMed, Neuville-sur-Oise, France). Ecarin-based assays, including the ecarin clotting time and chromogenic ecarin assays, correlate well with dabigatran concentration, but are not widely available.

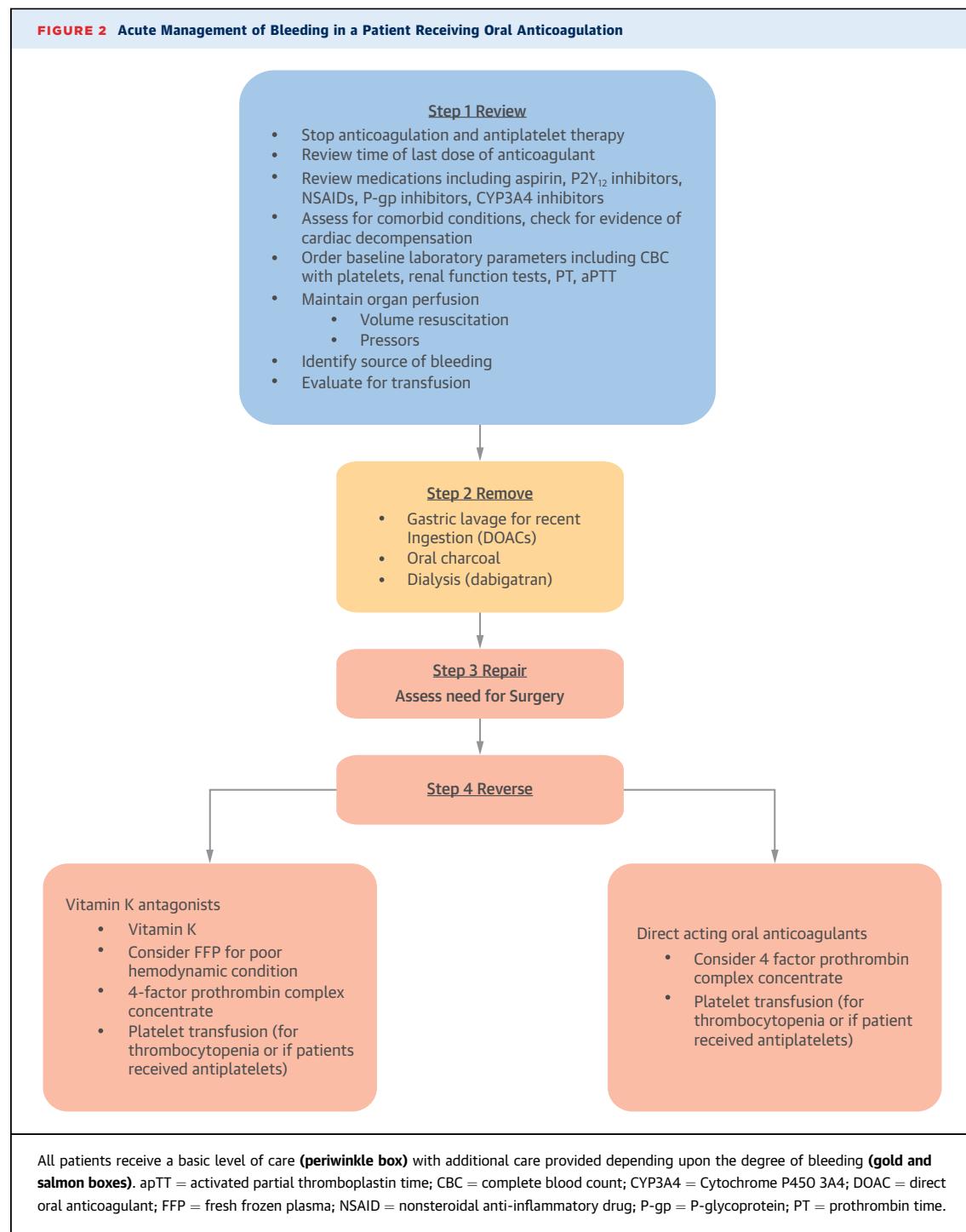
The anticoagulant effect of FXa inhibitors can be assessed by anti-FXa levels. Data linking anti-FXa levels with bleeding and thrombosis related to FXa inhibitors are unavailable. Calibration of anti-factor Xa assays with specific FXa inhibitors is recommended.

AGENTS TO REVERSE ANTICOAGULATION

The introduction of DOACs has made therapy to reverse anticoagulation more complex. Newer agents (such as prothrombin complex concentrate [PCC]) are expensive and not always readily available. Many institutions have developed protocols for management of the patient treated with OACT who experiences major bleeding. Consultation with a hematologist is recommended.

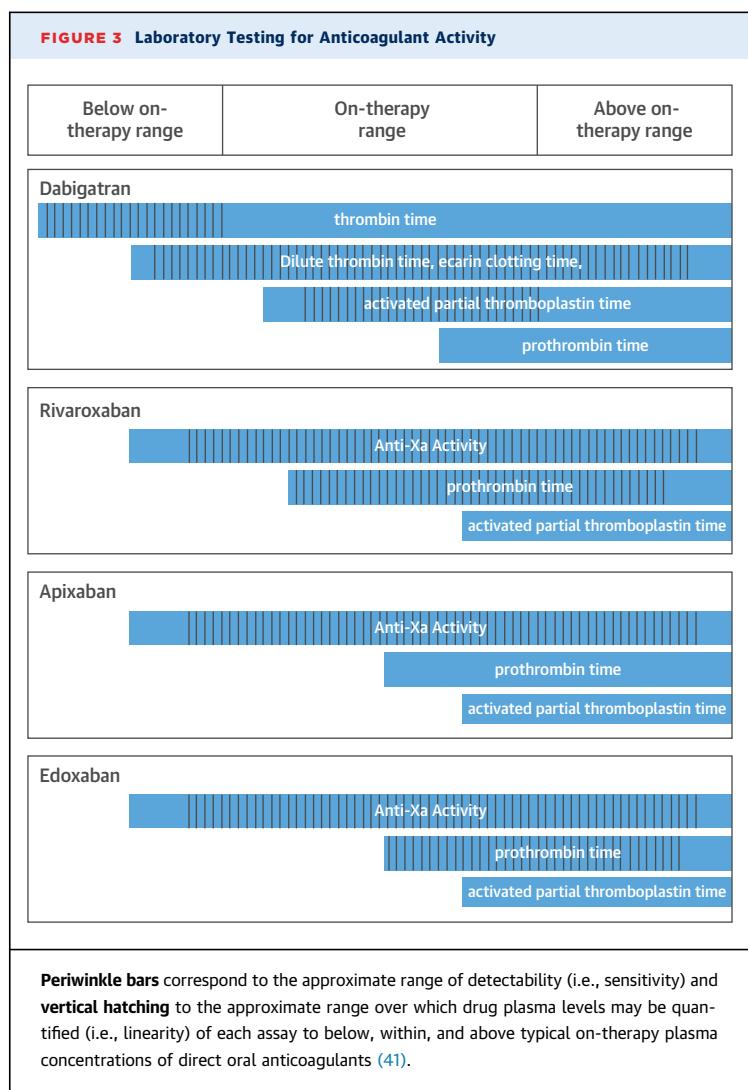
VITAMIN K. VKAs reduce the synthesis of functional vitamin K-dependent coagulation factors, providing a rationale for vitamin K therapy as a reversal agent. IV vitamin K does not begin to reduce INR for 6 h, often taking longer than 24 h for complete reversal (44). IV vitamin K may result in allergic reactions (particularly when given as a bolus), and IV infusions should generally be limited to patients with major bleeding. Subcutaneous and intramuscular administration is not recommended. Oral vitamin K is used for minor bleeding with an elevated INR. Although effective at lowering the INR, there are few data demonstrating improvement in outcomes with vitamin K. High doses of vitamin K will prolong the time to achieve a therapeutic INR when warfarin is restarted. Vitamin K does not reverse the anticoagulant effect of DOACs.

FRESH FROZEN PLASMA. Fresh frozen plasma (FFP) and blood transfusion provide volume, which is a potential advantage in a volume-depleted patient, but a potential disadvantage in patients with heart failure or renal dysfunction. FFP is readily available, although there are delays associated with thawing



frozen plasma. For a patient with a high INR who is actively bleeding, it may be necessary to administer >1,500 mL of FFP to meaningfully increase coagulation factors. Even with a reduction in INR, there are few data showing improvement in outcomes with FFP. FFP in clinically-feasible quantities does not reverse the anticoagulant effect of DOACs.

PROTHROMBIN COMPLEX CONCENTRATE. For patients with an elevated INR receiving VKA, a 10 to 30 min infusion of PCC improves INR values within minutes and lasts for 12 to 24 h. The half-lives of infused factors are similar to endogenous factors. Vitamin K is generally recommended for use with PCC to sustain the reversal effect.



The impact of PCC appears to be different with different DOACs. PCC did not normalize the aPTT, ecarin clotting time, and thrombin time in healthy volunteers who had received dabigatran, but immediately reversed a prolonged PT and an abnormal thrombin potential in rivaroxaban-treated healthy volunteers (45). Studies show that reversal of an anticoagulation effect can occur within 15 min, but may differ between direct thrombin inhibitors and FXa inhibitors. Recent studies show that PCC reverses anticoagulant activity in healthy volunteers given either dabigatran or rivaroxaban within 2 h (46). The composition of PCC varies with the manufacturer. The 4-factor PCC contains factors II, VII, IX, and X. The 3-factor PCC contains little or no factor VII. In healthy volunteers who received rivaroxaban, 3-factor PCC restored thrombin generation better than 4-factor PCC, but 4-factor PCC produced larger

reductions in mean prothrombin time within 30 min. These discrepancies may be related to differences in factor concentration in these agents (47).

Data linking improved clinical outcomes with the use of PCC in DOAC-treated patients are lacking. In addition, there is concern about myocardial infarction (MI) and arterial thromboembolism with the more potent agents (48,49) that must be balanced against potential benefits. Some forms of PCC contain heparin, a concern in patients with heparin-induced thrombocytopenia. The dose of PCC is 20 to 50 U/kg, and the wholesale cost is about \$1.25/U.

OTHER REVERSAL AGENTS. Recombinant factor VIIa has been effective for reversal of the anticoagulant effect of VKA (50–52). Impact on laboratory parameters occurs within minutes and lasts 2 to 6 h, but the effect on bleeding consequences remains to be determined (53), and there is concern about the risk of thrombosis (48).

Three additional reversal agents are currently being evaluated. Idarucizumab, a specific antibody to dabigatran, has been reported to restore systemic blood coagulation in animal studies (43) and in healthy volunteers. The REVERSE-AD (A study of the Reversal Effects of Idarucizumab on Active Dabigatran) trial studying the use of this agent in uncontrolled bleeding is underway. Andexanet alfa, a modified FXa molecule that binds to FXa inhibitor allowing the patient's intrinsic FXa to participate in coagulation, has been reported to provide rapid and near-complete reversal of factor X inhibitors in healthy volunteers. Aripazine, a small synthetic molecule with broad activity against heparin products and factor X agents, is undergoing testing in healthy subjects (54).

MANAGEMENT OF MAJOR BLEEDING

Standard measures in the management of major bleeding in a patient taking an oral anticoagulant include fluid and blood resuscitation, identification and treatment of the bleeding source, and avoidance of administration of additional antithrombotic agents or antiplatelet drugs. Prompt reversal of the anti-thrombotic effects is desirable.

VITAMIN K ANTAGONISTS. Reversal of anticoagulation should be considered in a patient receiving VKAs who has major bleeding and an INR ≥ 1.5 . Vitamin K 5 to 10 mg should be administered by slow IV infusion (14).

In 40 patients with a mean INR of 9.4, low-dose 3-factor PCC (25 U/kg) and high-dose 3-factor PCC (50 U/kg) lowered the INR by 50% and 43%, respectively (55). Adding plasma further reduced the INR by 89% and 88%. In another randomized study, 4-factor PCC

was compared with FFP in 219 nonsurgical patients with warfarin-associated bleeding (mean INR 3.7). Within 1 h of the start of infusion, more than two-thirds of the 4-factor PCC group had an INR <1.3 compared with none in the FFP group (56).

The use of PCC is recommended as first-line therapy in patients taking VKAs with life-threatening major bleeding (14). Doses can be repeated in 6 h. Delays in the administration of PCC have been reported (57), perhaps reflecting a lack of familiarity with new therapies or the lack of ready availability of these products.

DIRECT-ACTING ORAL ANTICOAGULANT AGENTS. Gastric lavage could be considered for patients who experience major bleeding, if DOAC ingestion has been recent. Administration of activated charcoal may be helpful if the DOAC has been ingested within 2 to 6 h (58).

Data on patients treated with DOACs who have major bleeding are limited. Given the poor prognosis of major bleeding, especially CNS bleeding, in patients treated with DOACs, some recommend PCC, activated PCC, or as a last choice, activated factor VIIa to treat severe or life-threatening bleeding (59). However, there is no clinical evidence to support this recommendation.

Because dabigatran is approximately 35% plasma-bound, dialysis is a consideration in the event of major bleeding, particularly in the setting of renal insufficiency. Rivaroxaban, apixaban, and edoxaban are highly protein-bound, and hemodialysis is likely to be ineffective.

A high mortality rate associated with ICH occurs regardless of the type of anticoagulant. Measures to reverse the anticoagulant effect of VKAs have been shown to improve INR values but not clinical outcomes. Agents to reverse the anticoagulant effect of DOACs are in development, but there is concern that after ICH has occurred, even timely reversal of the anticoagulant effect may not improve clinical outcomes.

MANAGEMENT OF CLINICALLY-RELEVANT NONMAJOR BLEEDING

VITAMIN K ANTAGONISTS. The use of reversal agents in patients with clinically-relevant nonmajor bleeding depends on the age of the patient, the amount of bleeding, whether bleeding is ongoing, the INR, the severity of anemia, and comorbid conditions of the patient. Oral vitamin K could be considered in this situation (14) but the risks of a prolonged period of time with subtherapeutic INR values must be weighed against the benefits. Determining and

treating the cause of bleeding is important, so that anticoagulation can be safely resumed.

DIRECT-ACTING ORAL ANTICOAGULANT AGENTS. Given the short half-life of DOACs, the potential thrombotic risk of nonspecific reversal agents, and the lack of evidence to support their use, reversal agents are not recommended for patients with clinically-relevant nonmajor bleeding (59).

MANAGEMENT OF MINOR BLEEDING OR ELEVATED INR VALUES

VITAMIN K ANTAGONISTS. In a patient with minor bleeding, decisions on warfarin dosing should be made dependent upon the INR.

If the INR is >10, management includes the following steps: 1) stop VKA therapy; 2) administer 2.5 to 5 mg of oral vitamin K (13); 3) monitor the INR every 12 to 14 h; and 4) restart VKA therapy as INR approaches therapeutic range.

If the patient is at high risk for bleeding on the basis of advanced age, recent bleeding, anemia, heart failure, malignancy, renal dysfunction, and other variables (60), oral vitamin K can be considered in the nonbleeding patient with an INR >10. In a non-bleeding patient with an INR >4.5 and <10, VKA should be held for 1 or 2 doses. Data on bleeding risk are conflicting in this situation (61,62). Vitamin K is generally not recommended unless there are patient-specific reasons that make bleeding more likely as previously outlined.

DIRECT-ACTING ORAL ANTICOAGULANTS. Given DOACs have short half-lives, and for patients with minor bleeding, omitting several doses of the anticoagulant may be the only therapy required beyond local measures (e.g., applying pressure). The duration of DOAC hiatus depends on the amount of bleeding and the thromboembolic risk.

MANAGEMENT AFTER BLEEDING

Patients recovering from major bleeding are frequently anemic, but are at risk for future bleeding (5). Resumption of anticoagulant therapy in such patients is problematic, and yet, these patients may also be at high risk of thromboembolic events (63). In 1 study of 442 patients with a gastrointestinal bleed associated with warfarin, 260 (58.8%) restarted warfarin, sometimes as early as 4 days later (64). Those patients who did not resume warfarin had a higher risk of death and thromboembolic events. Similar findings were noted in patients after warfarin-associated CNS bleeding. Of 284 patients, 91 (32%) were restarted on warfarin prior to hospital discharge.

Compared with those not started on warfarin, patients who were restarted on warfarin had lower mortality and had no increase in bleeding (65). After major bleeding, the location and severity of bleeding and whether the source of bleeding was effectively treated affects the decision of when and if anticoagulation should be restarted.

VKA-TREATED PATIENTS. If bleeding occurred in a VKA-treated patient with a high INR who is at high risk for stroke, a reasonable course of action after resolution of the bleeding episode might be to restart warfarin with careful follow-up of INR values. If a drug interaction with warfarin can be identified and avoided, VKAs can be restarted with more confidence. Alternatively, if the bleeding was not gastrointestinal or the TTR was low, it may be appropriate to substitute a DOAC for warfarin therapy. Recent guidelines suggest the use of antiplatelet agents in this situation, although at a Class IIb level of recommendation (66).

If bleeding occurs in a VKA-treated patient with an INR of 2 to 3, the clinician should avoid the temptation to lower the INR goal, due to increased risk of thromboembolic events with an INR <2 (67). In patients with bleeding and a normal INR, knowledge of the TTR (68) may be helpful.

DOAC-TREATED PATIENTS. Minor bleeding in a DOAC-treated patient presents a unique challenge. Reducing the dose of the DOAC also may reduce stroke prevention benefits. Changing to an alternative DOAC in cases of minor bleeding may be an option. If minor gastrointestinal bleeding occurs in a patient taking dabigatran or rivaroxaban, the patient should switch to apixaban or edoxaban 30 mg, because gastrointestinal bleeding is more common with dabigatran (33) and perhaps with rivaroxaban (34) than the other 2 agents. Other patients might benefit from a switch from a DOAC to a VKA.

No clinical trials currently address the question of administration of either warfarin or a DOAC following major bleeding. However, if a patient at high risk for stroke has a major bleeding episode associated with VKA and a normal INR, alternative therapies might be considered. Clinical trials of direct thrombin inhibitors and FXa inhibitors in stroke prevention in AF have consistently shown a >50% reduction in CNS bleeding with the newer agents compared with warfarin, although the mechanism is uncertain.

CONCOMITANT COMPLEX DISEASE STATES THAT OCCUR IN AF PATIENTS TAKING OACT

Patients with AF requiring OACT frequently have comorbid conditions that increase risks of bleeding,

affect the risk-benefit ratio of anticoagulation, or require additional therapy such as antiplatelet agents. The evolution of therapy in such patients is ongoing. This is especially true with the use of DOACs plus antiplatelet therapy (either single or dual).

Combining antiplatelet agents with anticoagulant agents increases the risk of bleeding. In the RE-LY (Randomized Evaluation Of Long-Term Anticoagulation Therapy) trial (20), the risk of major bleeding increased from 2.8% to 4.8%/year when antiplatelet agents were added to warfarin. The risk of major bleeding was 2.6%/year with dabigatran 150 mg twice daily (bid), but increased to 4.4%/year with the addition of antiplatelet agents. A similar analysis from the ARISTOTLE (Apixaban for Reduction of Stroke and Other Thromboembolic Events in Atrial Fibrillation) trial noted increased bleeding when aspirin was used in conjunction with either warfarin or apixaban, although the absolute bleeding risk was higher with the combination of aspirin and warfarin compared with aspirin and apixaban (69).

Two ongoing trials may inform the question. The RE-DUAL PCI (Randomized Evaluation of Dual Therapy with Dabigatran vs. Triple Therapy Strategy with Warfarin in patients with non-valvular AF that have undergone PCI with stents [NCT02164864]) will evaluate clinically-relevant bleeding and thromboembolic events in patients treated with dabigatran plus a P2Y₁₂ inhibitor compared with the current standard of warfarin plus dual antiplatelet therapy (DAPT). The PIONEER-AF PCI (Open-label, Randomized, Controlled, Multicenter Study Exploring Two Treatment Strategies of Rivaroxaban and a Dose-Adjusted Oral Vitamin K Antagonist Treatment Strategy in Subjects with Atrial Fibrillation Who Undergo Percutaneous Coronary Intervention [NCT01830543]) will compare clinically-significant bleeding in 3 arms of therapy: 1) rivaroxaban 15-mg daily plus a P2Y₁₂ inhibitor; 2) rivaroxaban 2.5-mg bid plus a P2Y₁₂ inhibitor and aspirin 75 to 100 mg daily; or 3) a VKA adjusted to an INR of 2 to 3, plus a P2Y₁₂ inhibitor and aspirin 75 to 100 mg daily.

RECENT CORONARY STENT AND NEW-ONSET AF

AF occurs in 5% to 10% of patients with MI and is associated with higher mortality compared with patients without AF (70). If stroke risk is low on the basis of CHA₂DS₂-VASc score, then such patients could be treated with DAPT without the addition of anticoagulation. Observational data from the Danish registry (18) suggest that anticoagulant agents plus clopidogrel appear to be safer than triple therapy,

although the efficacy of this combination has not been evaluated in randomized trials. Data from an open-label randomized trial in PCI patients (71) reported less bleeding and no increase in ischemic complications in patients treated with clopidogrel plus VKA compared with triple therapy. However, larger, blinded studies are needed to confirm these findings. In patients who require triple therapy, the use of bare-metal stents should be encouraged, and the duration of triple therapy should be kept as short as possible.

ELECTIVE STENTING IN PATIENTS WITH ESTABLISHED AF TAKING ANTICOAGULANT AGENTS

In patients with established AF taking warfarin who require elective stenting, concomitant glycoprotein IIb/IIIa inhibitors should generally be avoided. Radial access and bare-metal stenting are preferred, as the former reduces access site bleeding and the latter minimizes the duration of triple therapy. As the duration of DAPT shortens with newer-generation drug-eluting stents, this approach is changing and clinical trials are ongoing. Previously, such patients may have been transitioned to warfarin, but these studies may affect this approach. If triple therapy (including VKA) is used, low-dose aspirin plus clopidogrel is recommended in lieu of ticagrelor or prasugrel, because bleeding risks with VKA in conjunction with ticagrelor or prasugrel are higher than with clopidogrel. A lower-target INR for warfarin (2.0 to 2.5) should be considered (72). A recent European Consensus paper (73) suggests a 3-phase approach in patients with AF and elective stenting. Patients at high stroke and high bleeding risk (CHA₂DS₂-VASC ≥ 2 and HAS-BLED ≥ 3) should receive 4 weeks of triple therapy, up to 12 months of clopidogrel or aspirin plus an anticoagulant, and lifetime anticoagulation with or without an antiplatelet drug. Patients at lower stroke and bleeding risk (CHA₂DS₂-VASC of 1 and HAS-BLED 0 to 2) should receive 4 weeks to 6 months of triple therapy, up to 12 months of clopidogrel or aspirin plus an anticoagulant, and lifetime anticoagulation.

ACUTE CORONARY SYNDROMES IN PATIENTS WITH ESTABLISHED AF TAKING ANTICOAGULANT AGENTS

Low-dose rivaroxaban (2.5 mg bid) for acute coronary syndromes (ACS) is approved in Europe as adjunctive therapy. This dose may not be optimal for the prevention of stroke in patients with AF, and rivaroxaban is not approved for this indication in the United States. Temporary discontinuation of DOAC should

be considered in patients who are on DOACs at the time of an ACS, and if either ticagrelor or prasugrel is administered, because bleeding risks with these agents plus DOACs are unknown. Low-dose is preferable to full-dose aspirin. Bivalirudin may be a preferable acute anticoagulant, due to bleeding risk in the face of residual DOAC effect. Parenteral anticoagulation with heparin can be undertaken after DOAC effect has dissipated (16). Bare-metal stenting and a radial approach is preferable (59). Recent ACC/American Heart Association ACS guidelines state that anticoagulation may be interrupted at the time of procedure and that it “may be reasonable” to consider clopidogrel and anticoagulant agents in lieu of triple therapy (2). The European Consensus paper (74) suggested a similar 3-phase approach in ACS, in which the patients at highest risk of both stroke and bleeding receive 4 weeks of triple therapy followed by up to 12 months of a single antiplatelet drug plus anticoagulation, and patients at low risk receive 6 months of triple therapy followed by up to 12 months of a single antiplatelet drug plus anticoagulation.

PATIENTS WITH ESTABLISHED AF TAKING ANTICOAGULANT AGENTS WITH MEDICALLY-MANAGED CORONARY DISEASE

Although patients with medically-managed coronary artery disease following ACS may benefit from dual antiplatelet therapy (74), treatment must be individualized in patients who are concomitantly on anticoagulant agents. The WARIS II (Warfarin-Aspirin Reinfarction II) trial demonstrated a reduction in subsequent MI rates with warfarin and aspirin compared with warfarin alone (75), although it should be noted that this was not an AF trial. Data from the ACTIVE W (Atrial Fibrillation Clopidogrel Trial with Irbesartan for Prevention of Vascular Events) (76) also support the use of warfarin instead of antiplatelet therapy in stable CAD by showing that the MI rate in AF patients assigned to warfarin was similar to those assigned to aspirin plus clopidogrel. In patients with stable CAD with AF and an ACS >1 year previously, care should be individualized; single antiplatelet therapy or no antiplatelet therapy with anticoagulation may be preferred options (2).

PATIENTS WHO DEVELOP AF >1 MONTH AFTER BARE-METAL STENT OR >6 MONTHS AFTER DRUG-ELUTING STENT

Data are conflicting about whether patients with stable CAD should be treated with a DOAC or warfarin alone, assuming this is warranted on the basis of CHA₂DS₂-VASC score. In the RE-LY trial (31), there was

a trend toward increased MI, and meta-analysis suggested an association with direct thrombin inhibitors and MI (77). However, ischemic events were not increased in RE-LY (78), and a “real world” Danish study of dabigatran use did not suggest an increased frequency of MI (79). Similarly, a survey of 134,414 Medicare patients (37,587 patient-years) treated with dabigatran or warfarin for nonvalvular AF showed no increase in MI with dabigatran (80). **Figures 4A and 4B** summarize recommendations for OACT with various coronary artery disease conditions.

PATIENTS WITH CEREBRAL VASCULAR DISEASE AND ATRIAL AF PATIENTS NOT PREVIOUSLY TAKING ANTICOAGULANT AGENTS. Patients presenting with acute ischemic stroke or transient ischemic cerebral attack of presumed cardioembolic origin should receive anticoagulation therapy. The timing and initiation of therapy depends upon the size of the stroke and the perceived risk of hemorrhagic transformation (66). In such patients, all DOACs may be preferable to warfarin because of the universally reduced risk of ICH. Although this is true in the convalescent phase of presumed thromboembolic stroke (after >1 month), it has not been studied in the acute phase of such strokes. New American Heart Association/American Stroke Association guidelines recommend individualized therapy with VKA (Class I, Level of Evidence: A), apixaban (Class I, Level of Evidence: A), dabigatran (Class I, Level of Evidence: B), or rivaroxaban (Class IIa, Level of Evidence: B) (66). The European Society of Cardiology AF guidelines suggest the use of DOAC rather than VKA in most patients with nonvalvular AF on the basis of net clinical benefit (Class IIa recommendation) (81). Because of the rapid onset of action, bridging therapy with low-molecular-weight heparin is not required. For patients unable to take anticoagulant agents, aspirin is an alternative option, and the addition of clopidogrel might be reasonable. Two clinical trials of DOACs compared with aspirin in patients with embolic strokes of undetermined source (RE-SPECT ESUS [Dabigatran Etexilate for Secondary Stroke Prevention in Patients With Embolic Stroke of Undetermined Source] and NAVIGATE ESUS [Rivaroxaban Versus Aspirin in Secondary Prevention of Stroke and Prevention of Systemic Embolism in Patients With Recent Embolic Stroke of Undetermined Source]) are currently recruiting patients (82,83).

Previous studies have demonstrated a high prevalence of AF detected by prolonged monitoring in patients presenting with cryptogenic transient ischemic attack or stroke (66,84). Anticoagulation strategies in this subset of patients have not been rigorously tested for risk and benefit.

PATIENTS PREVIOUSLY MAINTAINED TAKING OACT PRESENTING WITH ACUTE ISCHEMIC STROKE

In patients previously maintained on DOACs, the balance of risks versus benefits of thrombolytic therapy for acute ischemic stroke is unclear. If there is uncertainty about the time since last administration of the DOAC or if blood studies (e.g., PTT for dabigatran or PT for FXa inhibitors) indicate residual drug effect, thrombolysis should generally not be offered. In patients treated with warfarin, the risk of ICH with use of recombinant tissue plasminogen activator appears to be low when the INR is ≤1.7 (85).

PATIENTS IN CONVALESCENT PHASE OF ISCHEMIC STROKE TREATED WITH VKAs

In theory, patients presenting with an ischemic stroke and a therapeutic INR represent a drug failure of VKA and may be candidates for DOACs. Patients with stroke ≥2 weeks prior to presentation appear to have the same relative benefits of DOAC versus warfarin (86,87). If early initiation of a DOAC is contemplated in a patient previously taking warfarin, it would seem prudent to allow the effect of warfarin to dissipate prior to initiating therapy.

PATIENTS WITH HEMORRHAGIC STROKE TAKING OACT

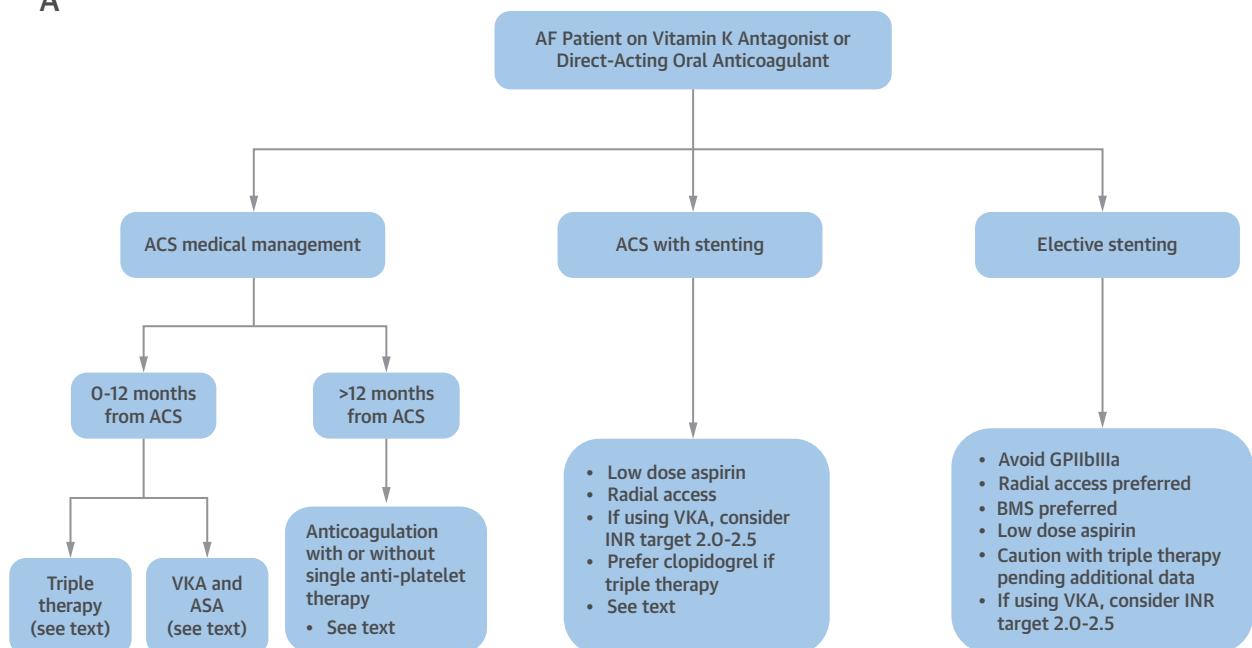
Hemorrhagic stroke is a complication of anticoagulant therapy. VKAs account for 12% to 14% of patients with ICH (88). Anticoagulant agents should be immediately discontinued, and efforts to reverse anticoagulation should be undertaken as previously described. Although patients who develop hemorrhagic stroke on warfarin could theoretically be candidates for a DOAC in the convalescent phase, this hypothesis is untested, as most DOAC studies exclude patients with prior ICH. Package labeling for both VKAs and DOACs state that ICH is a contraindication for anticoagulation unless the cause of the hemorrhage has been identified and corrected. According to the stroke guidelines, patients at high risk for recurrent hemorrhage may be considered candidates for antiplatelet therapy in lieu of anticoagulation. (Class IIb, Level of Evidence: B) (66).

PATIENTS WITH SIGNIFICANT CAROTID STENOSIS AND AF

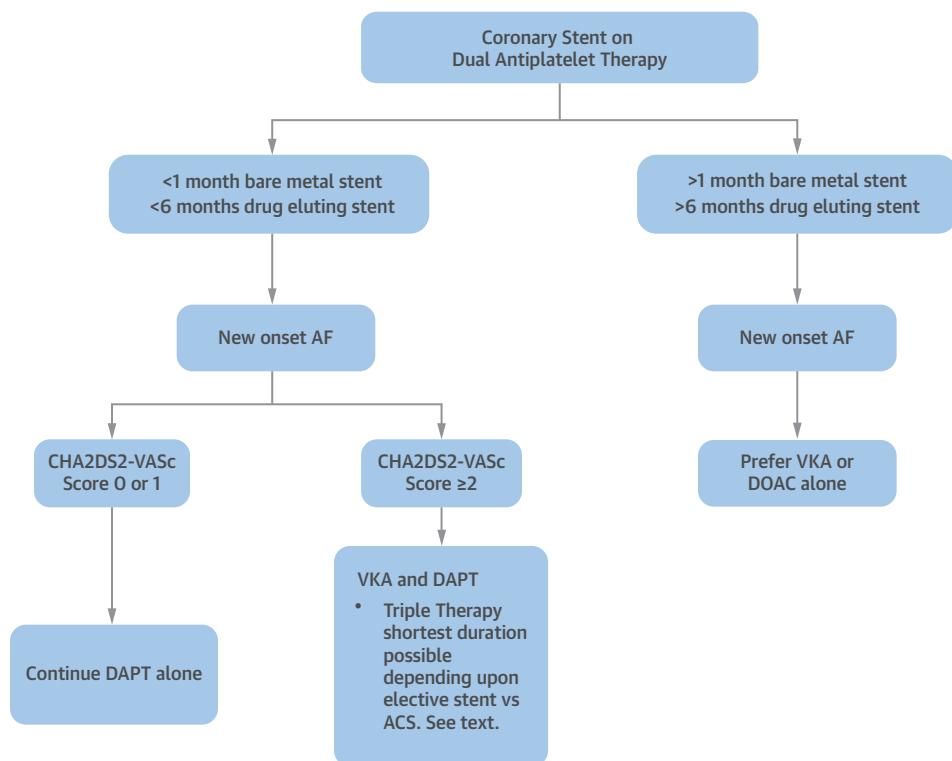
Patients with carotid stenosis are often prescribed antiplatelet therapy for stroke prevention. At this

FIGURE 4 Management of Patients with Both AF and Coronary Stents

A



B



(A) Patients taking anticoagulants for AF requiring coronary artery stenting. **(B)** Patients taking DAPT for coronary artery stent who develop AF. ACS = acute coronary syndrome(s); AF = atrial fibrillation; ASA = aspirin; BMS = bare-metal stent(s); DAPT = dual antiplatelet therapy; DOAC = direct-acting oral anticoagulant; INR = international normalized ratio; VKA = vitamin K antagonist.

time, it is unknown whether the addition of antiplatelet therapy improves outcomes compared with anticoagulation alone in patients with AF and carotid disease. Carotid endarterectomy for which single-agent antiplatelet therapy is usually prescribed may be preferred over carotid artery stenting that requires DAPT (59,89). More data are needed, and this topic is not addressed in the new stroke guidelines.

PATIENTS WITH PERIPHERAL ARTERY DISEASE AND AF

There are no data on the combination of DAPT and anticoagulation in patients with AF and peripheral artery disease managed with percutaneous intervention (89). Patients with medically-managed peripheral artery disease are generally prescribed antiplatelet therapy. The addition of anticoagulation increases bleeding risk, as demonstrated in the WAVE (Warfarin Antiplatelet Vascular Evaluation Trial) trial (88), in which patients with peripheral artery disease were assigned to warfarin plus an antiplatelet agent compared with an antiplatelet agent alone. Combined therapy was not associated with an improvement in the combined endpoints of either MI, stroke, or cardiovascular death; or MI, stroke, cardiovascular death, or severe ischemia (coronary or peripheral arterial). The risk of life-threatening bleeding, however, occurred in 4.0% of the combined group and 1.2% of the antiplatelet group. Therefore, the risk-benefit ratio needs to be estimated when deciding whether these patients should receive concomitant

antiplatelet therapy and anticoagulation. Single antiplatelet therapy makes good clinical sense under these circumstances, because the CHARISMA (Clopidogrel for High Atherothrombotic Risk and Ischemic Stabilization, Management, and Avoidance) trial (90) of aspirin alone compared with clopidogrel plus aspirin in patients at high risk for cardiovascular events demonstrated that the addition of clopidogrel did not reduce the rate of the primary endpoint of MI, stroke, or cardiovascular death, but that bleeding increased with DAPT.

THE USE OF DOACs IN PATIENTS WITH MECHANICAL HEART VALVES AND IN THE SETTING OF CARDIAC SURGERY

The RE-ALIGN (Randomized, Phase II Study to Evaluate the Safety and Pharmacokinetics of Oral Dabigatran Etexilate in Patients After Heart Valve Replacement) study (91) tested high-dose dabigatran as an alternative to warfarin in patients with mechanical heart valves. This study was stopped early due to excessive bleeding and higher thromboembolic events in patients treated with dabigatran. The rapid onset of action of dabigatran in the post-operative cardiac surgery setting appears to pose a risk of serious bleeding, particularly pericardial bleeding requiring reoperation. Until further results are available, the use of all DOACs should be avoided for patients with mechanical prosthetic valves outside of a clinical trial. The FDA's prescribing information for the DOACs are even more restrictive, stating that they should be avoided in all prosthetic valves, although DOACs were used in patients with bioprosthetic valves in several AF clinical trials. The data from RE-ALIGN with high-dose dabigatran raised concern for the use of these drugs in the immediate cardiac post-operative surgical setting (91).

DOACs AT THE TIME OF CARDIOVERSION

Patients who have AF or atrial flutter lasting >48 h are required to have therapeutic INR (2 to 3) for 3 to 4 weeks prior to cardioversion regardless of method (pharmacological or electrical) or CHA₂DS₂-VAsc score (2,92-94). Alternatively, for patients who have not been taking 3 to 4 weeks of continuous therapeutic VKAs, transesophageal echocardiography is reasonable prior to cardioversion (2,95). With VKAs, awaiting therapeutic INRs weekly up to the time of cardioversion has led to delays in cardioversion (96).

Three major randomized clinical trials have evaluated subsets of patients who underwent cardioversion (RE-LY, ROCKET AF [Rivaroxaban Once Daily Oral Direct Factor Xa Inhibition Compared with

FIGURE 5 Unanswered Questions

1. Methods to reduce variations in care and disparities in care.
2. Performance metrics that indicate best practice.
3. Tools for shared decision making.
4. Better information on interaction of DOACs with food/herbs, supplements and other non-prescription agents.
5. Protocols to manage the bleeding patient / reversal agents.
6. Evidence based strategies for management of patients with concomitant ACS and AF.
7. Evidence based strategies for management of patients undergoing procedures such as ablation or DC cardioversion.
8. More data in the frail and the elderly
9. Need to monitor drug concentrations or level of anticoagulation with a DOAC
10. Dose selection / adjustment of DOACs in high-risk subgroups
11. Assays allowing fast quantification of drug levels of the DOACs
12. Anticoagulation in patients with liver disease
13. More data on the relationship between laboratory measurement of the anticoagulant activity of DOACs and clinical outcomes

Vitamin K Antagonist for Prevention of Stroke and Embolism Trial in Atrial Fibrillation], and ARISTOTLE) (33-35). A prospective study involving the use of rivaroxaban has also been published (97). In all studies, the risk of stroke was low in the weeks following cardioversion and was comparable to that with VKA. Of note is the fact that transesophageal echocardiography did not reduce the rate of thromboembolic events (98).

On the basis of these data, for patients with AF or atrial flutter of unknown duration, or duration ≥ 48 h, anticoagulation with DOACs is required for ≥ 3 weeks prior to cardioversion and should be continued for ≥ 4 weeks post-cardioversion (2).

THE ROLE OF DOACs IN AF ABLATION

Current recommendations for the prevention of stroke at the time of AF ablation are for continuous VKA (warfarin) anticoagulation with a low-level therapeutic range (2.0 to 2.5). Because it is difficult to maintain an INR within this narrow range, DOACs may assume a more important role. Single-center and multicenter studies have examined the efficacy and safety of DOACs compared with uninterrupted warfarin in patients undergoing AF ablation (99-104). In general, centers and operators are either transitioning patients to warfarin for the periprocedural period or stopping the DOAC 1 to 2 days prior to procedure without bridging (105).

A prospective-matched, multicenter, observational study of 290 patients compared therapeutic warfarin (2 to 3.5) with dabigatran 150 mg bid for 3 weeks prior to ablation (with dabigatran held morning of procedure and resumed 3 h post-procedure). A significant increase in composite bleeding and thromboembolic complications was noted with dabigatran (100). Several studies in which dabigatran was held at least 24 h prior to procedure and restarted 4 to 22 h

later did not show any significant bleeding or thromboembolic complications compared with warfarin. These data suggest dabigatran should be interrupted ≥ 24 h prior to the procedure to prevent significant bleeding (101-103).

A multicenter, prospective study evaluated the safety and efficacy of rivaroxaban in comparison with uninterrupted warfarin therapy during AF ablation. Rivaroxaban was held 16 h prior to ablation and resumed 6 h after hemostasis was obtained. There was no difference in major or minor bleeding complications. One transient ischemic attack occurred in each group, and no periprocedural stroke or deaths occurred in either group. The authors concluded that rivaroxaban, with the dose held on the day of procedure, appears to be equally safe and effective when compared with uninterrupted warfarin (100).

CONCLUSIONS

Roundtable discussion of 4 major topics related to the integration of DOACs into clinical practice resulted in consensus in many areas, but questions and challenges in others. A poll of the participants was unanimous in the opinion that the stakeholder groups need to continue dialogue about the integration of these drugs into practice. Figure 5 includes a list of unanswered questions.

ACKNOWLEDGMENTS The authors wish to thank Lea Binder and Matthew Cirincione of the ACC for their expert assistance with the Anticoagulation Consortium and the development of this paper.

REPRINT REQUESTS AND CORRESPONDENCE: Dr. Richard J. Kovacs, Krannert Institute of Cardiology, Indiana University of Medicine, 1801 North Senate Boulevard, Suite E4000, Indianapolis, Indiana 46202. E-mail: rikovacs@iu.edu.

REFERENCES

1. Chan PS, Maddox TM, Tang F, Spinler S, Spertus JA. Practice-level variation in warfarin use among outpatients with atrial fibrillation (from the NCDR Pinnacle Program). *Am J Cardiol* 2011;108:1136-40.
2. January CT, Wann LS, Alpert JS, et al. 2014 AHA/ACC/HRS guideline for the management of patients with atrial fibrillation: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the Heart Rhythm Society. *J Am Coll Cardiol* 2014;64:2246-80.
3. Mason PK, Lake DE, Dimarco JP, et al. Impact of the CHA₂DS₂-VASc score on anticoagulation recommendations for atrial fibrillation. *Am J Med* 2012;125:603-6.
4. Pisters R, Lane DA, Nieuwlaat R, De Vos CB, Crijns HJ, Lip GY. A novel user-friendly score (HAS-BLED) to assess 1-year risk of major bleeding in patients with atrial fibrillation: the Euro Heart survey. *Chest* 2010;138:1093-100.
5. Fang MC, Go AA, Chang Y, et al. A new risk scheme to predict warfarin-associated hemorrhage: the ATRIA (Anticoagulation and Risk Factors in Atrial Fibrillation) study. *J Am Coll Cardiol* 2011;58:395-401.
6. American College of Cardiology. Anticoagulation app. December 13, 2014. Available at: <https://itunes.apple.com/us/app/anticoagevaluator/id609795286?mt=8>. Accessed February 9, 2015.
7. Loewen P. SPARC—Stroke Prevention In Atrial Fibrillation Risk Tool. January 7, 2015. Available at: www.sparctool.com. Accessed February 9, 2015.
8. Ruff CT, Giugliano RP, Braunwald E, et al. Comparison of the efficacy and safety of new oral anticoagulants with warfarin in patients with atrial fibrillation: a meta-analysis of randomised trials. *Lancet* 2014;383:955-62.
9. Wan Y, Heneghan C, Perera R, et al. Anticoagulation control and prediction of adverse events in patients with atrial fibrillation: a systematic review. *Circ Cardiovasc Qual Outcomes* 2008;1:84-91.

10. Gallagher AM, Setakis E, Plumb JM, Clemens A, Van Staa TP. Risks of stroke and mortality associated with suboptimal anticoagulation in atrial fibrillation patients. *Thromb Haemost* 2011;106:968-77.

11. Connolly SJ, Pogue J, Eikelboom J, et al. Benefit of oral anticoagulant over antiplatelet therapy in atrial fibrillation depends on the quality of international normalized ratio control achieved by centers and countries as measured by time in therapeutic range. *Circulation* 2008;118:2029-37.

12. Pirmohamed M, Burnside G, Eriksson N, et al. A randomized trial of genotype-guided dosing of warfarin. *N Engl J Med* 2013;369:2294-303.

13. Kimmel SE, French B, Kasner SE, et al. A pharmacogenetic versus a clinical algorithm for warfarin dosing. *N Engl J Med* 2013;369:2283-93.

14. Holbrook A, Schulman S, Witt DM, et al. Evidence-based management of anticoagulant therapy: antithrombotic therapy and prevention of thrombosis, 9th edition: American College of Chest Physicians evidence-based clinical practice guidelines. *Chest* 2012;141:E152s-84s.

15. Clot Connect. INR Self-Testing. July 1, 2013. Available at: http://files.www.clotconnect.org/INR_Self_Testing.pdf. Accessed February 9, 2015.

16. Heidbuchel H, Verhamme P, Alings M, et al. EHRA practical guide on the use of new oral anticoagulants in patients with non-valvular atrial fibrillation: executive summary. *Eur Heart J* 2013;34:2094-106.

17. Holbrook AM, Pereira JA, Labiris R, et al. Systematic overview of warfarin and its drug and food interactions. *Arch Intern Med* 2005;165:1095-106.

18. Lamberts M, Gislason GH, Olesen JB, et al. Oral anticoagulation and antiplatelets in atrial fibrillation patients after myocardial infarction and coronary intervention. *J Am Coll Cardiol* 2013;62:981-9.

19. Hansen ML, Sorensen R, Clausen MT, et al. Risk of bleeding with single, dual, or triple therapy with warfarin, aspirin, and clopidogrel in patients with atrial fibrillation. *Arch Intern Med* 2010;170:1433-41.

20. Dans AL, Connolly SJ, Wallentin L, et al. Concomitant use of antiplatelet therapy with dabigatran or warfarin in the randomized evaluation of long-term anticoagulation therapy (RE-LY) trial. *Circulation* 2013;127:634-40.

21. Alexander JH, Lopes RD, James S, et al. Apixaban with antiplatelet therapy after acute coronary syndrome. *N Engl J Med* 2011;365:699-708.

22. Wessler JD, Grip LT, Mendell J, Giugliano RP. The P-glycoprotein transport system and cardiovascular drugs. *J Am Coll Cardiol* 2013;61:2495-502.

23. Mendell J, Zahir H, Matsushima N, et al. Drug-drug interaction studies of cardiovascular drugs involving p-glycoprotein, an efflux transporter, on the pharmacokinetics of edoxaban, an oral factor Xa inhibitor. *Am J Cardiovasc Drugs* 2013;13:331-42.

24. Daiichi Sankyo. Savaysa (Edoxaban) package insert. 2015. Available at: www.accessdata.fda.gov/drugsatfda_docs/label/2015/206316lbl.pdf. Accessed March 1, 2015.

25. Siegal D, Yudin J, Kaatz S, Douketis JD, Lim W, Spyropoulos AC. Periprocedural heparin bridging in patients receiving vitamin K antagonists: systematic review and meta-analysis of bleeding and thromboembolic rates. *Circulation* 2012;126:1630-9.

26. Beyer-Westendorf J, Gelbricht V, Forster K, et al. Peri-interventional management of novel oral anticoagulants in daily care: results from the prospective Dresden NOAC Registry. *Eur Heart J* 2014;35:1888-96.

27. Ruff CT, Giugliano P, Braunwald E, et al. Transition of patients from blinded study drug to open-label anticoagulation: the ENGAGE AF-TIMI 48 trial. *J Am Coll Cardiol* 2014;64:576-84.

28. Nutescu EA, Wittkowsky AK, Burnett A, Merli GJ, Ansell JE, Garcia DA. Delivery of optimized inpatient anticoagulation therapy: consensus statement from The Anticoagulation Forum. *Ann Pharmacother* 2013;47:714-24.

29. Garcia DA, Witt DM, Hylek E, et al. Delivery of optimized anticoagulant therapy: consensus statement from The Anticoagulation Forum. *Ann Pharmacother* 2008;42:979-88.

30. Agency for Healthcare Research and Quality. 30 safe practices for better health care. Fact sheet. Available at: <https://innovations.ahrq.gov/qualitytools/30-safe-practices-better-health-care-fact-sheet>. Accessed February 9, 2015.

31. National Quality Forum. Safe practices for better healthcare-2010 update. 2010. Available at: http://www.qualityforum.org/publications/2010/04/safe_practices_for_better_healthcare_%e2%80%93_2010_update.aspx. Accessed February 9, 2015.

32. Nutescu EA. Anticoagulation management services: entering a new era. *Pharmacotherapy* 2010;30:327-9.

33. Connolly SJ, Ezekowitz MD, Yusuf S, et al. Dabigatran versus warfarin in patients with atrial fibrillation. *N Engl J Med* 2009;361:1139-51.

34. Patel MR, Mahaffey KW, Garg J, et al. Rivaroxaban versus warfarin in nonvalvular atrial fibrillation. *N Engl J Med* 2011;365:883-91.

35. Granger CB, Alexander JH, McMurray JJ, et al. Apixaban versus warfarin in patients with atrial fibrillation. *N Engl J Med* 2011;365:981-92.

36. Giugliano RP, Ruff CT, Braunwald E, et al. Edoxaban versus warfarin in patients with atrial fibrillation. *N Engl J Med* 2013;369:2093-104.

37. Majeed A, Hwang HG, Connolly SJ, et al. Management and outcomes of major bleeding during treatment with dabigatran or warfarin. *Circulation* 2013;128:2325-32.

38. Flaker GC, Eikelboom JW, Shestakova O, et al. Bleeding during treatment with aspirin versus apixaban in patients with atrial fibrillation unsuitable for warfarin: the apixaban versus acetylsalicylic acid to prevent stroke in atrial fibrillation patients who have failed or are unsuitable for vitamin K antagonist treatment (Averroes) trial. *Stroke* 2012;43:3291-7.

39. 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.

40. Schulman S, Angeras U, Bergqvist D, Eriksson B, Lassen MR, Fisher W. Definition of major bleeding in clinical investigations of antihemostatic medicinal products in surgical patients. *J Thromb Haemost* 2010;8:202-4.

41. Cuker A, Siegal DM, Crowther MA, Garcia DA. Laboratory measurement of the anticoagulant activity of the non-vitamin K oral anticoagulants. *J Am Coll Cardiol* 2014;64:1128-39.

42. Van Ryn J, Stangier J, Haertter S, et al. Dabigatran etexilate—a novel, reversible, oral direct thrombin inhibitor: interpretation of coagulation assays and reversal of anticoagulant activity. *Thromb Haemost* 2010;103:1116-27.

43. Schiele F, Van Ryn J, Canada K, et al. A specific antidote for dabigatran: functional and structural characterization. *Blood* 2013;121:3554-62.

44. Lubetsky A, Yonath H, Olchovsky D, Loebstein R, Halkin H, Ezra D. Comparison of oral vs intravenous phytonadione (vitamin K1) in patients with excessive anticoagulation: a prospective randomized controlled study. *Arch Intern Med* 2003;163:2469-73.

45. Eerenberg ES, Kamphuisen PW, Sijpkens MK, Meijers JC, Buller HR, Levi M. Reversal of rivaroxaban and dabigatran by prothrombin complex concentrate: a randomized, placebo-controlled, crossover study in healthy subjects. *Circulation* 2011;124:1573-9.

46. Marlu R, Hodaj E, Paris A, Albaladejo P, Cracowski JL, Pernod G. Effect of non-specific reversal agents on anticoagulant activity of dabigatran and rivaroxaban: a randomised crossover ex vivo study in healthy volunteers. *Thromb Haemost* 2012;108:217-24.

47. Levi M, Moore KT, Castillejos CF, et al. Comparison of three-factor and four-factor prothrombin complex concentrates regarding reversal of the anticoagulant effects of rivaroxaban in healthy volunteers. *J Thromb Haemost* 2014;12:1428-36.

48. Levi M, Levy JH, Andersen HF, Truloff D. Safety of recombinant activated factor VII in randomized clinical trials. *N Engl J Med* 2010;363:1791-800.

49. Baudo F, Collins P, Huth-Kuhne A, et al. Management of bleeding in acquired hemophilia A: results from the European Acquired Hemophilia (EACH2) Registry. *Blood* 2012;120:39-46.

50. Lin J, Hanigan WC, Tarantino M, Wang J. The use of recombinant activated factor VII to reverse warfarin-induced anticoagulation in patients with hemorrhages in the central nervous system: preliminary findings. *J Neurosurg* 2003;98:737-40.

51. Deveras RA, Kessler CM. Reversal of warfarin-induced excessive anticoagulation with recombinant human factor VIIa concentrate. *Ann Intern Med* 2002;137:884-8.

52. Nishijima DK, Dager WE, Schrot RJ, Holmes JF. The efficacy of factor VIIa in emergency department patients with warfarin use and traumatic intracranial hemorrhage. *Acad Emerg Med* 2010;17:244-51.

53. Skolnick BE, Mathews DR, Khutoryansky NM, Pusateri AE, Carr ME. Exploratory study on the reversal of warfarin with rFVIIa in healthy subjects. *Blood* 2010;116:693-701.

54. Ansell JE, Bakrhu SH, Laulicht BE, et al. Use of PER977 to reverse the anticoagulant effect of edoxaban. *N Engl J Med* 2014;371:2141-2.

55. Holland L, Warkentin TE, Refaai M, Crowther MA, Johnston MA, Sarode R. Suboptimal effect of a three-factor prothrombin complex concentrate (Profinine-SD) in correcting supratherapeutic international normalized ratio due to warfarin overdose. *Transfusion* 2009;49:1171-7.

56. Sarode R, Milling TJ Jr, Refaai MA, et al. Efficacy and safety of a 4-factor prothrombin complex concentrate in patients on vitamin K antagonists presenting with major bleeding: a randomized, plasma-controlled, phase IIb study. *Circulation* 2013;128:1234-43.

57. Toth P, Van Veen JJ, Robinson K, et al. Real world usage of PCC to "rapidly" correct warfarin induced coagulopathy. *Blood Transfus* 2013;11:500-5.

58. Wang X, Mondal S, Wang J, et al. Effect of activated charcoal on apixaban pharmacokinetics in healthy subjects. *Am J Cardiovasc Drugs* 2014; 14:147-54.

59. Heidbuchel H, Verhamme P, Alings M, et al. European Heart Rhythm Association practical guide on the use of new oral anticoagulants in patients with non-valvular atrial fibrillation. *Europace* 2013;15:625-51.

60. Hylek EM, Regan S, Go AS, Hughes RA, Singer DE, Skates SJ. Clinical predictors of prolonged delay in return of the international normalized ratio to within the therapeutic range after excessive anticoagulation with warfarin. *Ann Intern Med* 2001;135:393-400.

61. Hylek EM, Chang YC, Skates SJ, Hughes RA, Singer DE. Prospective study of the outcomes of ambulatory patients with excessive warfarin anticoagulation. *Arch Intern Med* 2000;160:1612-7.

62. Crowther MA, Ageno W, Garcia D, et al. Oral vitamin K versus placebo to correct excessive anticoagulation in patients receiving warfarin: a randomized trial. *Ann Intern Med* 2009;150:293-300.

63. Oldgren J, Alings M, Darius H, et al. Risks for stroke, bleeding, and death in patients with atrial fibrillation receiving dabigatran or warfarin in relation to the CHADS₂ score: a subgroup analysis of the RE-LY trial. *Ann Intern Med* 2011;155:660-7, W205.

64. Witt DM, Delate T, Garcia DA, et al. Risk of thromboembolism, recurrent hemorrhage, and death after warfarin therapy interruption for gastrointestinal tract bleeding. *Arch Intern Med* 2012;172:1484-91.

65. Yung D, Kapral MK, Aslani E, Fang J, Lee DS. Reinitiation of anticoagulation after warfarin-associated intracranial hemorrhage and mortality risk: the best practice for reinitiating anti-coagulation therapy after intracranial bleeding (brain) study. *Can J Cardiol* 2012;28:33-9.

66. Kernan WN, Ovbiagele B, Black HR, et al., on behalf of the American Heart Association Stroke Council, Council on Cardiovascular and Stroke Nursing, Council on Clinical Cardiology, and Council on Peripheral Vascular Disease. Guidelines for the prevention of stroke in patients with stroke and transient ischemic attack: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke* 2014;45:2160-236.

67. Hylek EM, Skates SJ, Sheehan MA, Singer DE. An analysis of the lowest effective intensity of prophylactic anticoagulation for patients with nonrheumatic atrial fibrillation. *N Engl J Med* 1996;335:540-6.

68. Rosendaal FR, Cannegieter SC, Van Der Meer FJ, Briet E. A method to determine the optimal intensity of oral anticoagulant therapy. *Thromb Haemost* 1993;69:236-9.

69. Alexander JH, Lopes RD, Thomas L, et al. Apixaban vs. warfarin with concomitant aspirin in patients with atrial fibrillation: insights from the ARISTOTLE trial. *Eur Heart J* 2014;35:224-32.

70. Lopes RD, Pieper KS, Horton JR, et al. Short- and long-term outcomes following atrial fibrillation in patients with acute coronary syndromes with or without ST-segment elevation. *Heart* 2008;94:867-73.

71. Dewilde WJ, Oirbans T, Verheugt FW, et al. Use of clopidogrel with or without aspirin in patients taking oral anticoagulant therapy and undergoing percutaneous coronary intervention: an open-label, randomised, controlled trial. *Lancet* 2013;381:1107-15.

72. Faxon DP, Eikelboom JW, Berger PB, et al. Antithrombotic therapy in patients with atrial fibrillation undergoing coronary stenting: a North American perspective: executive summary. *Circ Cardiovasc Interv* 2011;4:522-34.

73. Lip GY, Windecker S, Huber K, et al. Management of antithrombotic therapy in atrial fibrillation patients presenting with acute coronary syndrome and/or undergoing percutaneous coronary or valve interventions: a joint consensus document of the European Society of Cardiology Working Group on Thrombosis, European Heart Rhythm Association (EHRA), European Association of Percutaneous Cardiovascular Interventions (EAPCI) and European Association of Acute Cardiac Care (ACCA) endorsed by the Heart Rhythm Society (HRS) and Asia-Pacific Heart Rhythm Society (APHRS). *Eur Heart J* 2014;35:3155-79.

74. Yusuf S, Zhao F, Mehta SR, Chrolavicius S, Tognoni G, Fox KK. Effects of clopidogrel in addition to aspirin in patients with acute coronary syndromes without ST-segment elevation. *N Engl J Med* 2001;345:494-502.

75. Hurlen M, Abdelnoor M, Smith P, Eriksson J, Arnesen H. Warfarin, aspirin, or both after myocardial infarction. *N Engl J Med* 2002;347:969-74.

76. Connolly SJ, Pogue J, Hart R, et al. Clopidogrel plus aspirin versus oral anticoagulation for atrial fibrillation in the Atrial Fibrillation Clopidogrel Trial with Irbesartan for Prevention of Vascular Events (ACTIVE W): a randomised controlled trial. *Lancet* 2006;367:1903-12.

77. Artang R, Rome E, Nielsen JD, Vidaillet HJ. Meta-analysis of randomized controlled trials on risk of myocardial infarction from the use of oral direct thrombin inhibitors. *Am J Cardiol* 2013;112:1973-9.

78. Hohnloser SH, Oldgren J, Yang S, et al. Myocardial ischemic events in patients with atrial fibrillation treated with dabigatran or warfarin in the RE-LY (Randomized Evaluation Of Long-Term Anticoagulation Therapy) trial. *Circulation* 2012; 125:669-76.

79. Larsen TB, Rasmussen LH, Skjøth F, et al. Efficacy and safety of dabigatran etexilate and warfarin in "real-world" patients with atrial fibrillation: a prospective nationwide cohort study. *J Am Coll Cardiol* 2013;61:2264-73.

80. Graham DJ, Reichman ME, Werneck M, et al. Cardiovascular, bleeding, and mortality risks in elderly Medicare patients treated with dabigatran or warfarin for non-valvular atrial fibrillation. *Circulation* 2015;131:157-64.

81. Camm AJ, Lip GY, De Caterina R, et al. 2012 focused update of the ESC guidelines for the management of atrial fibrillation: an update of the 2010 ESC Guidelines for the Management of Atrial Fibrillation. Developed with the special contribution of the European Heart Rhythm Association. *Eur Heart J* 2012;33:2719-47.

82. ClinicalTrials.gov. Dabigatran etexilate for secondary stroke prevention in patients with embolic stroke of undetermined source (RE-SPECT ESUS). Available at: <https://clinicaltrials.gov/ct2/show/NCT02239120>. Accessed February 9, 2015.

83. ClinicalTrials.gov. Rivaroxaban versus aspirin in secondary prevention of stroke and prevention of systemic embolism in patients with recent embolic stroke of undetermined source (ESUS) (NAVIGATE ESUS). Available at: <https://clinicaltrials.gov/ct2/show/NCT02313909>. Accessed February 9, 2015.

84. Tayal AH, Tian M, Kelly KM, et al. Atrial fibrillation detected by mobile cardiac outpatient telemetry in cryptogenic TIA or stroke. *Neurology* 2008;71:1696-701.

85. Xian Y, Liang L, Smith EE, et al. Risks of intracranial hemorrhage among patients with acute ischemic stroke receiving warfarin and treated with intravenous tissue plasminogen activator. *JAMA* 2012;307:2600-8.

86. Easton JD, Lopes RD, Bahit MC, et al. Apixaban compared with warfarin in patients with atrial fibrillation and previous stroke or transient ischaemic attack: a subgroup analysis of the ARISTOTLE trial. *Lancet Neurol* 2012;11:503-11.

87. Diener HC, Connolly SJ, Ezekowitz MD, et al. Dabigatran compared with warfarin in patients with atrial fibrillation and previous transient ischaemic attack or stroke: a subgroup analysis of the RE-LY trial. *Lancet Neurol* 2010;9:1157-63.

88. Radberg JA, Olsson JE, Radberg CT. Prognostic parameters in spontaneous intracerebral hematomas with special reference to anticoagulant treatment. *Stroke* 1991;22:571-6.

89. Hanna EB. Dual antiplatelet therapy in peripheral arterial disease and after peripheral percutaneous revascularization. *J Invasive Cardiol* 2012;24:679-84.

90. Bhatt DL, Fox KA, Hacke W, et al. Clopidogrel and aspirin versus aspirin alone for the prevention

of atherothrombotic events. *N Engl J Med* 2006; 354:1706–17.

91. Eikelboom JW, Connolly SJ, Brueckmann M, et al. Dabigatran versus warfarin in patients with mechanical heart valves. *N Engl J Med* 2013;369: 1206–14.

92. Moreyra E, Finkelhor RS, Cebul RD. Limitations of transesophageal echocardiography in the risk assessment of patients before nonanticoagulated cardioversion from atrial fibrillation and flutter: an analysis of pooled trials. *Am Heart J* 1995;129: 71–5.

93. Gallagher MM, Hennessy BJ, Edvardsson N, et al. Embolic complications of direct current cardioversion of atrial arrhythmias: association with low intensity of anticoagulation at the time of cardioversion. *J Am Coll Cardiol* 2002;40:926–33.

94. Jaber WA, Prior DL, Thamilarasan M, et al. Efficacy of anticoagulation in resolving left atrial and left atrial appendage thrombi: a transesophageal echocardiographic study. *Am Heart J* 2000;140:150–6.

95. Klein AL, Grimm RA, Murray RD, et al. Use of transesophageal echocardiography to guide cardioversion in patients with atrial fibrillation. *N Engl J Med* 2001;344:1411–20.

96. Kim MH, Krishnan K, Jain S, Decena BF. Time course and frequency of subtherapeutic anticoagulation for newly prescribed warfarin anticoagulation before elective cardioversion of atrial fibrillation or flutter. *Am J Cardiol* 2001;88: 1428–31. A8.

97. Cappato R, Ezekowitz MD, Klein AL, et al. Rivaroxaban vs. vitamin K antagonists for cardioversion in atrial fibrillation. *Eur Heart J* 2014;35: 3346–55.

98. Nagarakanti R, Ezekowitz MD, Oldgren J, et al. Dabigatran versus warfarin in patients with atrial fibrillation: an analysis of patients undergoing cardioversion. *Circulation* 2011;123:131–6.

99. Piccini JP, Stevens SR, Lohknygina Y, et al. Outcomes after cardioversion and atrial fibrillation ablation in patients treated with rivaroxaban and warfarin in the ROCKET AF trial. *J Am Coll Cardiol* 2013;61:1998–2006.

100. Lakkireddy D, Reddy YM, Di Biase L, et al. Feasibility and safety of dabigatran versus warfarin for periprocedural anticoagulation in patients undergoing radiofrequency ablation for atrial fibrillation: results from a multicenter prospective registry. *J Am Coll Cardiol* 2012;59:1168–74.

101. Winkle RA, Mead RH, Engel G, Kong MH, Patrawala RA. The use of dabigatran immediately after atrial fibrillation ablation. *J Cardiovasc Electrophysiol* 2012;23:264–8.

102. Kim JS, She F, Jongnarangsin K, et al. Dabigatran vs warfarin for radiofrequency catheter ablation of atrial fibrillation. *Heart Rhythm* 2013;10:483–9.

103. Bassiouny M, Saliba W, Rickard J, et al. Use of dabigatran for periprocedural anticoagulation in patients undergoing catheter ablation for atrial fibrillation. *Circ Arrhythm Electrophysiol* 2013;6: 460–6.

104. Eitel C, Koch J, Sommer P, et al. Novel oral anticoagulants in a real-world cohort of patients undergoing catheter ablation of atrial fibrillation. *Europace* 2013;15:1587–93.

105. Calkins H, Kuck KH, Cappato R, et al. 2012 HRS/EHRA/ECAS expert consensus statement on catheter and surgical ablation of atrial fibrillation: recommendations for patient selection, procedural techniques, patient management and follow-up, definitions, endpoints, and research trial design: a report of the Heart Rhythm Society (HRS) Task Force on Catheter and Surgical Ablation of Atrial Fibrillation. *Heart Rhythm* 2012;9:632–96.

106. Lip GY, Nieuwlaat R, Pisters R, Lane DA, Crijns HJ. Refining clinical risk stratification for predicting stroke and thromboembolism in atrial fibrillation using a novel risk factor-based approach: the Euro Heart Survey on Atrial Fibrillation. *Chest* 2010;137:263–72.

107. Boehringer Ingelheim. Pradaxa (dabigatran etexilate) package insert. Available at: http://bidocs.boehringer-ingelheim.com/BIWebAccess/ViewServlet.ser?docBase=renetnt&folderPath=/Prescribing_Information/Pls/Pradaxa/Pradaxa.pdf. Accessed February 9, 2015.

108. Bayer Healthcare. Xarelto (rivaroxaban) package insert. Available at: http://www.xareltohcp.com/sites/default/files/pdf/xarelto_0.pdf. Accessed February 9, 2015.

109. Bristol-Myers Squibb. Eliquis (apixaban) package insert. Available at: http://packageinserts.bms.com/pi/pi_eliquis.pdf. Accessed February 9, 2015.

KEY WORDS anticoagulation, atrial fibrillation, stroke

APPENDIX For a list of Anticoagulation Consortium roundtable participants, please see the online version of this article.