Harmonized outcome measures for use in atrial fibrillation patient registries and clinical practice

Endorsed by the Heart Rhythm Society Board of Trustees

Hugh Calkins, MD, FHRS,* Richard E. Gliklich, MD,†‡‡ Michelle B. Leavy, MPH,† Jonathan P. Piccini, MD, MHS, FHRS,‡ Jonathan C. Hsu, MD, MAS, FHRS,§ Sanghamitra Mohanty, MD, MS, FHRS,¶ William Lewis, MD, FHRS,‖ Saman Nazarian, MD, PhD, FHRS,** Mintu P. Turakhia, MD, MAS, FACC, FAHA, FHRS††

*From the *Cardiology Division, Johns Hopkins University, Baltimore, Maryland, †OM1, Inc., Boston, Massachusetts, ‡Duke University Medical Center and Duke Clinical Research Institute, Durham, North Carolina, §Sulpizio Cardiovascular Center, University of California San Diego, La Jolla, California, ¶Texas Cardiac Arrhythmia Institute, St. David's Medical Center, Austin, Texas, ‖MetroHealth System, Case Western Reserve University, Cleveland, Ohio, **The University of Pennsylvania Perelman School of Medicine, Philadelphia, Pennsylvania, ††VA Palo Alto Health Care System and Stanford University, Stanford, California, and ‡‡Harvard Medical School, Boston, Massachusetts.*

BACKGROUND Atrial fibrillation (AF) affects an estimated 33 million people worldwide, leading to increased mortality and an increased risk of heart failure and stroke. Many AF patient registries exist, but the ability to link and compare data across registries is hindered by differences in the outcome measures collected by each registry and a lack of harmonization.

OBJECTIVES The purpose of this project was to develop a minimum set of standardized outcome measures that could be collected in AF patient registries and clinical practice.

METHODS AF patient registries were identified through multiple sources and invited to join the workgroup and submit outcome measures. Additional measures were identified through literature searches and reviews of consensus statements. Outcome measures were categorized using the Agency for Healthcare Research and Quality's supported Outcome Measures Framework (OMF). A minimum set of broadly relevant measures was identified. Measure definitions were harmonized through in-person and virtual meetings.

RESULTS One hundred twelve outcome measures, including those from thirteen registries, were curated according to the OMF and then harmonized into a minimum set of measures in the OMF categories of survival (3 measures), clinical response (3 measures), events of interest (9 measures), patient-reported outcomes (2 measures), and resource utilization (3 measures). The harmonized definitions build on existing consensus statements.

CONCLUSIONS The harmonized measures represent a minimum set of outcomes that are relevant in AF research and clinical practice. Routine and consistent collection of these measures in registries and in other systems would support creation of a research infrastructure to efficiently address new questions and improve patient outcomes.

TABLE OF CONTENTS

KEYWORDS Atrial fibrillation; Common data element; Data standard; Harmonization; Outcome measure; Patient outcome; Patient registry (Heart Rhythm 2019;16:e3–e16)

This project was funded under Contract HHSA290201400004C from the Agency for Healthcare Research and Quality (AHRQ), U.S. Department of Health and Human Services (HHS). The authors of this manuscript are responsible for its content. Statements in the manuscript do not necessarily represent the official views of or imply endorsement by AHRQ or HHS. This work was supported by the Office of the Secretary Patient-Centered Outcomes Research Trust Fund under Interagency Agreement #16-566R-16. **Address reprint requests and correspondence:** Dr Richard E. Gliklich, OM1, Inc., 800 Boylston Street, Suite 1410, Boston, MA 02199. E-mail address: rgliklich@om1.com.

https://doi.org/10.1016/j.hrthm.2018.09.021

Introduction

Atrial fibrillation (AF) is a common arrhythmia that affects an estimated 33 million people worldwide.[1] Risk factors for AF include age, hypertension, obesity, obstructive sleep apnea, thyroid disease, and alcohol consumption[2] and, due to the aging population, it is estimated that more than 8 million people in the United States will have AF by 2050.[3] AF increases the risk of stroke, heart failure, and sudden death[4] and has been linked to the development of dementia.[5] In the United States, AF results in over 450,000 hospitalizations per year, and individuals with AF incur approximately $8,705 in additional medical costs per year, compared to individuals without AF.[6]

Multiple treatments are used in AF depending on the type of AF, treatment goals, and patient preferences. Treatment goals include reducing the risk of stroke, heart rate control, restoring normal sinus rhythm, and improvement in quality of life. Anticoagulants (warfarin, non-vitamin K antagonist oral anticoagulants) are used to reduce the risk of stroke. Beta blockers, calcium channel blockers, and digoxin are used for heart rate control. Antiarrhythmic drug therapy, cardioversion, catheter ablation, and some surgical procedures are performed to restore and maintain normal sinus rhythm.

Advances have been made in AF diagnosis and treatment in the past decade. Cardiac implantable electronic devices (CIEDs) with AF detection algorithms have been used to improve diagnosis of asymptomatic AF. Newer direct acting oral anticoagulants (dabigatran, rivaroxaban, apixaban, edoxaban) have been introduced in clinical practice as well as non-pharmacologic methods of stroke prevention, including percutaneous left atrial appendage closure. Moreover, effectiveness and subsequent utilization of catheter ablation to restore sinus rhythm have increased in both paroxysmal and persistent forms of AF. Questions remain, however, about when and how to screen for asymptomatic AF, the comparative effectiveness of different treatment approaches for reducing long-term mortality and morbidity associated with AF, and the patient populations most likely to benefit from different approaches.[2] In addition, the potential role of consumer devices that monitor heart rate is still to be defined.[7]

Observational studies, such as patient registries, are well suited to address some of these questions because of their ability to enroll large numbers of patients and follow them over several years to assess long-term outcomes. A patient registry is defined as "an organized system that uses observational study methods to collect uniform data (clinical and other) to evaluate specified outcomes for a population defined by a particular disease, condition, or exposure and that serves one or more pre-determined scientific, clinical, or policy purposes."[8]

Many patient registries exist in AF to support quality improvement, address specific research questions, and fulfill regulatory commitments. Observational data, particularly in large registries, can provide important data on practice patterns, appropriate utilization, and safety outcomes, and hypothesis generating data via comparative effectiveness to help inform future randomized trials. Linkage of data across these registries would offer the opportunity to address new research questions efficiently, drawing on large populations of patients receiving different treatments; for example, the three largest registry programs (ORBIT-AF I[9] and II,[10] GARFIELD-AF,[11] GLORIA-AF[12]) examining anticoagulation in AF patients have collected long-term data on over 87,000 patients. However, because AF registries are designed to address different areas of practice and disease management, they often focus on different outcome measures. Even when the same outcome is studied (e.g., bleeding), registries often use different definitions of the measure, reflecting the lack of harmonization of outcome measure definitions across professional societies and research funding agencies. These variations make linkages and comparisons of data across registries challenging, thus reducing the utility of AF registries for addressing new research questions.

To address these issues, the U.S. Department of Health & Human Services, led by the Agency for Healthcare Research and Quality (AHRQ) and in collaboration with the Food & Drug Administration (FDA) and the National Library of Medicine, has supported the development of the Outcome Measures Framework (OMF). The OMF is a conceptual model for classifying outcomes that are relevant to patients and providers across most conditions.[13] The OMF is designed to serve as a content model for developing harmonized outcome measures in specific disease areas; the framework was developed with input from over 400 stakeholders and refined through analyses of outcome measures used in existing registries.

The goal of this project was to develop a minimum set of standardized outcome measures for use in AF patient registries and clinical practice. The objectives were to 1) test the utility of the OMF for categorizing AF outcomes and for supporting harmonization of outcomes across treatment pathways; 2) identify a minimum set of outcome measures that could be captured in AF patient registries and clinical practice; 3) agree on harmonized definitions for each outcome in the minimum measure set; and 4) map the harmonized definitions to standardized terminologies to support consistent implementation and collection of the outcome measures within electronic health records (EHRs).

Methods

This harmonization effort focused on outcome measures that are currently collected in registries and clinical practice. Existing AF registries were identified through a multi-step process including searches of the Registry of Patient Registries (RoPR),[14] ClinicalTrials.gov,[15] and HSRProj; review of the Centers for Medicare and Medicaid Services' list of Qualified Clinical Data Registries, FDA Post-Marketing Commitment lists, projects funded by the Patient-Centered Outcomes Research Institute (PCORI); and a systematic search of the published medical literature using PubMed and Google Scholar and the "gray literature" including conference abstracts.

Identified registries meeting definitional criteria for a patient outcomes-focused registry[8] and collecting data in the United States were invited to participate as voluntary members of the registry workgroup. In addition, a stakeholder group, including clinicians, researchers, and representatives from specialty associations, health systems, regulatory agencies, funding agencies, payers, patient advocacy organizations, measure developers, and measure endorsement organizations, was formed.

Outcome measure specifications were obtained from the participating registries, the sources described above, and additional resources including the COMET (Core Outcome Measures in Effectiveness Trials) Initiative database[16] and the National Quality Forum database.[17] The workgroup met virtually and in-person to categorize and harmonize the measures and to define a minimum measure set. The minimum measure set is intended for use as a core set of outcomes that will be collected in all future AF registries and would also be suitable for use in clinical practice; some studies may collect additional outcomes using other definitions to meet specific purposes. All outcome measures were categorized using the OMF categories of survival, clinical response, events of interest, patient-reported, and resource utilization. Within each category, measures representing similar concepts were identified, and detailed comparisons highlighting differences in definitions were prepared. The registry workgroup discussed the clinical significance of the differences, reasons for the differences, and possible approaches to harmonization (e.g., recommending use of an existing definition, modifying an existing definition to incorporate concepts from other definitions).

The combined workgroup and stakeholder group met to reach consensus on the minimum measure sets. Clinical informaticists then mapped the narrative definitions produced by the workgroup to standardized terminologies (primarily ICD-10 and SNOMED) to produce a library of common data definitions suitable for implementation within EHRs. For each measure, the recommended reporting period, initial population for measurement, outcome-focused population, and data criteria and value sets were defined. Where possible, existing common data elements and value sets were used. The narrative definitions and standardized definitions were posted for public comment. Following modifications based on public comments, the measure set was finalized.

Results

Twenty registries were identified, and 12 registry sponsors agreed to participate, representing 13 registries. Participating registries (Table 1) represented multiple purposes, patient populations, and treatment pathways. Of the eight registries that declined to participate, seven enrolled less than 550 patients, and enrollment was complete in six of these registries. One registry enrolled over 1,000 patients, and enrollment is ongoing; this registry and linked biorepository focus on identifying clinical, genetic, and serological predictors of response to AF ablation. Appendix A1 describes registries that declined to participate. Three professional associations (American Heart Association, American College of Cardiology, Heart Rhythm Society) participated in the registry workgroup. Six stakeholders participated, representing StopAFib.org (a patient advocacy organization), the National Library of Medicine, the FDA, the National Quality Forum, and two health systems (Lahey Clinic and Veterans Health Administration).

One hundred twelve outcome measures were identified from registries and other sources and curated according to the OMF. Of these, 81 (72%) were categorized as events of interest, such as bleeding, stroke, and myocardial infarction. The remaining measures were categorized as survival (10%), resource utilization (9%), patient reported (5%), and clinical response (4%). The project team identified seven consensus statements with relevant outcome measure definitions for AF.[2,18–23]

Twenty measures are included in the minimum measure set. Measure definitions and sources are listed in Table 2; the rationale for selection of the measures and definitions is described below. It is important to note that these measures are intended to track patient outcomes over time to support patient management, inform clinical decision-making, and facilitate clinical research. While it is possible that these measures could be adapted for use in quality measurement programs, the measures presented here are not intended for use as measures of quality.

Survival

Three survival measures are included in the minimum set: all-cause mortality, cardiovascular death, and procedure-related death. The minimum measure set is intended to be feasible to collect in all registries, so burden of collection and reporting are important considerations. Several definitions of cardiovascular death were reviewed; the primary difference among definitions was the inclusion of procedure-related deaths. The workgroup recommended reporting procedure-related deaths, defined as all-cause mortality within 30 days of the procedure or during the index procedure hospitalization, separately and recommended use of a standard definition of cardiovascular death developed by the American Heart Association and American College of Cardiology.[18]

Clinical Response

Three clinical response measures are included in the minimum set and are divided into “Treatment Response” and ”Overall Management Response” to reflect the different intents of AF treatment. AF, atrial flutter (AFL), or atrial tachycardia (AT) recurrence and AF progression (paroxysmal to persistent AF) are recommended to capture treatment response for treatments such as catheter ablation, surgical ablation, or antiarrhythmic drug therapy, where the intent is to restore and maintain sinus rhythm. Thromboembolic events, defined as stroke, transient ischemic attack, and systemic embolism, should be measured to assess clinical response with respect to AF management; these outcomes are defined below.

Table 1 Participating registries

Registry name	Sponsoring organization	Primary purpose
A Novel Healthcare Information Technology Tool to Improve Care in Patients With Atrial Fibrillation (AFCare)	Biosense Webster, Inc.	Examine differences in detection of cardiac rhythm disturbances including AF with utilization of screening in the emergency room, and how often treatment plans change in patients who have a heart rhythm abnormality detected
Does Atrial Fibrillation (AF) Termination Without Additional Ablation Influence Outcome? (TARGET)	Texas Cardiac Arrhythmia Institute	Investigate if termination of AF after pulmonary vein antrum isolation without additional ablation of non-PV triggers, in long-standing persistent AF, is enough to ensure long-term success
Get With The Guidelines—Afib	American Heart Association	Support hospital care teams in consistently providing the latest evidence-based treatment for their AF patients, while monitoring the quality of AF care in U.S. hospitals and building a database for continued research and further quality improvement
Global Anticoagulant Registry in the Field (GARFIELD-AF)	Thrombosis Research Institute	Characterize real-life anticoagulant treatment patterns and outcomes, including rates of stroke and bleeding complications, as well as provide data on physicians' compliance with guidelines and patients' adherence to therapy
Global Registry on Long-Term Oral Antithrombotic Treatment In Patients With Atrial Fibrillation (GLORIA-AF)	Boehringer Ingelheim	Characterize the newly diagnosed non-valvular AF patient population at risk for stroke and the selection of antithrombotic treatment for stroke prevention in a real-world setting
LAAO Registry	American College of Cardiology	Captures data on left atrial appendage occlusion (LAAO) procedures to assess real-world procedural outcomes, short and long-term safety, comparative effectiveness and cost effectiveness
Outcomes Registry for Better Informed Treatment of Atrial Fibrillation Program (ORBIT-AF I and II)	Janssen	Evaluate the utilization of target-specific antithrombotic agents, such as FXa (factor Xa) inhibitors and direct thrombin inhibitors, and associated outcomes
PaTH Clinical Data Research Network (CDRN) Atrial Fibrillation (AF) Clinician-Patient Partnership Cohort	Patient-Centered Outcomes Research Institute (PCORI)	Create a network of electronic health records and patient reported outcomes to allow for the conduct of patient-centered observational studies on AF across the multiple institutions
PINNACLE Registry	American College of Cardiology	Support quality improvement in outpatient setting in coronary artery disease, hypertension, heart failure and atrial fibrillation
Postmarket Evaluation of the Phased Radio Frequency Ablation System (GOLD AF Registry)	Medtronic	Document use of Phased Radio Frequency Ablation System in a real-world patient population with atrial fibrillation and evaluate its performance
Registry on WATCHMAN Outcomes in Real-Life Utilization (EWOLUTION)	Boston Scientific Corporation	Compile real-world clinical outcomes data for WATCHMAN LAA (left atrial appendage) Close Technology in patients who are implanted with the WATCHMAN device in a commercial clinical setting
Retrospective Evaluation and Assessment of Therapies in AF (TREAT-AF)	American Heart Association, Veterans Health Administration	Retrospective cohort study of patients with new-onset AF treated in the Veterans Administration health care system
Reveal LINQ Registry	Medtronic	Characterize clinical actions initiated by Reveal LINQ arrhythmia detection and estimate procedure-related acute infection rate

Table 2 Atrial fibrillation minimum measure set and harmonized definitions

OMF category	Outcome measure	Definition	References
Survival	All-cause mortality	All-cause mortality	Workgroup recommendation
	Cardiovascular death	Cardiovascular death indicates cause of death was sudden cardiac death, myocardial infarction (MI), unstable angina, or other coronary artery disease; vascular death (e.g., stroke, arterial embolism, pulmonary embolism, ruptured aortic aneurysm, or dissection); congestive heart failure; or cardiac arrhythmia.	2004 ACC/AHA Key Data Elements[18]
	Procedure-related death	All-cause mortality within 30 days of the procedure or during the index procedure hospitalization (if the postoperative length of stay is >30 days). Procedure-related deaths include those related to a complication of the procedure or treatment for a complication of the procedure.	VARC Statement[22]
Clinical Response	AF/AFL/AT Recurrence	Recurrent AF/AFL/AT is defined as AF/AFL/AT of at least 30 seconds' duration that is documented by an ECG or device recording system and occurs following catheter ablation or drug therapy. In the setting of catheter ablation, recurrent AF/AFL/AT may occur within or following the post ablation 3-month blanking period. Recurrent AF/AFL/AT that occurs within the post ablation blanking period is not considered a failure of AF ablation.	2017 HRS Consensus Statement[2]
	AF progression (paroxysmal to persistent AF)	AF should be classified as paroxysmal or persistent in accordance with the 2014 AHA/ACC/HRS joint committee guidelines on the management of patients with AF: ■ Paroxysmal AF: AF that terminates spontaneously or with intervention within 7 days of onset. Episodes may recur with variable frequency. ■ Persistent AF: Continuous AF that is sustained >7 days. Progression occurs when patients previously classified as paroxysmal AF are classified as persistent AF.	Modified from 2014 AHA/ACC/HRS joint committee guidelines on the management of patients with AF[24] Definition of progression is adapted from Padfield et al[25]
	Thromboembolic events (with respect to persistent AF management)	■ Stroke: An acute episode of focal or global neurological dysfunction caused by brain, spinal cord, or retinal vascular injury as a result of hemorrhage or infarction. Symptoms or signs must persist ≥24 hours, or if documented by CT, MRI or autopsy, the duration of symptoms/signs may be less than 24 hours. Stroke may be classified as ischemic (including hemorrhagic transformation of ischemic stroke), hemorrhagic, or undetermined. Stroke disability measurement should be performed using the modified Rankin Scale (mRS) at discharge and 6 months post-discharge. The mRS scores should be recorded. ■ Transient Ischemic Attack: Transient episode of focal neurological dysfunction caused by brain, spinal cord, or retinal ischemia without acute infarction and with signs and symptoms lasting less than 24 hours. ■ Systemic embolism: Acute arterial insufficiency or occlusion of the extremities or any non-central nervous system (CNS) organ associated with clinical, imaging, surgical/autopsy evidence of arterial occlusion in the absence of other likely mechanism (e.g., trauma, atherosclerosis, or instrumentation).	Workgroup recommendation
Events of Interest	Stroke	An acute episode of focal or global neurological dysfunction caused by brain, spinal cord, or retinal vascular injury as a result of hemorrhage or	2014 ACC/AHA Key Data Elements[26]

(*Continued*)

Table 2 (*Continued*)

OMF category	Outcome measure	Definition	References
		infarction. Symptoms or signs must persist ≥24 hours, or if documented by CT, MRI or autopsy, the duration of symptoms/signs may be less than 24 hours. Stroke may be classified as ischemic (including hemorrhagic transformation of ischemic stroke), hemorrhagic, or undetermined. Stroke disability measurement should be performed using the modified Rankin Scale (mRS) at discharge and 6 months post-discharge. The mRS scores should be recorded.	
	TIA	Transient episode of focal neurological dysfunction caused by brain, spinal cord, or retinal ischemia without acute infarction and with signs and symptoms lasting less than 24 hours.	2014 ACC/AHA Key Data Elements[26]
	Systemic embolism	Acute arterial insufficiency or occlusion of the extremities or any non-CNS organ associated with clinical, imaging, surgical/autopsy evidence of arterial occlusion in the absence of other likely mechanism (e.g., trauma, atherosclerosis, or instrumentation).	Modified from the Munich Consensus Statement[23]
	Major bleeding at 12 month interval of interest (no peri-procedural association)	Fatal bleeding AND/OR symptomatic bleeding in a critical area or organ, such as intracranial, intraspinal, intraocular, retroperitoneal, intraarticular, pericardial, or intramuscular with compartment syndrome AND/OR bleeding causing a fall in hemoglobin level of 2 g/dL (1.24 mmol/L) or more, or leading to transfusion of two or more units of blood.	ISTH definition[19]
	Periprocedural bleeding (any bleeding during 12-month interval which occurs within 30d of procedure)	■ Major bleeding: Fatal bleeding AND/OR symptomatic bleeding in a critical area or organ, such as intracranial, intraspinal, intraocular, retroperitoneal, intraarticular, pericardial, or intramuscular with compartment syndrome AND/OR bleeding causing a fall in hemoglobin level of 2 g/dL (1.24 mmol/L) or more, or leading to transfusion of two or more units of blood. ■ Clinically relevant non-major bleeding: An acute or subacute clinically overt bleed that does not meet the criteria for a major bleed but prompts a clinical response such that it leads to one of the following: hospital admission for bleeding; physician-guided medical or surgical treatment for bleeding; change in antithrombotic therapy (including interruption or discontinuation). ■ Minor bleeding: All nonmajor bleeds. Minor bleeds are further divided into clinically relevant and not. Note: Registries should clearly report how they communicate with patients (phone, in-person visit) to obtain information on bleeding events.	ISTH definition[19]
	Myocardial infarction *Note: Myocardial infarction in the context of surgical ablation is defined separately.*	The term acute myocardial infarction (MI) should be used when there is evidence of myocardial necrosis in a clinical setting consistent with acute myocardial ischemia. Under these conditions any one of the following criteria meets the diagnosis for MI: ■ Detection of a rise and/or fall of cardiac biomarker values [preferably cardiac troponin (cTn)] with at least one value above the 99th percentile upper reference limit (URL) and with at least one of the following: ○ Symptoms of ischemia. ○ New or presumed new significant ST-segment-T wave (ST-T) changes or new left bundle branch block (LBBB).	Third universal definition of myocardial infarction[27]

Table 2 (*Continued*)

OMF category	Outcome measure	Definition	References
		○ Development of pathological Q waves in the ECG. ○ Imaging evidence of new loss of viable myocardium or new regional wall motion abnormality. ○ Identification of an intracoronary thrombus by angiography or autopsy. ■ Cardiac death with symptoms suggestive of myocardial ischemia and presumed new ischemic ECG changes or new LBBB, but death occurred before cardiac biomarkers were obtained, or before cardiac biomarker values would be increased. ■ Percutaneous coronary intervention (PCI) related MI is arbitrarily defined by elevation of cTn values (>5 × 99th percentile URL) in patients with normal baseline values (99th percentile URL) or a rise of cTn values >20% if the baseline values are elevated and are stable or falling. In addition, either (i) symptoms suggestive of myocardial ischemia or (ii) new ischemic ECG changes or (iii) angiographic findings consistent with a procedural complication or (iv) imaging demonstration of new loss of viable myocardium or new regional wall motion abnormality are required. ■ Stent thrombosis associated with MI when detected by coronary angiography or autopsy in the setting of myocardial ischemia and with a rise and/or fall of cardiac biomarker values with at least one value above the 99th percentile URL. ■ Coronary artery bypass grafting (CABG) related MI is arbitrarily defined by elevation of cardiac biomarker values (>10 × 99th percentile URL) in patients with normal baseline cTn values (99th percentile URL). In addition, either (i) new pathological Q waves or new LBBB, or (ii) angiographic documented new graft or new native coronary artery occlusion, or (iii) imaging evidence of new loss of viable myocardium or new regional wall motion abnormality.	
	Myocardial infarction (as a complication of ablation procedure)	MI, in the context of catheter or surgical ablation, is defined as the presence of any one of the following criteria: (1) detection of ECG changes indicative of new ischemia (new ST-T changes or new LBBB) that persist for more than 1 hour; (2) development of new pathological Q waves on an ECG; (3) imaging evidence of new loss of viable myocardium or new regional wall motion abnormality.	2017 HRS Consensus statement[2]
	Heart Failure	Heart failure is defined as physician documentation or report of any of the following clinical symptoms of heart failure described as unusual dyspnea on light exertion, recurrent dyspnea occurring in the supine position, fluid retention; or the description of rales, jugular venous distention, or pulmonary edema on physical examination. A low ejection fraction without clinical presentation does not qualify as heart failure. Studies that wish to classify heart failure should use the New York Heart Association (NYHA) Functional Classification.	2013 ACCF/AHA key data elements and definitions[21]
	Other major complications of the procedure	A major complication is a complication results in permanent injury or death, requires intervention for treatment, or prolongs or requires hospitalization for more than 48 hours or results in re-hospitalization within 30 days.	2017 HRS Consensus Statement[2]

(*Continued*)

Table 2 (*Continued*)

OMF category	Outcome measure	Definition	References
		Because early recurrences of AF/AFL/AT are to be expected following AF ablation, recurrent AF/AFL/AT within 3 months that requires or prolongs a patient's hospitalization should not be considered to be a major complication of AF ablation. Because early recurrences of AF/AFL/AT following antiarrhythmic drug therapy are a failure of therapy and not a complication, they should be excluded from this measure as it relates to prolonged hospitalization or readmission within 30 days.	
Patient Reported	AF-related quality of life	AF-related quality of life should be measured using an AF-specific quality of life instrument that is validated and commonly used, such as AFEQT.	Workgroup recommendation
	Generic quality of life	General quality of life should be measured using a quality of life instrument that is validated and commonly used.	Workgroup recommendation
Resource Utilization	All-cause hospitalization	All-cause hospitalization	Workgroup recommendation
	Cause-specific hospitalization	Hospitalization for which the primary admitting diagnosis was for heart failure, stroke, bleeding, atrial fibrillation, repeat AF-ablations, periprocedural complication, other cardiovascular causes.	Workgroup recommendation
	Other resource utilization related to treatment or management of AF or associated complications	Other resource utilization related to treatment or management of AF or associated complications, e.g., because hospitalization doesn't include office visits, emergency room visits, drug costs, etc.	Workgroup recommendation

Recurrent AF/AFL/AT is defined as AF/AFL/AT of at least 30 seconds' duration that is documented by an ECG or device recording system and occurs following catheter ablation or drug therapy. In the setting of catheter ablation, recurrent AF/AFL/AT may occur within or following the post ablation 3-month blanking period. Recurrent AF/AFL/AT that occurs within the post ablation blanking period is not considered a failure of AF ablation. This definition was adapted from the 2017 consensus statement on catheter ablation for AF[2] to apply to drug therapy as well as catheter ablation. This definition includes recurrences of AF/AFL/AT that are documented at any time following drug therapy, but only includes recurrences that are documented at least 3 months post-ablation. This distinction is important because catheter ablation results in inflammation that is proarrhythmic for the first three months post-ablation; a similar issue does not occur with drug therapy. However, it is reasonable to allow for some time for drug therapy to reach maximum effectiveness (approximately 3 days to 1 month depending on the drug) before monitoring for recurrence. In addition, while the 30 seconds' duration used in this definition is recognized to be arbitrary, there is no scientific basis to select a different definition; furthermore, this cutoff is widely used in the literature on AF ablation and has been adopted by numerous international writing groups and professional societies, and is supported by theFDA.[2] Because the definition does not specify the duration of monitoring, registries are encouraged to describe the frequency and duration of ECG monitoring when reporting on this outcome.

The concept of AF progression, based on the definition of progression used in the Canadian Registry of Atrial Fibrillation,[25] is included in the minimum measure set as an emerging area of interest. However, participants cautioned that not all patients progress (as some are in persistent AF at time of diagnosis), and the impact of progression depends on the individual patient's symptomology.

Events of Interest

Nine events of interest are captured in the minimum measure set: major bleeding including cardiac tamponade, stroke, transient ischemic attack, systemic embolism, myocardial infarction, heart failure, and other major complications of the procedure. The workgroup did not define a composite endpoint, but noted that studies may define composite endpoints using the harmonized outcome measures. An example of an increasingly utilized composite endpoint is major adverse cardiovascular or neurological events (MACNE), defined as a composite of cardiovascular death, myocardial infarction, stroke/non-central nervous system (CNS) systemic embolism, or transient ischemic attack.[28] Of the 81 events of interest submitted by registries, many represented the same or similar concepts and were harmonized for the minimum set. For example, six definitions of bleeding and three definitions of transient ischemic attack were submitted.

Discussions on bleeding focused on the clinical significance of the bleeding described by each definition, the intended use of the definition (surgical procedures, anticoagulation), and feasibility of capturing the definition outside of clinical trials. The 2017 consensus statement on catheter ablation[2] uses the International Society on Thrombosis and Haemostasis definition[19]; the major randomized trials of direct acting oral anticoagulants, as well as several registries, also use this definition. The workgroup noted this is a sensitive definition, particularly because it captures fall in hemoglobin, and recommends it for use in all registries. Some registries may report supplemental bleeding outcomes using other definitions. Lastly, the workgroup noted the importance of clearly stating how data on bleeding events was captured (e.g., by telephone follow-up, office visit, chart abstraction).

Several registries use the definition of stroke from the 2014 American College of Cardiology/American Heart Association (ACC/AHA) Task Force on Clinical Data Standards report.[26] Other definitions of stroke reviewed by the group specify a level of disability and corresponding scores on the modified Rankin Scale (mRS). However, harmonization of cutpoints for disability was determined to be beyond the scope for the workgroup. Instead, the workgroup recommends strengthening the 2014 definition to specifically state that disability measurement should be performed and mRS scores recorded at set time points. The workgroup also recommends use of the definition of transient ischemic attack from the 2014 ACC/AHA report.[26] Several registries use this definition, and it is also recommended in the 2017 consensus statement on catheter ablation.

Systemic embolism is defined as "acute arterial insufficiency or occlusion of the extremities or any non-CNS organ associated with clinical, imaging, surgical/autopsy evidence of arterial occlusion in the absence of other likely mechanism (e.g., trauma, atherosclerosis, or instrumentation." This definition was adapted from a 2016 consensus document on definitions and endpoints for percutaneous left atrial appendage occlusion.[23] The term "acute vascular insufficiency" was replaced with "acute arterial insufficiency" to be more specific.

Cardiac tamponade/perforation was included in the minimum measure set as a component of major bleeding. This outcome is defined in an existing quality measure, "Cardiac Tamponade and/or Pericardiocentesis following Atrial Fibrillation Ablation," that is used by the Centers for Medicare and Medicaid Services in the Merit-based Incentive Payment System. The group recommends using the existing quality measure definition and timeframe.

Two myocardial infarction definitions are recommended by the workgroup, reflecting the importance of a specific definition for use in the context of surgical ablation as well as a general definition. The Third Universal Definition of Myocardial Infarction[27] is widely used and is recommended by this workgroup as a general definition for capturing myocardial infarction as an event of interest. However, in this definition, myocardial infarction is broken down into five types. Type II is generally felt to be due to supply and demand ischemia resulting in a troponin leak. This may occur in patients with AF with a rapid ventricular response. This may not be considered an event of interest in this setting. Depending on the intent of the registry, some registries may need to specify the type of myocardial infarction (type I or type II) to support subcategorization or may exclude type II events. The Third Universal Definition is also not appropriate in the context of surgical or catheter AF ablation procedures because of its reliance on cardiac biomarkers, which increase in patients undergoing AF ablation as a consequence of the ablation of myocardial tissue. In the context of myocardial infarction as a complication of surgical or catheter ablation, the workgroup recommends use of the definition from the 2017 consensus statement on catheter ablation.

Development of heart failure is an important outcome to report in AF studies. The workgroup recommends the 2013 definition from the American College of Cardiology Foundation/American Heart Association Task Force on Clinical Data Standards.[21] The workgroup modified this definition by adding a recommendation to use of the New York Heart Association Functional Classification for classification of heart failure.

Several other events of interest, such as pulmonary vein stenosis, gastric motility/pyloric spasm disorder, and esophageal injury, were considered for inclusion in the minimum measure set. To minimize burden, the workgroup recommends use of a broad measure, other major complications from a procedure, to capture all other major complications. The definition from the 2017 consensus statement on catheter ablation is used for this measure and was modified to apply to other procedures (e.g., chemical cardioversion).

The timeframe for reporting on outcomes differs for periprocedural complications and outcomes of interest. The workgroup recommends reporting periprocedural complications at 30 days post-procedure and outcomes of interest at 12-month intervals for the duration of observation. This recommendation applies to major bleeding, stroke, transient ischemic attack, systemic embolism, and myocardial infarction. Development of heart failure should be reported at 12-month intervals. Other major complications of the procedure should be reported at 30 days.

Patient-Reported

Patient-reported outcome (PRO) measures are particularly important in AF because a primary goal of treatment is improving quality of life. Several AF-specific PROs have been developed and validated.[2,29] Workgroup participants agreed on the importance of collecting quality of life information, but few of the registries participating in this project collect PROs currently. Of those collecting PROs, the Atrial Fibrillation Effect on QualiTy-of-life (AFEQT) Questionnaire[30] was most commonly used. However, there are wide variations in use in research and quality practice. The workgroup's recommendation is for registries to collect AF-specific quality of life, as well as general quality of life, using validated, publically available measures. This

recommendation aligns with the 2017 consensus statement on catheter ablation. Symptom scales, such as the European Heart Rhythm Association (EHRA) score of AF-related symptoms, were considered, but no participating registries reported capturing symptom scales as an outcome measure, and so they were not included in the minimum set.

Resource Utilization

Resource utilization measures capture the cost of care for a specific condition and are typically calculated using existing data sources (EHR data, claims data). In AF, the most important drivers of cost are hospitalizations; other costs include office visits, emergency room visits, medication costs, and procedure costs. Measures have not been defined for these concepts, but, in general, the workgroup recommends capturing and reporting on any patient hospitalization, hospitalizations for which the primary admitting diagnosis was heart failure, stroke, bleeding, AF, periprocedural complications, and other cardiovascular diagnoses, and all other resource utilization related to AF.

Characteristics

In addition to defining the minimum measure set, the workgroup identified AF-specific characteristics of the participant, disease, and provider for which there is published evidence showing a correlation with patient outcomes (Figure 1); these characteristics are important to consider for risk adjustment when measuring AF outcomes. The workgroup also recommended collection of metrics that quantify patient comorbidities and health attributes other than AF that are independently associated with several outcome categories including survival, events of interest, and resource utilization. Further work is needed to recommend specific approaches for risk adjustment for each outcome measure included in the minimum measure set.

Standardized Library

Narrative definitions were translated into standardized terminologies to facilitate implementation within EHRs. Some challenges were encountered in translating the text definitions produced by the workgroup into standardized definitions and value sets. Of note, two outcome measure definitions (procedure-related death and major complications) included the concept of complications related to a procedure or treatment. Within the EHR setting, it is often not feasible to attribute causality. Some events may be recorded as procedure complications. For other events, it is feasible to identify an event that occurs in a specified time window after a procedure or treatment, but these events are not definitively linked to the procedure as a complication. In addition, the ability to distinguish whether a complication was "major" is difficult and may not be possible in some cases. The criteria

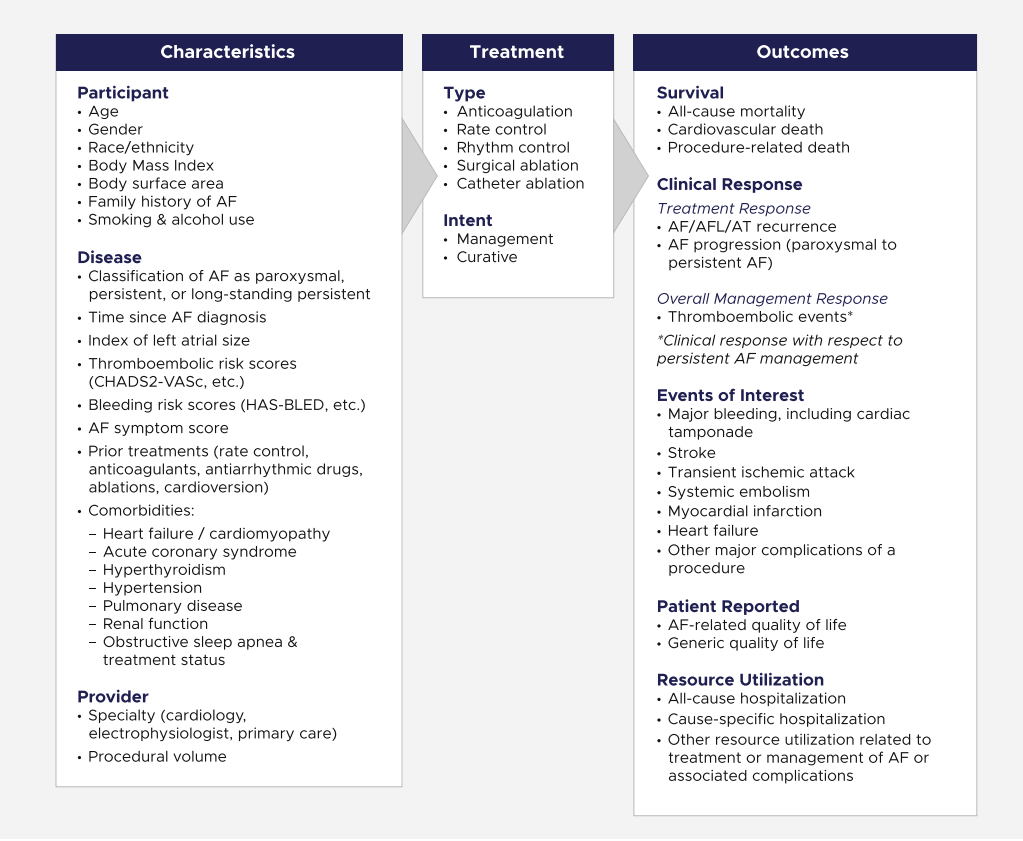

Figure 1 Outcome measures framework, as completed for atrial fibrillation characteristics and outcomes.

that distinguish a major complication, as specified in the definition, are "permanent injury or death, requires intervention for treatment, or prolongs or requires hospitalization for more than 48 hours or results in re-hospitalization within 30 days." Within the EHR setting, "permanent" injury is not indicated, although it may be assumed for events with no end date. It is also not feasible in most cases to determine if a specific complication prolonged a hospital stay.

Lastly, the definitions produced by the workgroup lacked some specificity that is necessary for producing standardized definitions. Some definitions provide examples but do not include all potential events. Timeframes also must be clearly specified. For example, the major bleeding definition references a hemoglobin drop of 2 g/dL, but does not specify the timeframe in which the two measurements must occur for the drop to count as major bleeding.

Discussion

This initiative leverages prior efforts to develop data standards in AF and cardiovascular disease generally and expands on those efforts in two important ways. First, many prior efforts in AF have focused on a specific treatment area. This has improved the ability to link data across similar studies, but heterogeneity and discontinuities still exist when comparing data across treatment pathways. The OMF standardized outcome measures for AF are designed to apply across AF treatment pathways. Second, prior harmonization efforts generally have not addressed the informatics components of the definitions, such as how the data could be captured in and extracted from an EHR. This is an important and major challenge for new registries and other research projects. For example, the ability to expand pragmatic clinical trials, such as those conducted in PCORnet, is highly dependent on EHR-derived outcomes with standard definitions. The OMF effort includes development of standardized definitions that could be implemented within an EHR as a core component. Key goals of this effort are to reduce duplicate data collection (and therefore data collection costs) by harmonizing data requirements across the learning healthcare system and to increase the utility of registry data for improving patient outcomes and facilitating shared decision-making.

The minimum measure set has some limitations. First, while implementing the measure set in new registries should reduce burden, a major barrier to use in existing registries is mapping existing data to the new measures and updating registry infrastructure. This requires substantial resources, and, in some cases, mapping existing data to the new measures may not be feasible. To encourage implementation in both new registries and existing registries, clear evidence of the value and validity of the measures is needed; a pilot test to document the burden of implementing the measures and the value of the measures in terms of reducing data collection costs and increasing data quality would be useful.

Second, additional work is needed to improve capture of the patient's perspective through systematic use of PROs. Consistent collection of PROs within registries would provide important information on quality of life as it relates to specific treatments and help inform future research on how best to incorporate patient-reported information into clinical practice and shared decision-making in AF.

Lastly, effective governance is necessary for sustainability of the minimum measure set. A transparent governance structure is still needed to develop processes for regular review and updates of the minimum measure set, monitor implementation of the measure set, and set and monitor benchmarks for success.

Conclusion

The harmonized measures represent a minimum set of outcomes that are relevant in AF research and clinical practice. Consistent collection of these measures in registries and in other systems would support creation of a national research infrastructure to efficiently address new questions and improve patient outcomes.

Acknowledgments

Numerous individuals participated in the workgroup discussions and coordination of this effort. We wish to acknowledge the contributions of these individuals: Elise Berliner, Kyle Cobb, Anita-Marie Holz, Suchitra Iyer, Margaret Johnson, Jamie Jouza, Ferhat Kassamali, Elisabeth Kato, Gloria Kayani, Robert Kowal, Lisa Lang, Danica Marinac-Dabic, Laura Blum Meisnere, Mary Nix, Rosina Pradhananga, Mathew Reynolds, Lisa Rosenblatt, Raj Sabharwal, Claudia Schur, Lara Slatterly, Mellanie True Hills, Elisa Vireca, and Paul Wallace.

References

1. Chugh SS, Havmoeller R, Narayanan K, et al. Worldwide epidemiology of atrial fibrillation: a Global Burden of Disease 2010 Study. Circulation Feb 25 2014; 129:837–847.
2. Calkins H, Hindricks G, Cappato R, et al. 2017 HRS/EHRA/ECAS/APHRS/SOLAECE expert consensus statement on catheter and surgical ablation of atrial fibrillation. Heart Rhythm 2017;14:e275–e444.
3. Colilla S, Crow A, Petkun W, Singer DE, Simon T, Liu X. Estimates of current and future incidence and prevalence of atrial fibrillation in the U.S. adult population. Am J Cardiol 2013;112:1142–1147.
4. Lubitz SA, Moser C, Sullivan L, et al. Atrial fibrillation patterns and risks of subsequent stroke, heart failure, or death in the community. J Am Heart Assoc 2013; 2:e000126.
5. Jacobs V, Cutler MJ, Day JD, Bunch TJ. Atrial fibrillation and dementia. Trends Cardiovasc Med 2015;25:44–51.
6. Mozaffarian D, Benjamin EJ, Go AS, et al. Heart Disease and Stroke Statistics—2015 Update. A Report From the American Heart Association. Circulation 2015; 131:e29–e322.
7. Sanchez JM, Ballinger B, Olgin JE, Pletcher MJ, Vittinghoff E, Lee E, Fan S, Sohoni N, Mikell C, Hsieh J, Gladstone RA, Marcus GM. AF detection and ablation outcomes: answering questions that matter to patients: detecting atrial fibrillation using a smart watch —the mRhythm study. Paper presented at: HRS Heart Rhythm 2017; May 11, 2017; Chicago, IL.
8. Gliklich R, Dreyer N, Leavy M, eds. Registries for Evaluating Patient Outcomes: A User's Guide. Third edition. Two volumes. (Prepared by the Outcome DEcIDE Center [Outcome Sciences, Inc., a Quintiles company] under Contract No. 290 2005 00351 TO7.) AHRQ Publication No. 13(14)-EHC111. Rockville, MD: Agency for Healthcare Research and Quality. April 2014. https://effectivehealthcare.ahrq.gov/topics/registries-guide-3rd-edition/research.

9. Piccini JP, Fraulo ES, Ansell JE, et al. Outcomes registry for better informed treatment of atrial fibrillation: rationale and design of ORBIT-AF. Am Heart J 2011; 162:606–612.e601.
10. Steinberg BA, Blanco RG, Ollis D, et al. Outcomes Registry for Better Informed Treatment of Atrial Fibrillation II: rationale and design of the ORBIT-AF II registry. Am Heart J 2014;168:160–167.
11. Kakkar AK, Mueller I, Bassand JP, et al. International longitudinal registry of patients with atrial fibrillation at risk of stroke: Global Anticoagulant Registry in the FIELD (GARFIELD). Am Heart J 2012;163:13–19.e11.
12. Huisman MV, Lip GY, Diener HC, Dubner SJ, Halperin JL, Ma CS, Rothman KJ, Teutsch C, Zint K, Ackermann D, Clemens A, Bartels DB. Design and rationale of Global Registry on Long-Term Oral Antithrombotic Treatment in Patients with Atrial Fibrillation: a global registry program on long-term oral antithrombotic treatment in patients with atrial fibrillation. Am Heart J 2014;167:329–334.
13. Gliklich RE, Leavy MB, Karl J, Campion DM, Levy D, Berliner E. A framework for creating standardized outcome measures for patient registries. J Comp Eff Res 2014;3:473–480.
14. Registry of Patient Registries (RoPR). Agency for Healthcare Research and Quality. Accessed March 31, 2018, https://patientregistry.ahrq.gov/. Vol 2018.
15. ClinicalTrials.gov. National Library of Medicine. Accessed March 31, 2018, https://clinicaltrials.gov/.
16. The COMET (Core Outcome Measures in Effectiveness Trials) Initiative. Accessed January 10, 2018. http://www.comet-initiative.org/. Vol 2018.
17. National Quality Forum. Accessed March 31, 2018, https://www.qualityforum.org/QPS.
18. McNamara RL, Brass LM, Drozda JP Jr, et al. ACC/AHA key data elements and definitions for measuring the clinical management and outcomes of patients with atrial fibrillation: A report of the American College of Cardiology/American Heart Association Task Force on Clinical Data Standards (Writing Commitee to Develop Data Standards on Atrial Fibrillation). J Am Coll Cardiol 2004; 44:475–495.
19. Schulman S, Kearon C. Definition of major bleeding in clinical investigations of antihemostatic medicinal products in non-surgical patients. J Thromb Haemost 2005;3:692–694.
20. Mehran R, Rao SV, Bhatt DL, et al. Standardized bleeding definitions for cardiovascular clinical trials: a consensus report from the Bleeding Academic Research Consortium. Circulation 2011;123:2736–2747.
21. Cannon CP, Brindis RG, Chaitman BR, et al. 2013 ACCF/AHA key data elements and definitions for measuring the clinical management and outcomes of patients with acute coronary syndromes and coronary artery disease: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Clinical Data Standards (Writing Committee to Develop Acute Coronary Syndromes and Coronary Artery Disease Clinical Data Standards). Circulation 2013;127:1052–1089.
22. Kappetein AP, Head SJ, Genereux P, et al. Updated standardized endpoint definitions for transcatheter aortic valve implantation: the Valve Academic Research Consortium-2 consensus document. J Thorac Cardiovasc Surg 2013;145:6–23.
23. Tzikas A, Holmes DR Jr, Gafoor S, et al. Percutaneous left atrial appendage occlusion: the Munich consensus document on definitions, endpoints and data collection requirements for clinical studies. EuroIntervention 2016;12:103–111.
24. January CT, Wann LS, Alpert JS, et al. 2014 AHA/ACC/HRS guideline for the management of patients with atrial fibrillation: 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:e1–e76.
25. Padfield GJ, Steinberg C, Swampillai J, Qian H, Connolly SJ, Dorian P, Green MS, Humphries KH, Klein GJ, Sheldon R, Talajic M, Kerr CR. Progression of paroxysmal to persistent atrial fibrillation: 10-year follow-up in the Canadian Registry of Atrial Fibrillation. Heart Rhythm 2017;14:801–807.
26. Hicks KA, Tcheng JE, Bozkurt B, et al. 2014 ACC/AHA Key Data Elements and Definitions for Cardiovascular Endpoint Events in Clinical Trials. Circulation 2015;132:302.
27. Thygesen K, Alpert JS, Jaffe AS, et al. Third universal definition of myocardial infarction. J Am Coll Cardiol 2012;60:1581–1598.
28. Inohara T, Shrader P, Pieper K, et al. Association of of atrial fibrillation clinical phenotypes with treatment patterns and outcomes: a multicenter registry study. JAMA Cardiol 2018;3:54–63.
29. Ha AC, Dorian P. Health-related quality of life questionnaires: an important method to evaluate patient outcomes in atrial fibrillation ablation. J Interv Card Electrophysiol 2013;36:177–184; discussion 184.
30. Spertus J, Dorian P, Bubien R, Lewis S, Godejohn D, Reynolds MR, Lakkireddy DR, Wimmer AP, Bhandari A, Burk C. Development and validation of the Atrial Fibrillation Effect on QualiTy-of-Life (AFEQT) Questionnaire in patients with atrial fibrillation. Circ Arrhythm Electrophysiol 2011;4:15–25.

Appendix A1 Invited Registries that Declined to Participate

Registry Name	Sponsoring Organization	Primary Purpose
ABLATE Post Approval Study—Synergy Ablation Lesions for Non-Paroxysmal AF (ABLATE PAS)	AtriCure, Inc.	Monitor the AtriCure Synergy Ablation System continued safety and efficacy during the peri-procedural and long-term phase during commercial use in patients being treated for non-paroxysmal forms of atrial fibrillation who are undergoing a concomitant open, on-pump cardiac surgical procedure.
Antithrombotic Strategy Variability In ATrial Fibrillation and Obstructive Coronary Disease Revascularized With PCI—The AVIATOR 2 Registry	Icahn School of Medicine at Mount Sinai	Compare the safety and efficacy of an antithrombotic regimen comprising one single antiplatelet agent plus an oral anti-thrombotic versus those consisting of DAPT alone or DAPT plus oral antithrombotic therapy in patients with AF undergoing percutaneous coronary intervention (PCI).
The Vanderbilt Atrial Fibrillation Ablation Registry (VAFAR)	Vanderbilt University	Prospective clinical and genetic biorepository that systematically enrolls patients undergoing atrial fibrillation (AF) ablation. The goals of VAFAR are to: 1) identify clinical, genetic, and serological predictors of response to AF ablation in order to improve patient selection, and 2) to provide a resource for translational research investigating the electrophysiologic mechanisms of AF pathogenesis.
Eliminate Thromboembolism: Improving Anticoagulation in Non-valvular Atrial Fibrillation Patients (ELITE)	Duke University	Characterize demographics, comorbidities, risk profiles, socioeconomic status, and patient preferences related to anticoagulation management. The primary study endpoint will be warfarin discontinuation without resumption as documented in the medical record.
Impact of the Pulmonary Vein Isolation on Exercise Capacity in Patients With Chronic Atrial Fibrillation (Exercise)	Texas Cardiac Arrhythmia Research Foundation	Assess the impact of radio-frequency catheter ablation on exercise capacity and quality of life in long-standing persistent atrial fibrillation (LSP-AF) patients.
Low Fluoroscopy Afib Ablation Registry	Stanford University	Track adverse events associated with low dose fluoroscopy including use of Carto Mapping system.
OSB Lead-Atrial Fibrillation Registry	Biosense Webster, Inc.	Clinical evaluation of PAF patients treated with the radio frequency ablation with Thermocool catheters.
Registry on WATCHMAN Outcomes in Real-Life Utilization WASP Registry (WASP)	Boston Scientific Corporation	Compile real-world clinical outcomes data for WATCHMAN Left Atrial Appendage Closure Technology in patients who are implanted with the WATCHMAN device in a commercial clinical setting and collect health care usage data that may be needed for reimbursement of WATCHMAN technology in certain countries.

Appendix A2 Writing group author disclosure table

Writing group	Employment	Consultant/advisory board/ honoraria	Speakers' Bureau	Research grant	Fellowship support	Equity interests/stock options	Others
Hugh Calkins, MD, FHRS	Johns Hopkins University	Abbott (1), Medtronic (2), Biosense Webster (1), Boehringer Ingelheim (2), Academy Health (1)	None	None	None	None	None
Richard E. Gliklich, MD	OM1, Inc.	None	None	None	None	None	None
Michelle B. Leavy, MPH	OM1, Inc.	None	None	None	None	None	None
Jonathan P. Piccini, MD, MHS, FHRS	Duke University Medical Center and Duke Clinical Research Institute	Abbott (1), Allergan (1), ARCA Biopharma (1), Bayer (1), Johnson & Johnson (1), Medtronic (2), Motif Bio (1), Sanofi (1), Phillips (2)	None	American Heart Association (5), Abbott (5), ARCA Biopharma (5), Boston Scientific (5), Gilead (4), Janssen Pharmaceuticals (5)	None	None	None
Jonathan C. Hsu, MD, MAS, FHRS	University of California, San Diego	Medtronic (1), Boston Scientific (1), Abbott (1), Biotronik (1)	None	Biosense-Webster (3), Biotronik (3)	None	None	None
Sanghamitra Mohanty, MD, MS, FHRS	Texas Cardiac Arrhythmia Institute	None	None	None	None	None	None
William Lewis, MD, FHRS	MetroHealth System, Case Western Reserve University	None	None	None	None	None	None
Saman Nazarian, MD, PhD, FHRS	The University of Pennsylvania Perelman School of Medicine	Biosense Webster (1), Siemens (1), CardioSolv (0), ImriCor (1)	None	NIH/NHLBI (5), Biosense Webster (5), Siemens (4), ImriCor (4)	None	None	None
Mintu P. Turakhia, MD, MAS, FHRS	VA Palo Alto Health Care System and Stanford University	Abbott (1), Medtronic (1), Biotronik (1)	None	Apple (5), Janssen (5), Astra Zeneca (5), Bristol Myers Squibb (5), Boehringer Ingelheim (4), American Heart Association (5)	None	AliveCor (1)	None

Number Value: 0 = $0; 1 = <$10,000; 2 = >$10,000 to <$25,000; 3 = >$25,000 to <$50,000; 4 = >$50,000 to <$100,000; 5 = >$100,000