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ORIGINAL RESEARCH PAPER

Stroke and Bleeding Risks of Endocardial Ablation for Ventricular Arrhythmias

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ABSTRACT

BACKGROUND Risks of radiofrequency catheter ablation for ventricular arrhythmias include emboli and bleeding complications but data on antithrombotic regimens are limited and guidelines do not specify a systematic approach.

OBJECTIVES This study sought to assess embolic and bleeding complications in relation to pre- and post-periprocedure antithrombotic regimens.

METHODS Prospective assessment for complications was performed for 663 endocardial radiofrequency catheter ablation procedures in 616 consecutive patients (median age 64 years [Q1-Q3: 54-73 years], 70.3% men, 71.6% with cardiomyopathy, 44.5% with sustained ventricular tachycardia).

RESULTS There were 2 strokes (0.3%; 95% CI: 0.0%-0.8%), 1 transient ischemic attack (0.15%), and 2 pulmonary emboli (0.3%). There were 39 bleeding complications (5.9%) including 11 pericardial effusions (1.7%), and 28 related to vascular access (4.2%). Consistent with the prevalence of coronary artery disease (47.5%), atrial fibrillation (30.0%), and prior stroke (10.6%), preprocedure, 464 patients (70.0%) were taking antithrombotic agents including 220 (33.2%) taking aspirin alone (ASA), and 163 (24.6%) taking warfarin or a direct acting oral anticoagulant (DOAC). Preprocedure non-ASA antiplatelet use (OR: 2.846; $P = 0.011$) and DOAC use (OR: 2.585; $P = 0.032$) were associated with risk of bleeding complications. Following ablation, 49.8% of patients were treated with ASA 325 mg/d and 30.3% received DOACs or warfarin. New DOAC or warfarin administration was initiated in only 6.6% of patients. Overall, 39.7% of patients continued the same preprocedure antithrombotic regimen.

CONCLUSIONS Stroke is a rare complication of radiofrequency catheter ablation for ventricular arrhythmia using ASA 325 mg/d as a minimal postprocedure regimen with more potent regimens for selected patients.
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The safety profile of radiofrequency (RF) catheter ablation is generally favorable, and it is now a common treatment option for ventricular tachycardia (VT) and premature ventricular contractions (PVCs).[1-3] Stroke is one of the most feared complications, and an early multicenter trial reported cerebral or systemic embolism in 2.7% of patients.[4] Subsequently, several large studies reported

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ABBREVIATIONS AND ACRONYMS

ASA = aspirin

DOAC = direct oral anticoagulant

LV = left ventricle

PVC = premature ventricular contraction

RF = radiofrequency

VT = ventricular tachycardia

no arterial embolic events in a total of 731 patients.[3,5,6] A recent scientific consensus statement noted the concomitant low incidence of embolic events and the paucity of data regarding antithrombotic regimens, leaving the antithrombotic strategy to the preference of the treating physician.[2] Other recent studies suggest more reason for concern. A small study of cerebral imaging showed evidence of asymptomatic emboli in 58% of patients.[7] A recent randomized trial of direct oral anticoagulant (DOAC) vs low-dose aspirin (ASA) reported a very high frequency of symptomatic stroke (6.5%) and transient ischemic events (17.9%) in 123 patients treated with 81 mg of ASA after ablation and called for routine DOAC use.[8] This approach would be a major change in practice that also raises questions of how to deal with patients who are already receiving other antithrombotic therapies. Although coronary disease and atrial fibrillation are common in this patient population, the frequency of preprocedure anticoagulation has not been examined in detail and likely influences procedure risks.

To clarify the bleeding and embolism risks of endocardial ventricular arrhythmia ablation in the context of antithrombotic treatments, we evaluated a large consecutive patient cohort who had prospective follow-up for procedure complications.

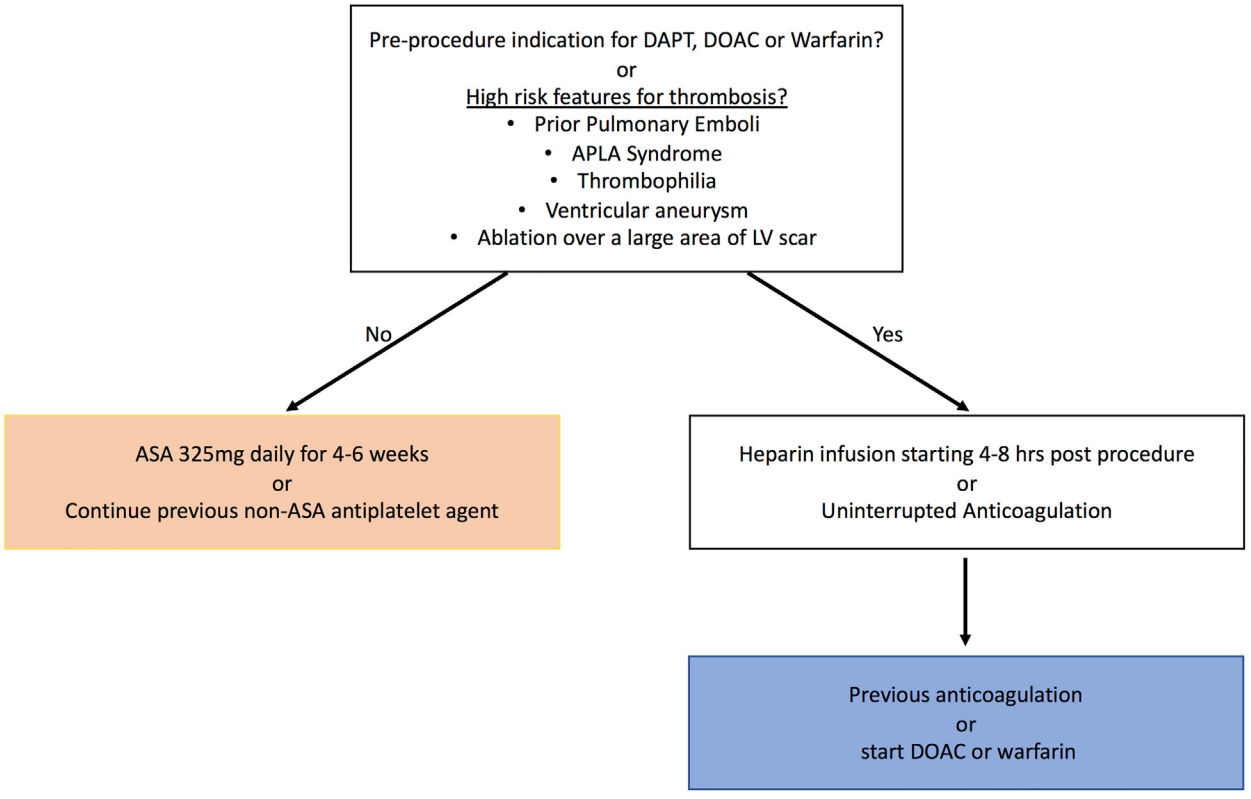
METHODS

The study population included 663 consecutive patients undergoing endocardial radiofrequency (RF) catheter mapping and ablation for ventricular arrhythmias from October 2018 to September 2021 at Vanderbilt University Medical Center. Complications are prospectively tracked and entered into a database by a dedicated nurse. For this analysis, we screened 852 patients and excluded patients who had 67 epicardial mapping or ablations, which introduces additional anticoagulation management issues, 44 investigational needle ablations, 7 epicardial mapping or ablation and investigational needle ablation, 1 transcoronary arterial alcohol ablation, and 100 concurrent ablations for atrial fibrillation or other supraventricular tachycardias. All patients gave written informed consent for the procedure. Data collection was conducted in accordance with the protocols approved by the Institutional Review Board.

MAPPING AND ABLATION PROCEDURES. Ablation procedures were performed under conscious sedation or general anesthesia as previously described.[9,10] In brief, femoral vessels were accessed with 18-G or micropuncture needles with use of ultrasound assistance at the operators' discretion. Electrophysiologic catheters and an intracardiac echocardiography catheter (SoundStar, Biosense Webster) were placed. Left ventricular (LV) access was achieved by a retrograde aortic or transseptal atrial approach, at the operator's discretion. Electroanatomical maps were created using a 3-dimensional mapping system (CARTO3, Biosense Webster; Precision, Abbott). Ventricular anatomy and catheter position were observed with intracardiac echocardiography to observe evidence of heating (increase in bubble formation or tissue whitening) and pericardial effusion. Endocardial maps of the chamber of interest were generated with a 3.5-mm tip standard ablation catheter (ThermoCool, ThermoCool SmartTouch, ThermoCool SmartTouch SurroundFlow, Biosense Webster; TactiCath, FlexAbility, Abbott) or multielectrode catheters (Decanav or PentaRay, Biosense Webster; HD Grid, Abbott). Intracardiac electrograms were recorded in digital format (Cardiolab EP system, General Electric Healthcare; CARTO electroanatomic mapping system, Biosense Webster; EnSite electroanatomic mapping system, Abbott). A 480-kHz alternating current RF generator (Stockert, Biosense Webster; Ibi 500T, Abbott) was used at 20-50 W, in power control mode at the manufacturer's nominal irrigation flow rates of 17-30 cm^3/min for ThermoCool, SmartTouch, TactiCath, and FlexAbility catheters and 8-15 cm^3/min for SurroundFlow catheters. The choice of normal saline or half normal saline for catheter irrigation was selected by the operator. We attempted to achieve a contact force of at least 5 g but no more than 40 g at ablation sites. RF ablation was usually initiated at a power of 30 W and titrated to a maximum of 50 W, or until impedance had decreased by at least 10 to 15 Ω. Power was decreased for impedance falls exceeding 15 Ω, intracardiac ultrasound imaging showing increasing spontaneous echocardiographic contrast, or tissue whitening. RF duration was generally 60-300 seconds at the operator's discretion. At the end of the procedure, a final review using intracardiac echocardiography was conducted to detect pericardial effusion or any change in pre-existing effusion.

ANTICOAGULATION. Pre- and postprocedural antithrombotic therapies were generally managed as illustrated in Figure 1 at the discretion of the treating physician. For patients receiving warfarin, DOACs, or antiplatelet agents, this therapy was either continued or interrupted at the discretion of the treating physician. During the procedure, heparin was

FIGURE 1 **Postablation Anticoagulation Strategy**



The postablation anticoagulation strategy is shown. APLA = antiphospholipid antibody syndrome; ASA = aspirin; DAPT = dual antiplatelet therapy; DOAC = direct oral anticoagulant; LV = left ventricular.

administered after vascular access was obtained and before transeptal puncture or LV access. Two patients received bivalirudin instead of heparin due to a history of heparin-induced thrombocytopenia. The activated clotting time goal was >250 seconds for retrograde aortic access and >300 seconds for transeptal access. All transeptal sheaths were continuously flushed with heparinized saline. Following ablation, after removal of catheters from the arterial circulation, protamine was administered to reverse heparin for sheath removal. Hemostasis was achieved with manual pressure and a figure-8 suture was generally employed and removed the following day. Preprocedure anticoagulation with DOACs, warfarin, and or antiplatelet therapy was continued or resumed generally 6-12 hours after the procedure. In selected patients who were not on continued antithrombotic regimens and who were felt to be an increased risk of emboli due to a large area of LV ablation or atrial fibrillation, intravenous heparin was initiated 4-8 hours after sheath removal and continued until the following day when they were transitioned to an oral regimen. Patients who preprocedure were on only low-dose ASA or no antithrombotic medication were treated with 325 mg of ASA daily for 4-6 weeks.

ENDPOINTS. After the procedure, patients were monitored in a dedicated cardiovascular procedure recovery room and examined by the treating physicians, nurse practitioners, and the anesthesiologists prior to discharge. Hospitalized patients were interviewed and examined daily by an electrophysiologist or nurse practitioner. At 1-3 months following discharge, patients were seen in clinic or contacted by phone with inquiry regarding any symptoms, arrhythmias, and hospitalizations. These data focusing on complications were recorded in a quality improvement database by a dedicated nurse and reviewed quarterly by the staff. Additional clinical data were obtained from review of the patient's electronic health record. The primary endpoints were bleeding complications that required treatment or

TABLE 1 Baseline Characteristics (N = 616)

Age, y	64 (54-73)
Male	433 (70.3)
Body mass index, kg/m^2	29.1 (25.5-33.7)
Cardiomyopathy	441 (71.6)
Ischemic cardiomyopathy	199 (32.3)
Nonischemic cardiomyopathy	222 (36.0)
Mixed cardiomyopathy	20 (3.2)
Ablation target	
Ventricular tachycardia	227 (36.9)
Premature ventricular contraction	342 (55.5)
Both	47 (7.6)
Left ventricular ejection fraction, %	40 (25-55)
Hypertension	424 (68.8)
Diabetes mellitus	162 (26.3)
COPD	91 (14.8)
Obstructive sleep apnea	161 (26.1)
Previous stroke	66 (10.7)
Peripheral arterial disease	43 (7.0)
Creatinine, mg/dL	1.02 (0.84-1.25)
Atrial fibrillation	185 (30.0)
Prior atrial fibrillation ablation	49/185 (26.9)
Coronary artery disease	287 (46.6)
Prior PCI	199 (32.3)
Prior CABG	107 (17.4)
CHA_2DS_2-VASc score	3 (2-4)

Values are median (Q1-Q3), n (%), or n/N (%).
CABG = coronary artery bypass graft; COPD = chronic obstructive lung disease; PCI = percutaneous coronary intervention.

TABLE 2 Ablation Characteristics for 663 Procedures

Ablation target	
Ventricular tachycardia	254 (38.3)
Premature ventricular contraction	355 (53.5)
Both VT and PVCs	54 (8.1)
LV mapping/ablation	573 (86.4)
Transatrial septal access	332 (50.1)
Retrograde aortic access	275 (41.5)
Both transatrial septal and retrograde aortic	35 (5.3)
RF ablation sites	
LV	563 (84.9)
RV	232 (34.9)
Both LV and RV	132 (19.9)
RF applications per procedure, n	21 (10-36)
Total RF time, s	1,244 (642-2,396)
Femoral arterial sheath	504 (76.0)
None	159 (24.0)
4- to 6-F	233 (35.1)
≥8.0-F	271 (40.9)
Mechanical hemodynamic support	17 (2.6)

Values are n (%) or median (Q1-Q3).
LV = left ventricle; PVC = premature ventricular contraction; RF = radiofrequency; RV = right ventricle; VT = ventricular tachycardia.

prolonged hospital stay and stroke and all embolic complications including stroke, symptomatic transient ischemic attack, peripheral arterial embolism, and pulmonary embolism. For suspected cerebral events, neurologists, in addition to the treating physicians, examined the patients, and appropriate imaging was available.

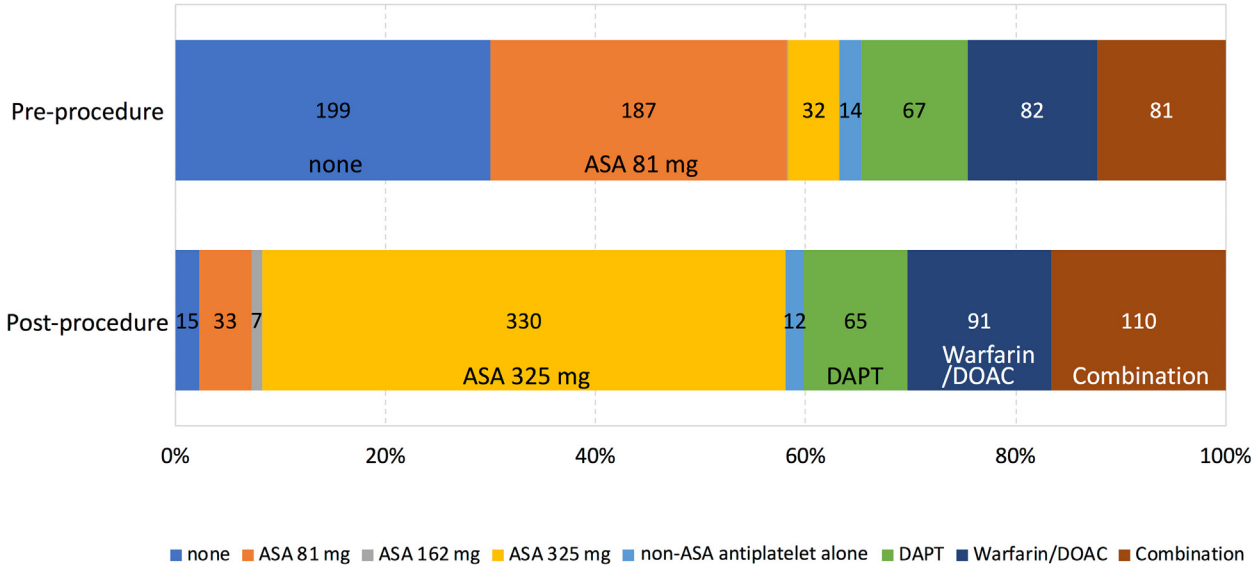
STATISTICAL ANALYSIS. Continuous variables are presented as median (Q1-Q3) and categorical data as number (percentage). As an evaluation of uncertainty for rare events, bootstrapped CIs with 10,000 replications were obtained for point estimates. Univariate analyses for categorical variables were performed as Fisher exact tests. To avoid the assumption of normality, univariate analyses for continuous variables were performed as Wilcoxon rank-sum tests. For the primary endpoint of bleeding complications, multivariable logistic regression of antithrombotic regimens with prespecified adjustment for age, sex, body mass index, creatinine, retrograde aortic access, and use of femoral sheath were used. All statistical analyses were performed with SPSS (Statistical Package for the Social Sciences, version 26 software, IBM Inc) and Stata (version 16, StataCorp LLC).

RESULTS

CHARACTERISTICS OF THE STUDY POPULATION. There were 663 endocardial RF ablation procedures for ventricular arrhythmias in 616 patients (Table 1). The median age was 64 (Q1-Q3: 54-73) years and 70.3% were male. Cardiomyopathy was present in 441 patients (71.6%). The median CHA_2DS_2-VASc score was 3 (Q1-Q3: 2-4) (Supplemental Figure 1). The arrhythmia target was VT in 254 procedures (38.3%), PVCs in 355 (53.5%), and both VT and PVC in 54 (8.1%). LV mapping or ablation was performed in 573 procedures (86.4%). Access to the LV was via an atrial transeptal approach in 50.1%, a retrograde aortic approach in 41.5%, and both approaches in 5.3% of procedures. Ablation was performed in the LV in 563 procedures (84.9%) and in only the RV (right ventricle) in 100 (15.1%) (Table 2). All patients had follow-up after the procedure in hospital. There were 29 patients who were lost to follow-up after hospital discharge and who did not have 1-month follow-up data.

PERIPROCEDURE ANTITHROMBOTIC AGENTS. Preprocedure, 199 patients (30.0%) were not taking antithrombotic agents, and 464 (70.0%) were taking antithrombotic agents (Figure 2, Table 3). The same preprocedure oral anticoagulation regimen was continued postprocedure in 251 patients (37.9%) (Figure 2, Table 3). Prior to the procedure, 163 patients (24.6%) were receiving warfarin or a DOACs alone or

FIGURE 2 **Preprocedure and Postprocedure Antithrombotic Regimens**



Bar graph showing preprocedure (top) and postprocedure (bottom) antithrombotic regimens. Combination is warfarin or DOAC combined with ASA or a non-ASA antiplatelet agent. Abbreviations as in Figure 1.

in combination with an antiplatelet agent and this increased to 201 patients (30.3%) after the procedure. Overall, the most common oral regimen after ablation was ASA 325 mg/d, which was used in 49.8% of patients. Further details are provided in the discussion that follows and in **Table 3** and **Figure 2**.

The most common preprocedure regimen was low-dose ASA (81 mg/d), which was taken by 187 patients (28.2%). Other antithrombotic regimens taken by 277 patients (41.8%) were higher-dose ASA in 5.0%, non-ASA antiplatelet regimens (clopidogrel, prasugrel, ticagrelor, or cilostazol) in 2.1%, dual antiplatelet therapy in 10.1%, DOACs in 8.0%, warfarin in 4.4%, and a combination of antiplatelet agents and warfarin or DOACs in 12.2%. Potential indications for antithrombotic therapy included coronary artery disease in 315 patients (47.5%), history of atrial fibrillation in 199 (30.0%), and history of stroke in 70 (10.6%). Chronic oral anticoagulants were interrupted for the procedure in 120 patients (73.6%). DOACs were held from the morning of the procedure day in 20 patients (22.7%), for 1 day prior to the procedure in 23 (26.1%), for 2 days prior in 29 (32.9%), and for 3 or more days in 16 (18.1%) (Supplemental Figure 2). Bridging with heparin was used in 24 of 32 patients (75.0%) who interrupted warfarin and 30 of 88 patients (34.1%) who interrupted a DOAC. Overall, preprocedure intravenous heparin was administered to 86 patients (13.0%): 25.6% of VT ablations and 2.0% of PVC ablations.

Of the 464 patients (70.0%) who were receiving an oral antithrombotic regimen prior to ablation, the same preprocedure regimen was continued without change after the procedure in 251 (54.1%) (blue squares in Supplemental Table 1). In 187 patients (40.3%) who had been on low-dose ASA alone, the dose was increased to 325 mg/d in 132 (28.4%) and to 162 mg in 6 (1.3%); a DOAC or warfarin was added to or replaced ASA in 18 patients (3.8%); and a non-ASA antiplatelet agent was changed in 6 (1.2%). In these 464 patients, a new DOAC or warfarin was initiated in 27 patients (5.8%).

Of the 199 patients not receiving antithrombotic agents preprocedure, 80.9% were started on 325 mg of ASA daily after the procedure (**Table 3**); 3.5% started lower dose ASA or other antiplatelet agents; 17 (8.5%) started a DOAC or warfarin combined with ASA or an antiplatelet agent (**Table 3**).

Following the procedure, intravenous heparin was administered to 123 patients (18.6%), including 113 (36.7%) of those who had ablation for VT and 10 (2.8%) of those who had ablation for PVCs, as they were transitioned to an oral regimen (Supplemental Figure 2).

TABLE 3 Periprocedure Antithrombic Regimens

	Preprocedure (n = 663)	Postprocedure (n = 663)	Postprocedure Regimen in Patients on Preprocedure Antithrombotic Drugs (n = 464)	Postprocedure Regimen in Patients on No Preprocedure Antithrombotic Drugs (n = 199)
None	199 (30.0)	15 (2.3)	2 (0.4)	13 (6.5)
ASA alone	220 (33.2)	370 (55.8)	205 (44.2)	165 (82.9)
Non-ASA antiplatelet alone	14 (2.1)	12 (1.8)	9 (1.9)	3 (1.5)
DAPT	67 (10.1)	65 (9.8)	64 (13.8)	1 (0.5)
Warfarin or DOAC	82 (12.4)	91 (13.7)	79 (17.0)	12 (6.0)
Combination	81 (12.2)	110 (16.6)	105 (22.6)	5 (2.5)

Values are n (%). Non-ASA antiplatelet regimens include clopidogrel, prasugrel, ticagrelor, or cilostazol. Combination regimens are warfarin or DOAC with ASA or other antiplatelet agent.

ASA = aspirin; DAPT = dual antiplatelet therapy; DOAC = direct oral anticoagulant.

TABLE 4 Adverse Events (in 663 Procedures)

All adverse events	79
Procedures followed by adverse events	69 (10.4)
Bleeding complications	39 (5.9)
Vascular access complication	28 (4.2)
Surgical repair required	2 (0.3)
Transfusion required	3 (0.5)
Pericardial effusion	11 (1.7)
Surgical repair	3 (0.5)
Embolic events	5 (0.7)
Transient ischemic attack	1 (0.15)
Stroke	2 (0.3)
PE/DVT	2 (0.3)
High-degree heart block	11 (1.7)
Worsening heart failure	10 (1.5)
Others[a]	14 (2.1)
Death within 30 d[b]	9 (1.5)
Heart transplant within 30 d	4 (0.6)

Values are n or n (%). [a]Hematuria or urinary tract infection in 6 patients, pneumonia in 4 (including 2 COVID-19 pneumonia), allergic reaction to protamine in 2, nasopharyngeal bleeding in 1, and atrial lead dislodgement in 1. [b]Causes of death were recurrent VT after transition to palliative care (n = 2), heart failure (n = 2), pneumonia and sepsis (n = 1), urosepsis (n = 1), gastrointestinal bleeding (n = 1), hemothorax due to a fall (n = 1), and COVID-19 (n = 1).

DVT = deep vein thrombosis; PE = pulmonary emboli; VT = ventricular tachycardia.

EMBOLIC COMPLICATIONS. There were 79 adverse events in 69 procedures (10.4%) (Table 4). There were 5 possible embolic events (0.7% [5 of 663]; 95% CI: 0.2%-1.5%) including 2 strokes, a possible transient ischemic attack, and 2 pulmonary emboli (see Supplemental Table 2 for details and Supplemental Table 3). The risk of stroke was 0.3% (2 of 663; 95% CI: 0.0%-0.8%). All patients with cerebral embolic events had LV ablation or mapping and structural heart disease.

BLEEDING. There were 39 bleeding complications in 38 patients (5.7%; 95% CI: 4.1%-7.5%). There were 28 vascular access complications (4.2%; 95% CI: 2.7%-5.9%): 3 required surgical repair and 3 required transfusion. There were 11 pericardial effusions (1.7%; 95% CI: 0.8%-2.7%) (Supplemental Table 4): 3 required surgical repair and 5 were treated with percutaneous pericardial drainage. Details of the antithrombotic regimens and bleeding are provided in **Table 5** and Supplemental Tables 5 and 6. In univariable analysis, bleeding complications were associated with older age ($P = 0.016$), preprocedure non-ASA antiplatelet drug use ($P = 0.018$), and DOAC use ($P = 0.054$) (**Table 5**, Supplemental Tables 5 and 6). In the multivariable model, female sex (OR: 3.003; $P = 0.008$), preprocedure non-ASA antiplatelet drug use (OR: 2.846; $P = 0.011$), and preprocedure DOAC use (OR: 2.585; $P = 0.032$) were associated with bleeding complications (**Table 6**).

DISCUSSION

Vascular bleeding and pericardial effusion are the most common complications of ablation procedures and stroke is perhaps the most feared complication. Anticoagulation strategies seek to mitigate these risks. Very little information is available to guide the management of anticoagulation in patients undergoing ablation for ventricular arrhythmias. This study provides the most detailed report to date of periprocedure antithrombotic management along with bleeding and embolism complications (**Central Illustration**). We found that antithrombotic management is complex in part because the majority of patients are receiving various antithrombotic agents for a variety of indications prior to the procedure. Despite the diversity of antithrombotic regimens before and after the ablation procedure, clinically apparent cerebral embolic events were rare, with stroke occurring in only 2 patients (0.3%) and 1 patient having a possible transient ischemic attack. The most common serious complication was pericardial bleeding in 1.7%. The most common bleeding complications were related to vascular access and occurred in 4.2%. The preprocedure use of non-ASA antiplatelet agents and DOACs were associated with an increased chance of bleeding complications.

THROMBOEMBOLIC EVENTS. In multiple reports encompassing over 3,000 patients undergoing ablation for ventricular arrhythmias, stroke was reported in 0%-2.7% of patients.[2,3,5,6,11] The 0.3% incidence in the present study is in line with these previous reports. Antithrombotic regimens for ventricular arrhythmia have received limited attention. A recent scientific statement gives a class IIa recommendation

to the use of antiplatelet agents for "less extensive" ablation and a class IIb recommendation for unspecified oral anticoagulant therapy post-VT ablation after "extensive" ablation; these recommendations are based on expert consensus.[2] In addition, recent reports suggest that a re-examination of embolic events is warranted.[7,8] A study of cerebral magnetic resonance imaging pre- and postablation showed that 58% of patients had evidence of asymptomatic emboli.[7] A recent randomized trial in patients with ischemic or nonischemic cardiomyopathy undergoing LV ablation for VT or PVCs compared ASA 81 mg/d to DOACs initiated 3 hours after the ablation procedure.[8] They reported a 6.5% incidence of symptomatic stroke and 17.9% incidence of transient ischemic attack in the ASA-treated group, which is a strikingly high rate when contrasted with other available data. That study suggested that low-dose ASA may not be effective for post-RF ablation therapy and routine use of DOACs was suggested. We agree that low-dose ASA may be insufficient. In our cohort, only 5.0% of patients received 81 mg of ASA alone after the procedure. Although there were no strokes in this group, it is too small to meaningfully assess risk. Our study included a broader range of patients, with 72.7% with cardiomyopathy and 84.9% with LV ablation sites. Differences in the patient population and our routine administration of heparin prior to transeptal puncture may have also contributed to a lower risk in our population. It is not clear, however, that a DOAC is superior to a higher dose of ASA or other antiplatelet agents. There were no strokes among the 330 patients, comprising one-half of our population, treated with ASA 325 mg/d. Previous series have also used 325 mg of ASA without embolic events.[5] The present study suggests that this dose of ASA is reasonable for many patients post ventricular ablation. However, it is important to recognize that those at highest risk were generally treated with more aggressive regimens. The antithrombotic regimen was left to the treating physician. Prior to the procedure, 25% of patients were receiving warfarin or a DOAC, and this was generally continued afterward. Of 387 patients who were receiving no antithrombotic medication or only low-dose ASA prior to the procedure, warfarin or a DOAC was started after the procedure in 35 (9.0%) because the investigator perceived an increased risk in these patients, which in our practice is generally associated with poor ventricular function and ablation over large areas of ventricular scar. That DOACs can be avoided for most patients has important implications. The cost of daily therapy with DOACs can be more than 200-fold greater than for ASA and can be a factor in the patient's ability to comply with treatment.

Preprocedure antithrombotic therapy is another factor that may be contributing to the low risk of embolic events in our study and that has not previously been assessed in patients undergoing ablation for ventricular arrhythmias. Consistent with the prevalence of coronary artery disease and atrial fibrillation in our population, 70% of patients were receiving antiplatelet or oral anticoagulant

TABLE 5 Univariable Analysis for Risk of Bleeding Complications

	Total	Bleeding Complication	Without Bleeding Complication	*P* Value
Age, y	64 (54-73)	68 (59-76)	64 (54-72)	0.016
Male	473 (71.3)	24 (63.2)	449 (71.8)	0.269
Body mass index, kg/m^2	29.1 (25.5-33.6)	27.5 (24.2-32.0)	29.1 (25.5-33.7)	0.244
Creatinine	1.02 (0.84-1.27)	1.01 (0.79-1.30)	1.02 (0.84-1.26)	0.734
VT ablation	308 (46.5)	21 (55.3)	287 (45.9)	0.262
Structural heart disease	318 (50.9)	21 (55.3)	318 (50.9)	0.600
Cardiomyopathy	482 (72.7)	28 (73.7)	454 (72.6)	0.888
Retrograde approach	275 (41.5)	13 (34.2)	25 (41.9)	0.399
Femoral arterial sheath	506 (76.3)	31 (81.6)	475 (76)	0.556
Preprocedure				
None	199 (30.0)	7 (18.4)	192 (30.7)	0.144
ASA	351 (52.9)	21 (55.3)	330 (52.8)	0.867
Non-ASA antiplatelet	98 (14.8)	11 (29.0)	87 (13.9)	0.018
DOAC	97 (14.6)	10 (26.3)	87 (13.9)	0.054
Warfarin	66 (10.0)	2 (5.3)	64 (10.2)	0.415

Values are n (%) or median (Q1-Q3). Fisher exact tests were used for categorical variables. Wilcoxon rank-sum tests were used for continuous variables. Non-ASA antiplatelet regimens include clopidogrel, prasugrel, ticagrelor, or cilostazol. Combination regimens are warfarin or DOAC with ASA or other antiplatelet agent. VT ablation includes VT ablation or both VT and PVC ablation.

Abbreviations as in Tables 2 and 3.

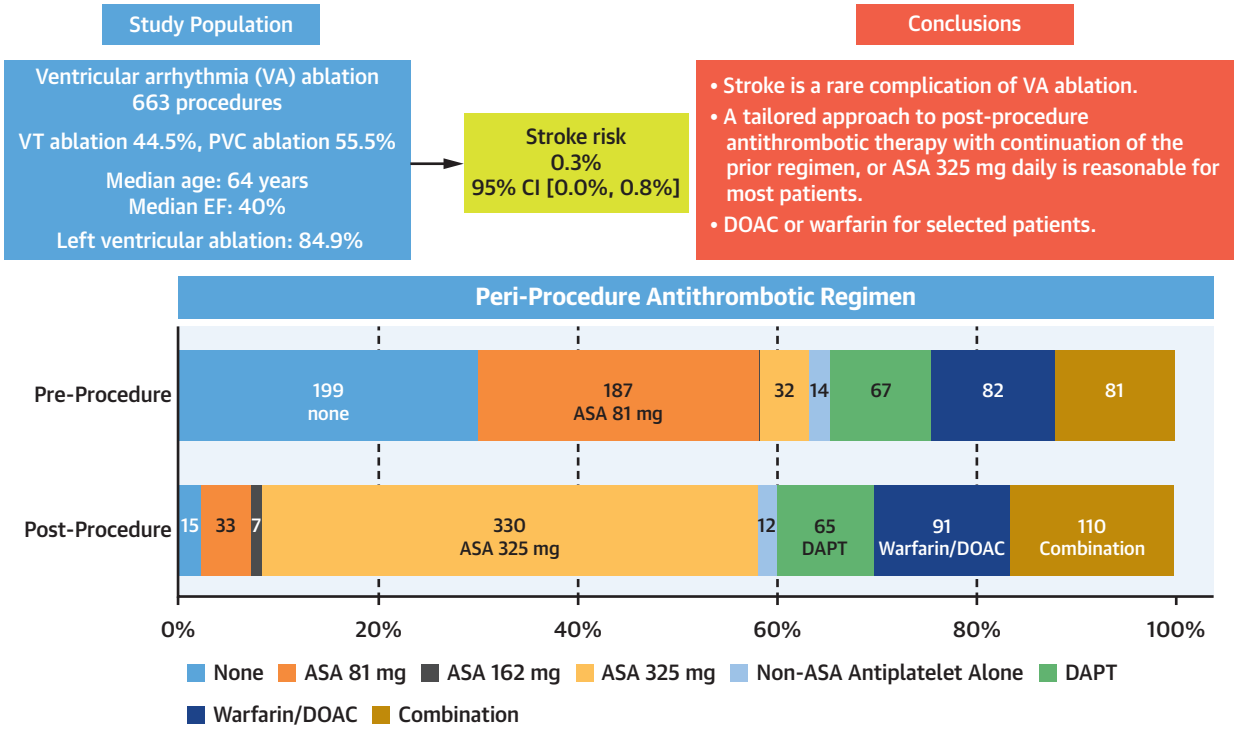
TABLE 6 Multivariable Model for Risk of Bleeding Complications

	OR (95% CI)	*P* Value
Age	1.027 (0.996-1.060)	0.088
Male Sex	0.333 (0.149-0.749)	0.008
Body mass index	0.977 (0.922-1.036)	0.446
Creatinine	1.152 (0.581-2.286)	0.685
Retrograde approach	0.647 (0.298-1.408)	0.273
Femoral arterial sheath	2.105 (0.825-5.369)	0.119
Preprocedure		
ASA	1.163 (0.561-2.413)	0.685
Non-ASA antiplatelet	2.846 (1.269-6.384)	0.011
DOAC	2.585 (1.083-6.169)	0.032
Warfarin	0.599 (0.132-2.715)	0.506

Non-ASA antiplatelet regimens include clopidogrel, prasugrel, ticagrelor, or cilostazol. Combination regimens are warfarin or DOAC with ASA or other antiplatelet agent.

Abbreviations as in Table 3.

CENTRAL ILLUSTRATION **Antithrombotic Regimens of Ablation for Ventricular Arrhythmias**



Hasegawa K, et al. J Am Coll Cardiol EP. 2023;■(■):■–■.

ASA = aspirin; DOAC = direct oral anticoagulant; EF = ejection fraction; PVC = premature ventricular contraction; VA = ventricular arrhythmia; VT = ventricular tachycardia.

medications prior to ablation. Our data do not allow assessment of whether this contributes to safety, as is felt to be the case for atrial fibrillation ablation procedures.[12] There does appear to be a small increase risk of bleeding for patients on non-ASA antiplatelet agents or DOACs, raising further concern around recommendations for their routine use postablation.

BLEEDING. The 1.7% incidence of pericardial effusion in the present study is consistent with previous reports.[13,14] As in prior studies, vascular access bleeding is the most common serious procedure complication. We commonly use ultrasound-guided vascular access, which has been shown to decrease vascular complications,[15] although this is at the discretion of the operator. The use of a larger atrial sheath (≥7.0-F) was reported to be associated with a high risk of femoral vascular events in atrial fibrillation ablation.[16] In our study, the size of the arterial sheath was not associated with increased bleeding complications, though our number of bleeding events is insufficient to detect small differences. Not surprisingly, preprocedure DOACs or non-ASA antiplatelet agents were associated with an increased risk of bleeding complications.

STUDY LIMITATIONS. Evidence of emboli was sought based on postprocedure examination and symptoms. Clinically silent events of emboli that have been described on routine magnetic resonance imaging would not have been detected in this study and is an important area for continued research. The significance of these, however, remains a topic of debate, and it seems likely that most occur during the procedure such that they would be less likely to be influence by the postprocedure anticoagulation regimen. A strength of our study is the prospective follow-up for complications. All patients were examined after the procedure, although a detailed neurologic examination was not performed in the absence of symptoms or gross findings. Initial follow-up after hospital discharge was by a telephone call for patients who were not seen in clinic. Thus, late occurring asymptomatic neurologic events would not have

been detected. The very small number of symptomatic emboli precludes evaluation of predictors. This was a single-center study and antithrombotic regimens were at the discretion of the treating physicians. Because our major focus is on stroke, we excluded patients undergoing percutaneous epicardial ablation procedures due to the increased bleeding risks and anticoagulation management complexity in these patients, as we have previously reported.[17] Other factors that may have contributed to a low incidence of embolic and bleeding events but could not be assessed include infrequent use of mechanical hemodynamic support and the routine use of intracardiac ultrasound during the procedures. Administration of intravenous heparin was also used selectively before and after the procedure in some patients before transitioning to an oral regimen.

CONCLUSIONS

For patients undergoing endocardial catheter ablation for ventricular arrhythmias the incidence of postprocedure embolic events is very low using ASA 325 mg/d as a minimal postprocedure regimen with more potent regimens for selected patients. For the 70.0% of patients receiving anticoagulation or antiplatelet therapy preprocedure, continuing these regimens after the procedure appears reasonable. Low-dose ASA alone was rarely used in our study and may be insufficient. Only 6% of patients received a new regimen with a DOAC or warfarin, and therefore our data do not support the routine use of DOACs after ablation of ventricular arrhythmias.

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PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: Arterial embolism is a serious potential complication of catheter ablation for ventricular arrhythmias and antithrombotic therapy is warranted. Of patients undergoing catheter ablation for ventricular arrhythmias, 70% are receiving antithrombotic medications for other indications and the incidence of periprocedural embolism is very low. Following ablation for ventricular arrhythmias, an individualized approach to antithrombotic therapy with aspirin 325 mg daily for most patients and more potent anticoagulants for selected patients is associated with a very low risk of embolic events.

TRANSLATIONAL OUTLOOK: A precision medicine approach for guiding antithrombotic regimens in patients requiring ablation for ventricular arrhythmias can potentially select the regimen according to the patients' profile.

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KEY WORDS ablation, bleeding, complication, stroke, ventricular arrhythmia

APPENDIX For supplemental figures and tables, please see the online version of this paper.