Systematic review and meta-analysis of catheter ablation of ventricular tachycardia in ischemic heart disease

Brandon K. Martinez, PharmD,[1,2] William L. Baker, PharmD,[1,2] Anna Konopka, PharmD,[1] Devon Giannelli, PharmD,[1] Craig I. Coleman, PharmD,[1,2] Jeffrey Kluger, MD,[3,4] Edmond M. Cronin, MB, BCh, BAO, FHRS, CCDS, CEPS-A[3,4]

Document Reviewers: Samuel J. Asirvatham, MD, FHRS; Sabine Ernst, MD, PhD.

From the [1]University of Connecticut School of Pharmacy, Storrs, Connecticut, [2]Hartford Hospital Evidence-Based Practice Center, Hartford, Connecticut, [3]Hartford HealthCare Heart and Vascular Institute, Hartford Hospital, Hartford, Connecticut, and [4]University of Connecticut School of Medicine, Farmington, Connecticut.

BACKGROUND Patients with ischemic heart disease (IHD) are at risk for ventricular tachycardia (VT). Catheter ablation (CA) may reduce this risk.

OBJECTIVE To perform a systematic review and meta-analysis of randomized controlled trials (RCTs) of CA of VT in patients with IHD.

METHODS Literature searches of MEDLINE, the Cochrane Central Register of Controlled Trials (CENTRAL), and the Cochrane Database of Systematic Reviews (CDSR) were performed from January 2000 through April 2018 to identify RCTs comparing a strategy of CA vs no ablation in patients with IHD and an implantable cardioverter defibrillator (ICD). Outcomes of interest included appropriate ICD therapies, appropriate ICD shocks, VT storm, recurrent VT/ventricular fibrillation (VF), cardiac hospitalizations, and all-cause mortality. Using an inverse variance random-effects model, odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for each endpoint.

RESULTS A total of 5 RCTs (N = 635 patients) were included, with a duration of follow-up ranging from 6 months to 27.9 months. Patients who underwent CA experienced decreased odds of appropriate ICD therapies (OR 0.49; 95% CI 0.28–0.87), appropriate ICD shocks (OR 0.52; 95% CI 0.28–0.96), VT storm (OR 0.64; 95% CI 0.43–0.95), and cardiac hospitalization (OR 0.67; 95% CI 0.46–0.97) vs those who did not undergo ablation. There was no evidence of a benefit for recurrent VT/VF (OR 0.87; 95% CI 0.41–1.85), although this endpoint was not reported in all trials, or for all-cause mortality (OR 0.89; 95% CI 0.60–1.34).

CONCLUSION In this systematic review and meta-analysis of RCTs, CA was associated with a significant reduction in the odds of appropriate ICD therapies, appropriate ICD shocks, VT storm, and cardiac hospitalizations in patients with IHD.

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Background

Patients with ischemic heart disease (IHD) are at increased risk of incident or recurrent ventricular tachycardia (VT), ventricular fibrillation (VF), and sudden cardiac death. Implantable cardioverter defibrillators (ICDs) are the mainstay of treatment to reduce the incidence of sudden cardiac death by terminating ventricular arrhythmias either by antitachycardia pacing (ATP) or by delivering a shock.[1–3] However, ICD shocks, whether appropriate or inappropriate, can have negative effects on patients' quality of life[4–7] and are associated with an increased risk of subsequent mortality.[8,9] Thus, therapies that can effectively reduce the risk of ICD shocks are of great importance. Catheter ablation (CA) of VT has become established as a means to treat VT and prevent recurrence.[10] Several randomized controlled trials (RCTs) have been conducted comparing CA with other strategies, such as antiarrhythmic drug (AAD) therapy or control, in patients with IHD.

The Heart Rhythm Society (HRS), the European Heart Rhythm Association (EHRA), the Asia Pacific Heart Rhythm Society (APHRS), and the Latin American Heart Rhythm Society (LAHRS), in collaboration with the American Heart Association (AHA), the American College of Cardiology (ACC), the Japanese Heart Rhythm Society (JHRS), the Brazilian Society of Cardiac Arrhythmias (Sociedade Brasileira de Arritmias Cardíacas [SOBRAC]), and the Pediatric and Congenital Electrophysiology Society (PACES), appointed a writing committee to draft an expert consensus statement to update the 2009 *EHRA/HRS Expert Consensus on Catheter Ablation of Ventricular Arrhythmias*.[10] The Scientific and Clinical Documents Committee of HRS recognized the need for a high-quality systematic review and meta-analysis of the published literature by an Evidence Review Committee (ERC) to inform recommendations. Such an effort must be directed toward areas where key clinical questions can be formed and where published data exist. Here, we report the findings of this effort, with the purpose of evaluating the use of CA in preventing VT events in patients with IHD through a systematic review and meta-analysis. For transparency, ERC members' comprehensive disclosure information is available in Appendix 1, as is comprehensive disclosure information for the peer reviewers in Appendix 2.

Methods

This meta-analysis conforms to standard guidelines and is written in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[11] The PICOT format (P = population, I = intervention, C = comparator, O = outcome, T = timing, S = setting)[12] was used to derive the key clinical question. This question was, "In adults with a history of sustained ventricular tachycardia and ischemic cardiomyopathy, what are the effectiveness and harms of catheter ablation compared to other interventions?"

Data Sources and Search Strategy

We systematically searched MEDLINE, the Cochrane Central Register of Controlled Trials (CENTRAL), and the Cochrane Database of Systematic Reviews (CDSR) from January 2000 through April 2018 to identify RCTs comparing a strategy of CA vs no ablation in patients with IHD, an ICD, and a history of VT. The following Medical Subject Headings (MeSH) and keywords were used: ventricular tachycardia, ventricular arrhythmia, ventricular fibrillation, catheter ablation, antiarrhythmic agents, and antiarrhythmic drug. All searches were limited to full-text articles published in English. A manual search of references from included studies was also performed.

Study Selection

For the title, abstract, and full-text article review, two investigators independently examined all potentially relevant citations and articles in a parallel manner, using predefined inclusion and exclusion criteria. Studies were included in this systematic review and meta-analysis if they 1) were RCTs; 2) enrolled adults (>18 years of age); 3) enrolled patients with IHD implanted with an ICD and a history of spontaneous VT or syncope with inducible VT; 4) had at least one CA treatment group; and 5) had outcomes of interest data suitable for pooling. Studies were excluded if they were case reports, reviews, editorials, or non-English language publications. The outcomes of interest included appropriate ICD therapies (ICD shock or ATP), appropriate ICD shocks, VT storm (defined as ≥3 shocks within 24 hours), recurrent VT/VF, cardiac hospitalizations, and all-cause mortality.

Data Extraction

For each study, two investigators used a standardized data abstraction tool to extract all the relevant and specific information. Disagreements were resolved by consensus. Information collected from each study included author, year of publication, interventions, sample size, key inclusion criteria, months of follow-up, class I or III AADs, other cardiovascular drugs, time to last myocardial infarction (MI), prior revascularization, and pertinent patient characteristics. Study authors were contacted for clarification of information not covered in the publication. All included studies are multicenter prospective RCTs. The risk of bias for each study was independently assessed by two investigators using the Cochrane Risk of Bias Tool.[13] This tool includes 7 items covering the following domains: selection bias due to inadequate generation of a randomized sequence, or inadequate concealment of allocations prior to assignment; performance bias due to knowledge of the allocated interventions by participants and personnel during the study; detection bias due to knowledge of the allocated interventions by outcome assessors; attrition bias due to amount, nature, or handling of incomplete outcome data; reporting bias due to selective outcome reporting; and other bias due to problems not previously covered.[13]
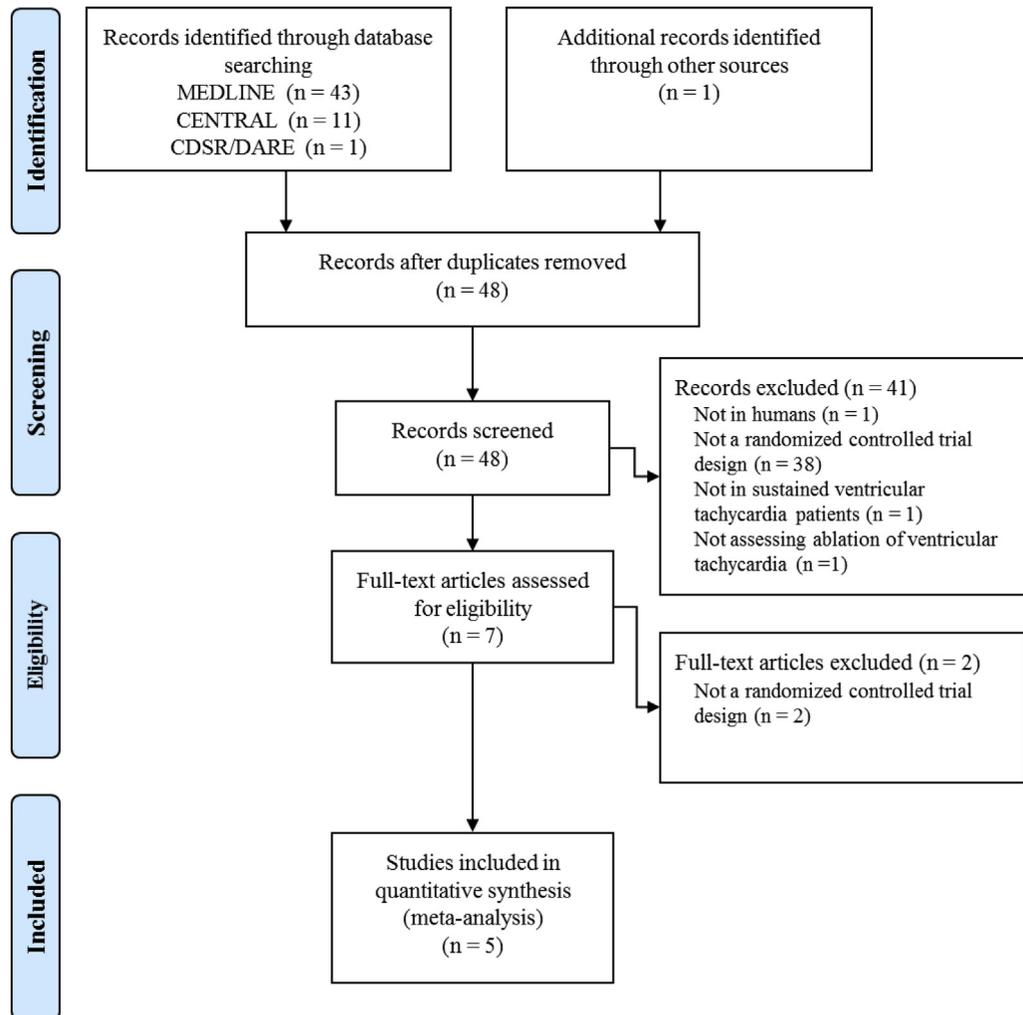
Figure 1 PRISMA flow diagram.

Statistical Analysis

All outcome data were pooled using an inverse variance random-effects model producing odds ratios (ORs) and accompanying 95% confidence intervals (CIs) for each endpoint, with between-study heterogeneity (τ^2) calculated using the Paule-Mandel estimator. The I^2 statistic was calculated to estimate the percentage of variability in the treatment estimate attributable to statistical heterogeneity between studies, with a value >50% considered substantial.[14] Small study effects, including publication bias, were not examined, given fewer than 10 eligible studies were identified. All analyses were performed using the 'meta' package in R (version 3.4.3; the R Project for Statistical Computing).

In order to better quantify the effects of CA on our outcomes of interest, we conducted a random-effects meta-regression via iterative maximum likelihood.[15] An analysis evaluating the impact of baseline amiodarone therapy on each of the outcomes of interest was performed. The percentage of patients administered baseline amiodarone was used to conduct meta-regression to examine whether baseline amiodarone therapy altered the effectiveness of CA.

Results

The inclusion and exclusion of citations and articles identified through our systematic literature search is illustrated in Figure 1. A total of 5 studies evaluating the use of CA in patients with IHD and an ICD published between 2007 and 2017 were included in the analysis (Table 1).[16–20] All included studies were multicenter RCTs. Individual study sample sizes ranged from 27 patients to 259 patients. The mean patient age ranged from 64 years to 68 years, and the duration of follow-up was 6–27.9 months. The time to last MI ranged from <1 year to 15.7 years. The use of AADs varied between studies. The Substrate Mapping and Ablation in Sinus Rhythm to Halt Ventricular Tachycardia (SMASH-VT) study excluded patients treated with class I or III antiarrhythmics[20]; 3 studies included between 32% and 37% of patients treated with amiodarone and sotalol[16,18,19]; and the

Table 1 Baseline characteristics of included studies

Study Year N	Interventions (N)	Key inclusion criteria	Actual FU (months)	LVEF	NYHA class	Age, years (range of means)	Other CV drugs	Class I or III AADs	Time to last MI, years	Prior revascularization
SMS 2017 N = 111	Catheter ablation (N = 54) No ablation (N = 57)	CAD, LVEF ≤40%, and clinically unstable spontaneous VT; or cardiac arrest or syncope with unstable VT inducible at electrophysiological study	27.6 ± 13.2	≤30 = 45% >30 = NR	I–III = 100% IV = 0%	66–68	ACEI/ARB = 95% BB = 91% Digoxin = NR Diuretic = NR Statin = NR ASA = NR AC = NR	32% (amiodarone)	9.8 ± 7.3	PCI = 46% Surgical = 42%
VANISH 2016 N = 259	Catheter ablation + background of AAD (N = 132) No ablation + escalation of AAD (N = 127)	Previous MI; undergone placement of an ICD; had an episode of VT during treatment with amiodarone or another class I or III AAD within the previous 6 months	27.9 ± 17.1	31 (mean)	I = 24% II = 53% III = 24% IV = 0%	67–70	ACEI/ARB = 88% BB = 95% Digoxin = 20% Diuretic = 69% Statin = NR ASA = 71% AC = 43%	100%	15.7	PCI = 43% CABG = 46%
CALYPSO 2015 N = 27	Catheter ablation + no AAD (N = 13) No ablation + AAD (N = 14)	ICD implanted for primary or secondary prevention indication; IHD; ≥1 documented ICD shock or ≥ 3 ATP therapies within 6 months for monomorphic VT	92% completed 3 months; 71% completed 6 months	23%–25% (range of medians)	I = 19% II = 30% III = 15% IV = 0%	64–65	ACEI/ARB = 93% BB = 93% Digoxin = NR Diuretic = NR Statin = 85% ASA = NR AC = NR	37% (amiodarone and sotalol)	<1 year = 7% 1–2 years = 0% >2 years = 41% Unknown = 48%	PCI = 52% CABG = 59%
VTACH 2010 N = 110	Catheter ablation (N = 54) No ablation (N = 56)	Indication for ICD as secondary prevention after documented stable clinical VT without a reversible cause; CAD; previous MI; and LVEF ≤50%	22.5 ± 9	≤30 = 40% >30 = 60%	NR	64–68	ACEI/ARB = NR BB = 75% Digoxin = NR Diuretic = NR Statin = NR ASA = NR AC = NR	35% (amiodarone)	12.9 ± 8.2	PTCA = 47% Surgical = 45%
SMASH-VT 2007 N = 128	Catheter ablation (N = 64) No ablation (N = 64)	MI ≥1 month; undergone a planned or recent (within 6 months) implantation of a defibrillator for VF, hemodynamically unstable VT, or syncope with inducible VT; class I or class III AAD-naïve	22.5 ± 5.5	≤30 = 52% >30 = 48%	I/II = 80% III/IV = 20%	66–67	ACEI/ARB = 92% BB = 96% Digoxin = NR Diuretic = NR Statin = 59% ASA = 71% AC = NR	0%	7.9–8.8 (range of means)	PTCA/ CABG = 67%

AAD = antiarrhythmic drug; AC = anticoagulant; ACEI = angiotensin converting enzyme inhibitor; ARB = angiotensin II receptor blocker; ASA = aspirin; ATP = antitachycardia pacing; BB = beta blocker; CABG = coronary artery bypass grafting; CAD = coronary artery disease; CV = cardiovascular; FU = follow-up; ICD = implantable cardioverter defibrillator; IHD = ischemic heart disease; LVEF = left ventricular ejection fraction; MI = myocardial infarction; N = number; NR = not reported; NYHA = New York Heart Association; PCI = percutaneous coronary intervention; PTCA = percutaneous transluminal coronary angioplasty; SMASH-VT = Substrate Mapping and Ablation in Sinus Rhythm to Halt Ventricular Tachycardia; VF = ventricular fibrillation; VT = ventricular tachycardia.
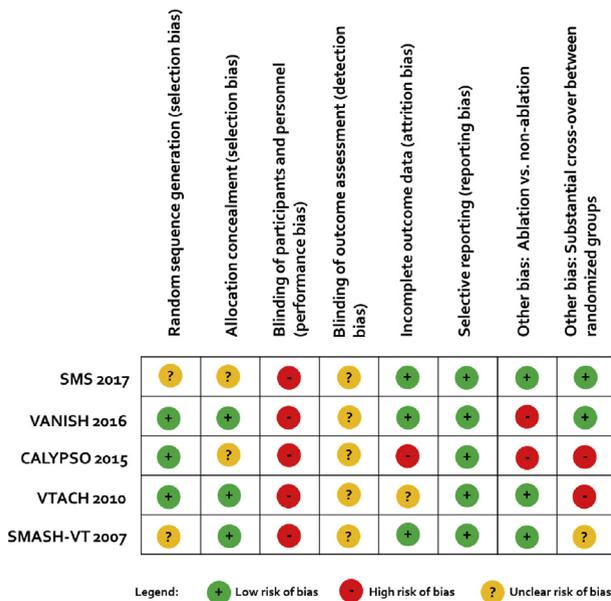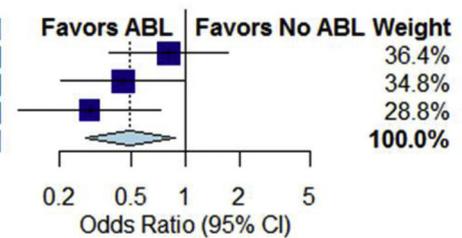
Figure 2 Cochrane risk of bias assessment.

Ventricular Tachycardia Ablation versus Escalated Antiarrhythmic Drug Therapy in Ischemic Heart Disease (VANISH) trial required patients to have received background amiodarone or another class I or class III AAD within the previous 6 months.[17] ICD programming was standardized in each study; however, recommendations varied between studies. Three studies reported the incidence of ICD therapies,[16,19,20] 4 studies reported ICD shocks and VT storm,[15,16,18,19] all studies reported all-cause mortality,[16–20] 4 studies reported hospitalizations for cardiac cause,[15–18] and 3 studies reported recurrent VT/VF.[16,18,19] Trial investigators provided additional outcome results: appropriate ATP or appropriate shocks in VANISH; and appropriate ATP or appropriate shocks, VT storm, and cardiac hospitalizations in Catheter Ablation for Ventricular Tachycardia in Patients with an Implantable Cardioverter Defibrillator (CALYPSO). The majority of studies were at low risk for selection bias, attrition bias, and reporting bias. All studies were at high risk of performance bias due to a lack of blinding of participants and personnel, given the

Figure 3 Pooled odds of appropriate ICD therapies (A), appropriate ICD shocks (B), and all-cause mortality (C). ABL = ablation; CI = confidence interval; ICD = implantable cardioverter defibrillator; OR = odds ratio.

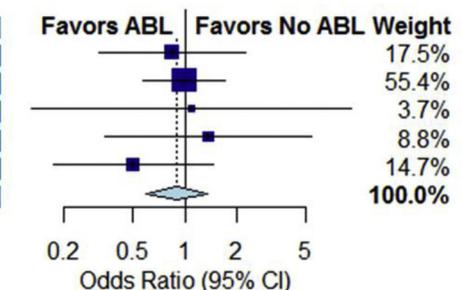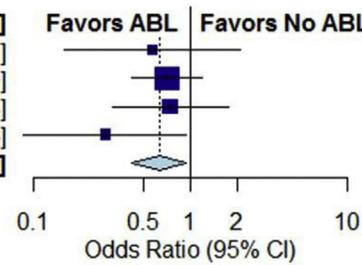**Figure 4**   Pooled odds of VT storm (A), recurrent VT/VF (B), and cardiac hospitalizations (C). ABL = ablation; CI = confidence interval; OR = odds ratio; VF = ventricular fibrillation; VT = ventricular tachycardia.

nature of patients being randomized to receiving a procedure or no procedure. Two studies were determined to be at high risk of other biases due to their study design comparing patients who received an ablation with those who received changes in AAD therapy.[17,18] Additionally, 2 studies were determined to possess a high risk of other biases due to substantial crossover between randomized groups throughout the study (Figure 2).[18,19]

Upon meta-analysis, patients who were randomized to CA had decreased odds of appropriate ICD therapies (OR 0.49; 95% CI 0.28–0.87), appropriate ICD shocks (OR 0.52; 95% CI 0.28–0.96), VT storm (OR 0.64; 95% CI 0.43–0.95), and cardiac hospitalizations (OR 0.67; 95% CI 0.46–0.97) vs those who did not undergo CA. There was no evidence of a significant difference in the odds of recurrent VT/VF (OR 0.87; 95% CI 0.41–1.85) or all-cause mortality (OR 0.89; 95% CI 0.60–1.34) between the ablation and no ablation groups (Figures 3 and 4).

Post Hoc Sensitivity Analysis and Meta-Regression
The VANISH and CALYPSO trials differed from the other studies included in this meta-analysis in that they compared CA with AAD therapy. Patients in the VANISH trial were randomly assigned to receive either CA (ablation group) with continuation of baseline AADs or escalated AAD therapy (escalated-therapy group).[17] The CALYPSO trial was a comparison of AADs with CA.[18] Due to the differences in trial design, we ran a sensitivity analysis with the removal of these two trials. Upon analysis, the removal of the VANISH and CALYPSO trials decreased the between-study heterogeneity ($I^2 = 0\%$ vs 65%) and showed a greater effect of ablation on appropriate ICD shocks (OR 0.38; 95% CI 0.22–0.64). The removal of these two studies resulted in lower odds of VT storm (OR 0.55; 95% CI 0.30–1.01), cardiac hospitalizations (OR 0.58; 95% CI 0.29–1.15), recurrent VT/VF (OR 0.71; 95% CI 0.34–1.50), and all-cause mortality (OR 0.77; 95% CI 0.41–1.46); however, statistical significance was lost for some outcomes, likely due to type 2 error (Figure 5). A random-effects meta-regression showed no significant association between baseline amiodarone therapy and appropriate ICD therapies ($P = .27$), VT storm ($P = .35$), cardiac hospitalizations ($P = .65$), or all-cause mortality ($P = .43$). There was, however, a significant association between baseline amiodarone therapy and appropriate ICD
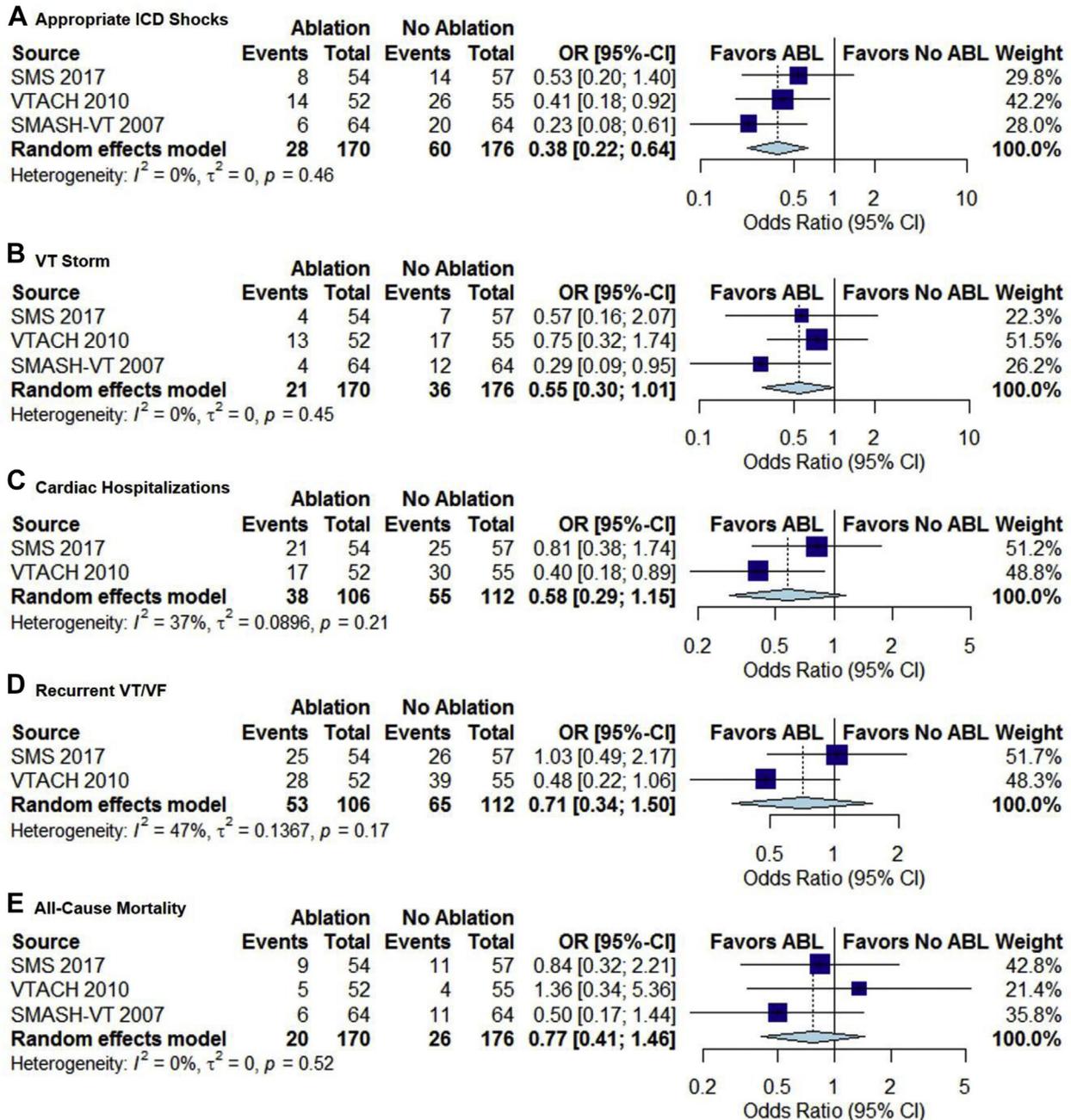
Figure 5 Sensitivity analysis of appropriate ICD shocks (A), VT storm (B), cardiac hospitalizations (C), recurrent VT/VF (D), and all-cause mortality (E). ABL = ablation; CI = confidence interval; ICD = implantable cardioverter defibrillator; OR = odds ratio; VF = ventricular fibrillation; VT = ventricular tachycardia.
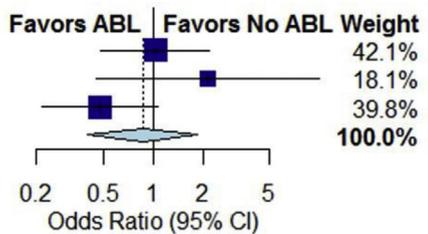
shocks ($P < .01$). A negative association was seen: as the percentage of patients on concomitant AAD therapy increased, the effectiveness of CA in preventing appropriate ICD shocks decreased (Figure 6).

Adverse Events
Adverse events were variably defined, and some protocols mandated ICD implantation at or soon after randomization, making attribution of adverse events to the ablation procedure or the ICD implantation procedure difficult. However, adverse events related to the ablation procedure

occurred in 30 of 315 (9.5%) patients in the ablation arms of the included trials. Adverse events in the control arms were not reported uniformly due to variations in control strategies. In the two trials that directly compared ablation versus AAD therapy, adverse events were more common in the AAD arm than in the ablation arm.[17,18]

Discussion
In this systematic review of the literature and a meta-analysis of 5 RCTs, we found that CA reduced the likelihood of appropriate ICD therapies, appropriate ICD shocks, VT
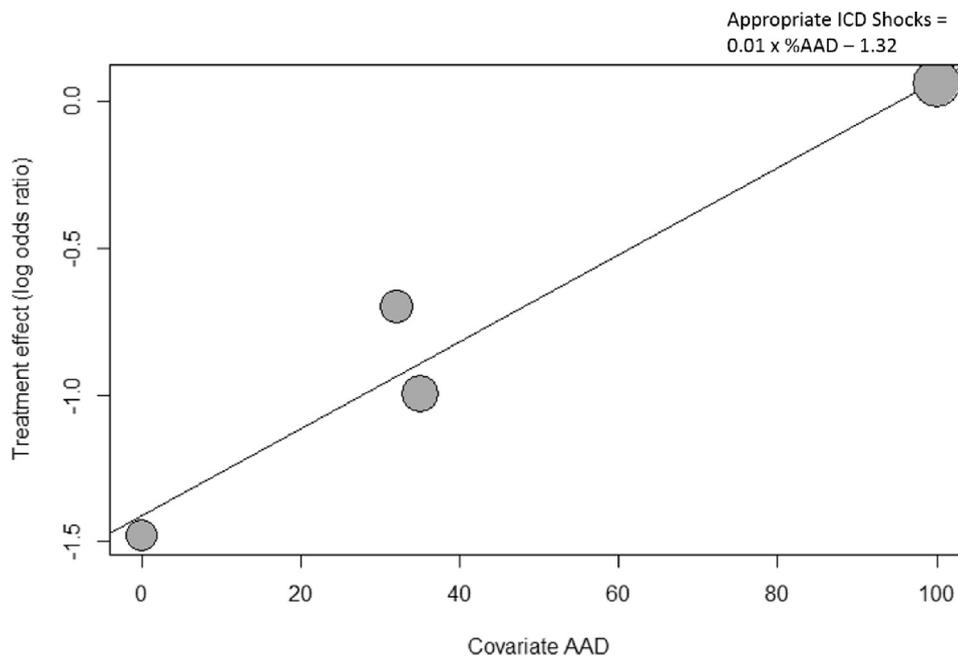
Figure 6 Random-effects meta-regression evaluating relationship between percentage of concomitant AAD and effectiveness of catheter ablation on reduction of appropriate ICD shocks. The circles represent individual studies, with the size of the circle proportional to the weight of each study. The line represents the best fit line describing the relationship between the percent AAD use in each study (x-axis) and the effect on appropriate ICD shocks (y-axis). As the percentage of AAD users in the studies increased, the beneficial effect of catheter ablation on reducing appropriate ICD shocks decreased. AAD = antiarrhythmic drug; ICD = implantable cardioverter defibrillator.

storm, and cardiac hospitalization vs controls. In a sensitivity analysis, excluding the 2 studies that specifically randomized patients to CA versus AAD, the magnitude of such reductions was increased, although CIs also widened. This result might suggest an effect of AAD in reducing the risk of VT recurrence and ICD therapies, as found in earlier pharmacotherapy trials.[21,22]

Although at first it might appear contradictory that ablation reduced the risk of several VT-related endpoints, but not recurrent VT/VF, this contradiction is likely explained by the different endpoints reported by the trials, meaning some trials did not contribute data to each endpoint in our analysis. For example, only 3 trials, including fewer than half of the total of 635 patients, contributed to the recurrent VT/VF endpoint. In contrast, 4 of 5 trials, including >95% of the total number of patients, contributed to the appropriate ICD shocks and VT storm endpoints; and all trials contributed to the all-cause mortality endpoint, leading to a higher degree of confidence for these findings. Overlap of events was possible; for example, slow VT underdetection of an ICD could count toward recurrent VT/VF but not toward appropriate ICD therapies.

The finding that baseline amiodarone therapy was associated with appropriate ICD shocks could indicate that patients receiving amiodarone had more advanced heart disease, as reported in a subgroup analysis of VANISH,[23] and therefore were at higher risk of receiving ICD shocks. It is also possible that amiodarone was stopped after an acutely successful ablation procedure in some patients, with subsequent recurrence of VT that had been suppressed

by amiodarone therapy. However, these interpretations are hypotheses that require confirmation. Of note, only VANISH included a 30-day "blanking" period to allow for full loading of amiodarone[17]; in the other trials, the duration of amiodarone therapy prior to an endpoint was not reported.

Our results are largely consistent with several other investigations in this field. Three previous meta-analyses did not include the most recently published trials,[24–26] or included studies available only in abstract form.[24] One systematic review and meta-analysis has focused on prophylactic CA only (excluding trials in which patients were randomized to AAD).[27] However, one of these trials enrolled patients who had received their first ICD shock from a primary prevention ICD after a protocol amendment,[20] whereas the other two enrolled patients after a qualifying VT event, and permitted AAD therapy in both arms.[16,19] In practice, the choice between starting or changing AAD therapy on the one hand, vs CA on the other, is often the most relevant decision to be made. This question was addressed by two of the included trials.[17,18] Due to the small size of one of these trials, a separate meta-analysis of these two was not performed. A recent systematic review and meta-analysis of the effect of AAD and CA in patients with an ICD (including substrates other than IHD) is also available.[28] The current study is the only one to use an expert ERC to systematically review the literature on CA in IHD and perform a meta-analysis.

Our study has several limitations. The trials included in this analysis mandated the presence of an ICD, or

Table 2 Ablation strategy characteristics

Study Year N	Ablation strategy description	Mapping strategies N (%)	VT induction (Yes/No)	Endpoint	Epicardial approach %	Total radiofrequency time (min)	Fluoroscopy time (min)
SMS 2017 N = 111	Catheter ablation was to be performed before ICD implantation. Mapping criteria for ablation in stable VT and the lesion design for substrate modification in cases of noninducible or unstable VT followed standard criteria. Inducibility of the targeted VT was assessed by programmed stimulation using the same protocol as before ablation, stimulation at 2 sites in the right ventricle, with ≤3 extrastimuli at 2 drive cycle lengths.	CARTO electroanatomical system* 36 (75%) EnSite NavX system 10 (21%) Conventional mapping 2 (4%)	Yes	Success: Noninducibility of the clinical tachycardia Failure: Lack of adequate endocardial target sites or ineffective lesions despite adequate target sites	No	NR	NR
VANISH 2016 N = 259	Procedures followed a standardized approach that specifically targeted all inducible VTs. VT induction was with programmed ventricular stimulation from two ventricular sites at two drive cycle lengths with ≤3 extrastimuli, coupled not closer than 180 msec. If clinical VT was not induced, isoproterenol could be administered 0.5–10 mcg/min in a dose adjusted to achieve a 30% increase in baseline heart rate. Hemodynamically tolerated VT was approached with activation and entrainment mapping. Nontolerated VT was mapped with pace mapping and bipolar voltage mapping and linear ablation performed parallel to the scar margin. Very fast or noninducible clinical VT ablated with a pure substrate-based approach was used, targeting late potentials and sites with a long stimulus-QRS.	Activation mapping 92 (41.1%) Entrainment mapping 80 (35.7%) Substrate mapping 197 (87.9%) Pace mapping 168 (75.0%)	Yes	Noninducibility; very fast VT (cycle length <300 msec) and polymorphic VTs were not specifically targeted	NR	Catheter Ablation Group: 38.7 ± 21.9 Antiarrhythmic Group: 36.8 ± 20.6	Catheter Ablation Group: 31.5 ± 20.8 Antiarrhythmic Group: 29.4 ± 35.1

CALYPSO 2015 N = 27	Although endocardial ablation was the preferred ablation strategy in this trial, epicardial ablation was allowed only if the clinical VT could not be ablated via an endocardial approach. The only ablation catheter that was allowed in this study was the Biosense Webster NaviStar ThermoCool externally irrigated 3.5-mm electrode catheter.‡	The selection of the mapping system and details of methods for identifying reentry circuit sites were left to the discretion of the treating physician within guidelines based on whether the VTs were hemodynamically stable or not.	Yes	Success: Achieve noninducibility of clinical or presumptive clinical VT if the clinical or presumptive clinical VT was known and was inducible at the beginning of the procedure. Other acute procedural endpoints: 1) modification of induced VT cycle length (elimination of all VTs with cycle lengths equal to or longer than the spontaneously documented or targeted VT); 2) noninducibility of any VT	NR§	NR	NR
VTACH 2010 N = 110	Mapping criteria for ablation in stable VT and the lesion design for substrate modification in case of noninducible or unstable VT followed standard criteria.	CARTO electroanatomical system* 32 (71.1%) EnSite noncontact system† 11 (24.4%) Conventional mapping 2 (4.4%)	Yes	Success: Noninducibility of any VT at the end of the procedure. For patients with noninducible VT, the ablation endpoint was substrate modification, defined as absence of all channels inside the area of interest or ablation with linear lesions based on pace mapping along the infarct scar target sites	No	NR	NR
SMASH-VT 2007 N = 128	The ablation procedure was performed in sinus rhythm. The procedure was divided into 3 steps: 1) induction of VT; 2) localization of the myocardial infarct; and 3) targeting the "arrhythmogenic portions" of the infarct for catheter ablation. Programmed stimulation was performed using up to triple extrastimuli and rapid pacing from the right ventricular apex, right ventricular outflow tract, or left ventricle. If only VF or polymorphic VT was inducible, stimulation was repeated after first infusing a class I antiarrhythmic drug intravenously (procainamide or ajmaline). Catheter mapping and radiofrequency ablation were performed using either the NaviStar 4-mm tip*	CARTO electroanatomical system* was used in all procedures	Yes	VT was repeatedly induced until either the same VT morphology was induced, or the patient required multiple shocks to terminate induced rhythms during the procedure	NR	NR	NR

Table 2 (Continued)

Study Year N	Ablation strategy description	Mapping strategies N (%)	VT induction (Yes/No)	Endpoint	Epicardial approach %	Total radiofrequency time (min)	Fluoroscopy time (min)
	standard or the Thermocool 3.5-mm tip saline-irrigated catheter.*						

ICD = implantable cardioverter defibrillator; mm = millimeter; msec = millisecond; N = number; NR = not reported; SMASH-VT = Substrate Mapping and Ablation in Sinus Rhythm to Halt Ventricular Tachycardia; VF = ventricular fibrillation; VT = ventricular tachycardia.

*Biosense Webster, Diamond Bar, CA.
†Abbott Laboratories, Abbott Park, IL.
‡Diamond Bar, CA.
§Epicardial approach allowed, no percentages reported.

implantation of one soon after randomization. Although this requirement likely improved the sensitivity and uniformity of arrhythmia detection, it limits applicability of our results to patients with an ICD and cannot be extrapolated to those without. Different ablation techniques, technologies, and endpoints were used during the timeframe in which these studies were conducted (Table 2). Causes of death were not uniformly reported across all trials. The absolute number of deaths was small, therefore a separate analysis by cause of death (arrhythmic, cardiac, noncardiac) was not performed. We limited our analysis to trials published as a full peer-reviewed article. The authors are aware of at least 3 other prospective trials that were presented in abstract form, and other studies that were closed due to low enrollment and remain unpublished. How inclusion of these trials would have affected our results is unknown.

Conclusion
This systematic review and meta-analysis of 5 RCTs found that patients with IHD who underwent CA for VT experienced decreased odds of appropriate ICD therapies, appropriate ICD shocks, VT storm, and cardiac hospitalization vs those who did not undergo ablation.

Acknowledgments

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Appendix 1   Author disclosure table

Committee member	Employment	Honoraria/Speaking/Consulting	Speakers' bureau	Research*	Fellowship support*	Ownership/Partnership/Principal/Majority stockholder	Stock or stock options	Intellectual property/Royalties	Other
Brandon K. Martinez, PharmD	University of Connecticut School of Pharmacy, Storrs, Connecticut; Hartford Hospital Evidence-Based Practice Center, Hartford, Connecticut	None	None	None	None	None	None	None	None
William L. Baker, PharmD	University of Connecticut School of Pharmacy, Storrs, Connecticut; Hartford Hospital Evidence-Based Practice Center, Hartford, Connecticut	None	None	None	None	None	None	None	None
Anna Konopka, PharmD	University of Connecticut School of Pharmacy, Storrs, Connecticut	None	None	None	None	None	None	None	None
Devon Giannelli, PharmD	University of Connecticut School of Pharmacy, Storrs, Connecticut	None	None	None	None	None	None	None	None
Craig I. Coleman, PharmD	University of Connecticut School of Pharmacy, Storrs, Connecticut; Hartford Hospital Evidence-Based Practice Center, Hartford, Connecticut	None	None	None	None	None	None	None	None
Jeffrey Kluger, MD	Hartford HealthCare Heart and Vascular Institute, Hartford Hospital, Hartford, Connecticut; University of Connecticut School of Medicine, Farmington, Connecticut	None	None	None	None	None	None	None	None
Edmond M. Cronin, MB, BCh, BAO, FHRS, CCDS, CEPS-A	Hartford HealthCare Heart and Vascular Institute, Hartford Hospital, Hartford, Connecticut; University of Connecticut School of Medicine, Farmington, Connecticut	None	None	None	None	None	None	None	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.

*Research and fellowship support are classed as programmatic support. Sources of programmatic support are disclosed but are not regarded as a relevant relationship with industry for writing group members or reviewers.

Appendix 2   Reviewer disclosure table

Peer reviewer	Employment	Honoraria/ Speaking/ Consulting	Speakers' bureau	Research*	Fellowship support*	Ownership/ Partnership/Principal/ Majority stockholder	Stock or stock options	Intellectual property/ Royalties	Other
Samuel J. Asirvatham, MD, FHRS	Mayo Clinic College of Medicine, Rochester, Minnesota	1: Abbott; 1: BIOTRONIK; 1: Boston Scientific; 1: Medtronic	None	None	None	None	None	1: AliveCor	None
Sabine Ernst, MD, PhD	Royal Brompton and Harefield Hospitals, London, England	2: Biosense Webster; 2: Stereotaxis	None	3: Catheter Precision; 4: Baylis; 4: Spectrum Dynamics	None	None	None	None	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.
*Research and fellowship support are classed as programmatic support. Sources of programmatic support are disclosed but are not regarded as a relevant relationship with industry for writing group members or reviewers.