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Research Paper

Catheter ablation compared to medical therapy for ventricular tachycardia in sarcoidosis: nationwide outcomes and hospital readmissions

Michael I. Gurin [a,*], Yuhe Xia [b], Constantine Tarabanis [c], Randal I. Goldberg [a], Robert J. Knotts [a], Robert Donnino [a], Alex Reyentovich [a], Scott Bernstein [a], Lior Jankelson [a], Alexander Kushnir [a], Douglas Holmes [a], Michael Spinelli [a], David S. Park [a], Chirag R. Barbhaiya [a], Larry A. Chinitz [a], Anthony Aizer [a]

[a] Leon H. Charney Division of Cardiology, NYU Langone Health, New York University Grossman School of Medicine, New York City, NY, United States of America
[b] Department of Population Health, New York University Grossman School of Medicine, New York City, NY, United States of America
[c] Department of Medicine, NYU Langone Health, New York University School of Medicine, New York, NY, United States of America

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ABSTRACT

Background: Catheter ablation (CA) for ventricular tachycardia (VT) can be a useful treatment strategy, however, few studies have compared CA to medical therapy (MT) in the sarcoidosis population.
Objective: To assess in-hospital outcomes and unplanned readmissions following CA for VT compared to MT in patients with sarcoidosis.
Methods: Data was obtained from the Nationwide Readmissions Database between 2010 and 2019 to identify patients with sarcoidosis admitted for VT either undergoing CA or MT during elective and non-elective admission. Primary endpoints were a composite endpoint of inpatient mortality, cardiogenic shock, cardiac arrest and 30-day hospital readmissions. Procedural complications at index admission and causes of readmission were also identified.
Results: Among 1581 patients, 1217 with sarcoidosis and VT underwent MT compared to 168 with CA during non-elective admission. 63 patients admitted electively underwent CA compared with 129 managed medically. There was no difference in the composite outcome for patients undergoing catheter ablation or medical therapy during both non-elective (9.0 % vs 12.0 %, $p = 0.312$) and elective admission (3.2 % vs. 7.8 %, $p = 0.343$). The most common cause of readmission were ventricular arrhythmias (VA) in both groups, however, those undergoing elective CA were less likely to be readmitted for VA compared to non-elective CA. The most common complication in the CA group was cardiac tamponade (4.8 %).
Conclusion: VT ablation is associated with similar rates of 30-day readmission compared to MT and does not confer increased risk of harm with respect to inpatient mortality, cardiogenic shock or cardiac arrest. Further research is warranted to determine if a subgroup of sarcoidosis patients admitted with VT are better served with an initial conservative management strategy followed by VT ablation.

1. Introduction

Patients with cardiovascular manifestations of sarcoidosis are at increased risk for ventricular arrhythmias (VA) and sudden cardiac death. Estimates of 5-year mortality can exceed 40% [1] with VA and congestive heart failure being leading predictors of morbidity and mortality [2–4]. The complex arrhythmic substrate in cardiac sarcoidosis (CS) can be further affected by an underlying inflammatory state, making management of ventricular tachycardia (VT) all the more challenging [5,6]. Immunosuppression, antiarrhythmic medications and implantable cardioverter defibrillators (ICDs) have been shown to be a feasible treatment strategy for VT in CS [7], with catheter ablation (CA) emerging in recent decades as an option for drug-refractory VT [8,9].

Because of the unique substrate and varied outcomes of sarcoidosis VT patients, determining optimal treatment strategies remains elusive. Current CS expert consensus recommends a stepwise

* Corresponding author at: Fellow in Cardiac Electrophysiology, Hospital of the University of Pennsylvania, 1 Convention Avenue, Philadelphia, PA, United States of America.
E-mail address: michael.gurin@pennmedicine.upenn.edu (M.I. Gurin).

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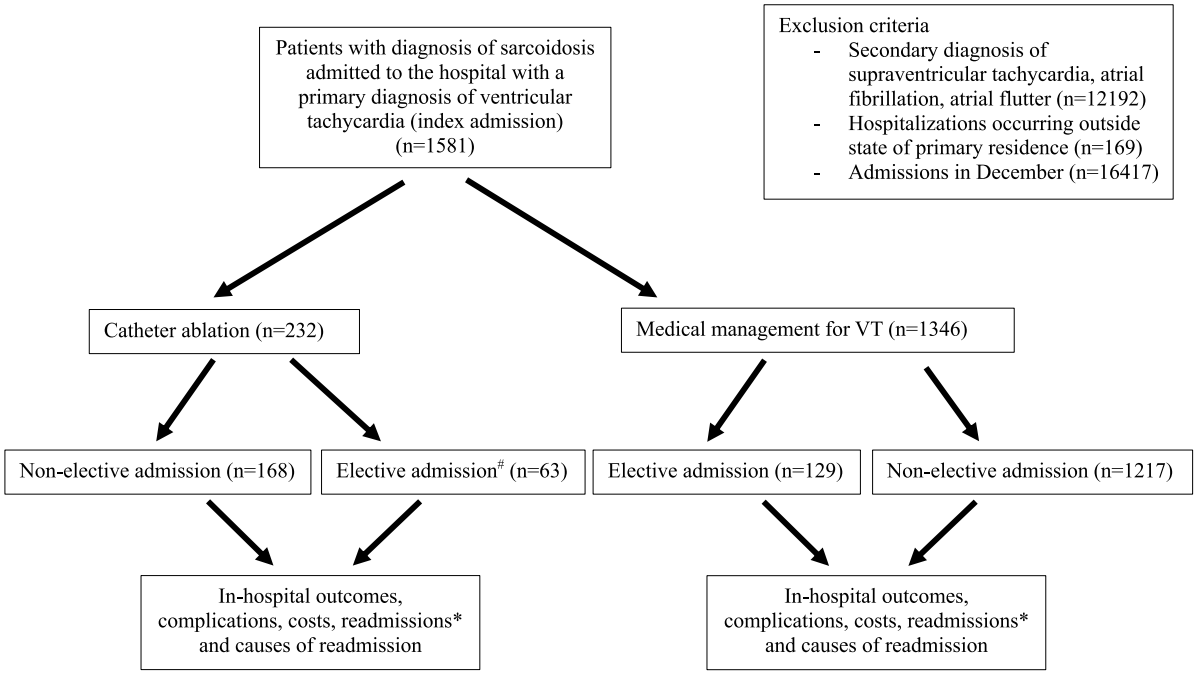
immunosuppression and antiarrhythmic therapy for VA with evidence of myocardial inflammation, with catheter ablation reserved for VA refractory to medical therapy [10]. Although catheter ablation can be helpful in a number of cases in CS, VT recurrence rates are high, and among non-ischemic cardiomyopathies, patients with CS have the worst prognosis with respect to all-cause death, need for heart transplantation, and hospital readmission [11–13]. In contrast to this, there is emerging data that in other patient populations, early, optimized VT ablation may have more favorable long term outcomes [14–16]. To our knowledge, limited studies have compared acute or long term outcomes between CS patients undergoing VT ablation based on non-elective or elective admission status as compared to inpatient medical therapy. As a result, there is little data to guide management in the acute setting.

The primary objective of this study is to assess in-hospital outcomes and unplanned readmissions following catheter ablation for VT in patients with sarcoidosis as compared to those with sarcoidosis admitted for VT undergoing medical therapy. Additionally, we compared in-hospital outcomes and readmission rates in both elective and unplanned (non-elective) hospital admissions in patients undergoing catheter ablation for VT for sarcoidosis.

2. Materials and methods

Data was obtained from the Nationwide Readmissions Database (NRD) between January 1, 2010 and December 31, 2019. The NRD is a publicly available deidentified database of hospitalizations in the United States specifically designed for readmission analyses and sponsored by the Agency for Healthcare Research and Quality (AHRQ) as part of the Healthcare Cost and Utilization Project. The database contains >100 clinical and nonclinical variables for each hospital stay, including diagnosis and procedure codes from the International Classification of Disease, Ninth and Tenth Revisions, Clinical Modification (ICD-9-CM and ICD-10-CM), and data from all payers as well as uninsured persons. Discharge data is available from 30 geographically dispersed states, accounting for 61.8 % of the total U.S. population and 60.4 % of all U.S. hospitalizations. As the NRD is a publicly available deidentified database, this study did not qualify as human subject research and is exempt from institutional review board approval.

The ICD-9-CM and ICD-10-CM codes specified in Supplemental Table 1 were used to identify patients aged 18 and older from the NRD with a diagnosis of sarcoidosis undergoing catheter ablation or sarcoidosis without catheter ablation. Patients were further selected by having a primary hospital admission for VT. Admissions with a secondary diagnosis of atrial fibrillation, supraventricular tachycardia, and atrial flutter were excluded due to overlap in the billing code used for atrial and ventricular ablations. The NRD also contains data elements that permit further sub-selection of patients based on elective versus non-elective admission. Elective admission was defined as any planned admission. Index admission was defined as the hospitalization during which a patient with sarcoidosis presented to the hospital with a primary diagnosis of ventricular tachycardia and either received catheter ablation or medical therapy (Fig. 1). Medical therapy encompassed all non-catheter based treatment therapies, which included, but were not limited to initiation and titration of antiarrhythmics, adjustment of ICD treatment zones, addition of antitachycardia pacing therapies, or procedures such as stellate ganglion block. To mitigate the risk of incomplete follow up, hospitalizations occurring in a state other than a patient's primary residence or during the month of December of each year did not contribute to admissions. The latter allowed all patients to have uniform follow-up of 30 days. Any planned readmission and patients who died during the index admission were excluded from the readmission analysis.The two primary study endpoints were a composite endpoint of mortality, cardiogenic shock, and cardiac arrest and unplanned all-cause 30-day readmissions. Additional endpoints were rates of mechanical circulatory support, cardiogenic shock, and cardiac arrest. Complications and causes of readmission were identified using the ICD codes available in the Supplemental Table 1. Causes of readmission were reported, stratified by cohort.



One patient in the elective group was excluded due to missing data.
*Any patient who died during index hospitalization or was scheduled for a planned readmission was excluded from the readmissions analysis.

Fig. 1. Patient selection.
Patient selection, inclusion and exclusion criteria.

Demographics, comorbidities, and outcomes were compared between the cohorts using chi-square analysis or Fisher's exact tests for categorical variables, and Student's *t*-test or Mann-Whitney *U* test for continuous variables. Proportions were expressed as percentages, which were calculated based on available data. A small number of patients within the NRD had missing variables, constituting <5 % of the total data analyzed. A two-sided $p < 0.05$ was considered to be statistically significant. Covariates were used for multivariable logistic regression if after univariable analysis they were significant at $p < 0.1$ and if the covariate was clinically relevant to the outcome variable. Subsequently, we adjusted for the following independent variables: age, sex, heart failure, atrioventricular block, left bundle branch block, right bundle branch block, immunosuppression/steroid use, implantable cardioverter-defibrillator, hypertension, chronic obstructive pulmonary disease, diabetes mellitus, renal failure, liver disease, fluid and electrolyte disorders, coagulopathy, anemia, obesity, smoking, hospital bed size, teaching status (teaching vs. non-teaching hospitals), and size of metropolitan area. Non-metropolitan hospitals were removed from the analysis due to limited sample size. Multivariate regression was used to estimate the odds of readmission, complications, and any adverse outcome (cardiac arrest, cardiogenic shock, or mortality) after adjusting for the differences in demographics and comorbidities between the cohorts. All analyses were conducted using Rstudio Version 4.0.3.

3. Results

During 2010–2019, there were 1581 patients meeting study criteria. Of these, 1346 patients had sarcoidosis and VT managed medically. Of the patients managed medically, 1217 were during non-elective admission and 129 were during elective hospital admission. Refer to Supplemental Table 2 for baseline characteristics in the elective admission cohort. Patients managed medically were mostly male (61.2 %) and the average age was 56 years. There were 168 patients meeting inclusion criteria for sarcoidosis undergoing CA for VT. The patients were mostly male (69.6 %) with an average age of 54 years. Sarcoidosis patients in both the MT and CA cohorts presented more frequently to large sized, non-profit hospitals, with teaching hospital affiliation within large metropolitan areas (Table 1).

At index admission for VT ablation, about one quarter of patients were admitted electively (27.1 %) compared with a 9.6 % elective admission rate for medical therapy. Compared to sarcoidosis patients medically managed, patients undergoing VT CA had greater prevalence of heart failure (53.6 % vs. 43.9 %) and conduction disease including left bundle branch block (10.1 vs. 5.4 %) and right bundle branch block (12.5 % vs. 7.1 %). There was no statistically significant difference between groups in atrioventricular block (7.7 % vs. 4.4 %). In patients admitted for VT undergoing catheter ablation, there was greater use of or history of immunosuppression and steroid therapy (16.7 % vs 10.9) and implantable cardioverter-defibrillators (54.8 % vs 48.0 %), however the latter did not meet statistical significance. Other medical comorbidities were similar between both groups (Table 1). In contrast, patients who were admitted electively for VT undergoing catheter ablation had a significantly higher prevalence of ICDs compared to patients receiving medical therapy (73.0 % vs. 35.7 %). Sarcoid patients receiving medical therapy were more likely to have hypertension (54.7 % vs. 35.6 %), chronic pulmonary disease (20.5 % vs. 6.8 %) and fluid and electrolyte disturbances (14.5 % vs. 3.4 %) compared to the CA cohort (Supplemental Table 2).

Procedural related complications in the catheter ablation cohort were compared between elective and non-elective admission. Overall, there were no significant differences in prevalence of cardiac tamponade (4.8 % vs. 4.8 %), pneumothorax (1.8 % vs 0 %), stroke (1.8 % vs 0 %), DVT & PE (4.2 % vs. 1.6 %) or vascular complications (2.4 % vs. 3.2 %), which included vessel puncture or laceration, pseudoaneurysm/aneurysm, dissection, fistula, and hematoma formation (Fig. 2). Multivariable logistic regression demonstrated that any complication (cardiac tamponade, pneumothorax, stroke, vascular complication, deep venous thrombosis and pulmonary embolism) was more likely to occur in the CA cohort compared to the MT cohort for non-elective admission (OR 2.17, [95 % CI 1.14, 3.96], $p < 0.014$) (Supplemental Table 3).

Table 1
Baseline characteristics, sarcoidosis patients managed medically versus catheter ablation, non-elective admission.

	Medical therapy (***N*** = 1217)	Catheter ablation (***N*** = 168)	P value
Demographics			
Male sex	745 (61.2)	117 (69.6)	0.043
Age, mean(SD)	56.21 (14.12)	54.57 (14.83)	0.16
Conduction Disease			
Atrioventricular block	54 (4.4)	13 (7.7)	0.093
LBBB	66 (5.4)	17 (10.1)	0.026
RBBB	86 (7.1)	21 (12.5)	0.02
Device and drug therapy			
Immunosuppression and steroid therapy	133 (10.9)	28 (16.7)	0.041
Implantable cardioverter defibrillator	584 (48.0)	92 (54.8)	0.118
Comorbidities			
Systolic, diastolic and combined heart failure	534 (43.9)	90 (53.6)	0.022
Hypertension	497 (42.4)	59 (36.9)	0.21
Chronic pulmonary disease/COPD	256 (21.9)	28 (17.5)	0.246
Diabetes	326 (27.8)	33 (20.6)	0.067
Renal failure	192 (16.4)	33 (20.6)	0.22
Coagulopathy	45 (3.8)	11 (6.9)	0.114
Obesity	267 (22.8)	35 (21.9)	0.872
Fluid and electrolyte disorders	318 (27.2)	39 (24.4)	0.516
Deficiency Anemias	125 (10.7)	18 (11.2)	0.933
Smoking	288 (23.7)	51 (30.4)	0.073
Index Hospital			
Bed size			<0.001
Small	83 (6.8)	7 (4.2)	
Medium	269 (22.1)	15 (8.9)	
Large	865 (71.1)	146 (86.9)	
Ownership			0.364
Government	147 (12.1)	24 (14.3)	
Private, non-profit	989 (81.3)	137 (81.5)	
Private, invest-own	81 (6.7)	7 (4.2)	
Teaching status			<0.001
Metropolitan, nonteaching	194 (15.9)	5 (3.0)	
Metropolitan, teaching	1003 (82.4)	163 (97.0)	
Nonmetropolitan	20 (1.6)	0 (0.0)	
Localization			0.001
Large metropolitan area	842 (69.2)	138 (82.1)	
Small metropolitan area	375 (30.8)	30 (17.9)	
Micropolitan area			
Non-urban			

Table 1. Demographic and baseline health patient characteristics, along with the institutional characteristics corresponding to patients with sarcoidosis managed medically versus with catheter ablation during nonelective admission, stratified by cohort.
COPD = chronic obstructive pulmonary disease, IQR = interquartile range, LBBB = left bundle branch block, RBBB = right bundle branch block, SD = standard deviation.

Primary endpoints for in-hospital outcomes are shown in Table 2 for non-elective admission. At index admission, unadjusted analyses did not demonstrate a difference between cohorts in use of mechanical circulatory support (0.3 % vs. 1.2 %, $p = 0.158$), inpatient mortality (2.8 % vs. 1.8 %, $p = 0.612$), or cardiogenic shock (4.0 % vs. 6.5 %, $p = 0.158$). Catheter ablation was associated with less cardiac arrest (2.4 % vs. 8.9 %, $p = 0.002$). There was no difference in the composite endpoint of mortality, cardiac arrest, and cardiogenic shock in either the non-elective group (12.0 % vs. 9.0 %, $p = 0.312$) (Fig. 3). After multivariable adjustment, catheter ablation did demonstrate any significant difference in occurrence of any adverse outcome (inpatient mortality, cardiogenic shock, or cardiac arrest) (OR 0.84, [95 % CI 0.46, 1.46] $p = 0.555$) as compared to medical therapy (Supplemental Table 3). Median

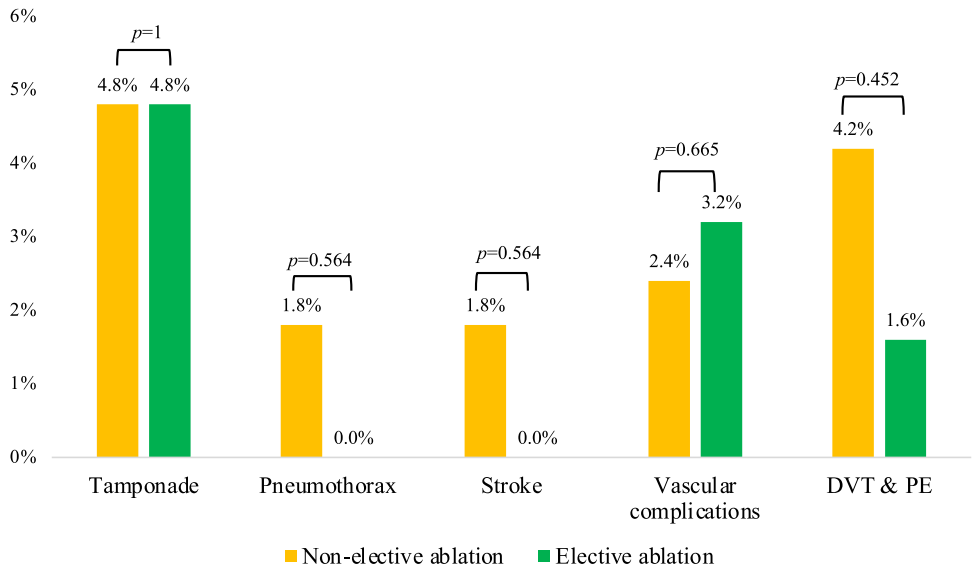


Fig. 2. In-hospital procedural complications at index admission.
In-hospital complications (percentage) in patients with sarcoidosis undergoing VT ablation during elective and non-elective admission. DVT = deep venous thrombosis, PE = pulmonary embolism.

Table 2
In-hospital outcomes, medical therapy compared to catheter ablation, non-elective admission.

	Medical therapy (N = 1217)	Catheter ablation (N = 168)	*P* value
In-hospital outcomes			
Mechanical circulatory support	4 (0.3)	2 (1.2)	0.158
Mortality	34 (2.8)	3 (1.8)	0.612
Cardiogenic shock	49 (4.0)	11 (6.5)	0.193
Cardiac arrest	108 (8.9)	4 (2.4)	0.002
Composite endpoint of mortality, cardiac arrest and cardiogenic shock	146 (12.0)	15 (9.0)	0.312
Hospitalization Characteristics			
Median length of stay (IQR), d	4.00 [2.00, 7.00]	6.00 [4.00, 10.25]	<0.001
Median cost of index admission (IQR), $	43,932.00 [17,916.50, 122,808.00]	132,528.00 [78,263.75, 263,141.50]	<0.001
Disposition at discharge			0.927
Home with no assistance	995 (81.8)	139 (83.2)	
Home with health aid	111 (9.1)	16 (9.6)	
Transfer to subacute nursing or intermediate care facility	75 (6.2)	8 (4.8)	
Other	36 (3.0)	4 (2.4)	

Table 2. Comparison of in-hospital outcomes, including inpatient mortality, cardiac arrest, cardiogenic shock, mechanical circulatory support use between patients with sarcoidosis medically managed versus with catheter ablation during non-elective admission.
d = days, IQR = interquartile range.

length of stay for those undergoing VT ablation was longer (6 vs 4 days, $p < 0.001$) and median cost of hospitalization was greater ($132,528 vs. $43,932; $p < 0.001$) compared to inpatient medical therapy. Sarcoidosis patients in both groups were discharged home without assistance (81.8 % vs. 83.2 %). Supplemental Table 4 shows comparison between medical therapy and catheter ablation for patients admitted electively. No significant between group differences for in-hospital outcomes were observed in the elective admission cohort. There was no significant difference in the primary composite outcome in patients admitted electively (7.8 % vs 3.2 %, $p = 0.343$). All patients who underwent CA during elective admission went home with no assistance (100.0 % vs. 84.5 %, $p = 0.003$) compared to those medically managed (Supplemental Table 4).

Unplanned 30-day readmission outcomes were assessed between CA and medical therapy groups. Readmission rates were not significantly different between sarcoidosis patients medically treated compared to catheter ablation at 30 days (11.3 vs 8.9 %, $p = 0.422$). The readmission rate between the MT and CA groups was not different in patients with an elective index admission (11.6 % vs. 6.3 %, $p = 0.311$) (Fig. 3). After multivariable adjustment, catheter ablation was not associated with a reduction in 30-day readmissions (OR 0.73, [95 % CI 0.38,1.30] $p = 0.307$) (Supplemental Table 3).

Among patients who were readmitted within 30-days, the chief reason for readmission were ventricular arrhythmias in both those undergoing CA and medical management (85.7 % vs 42.7 %; $p = 0.0034$) following non-elective index admission. Common reasons for readmission included other arrhythmias, heart failure, device-related complications, pulmonary embolism, hypertension and coronary disease, vascular complications and hypotension. Other arrhythmia (5.6 % vs. 0 %, $p = 1$), heart failure (5.6 % vs 0 %; $p = 1$), device-related complications (4.8 % vs 0 %; $p = 1$), pulmonary embolism (3.2 % vs. 0 %, $p = 1$), and hypertension/coronary disease (5.6 % vs 0 %; $p = 1$) were more common reasons for readmission in the medical therapy group, whereas hypotension (7.1 % vs 1.6 % $p = 0.276$), and vascular complications (7.1 % vs. 0.0 %; $p = 0.101$) were more common in the catheter ablation group (Fig. 4). Within the catheter ablation cohort, ventricular arrhythmias were a more common cause of readmission in the non-elective CA group compared to elective CA group (86 % vs. 25 %; $p = 0.028$) (Supplemental Fig. 1).

4. Discussion

There are few real-world studies evaluating in-hospital and short-term readmissions outcomes in the sarcoidosis population undergoing VT ablation as compared to medical therapy. To date, this is the largest cohort study to study VT ablation versus medical therapy in the sarcoidosis population. There were a number of unique findings in this study. First, sarcoidosis patients undergoing VT ablation revealed no difference in the composite of in-hospital mortality, cardiogenic shock, and cardiac arrest compared to those who were medically managed during the index admission when catheter ablation took place. During

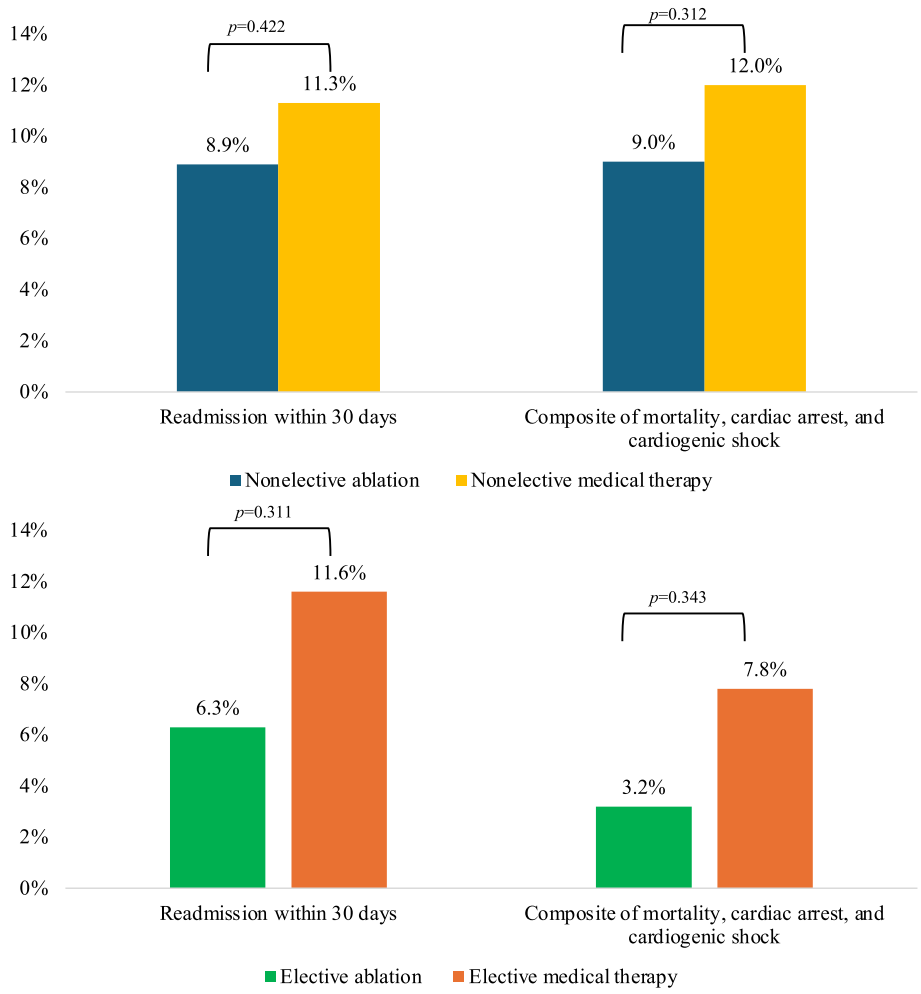


Fig. 3. Primary endpoints.
Comparison of in-hospital outcomes, including composite endpoint of inpatient mortality, cardiac arrest, cardiogenic shock and readmission rates and between patients with sarcoidosis medically managed versus with catheter ablation during non-elective and elective admission. Numbers in percentages.

non-elective admission, there was an association with reduced in-hospital cardiac arrest with catheter ablation. Second, there was no increase in 30-day readmission rates for patients with sarcoidosis treated with VT ablation, compared to medical therapy. Third, stroke, vascular complications, DVT & PE in both elective and non-elective VT ablation remained low. After multivariable analysis, catheter ablation during non-elective (unplanned) admission did not confer any added risk of adverse outcomes as compared to medical therapy. These results in total support the safety of VT ablation when compared to medical therapy in patients with sarcoidosis.

An additional finding in this study are inherent baseline differences within the elective and non-elective admitted cohorts. Compared to sarcoid patients undergoing medical therapy during unplanned (non-elective) admission, sarcoid patients receiving catheter ablation tended to have more advanced conduction disease, had received or were currently receiving immunosuppression and steroid therapy, and had greater prevalence of heart failure. Further, hospitalization was longer in the patients undergoing catheter ablation. Of the patients who were readmitted following catheter ablation, the most common reason were ventricular arrhythmias. In contrast, patients undergoing catheter ablation during elective hospitalization were not significantly different with respect to conduction disease or heart failure, treatment with immunosuppressives, and tended to have fewer medical comorbidities including pulmonary disease and hypertension. A greater proportion of patients undergoing catheter ablation during elective admission had an implantable cardioverter defibrillator. One explanation may be that elective ablation patients are inherently healthier and presented for ablation after preprocedural medical optimization, including treatment of heart failure and ICD implantation. Second, VT ablation is complex, with outcomes that are improved with periprocedural planning including the use of advanced imaging modalities. Computed tomography and cardiac MRI, aids in a critical way for procedural success by providing three dimensional maps that help identify anatomic corridors and areas of scar [17,18]. Third, patients undergoing elective ablation may have been treated with immunosuppressants and represent a different stage of disease compared to those who undergo non-elective ablation. Kaur et al. demonstrated that outcomes of VT ablation are worse in the inflammatory phase of sarcoidosis compared with the scar phase [2]. In another observational study assessing determinants of long-term outcomes in 158 CS patients undergoing catheter ablation for VT, inflammation on FDG-PET was associated with worse long-term prognosis, including recurrent VT, death, or need for heart transplantation [6]. These results suggest inflammation should be treated, if possible, prior to catheter ablation.

The observed in-hospital complications in this study are similar to published data in patients with structural heart disease undergoing VT ablation. In a large single center study of 548 patients with structural heart disease and a small percentage with idiopathic VT undergoing 722 ablation procedures, there was a 6.2 % major complications rate, with access site vascular complications being most common at 3.6 %; cardiac

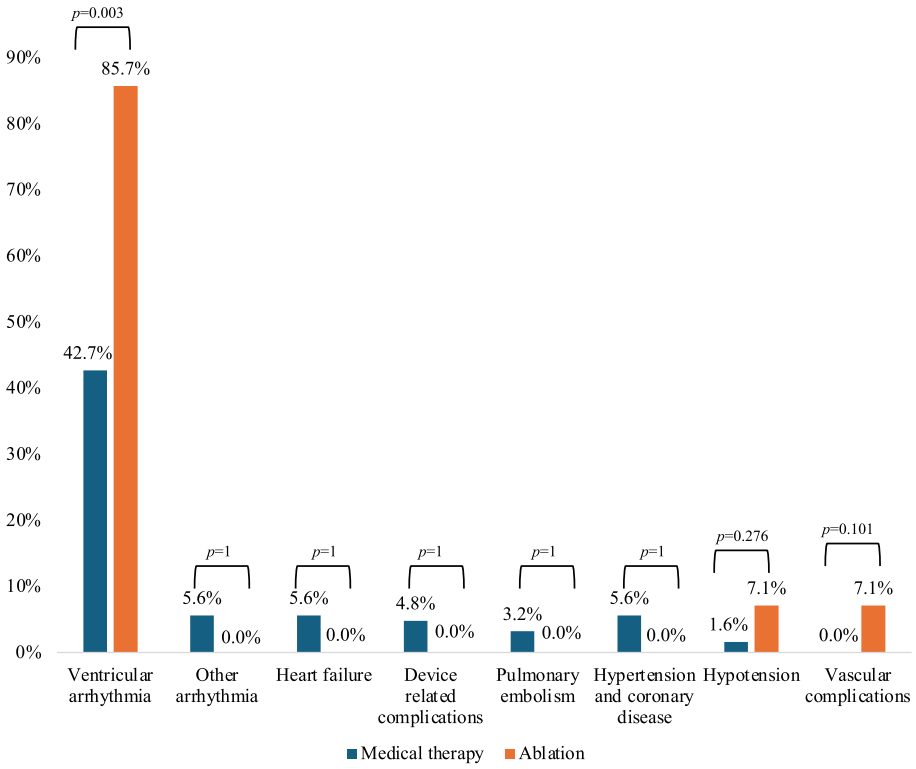


Fig. 4. 30-Day causes of readmission following non-elective admission, catheter ablation versus medical therapy.
Common causes of readmission examined, stratified by cohort, medical therapy compared to catheter ablation after non-elective index admission. Numbers expressed as percentages of total readmissions.

tamponade was only prevalent in 0.4 % of cases [19]. In another large study of 528 patients undergoing CA for VT with structural heart disease, the rate of post procedural tamponade was 2 % [14]. An additional NRD study in MI-associated VT ablation, the rate was 2.6 % [20]. In this study, the rate of cardiac tamponade at 4.8 % is slightly higher than published literature. This is likely due to other competing factors that we could not account for including operator experience, procedure time, and access site including need for epicardial access. Alternatively, cardiac tamponade may be an independent risk factor for tamponade. Given the proclivity for sarcoidosis to have patchy involvement of the myocardium, epicardial access for VT ablation is frequently necessary in cases when the VT cannot be ablated using an endocardial approach [8,9,13,21]. Although tamponade was the most common complication in the CA group, other feared complications such as stroke, pneumothorax, vascular complications, DVT & PE were low.

The primary cause for readmission in this study were ventricular arrhythmias; however, of the patients undergoing CA, VAs were far less common in the elective CA group. The difference between elective and non-elective CA may be explained by several factors including transient breakthrough arrhythmia, abrupt de-escalation of anti-arrhythmic medications, procedural failure, or a healthier cohort altogether. Additionally, patients in the elective group may have had PET-CT imaging available, either showing improvement or resolution of inflammation prior to scheduling ablation, while patients in the non-elective group may not have been able to obtain advance inpatient PET-CT imaging, thereby making treatment less effective if active inflammation were present. Patients presenting with VAs may also be more frequently readmitted due to shocks from ICDs, which provide life-saving therapies and prompt further medical attention. Other causes of readmission including non-VA arrhythmias, device-related complications, and coronary disease remained low and there was no signal of increased harm either during index admission or on readmission. Despite the VT CA cohort having greater baseline prevalence of heart failure, there were zero 30-day readmissions due to heart failure following CA for VT, suggesting that CA may be crucial in preventing short-term heart failure readmissions. Further studies are warranted to assess the potential benefit of ablation over medical therapy to prevent heart failure.

Patients with sarcoidosis and recurrent VT may not have time to wait until inflammation has been treated due to the high morbidity and mortality of this disease. Importantly, our findings indicate that VT ablation can be performed with favorable short-term outcomes and low rates of complications. Growing evidence suggests that timing is an important element of VT ablation in patients with CS. Studies suggest that VT ablation in the scar phase of the disease, after active inflammation has been adequately treated, is associated with the greatest freedom from VT recurrence post-ablation [2,6]. In-line with these findings, recent expert consensus recommends a stepwise approach to the management of VT in CS, with intensification of immunosuppression and antiarrhythmic drug therapy preceding catheter ablation in the absence of urgent indications for the latter (e.g. VT storm, ventricular fibrillation refractory to medical management) [6,7]. Alternatively, new evidence not specific to cardiac sarcoidosis, has emerged supporting VT ablation after first ICD shock or as an upfront therapy prior to escalation of antiarrhythmics [15,16,22,23].

An interesting observation of this study were the relatively low numbers of patients with an implantable cardioverter-defibrillator. Approximately three quarters of patients presenting for an elective ablation and half of those undergoing non-elective ablation had an ICD. There are several likely reasons for the lower than expected numbers of ICDs. One, not all the patients with ICDs may have been accounted for due to billing code omission. Two, many sarcoidosis patients presented to the hospital with ventricular tachycardia for the first time and would not have had an ICD. These patients probably required acute stabilization of their arrhythmia and ICD implantation. This phenomenon would also explain why the elective group was more likely to have an ICD when admitted for catheter ablation. Further, a diagnosis of ‘sarcoidosis’ might not have been established at first hospital presentation, leading to delays in ICD implantation.

It is important to acknowledge that some of the factors that were adjusted for in the multivariate analysis may not be permanent patient characteristics. Heart failure, renal failure, diabetes, liver disease, chronic obstructive pulmonary disease, anemia, electrolyte and coagulopathies can be modified and optimized. Additionally, VT storm necessitating admission may be the causative force worsening heart failure and other organ dysfunction. If so, these findings coupled with the high recurrence rate of VT treated with medical therapy would argue for elective VT ablation in the CS population. Further research is warranted to determine if there is a subgroup of CS patients admitted with VT who are better served with an initial conservative management strategy coupled with risk factor optimization followed by elective VT ablation.

Limitations of this study are primarily related to characteristics of the NRD. As part of a large administrative database relying on billing codes, NRD entries are susceptible to misclassification and their analysis subject to residual confounding due to non-randomized treatment assignment. The temporality of outcomes such as cardiac arrest and cardiogenic shock relative to the timing of catheter ablation could not be established. Selection bias may significantly affect our results as the elective VT ablation may represent a healthier patient population that would have less risk of adverse outcomes compared to those who were admitted non-electively. Operators may have selected healthier patients to undergo VT ablation rather than medical therapy. The lack of complete mortality data remains a major limitation in addition to many unmeasurable baseline differences. The study might have been underpowered to detect differences in readmissions and the primary in-hospital outcomes. There may also be a selection bias in patients with devices; having a defibrillator may portend better outcomes. Further, management of patients with VT, and in particular catheter ablation, took place at large, metropolitan teaching hospitals. There is also a limit to the database's granularity as it lacks data on procedural details, operator experience, pharmacotherapies, peri-procedural imaging and laboratory values. Medical therapy was broadly defined in this study and it is not clear how all of these patients were individually treated. Patient level data including cardiac MRI or FDG-PET findings, which may be crucial in procedural planning and understanding of VT substrate, were not available. The decision to pursue ablation or medical therapy may have been dictated by inflammatory status or nature of the patient's substrate. We were also unable to provide procedure level characteristics such as epicardial ablation and whether there was absence of VT inducibility, which may suggest lower recurrence rates [24]. At index admission, hospitalization requiring VT ablation was costlier than admission without VT CA. Further analyses to determine long term costs beyond the index admission should be pursued. Additionally, the NRD does not capture out-of-hospital death and hence our analysis could not account for the competing risk for post-discharge death and readmission. Lastly, the NRD does not include follow-up data for >1 year, hence longer-term endpoints could not be investigated.

5. Conclusion

In a national database of patients admitted with sarcoidosis and ventricular tachycardia, when compared to medical therapy, catheter ablation resulted in similar 30-day readmission rates and no major differences in the composite endpoint of inpatient mortality, cardiogenic shock, and cardiac arrest either during non-elective or elective admission. Procedure related complications in patients undergoing catheter ablation including stroke, vascular complications, DVT and PE, were similar between elective and non-elective admission. The data must be interpreted with attention to selection bias, incomplete mortality data, and unmeasurable baseline differences between patients undergoing catheter ablation compared to medical therapy. The study's findings remain observational in nature and prospective investigations are required to confirm the observed associations, and in particular the viability of CA as a possible alternative to medical therapy alone.

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Ethical statement

The final manuscript has been read and approved by all authors as original, and all have taken responsibility for the content of the work. This manuscript is not under consideration elsewhere, and none of its content has been previously published. As the Nationwide Readmissions Database is a publicly available deidentified database, this study did not qualify as human subject research and is exempt from institutional review board approval. **Informed consent:** Not applicable.

CRediT authorship contribution statement

Yuhe Xia: Writing – review & editing, Methodology, Formal analysis, Data curation. **Constantine Tarabanis:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Randal I. Goldberg:** Writing – review & editing. **Robert J. Knotts:** Writing – review & editing. **Robert Donnino:** Writing – review & editing. **Alex Reyentovich:** Writing – review & editing. **Scott Bernstein:** Writing – review & editing. **Lior Jankelson:** Writing – review & editing. **Alexander Kushnir:** Writing – review & editing. **Douglas Holmes:** Writing – review & editing. **Michael Spinelli:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Data curation, Conceptualization. **David S. Park:** Writing – review & editing. **Chirag R. Barbhaiya:** Writing – review & editing. **Larry A. Chinitz:** Writing – review & editing, Supervision. **Anthony Aizer:** Writing – review & editing, Supervision, Investigation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Chirag R. Barbhaiya reports a relationship with Abbott that includes: speaking and lecture fees. Chirag R. Barbhaiya reports a relationship with BIOTRONIK Inc that includes: funding grants, non-financial support, and speaking and lecture fees. Chirag R. Barbhaiya reports a relationship with Medtronic Inc. that includes: speaking and lecture fees. Douglas Holmes reports a relationship with Abbott that includes: funding grants and non-financial support. Alexander Kushnir reports a relationship with Biosense Webster Inc. that includes: consulting or advisory and speaking and lecture fees. Larry A. Chinitz reports a relationship with Abbott that includes: speaking and lecture fees. Larry A. Chinitz reports a relationship with Medtronic Inc that includes: funding grants, non-financial support, and speaking and lecture fees. Larry A. Chinitz reports a relationship with BIOTRONIK Inc that includes: funding grants, non-financial support, and speaking and lecture fees. Larry A. Chinitz reports a relationship with Biosense Webster Inc that includes: funding grants, non-financial support, and speaking and lecture fees. Anthony Aizer reports a relationship with Abbott that includes: funding grants and non-financial support. Anthony Aizer reports a relationship with BIOTRONIK Inc that includes: funding grants and non-financial support. Chirag R. Barbhaiya reports a relationship with ZOLL Medical Corporation that includes: speaking and lecture fees. Anthony Aizer reports a relationship with Biosense Webster Inc that includes: consulting or advisory, funding grants, and non-financial support. Anthony Aizer reports a relationship with Boston Scientific Corporation that includes: funding grants and non-financial support. Anthony Aizer reports a relationship with Medtronic Inc that includes: funding grants and non-financial support. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ahjo.2024.100421.

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