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Thirty-day readmission after catheter ablation for ventricular tachycardia: associated factors and outcomes

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Abstract

Background Patients with ventricular tachycardia (VT) who require VT ablation are at high risk for readmission. This study aimed to identify the causes and outcomes of 30-day readmission after VT ablation and to analyze the predictors of recurrent VT that required rehospitalization.

Methods Using the Nationwide Readmission Database, our study included patients aged ≥ 18 years who underwent VT catheter ablation between 2017 and 2020. Based on the International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM), we identified the causes of 30-day readmission by organ systems and analyzed their outcomes. Additional analysis was performed to determine the independent predictors of 30-day readmission for recurrent VT.

Results Of the 4228 patients who underwent VT ablation, 14.2% were readmitted within 30 days of the procedure. The most common cause of readmission was cardiac events (73.6%). Among the cardiac-related readmissions, recurrent VT (47.7%) and congestive heart failure (CHF) (12.9%) were the most common etiologies. Among the readmissions, patients readmitted for CHF had the highest rate of readmission mortality (9.2%). Of the patients readmitted within 30 days of the procedure, 278 patients (6.8%) were readmitted for recurrent VT. Via multivariable analysis, CHF (OR: 1.97; 95% CI: 1.12–3.47; $P=0.02$) and non-elective index admissions (OR: 1.63; 95% CI: 1.04–2.55; $P=0.03$) were identified as the independent predictors predictive of 30-day readmissions for recurrent VT.

Conclusions Recurrent VT was the most common cause of readmission after the VT ablation procedure, and CHF and non-elective index admissions were the significant predictors of these early readmissions. Readmission due to CHF had the highest mortality rate during readmission.

Keywords Ventricular tachycardia · Catheter ablation · Outcome of readmission · Recurrent ventricular tachycardia

Abbreviations

AHRQ	Agency for Healthcare Research and Quality
CHF	Congestive heart failure
HCUP	Healthcare Cost and Utilization Project
ICD-10-CM	International Classification of Diseases, Tenth Revision, Clinical Modification
IQR	Interquartile range
NRD	Nationwide Readmission Database
OR	Odds ratio
VT	Ventricular tachycardia

1 Introduction

Ventricular tachycardia (VT) is a common cause of hospitalization and death in patients [1]. Ablation therapy for VT has improved in its safety and efficacy over the past few decades

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[2, 3]. Patients with VT may have high-risk comorbidities predisposing them to early rehospitalization and death. Prior studies have reported a 30-day readmission rate of 19.2% following myocardial-infarct-associated VT ablation [4]. However, data outside of myocardial-infarct VT ablation is limited. Data on non-ischemic-related VT is important because there is an increasing number of patients undergoing ablation for non-ischemic VT substrate [5]. Furthermore, the outcomes of patients who required early rehospitalization after VT ablation are not well-established.

Therefore, we conducted this nationwide retrospective study to determine the causes and outcomes of readmission within 30 days of discharge from index admission for VT ablation—including all forms of VT (ischemic and non-ischemic)—and to assess risk factors of early recurrent VT hospitalizations (≤ 30-days) post-procedurally.

2 Methods

2.1 Data source

The data was obtained from the Nationwide Readmission Database (NRD), derived from the Healthcare Cost and Utilization Project (HCUP) State Inpatient Databases. The Healthcare Cost and Utilization Project is sponsored by the Agency for Healthcare Research and Quality (AHRQ). The Nationwide Readmission Database is a database designed to support various types of analyses of national readmissions for all patients, regardless of the expected payer for the hospital stay. It is constructed from more than 28 state inpatient databases and accounts for more than 58% of all US hospitalizations [6–8]. It is an annual database that includes approximately 17 million discharges yearly from 2017 to 2020, making it one of the nation's largest publicly available all-payer inpatient care databases. Using verified patient linkage numbers, it can reliably track patient admissions to any hospital in the same state over the course of a year. On the basis of the International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) codes, the patient's diagnoses and procedures during each admission were recorded. We queried this database using the ICD-10-CM codes to identify the patient demographic characteristics, the healthcare facility variables, and the in-hospital outcomes of each admission. Because NRD is publicly available and de-identified, our study did not require either institutional review board review or informed consent.

2.2 Study population

Using ICD-10-CM, we searched for all the patients 18 years of age or above with a primary diagnosis of VT (I47.2) and underwent catheter ablation for VT (025K3ZZ, 025M3ZZ, 025L3ZZ, and 02583ZZ) during the hospitalizations from January 2017 to November 2020. We excluded patients who underwent new pacemaker implantation or open surgical ablation, as well as those having other types of arrhythmias, including supraventricular tachycardia, premature ventricular complexes, pre-excitation syndromes, atrial flutter, and atrial fibrillation, in order to ensure a homogenous study population. Patients with missing data for in-hospital mortality and length of stay were also excluded. We used weighted data in our analysis. As the NRD is constructed using a calendar year of discharge data that does not track the patients over the years, index admissions from December were excluded given that the 30-day follow-up after discharge would not be available.

2.3 Study endpoints

The primary endpoint of our study was the hospital outcome of 30-day readmissions following the index hospitalizations for the VT catheter ablation procedure. The number of days from the discharge of the index hospitalization to the readmission was used to define the time of readmission. If there were multiple readmissions within 30 days after discharge from the index hospitalization, only the first readmission was included for analysis. Same-day transfers within the same hospital or between hospitals are not considered readmissions. The 30-day readmissions following the VT ablation procedure were categorized according to the organ system involved and were identified by the primary diagnosis for readmission. The causes of readmissions included cardiac, renal, infectious, respiratory, neurological, gastrointestinal, endocrinological, and hematological. Readmissions due to cardiac events were further stratified into VT, congestive heart failure (CHF), ischemic heart disease, and other cardiac causes (including arrhythmias other than VT, pulmonary embolism, pericarditis, and other non-specified cardiac events). The hospital outcomes included early mortality during readmission and length of hospital stay. The secondary endpoint of our study was the 30-day readmission for recurrent VT.

2.4 Definition of clinical variables

Patient-level and hospital-level variables, including age, sex, hospital characteristics (bed size and teaching status), and patient characteristics (median household income based on zip code, primary payer, type of index admission, and discharge disposition), were derived from NRD variables. Patient comorbidity diagnoses were identified by ICD-10-CM codes. Hospital volume was determined in terms of annual procedural volume tertiles based on cut-offs of the 25th, 50th, and 75th percentiles.

2.5 Statistical analysis

Continuous data were summarized as mean, standard deviation, median, interquartile range (IQR) (quartile 1, quartile 3), and range; differences between groups were tested using Wilcoxon's rank sum tests. Categorical data were summarized as counts and percentages; differences between groups were tested using Pearson's chi-squared test. All tests were 2-sided, with P values < 0.05 indicating statistical significance. Statistical analyses were conducted by using Stata version 12.1 (Stata Corporation, College Station, Texas). Patients who underwent VT ablation were stratified based on the occurrence of 30-day readmission for recurrent VT. Readmission for the recurrent VT model was run on the patients who survived the index admission. Multivariable predictors of 30-day readmission for recurrent VT were determined using Cox proportional hazard regression. For 30-day readmission due to recurrent VT, we first determined the known risk factors for recurrent VT-related readmission in Table 1. In multivariable analysis, only the variables with a statistically significant difference in VT-related readmission using univariable analysis were included. The Kaplan–Meier survival curve was generated for the independent multivariable predictors of readmission for recurrent VT, where a log-rank test was performed to compare the distribution of time until readmission. The Cochrane Armitage test was used to assess the trends of categorical variables, and simple linear regression was used to assess the trends of continuous variables.

3 Results

3.1 Study population

Our study included 4228 index admissions (median age 65 years old [IQR of 56–72], 19.7% female) for VT ablation between January 2017 and November 2020. The overall in-hospital mortality after VT ablation was 2.9% among the patients who were hospitalized for VT ablation. Among the 4102 patients who survived and were discharged alive from the index hospitalization, 583 patients (14.2%) were readmitted within 30 days of discharge from the index admission. There was an upward trend in the all-cause 30-day readmission rate from 12.9% in 2017 to 14.7% in 2020, but it was not statistically significant ($P = 0.34$) (Fig. 1).

3.2 Causes of 30-day readmission after ventricular tachycardia ablation and in-hospital outcomes

Among the patients who had early readmission within 30 days of discharge from index hospitalization, VT recurrence (47.7%, $n = 278/583$) was the most common reason, followed by congestive heart failure (12.9%), ischemic heart disease (3.8%), and other cardiac causes (9.3%) including arrhythmia other than VT, pulmonary embolism, pericarditis, and other unspecified cardiac events. For non-cardiac-related cause of readmissions, the most common cause was renal (3.6%), followed by infectious (3.3%), respiratory (3.1%), neurological (2.2%), gastrointestinal (2.1%), connective tissues or musculoskeletal (1.7%), hematological or oncological (1.5%), and endocrinological events (1.2%) (Fig. 2). Of all cardiac-related readmissions following the VT ablation procedure, early readmission for congestive heart failure has the highest rate of in-hospital mortality (9.2%) during readmission (Fig. 3). The overall median length of stay during readmissions was four days (IQR 2–8 days) in both cardiac and non-cardiac readmissions.

3.3 Early readmission for recurrent ventricular tachycardia and significant independent predictors

Following the VT ablation procedure, 278 patients (6.8%) were readmitted for recurrent VT within 30 days of discharge from VT ablation. After adjusting for the weighting factor, patients who were readmitted for recurrent VT (median age 67 years old [IQR of 58–72], 17.0% female) had a higher prevalence of chronic kidney disease (33.7% vs. 24.0%, $P < 0.01$), congestive heart failure (89.7% vs. 75.2%, $P < 0.01$), and peripheral arterial disease (73.9% vs. 55.9%, $P < 0.01$) (Table 1). These patients also had higher scores in the Elixhauser comorbidity score and the Charlson comorbidity index and were more likely to be associated with non-elective index admissions and a prolonged length of index hospital stay. Via multivariable analysis, congestive heart failure (adjusted odds ratio [OR]: 1.97; 95% CI: 1.12–3.47; $P = 0.02$) and non-elective index admissions (adjusted OR: 1.63; 95% CI: 1.04–2.55; $P = 0.03$) were identified as the independent predictors of 30-day readmissions (Table 2). The overall repeated VT ablation rate was 31.7% among those who were readmitted for recurrent VT. Patients who underwent repeated VT ablation during readmission had a longer median length of stay (8 days vs. 3 days, $P < 0.01$) than those who did not. The in-hospital mortality was similar between patients with and without repeated VT ablation (8.0% vs. 7.4%, $P = 0.86$).

3.4 Timing of readmission from index discharge

The median timing of readmission among all-cause early readmissions was 10 days (IQR 4–17 days) from index discharge. Most readmissions (66.9%) occurred within 14 days

Table 1 Baseline patient and hospital characteristics for patients with and without readmission for recurrent ventricular tachycardia

Characteristics	Overall		30-day readmission due to VT (before adjustment)				*P* value	30-day readmission due to VT (after adjustment)				*P* value
			Yes		No			Yes		No		
	n	%	*n*	%	*n*	%		*n*	%	*n*	%	
No. of admissions	4102	100.0	278	6.8	3824	93.2		525	7.1	6897	92.9	
Baseline characteristics												
Age, median (Q1–Q3), y	65 (56–72)		67.5 (58–73)		64 (55–72)		0.02	64 (55–72)		67 (58–72)		0.11
Female sex	824	20.09	44	15.83	780	20.40	0.07	89	16.99	1397	20.26	0.29
Chronic kidney disease	1010	24.62	93	33.45	917	23.98	< 0.01	177	33.66	1653	23.96	< 0.01
Chronic liver disease	143	3.49	12	4.32	131	3.43	0.43	17	3.30	229	3.32	0.98
Chronic pulmonary disease	820	19.99	69	24.82	751	19.64	0.04	136	25.85	1389	20.14	0.07
Coagulation disorder	256	6.24	13	4.68	243	6.35	0.26	23	4.30	416	6.03	0.32
Coronary artery disease	2566	62.55	191	68.71	2375	62.11	0.03	359	68.35	4290	62.20	0.10
Non-ischemic cardiomyopathy	692	16.87	55	19.78	637	16.66	0.18	103	19.53	1149	16.66	0.31
Congestive heart failure	3111	75.84	248	89.21	2863	74.87	< 0.01	471	89.70	5188	75.22	< 0.01
Hyperlipidemia	2425	59.12	171	61.51	2254	58.94	0.40	330	62.80	4078	59.12	0.32
Hypertension	3003	73.21	212	76.26	2791	72.99	0.23	394	75.06	5092	73.83	0.71
Obesity	797	19.43	62	22.30	735	19.22	0.21	118	22.51	1334	19.33	0.34
Obstructive sleep apnea	711	17.33	57	20.50	654	17.10	0.15	111	21.21	1245	18.06	0.30
Peripheral arterial disease	2333	56.87	208	74.82	2125	55.57	< 0.01	388	73.93	3852	55.85	< 0.01
Prior coronary artery bypass graft	850	20.72	73	26.26	777	20.32	0.02	130	24.82	1383	20.05	0.13
Prior myocardial infarction	1375	33.52	94	33.81	1281	33.50	0.92	183	34.94	2319	33.63	0.72
Prior percutaneous coronary intervention	989	24.11	82	29.50	907	23.72	0.03	152	29.02	1673	24.26	0.16
Prior stroke/transient ischemic attack	321	7.83	18	6.47	303	7.92	0.39	33	6.35	553	8.02	0.45
Pulmonary hypertension	233	5.68	22	7.91	211	5.52	0.10	45	8.63	384	5.56	0.10
Smoking	1894	46.17	140	50.36	1754	45.87	0.15	265	50.51	3249	47.11	0.36
Substance use disorder	130	3.17	10	3.60	120	3.14	0.67	19	3.59	219	3.17	0.73
Valvular heart disease	615	14.99	51	18.35	564	14.75	0.11	91	17.41	1003	14.55	0.25
Elixhauser comorbidity score							< 0.01					< 0.01
< 4	1002	24.43	40	14.39	962	25.16		79	15.08	1720	24.94	
≥ 4	3100	75.57	238	85.61	2862	74.84		446	84.92	5177	75.06	
Charlson comorbidity index							< 0.01					< 0.01
0	482	11.75	11	3.96	471	12.32		17	3.27	826	11.98	
1	551	13.43	21	7.55	530	13.86		43	8.27	961	13.93	
≥ 2	3069	74.82	246	88.49	2823	73.82		464	88.46	5110	74.08	
Median household income							0.45					0.58
First quartile	877	21.38	70	25.18	807	21.10		143	27.15	1550	22.80	
Second quartile	1037	25.28	73	26.26	964	25.21		143	27.15	1876	27.59	

Table 1 (continued)

Characteristics	Overall		30-day readmission due to VT (before adjustment)				*P* value	30-day readmission due to VT (after adjustment)				*P* value
			Yes		No			Yes		No		
	n	%	*n*	%	*n*	%		*n*	%	*n*	%	
Third quartile	1127	27.47	72	25.90	1055	27.59		131	24.96	1860	27.36	
Fourth quartile	1001	24.40	63	22.66	938	24.53		108	20.63	1513	22.26	
Primary payer							0.04					0.06
Medicare	2257	55.02	176	63.31	2081	54.42		334	63.59	3737	54.29	
Medicaid	307	7.48	20	7.19	287	7.51		41	7.76	506	7.35	
Private including health maintenance organization	1304	31.79	70	25.18	1234	32.27		130	24.68	2239	32.53	
Self-pay/no charge/others	226	5.51	12	4.32	214	5.60		21	3.97	401	5.83	
Hospital variables												
Non-elective index admissions	3153	76.94	236	84.89	2917	76.36	< 0.01	438	83.52	5228	75.89	0.03
Hospital procedural volume							0.10					0.29
1st tertile	1220	29.74	176	63.31	2081	54.53		144	27.48	2072	30.04	
2nd tertile	955	23.28	20	7.19	287	7.52		121	23.03	1621	23.50	
3rd tertile	976	23.79	70	25.18	1234	32.34		164	31.31	1744	25.29	
4th tertile	951	23.18	12	4.32	214	5.61		95	18.18	1460	21.17	
Hospital size							0.23					0.25
Small	158	3.85	16	5.76	142	3.71		36	6.83	291	4.21	
Medium	721	17.58	49	17.63	672	17.57		92	17.57	1251	18.13	
Large	3223	78.57	213	76.62	3010	78.71		397	75.60	5356	77.65	
Length of index hospital stay, median (Q1–Q3), d	5 (3–7)		5 (3–8)		5 (3–7)		0.01	4 (3–7)		5 (3–8)		-
Prolonged index hospital stay (length of stay, $d \geq 7$)	1276	31.11	101	36.33	1175	30.73	0.05	331	63.06	194	36.94	0.03

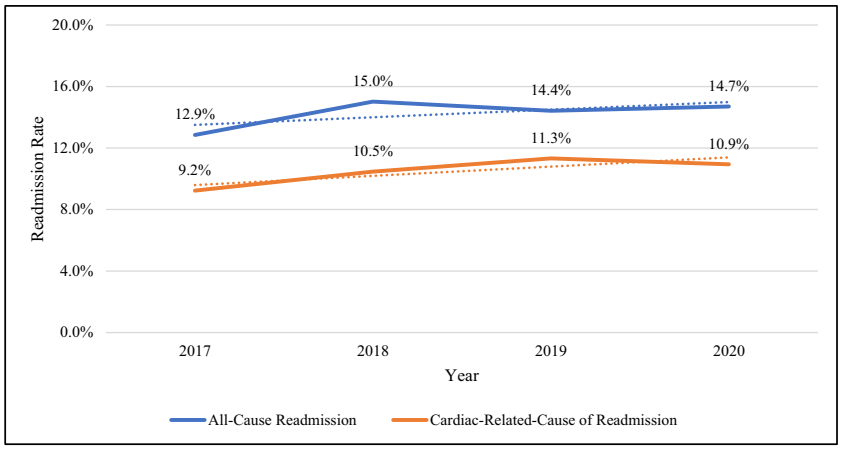

Fig. 1 Trend in 30-day readmissions rate after catheter ablation for ventricular tachycardia

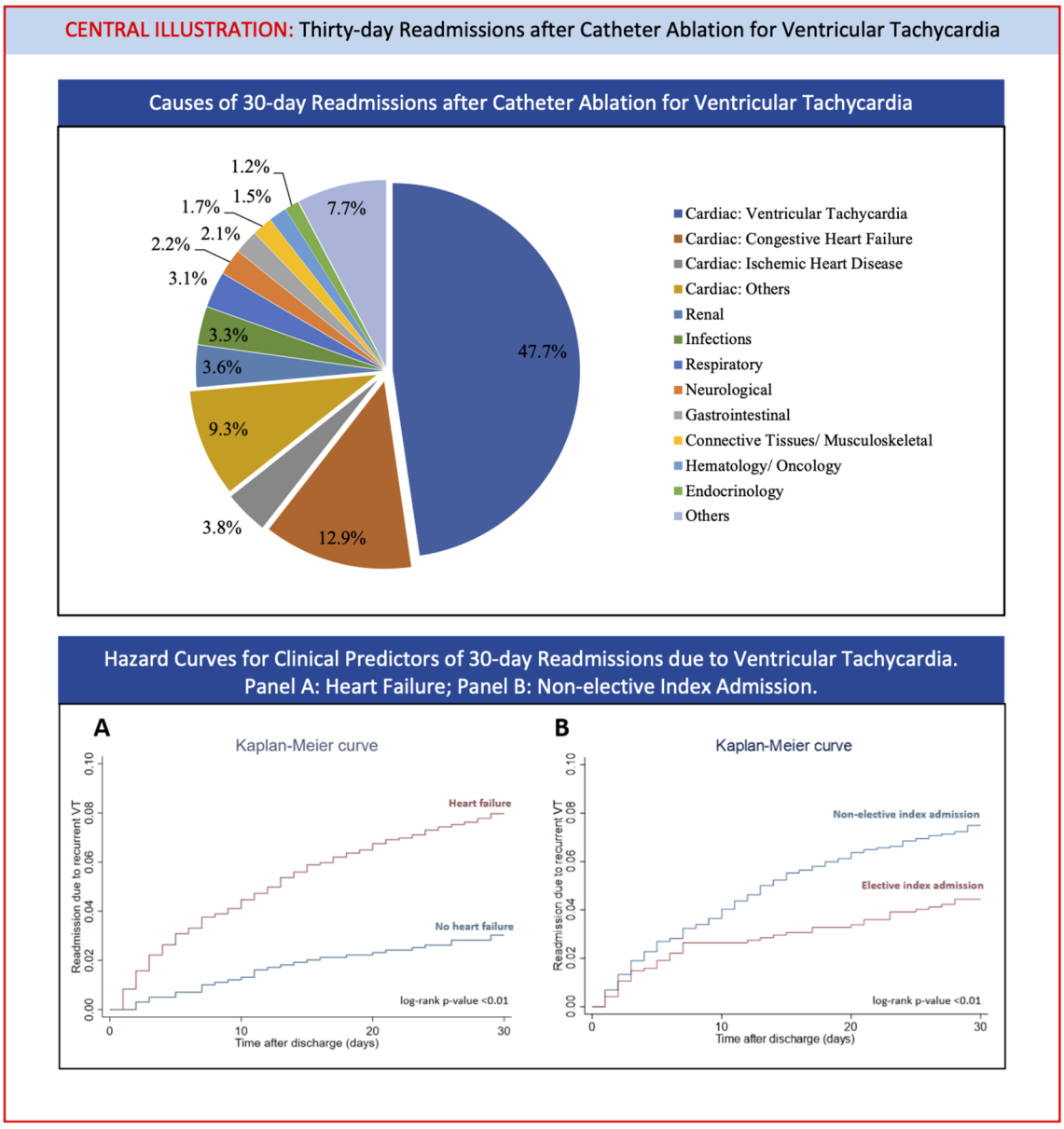

Fig. 2 Early readmission (≤30 days) after VT ablation

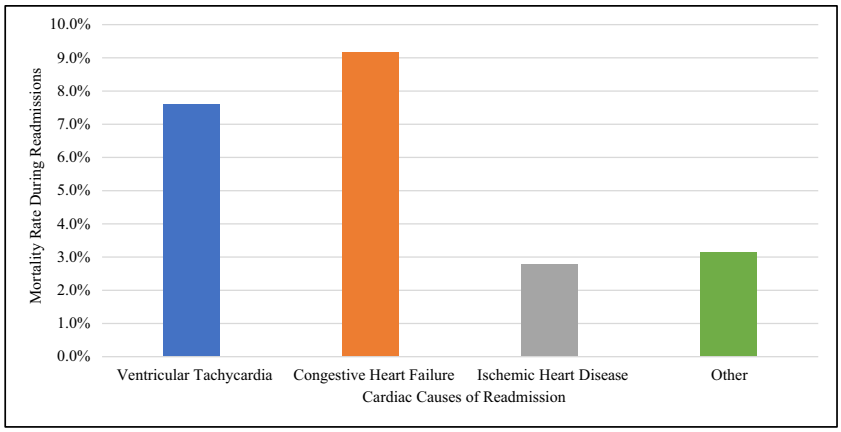

Fig. 3 In-hospital mortality during readmissions among patients readmitted for cardiac causes

Table 2 Significant independent predictors of 30-day readmissions for recurrent ventricular tachycardia (after adjustment)

Predictors of 30-day readmission due to recurrent VT	Univariable analysis		Multivariable analysis	
	Adjusted OR (95% CI)	*P* value	Adjusted OR (95% CI)	*P* value
Congestive heart failure	2.76 (1.71–4.45)	< 0.01	1.97 (1.12–3.47)	0.02
Non-elective index admissions	1.58 (1.03–2.43)	0.04	1.63 (1.04–.55)	0.03
Chronic kidney disease	1.52 (1.11–2.08)	< 0.01	1.29 (0.93–1.81)	0.13
Peripheral arterial disease	2.26 (1.57–3.24)	< 0.01	1.08 (0.45–2.61)	0.86
Prolonged index hospital stay (length of stay, $d \geq 7$)	1.29 (0.96–1.74)	0.09	1.12 (0.81–1.56)	0.49

of discharge. For the patients who were readmitted for recurrent VT, the median timing of readmission was 9 days (IQR 3–17 days), with 66.7% readmitted within 14 days of discharge. Among these patients, we further stratified the overall time to 30-day readmissions by subgroup based on heart failure or whether initial admissions were elective (Fig. 2).

4 Discussion

This is the largest contemporary all-payer data in the USAUnited States from a Nationwide Readmission Database on short-term post-discharge outcomes in patients who underwent catheter ablation for VT. Our analysis showed that (1) 14.2% of the patients undergoing VT ablation were readmitted within 30 days; (2) the most common cause of 30-day readmission after VT ablation was VT recurrence (rate of 6.8% post-VT ablation); (3) significant independent predictors of readmission for recurrent VT were congestive heart failure and non-elective index admissions; and (4) readmissions for CHF had the poorest in-hospital outcome among all early cardiac readmissions.

Early readmission following a procedure is an objective indicator of the procedure's safety and efficacy. It is thus important to determine the causes of readmission, particularly in patients who received any procedure, so that patient outcomes can be optimized.

The 30-day readmission rate of 14.2% was lower than an existing study of 19.2% in the population with myocardial infarction [4]. Our data better represents 30-day readmission post-VT ablation in general, as our data is not limited to myocardial-infarct-associated VT. Other reasons for the lower rate of 30-day readmission in our study could be different patient profiles with the inclusion of non-ischemic VT as well as procedural-associated improvement, as our dataset represents more contemporary numbers of 2017 to 2020 compared to 2010 to 2015 in the prior study [4].

A total of 6.8% of the patients were readmitted for recurrent VT within 30 days of discharge from the index hospitalization. This accounted for almost half of the 30-day readmissions (48%). Ventricular tachycardia recurrence is not rare in patients who received VT ablation, with an incidence of 30% within 12 months of the procedure [9]. Our data of 6.68% represents patients with VT who require hospital admission. An independent predictor for recurrent VT hospitalization is CHF. Patients with CHF may have a larger substrate for VT and, therefore, a greater risk of VT recurrence [10–12]. Another independent predictor for recurrent VT hospitalization is non-elective admissions, where VT ablation was performed on urgent or emergent basis admissions, as opposed to elective admissions for the VT ablation procedure. This result may be a reflection of the severity of the underlying substrate and VT. However, it may also potentially suggest that ablation outcomes may be better if it is performed electively as opposed

to urgently or emergently, similar to data from other types of procedures [13].

While most of the early readmission for cardiac causes occurred because of recurrent VT, readmission for CHF had the highest short-term mortality during readmission. In our study, more than 75% of the patients had CHF. It is estimated that 6.3% of the patients with heart failure who underwent VT ablation could develop decompensated heart failure following the procedure [14]. The reason for CHF decompensation after VT ablation could be related to the irrigation volume administered during VT ablation or myocardial stunning from the induction of VT and defibrillator shocks. Decompensated heart failure was also the second most common cause of early death among patients who underwent VT ablation procedures [15]. This highlights the importance of multi-disciplinary collaboration between electrophysiology and heart failure in both pre-procedural management and post-procedural care.

5 Limitations

Despite routine quality-control measures by HCUP to ensure the data validity and reliability, there are still some limitations in our study. Firstly, as with most large administrative database studies, the main limitation includes miscoding in primary diagnoses and underreporting of secondary diagnoses. Secondly, the out-of-hospital deaths that occurred prior to readmission are not recorded, which limits our early mortality to in-hospital mortality. Thirdly, specific patient variables such as left ventricular ejection fraction, medications, and procedural characteristics such as type of anesthesia, procedural duration, VT inducibility, VT mappability, ablative strategy, and location are unavailable. These limit our attempts to explore the impact of VT catheter ablation on procedural outcomes. Additionally, the analysis of causes of readmission is limited to the principal diagnosis of readmission. Lastly, our study included all forms of VT including those in ischemic cardiomyopathy, non-ischemic cardiomyopathy, and those without structural heart disease; thus, the outcome might be different compared to those in a specific population.

6 Conclusions

Recurrent VT was the most common cause of 30-day readmission after the VT ablation procedure, and heart failure and non-elective index admissions were the significant predictors of these early readmissions. Readmission due to CHF had the poorest outcome, with the highest mortality rate during the readmission. These highlight the importance of further research in ablation strategies to improve the efficacy of VT ablation and reduce the risk of cardiac reserve decompensation.

Data Availability We confirm that the data supporting the findings of this study are available within the article.

Declarations

Ethical approval Not applicable.

Informed consent Not applicable.

Conflict of interest The authors declare no competing interests.

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