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Clinical Research

Health Care Utilization After Ventricular Tachycardia Ablation: A Propensity Score-Matched Cohort Study

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See editorial by Nery et al., pages 147–149 of this issue.

ABSTRACT

Background: Catheter ablation of ventricular tachycardia (VT) can reduce the burden of ventricular arrhythmia (VA) but its effect on health care utilization and costs after such therapy is poorly known. We sought to compare the rates of cardiovascular (CV)-related hospitalizations, survival, and health care costs in patients with recurrent VT treated either with VT ablation or with medical therapy.

Methods: One-hundred implantable cardioverter-defibrillator patients with structural heart disease who underwent VT ablation were included. Propensity score-matched patients with recurrent VT treated with medical therapy were identified from a prospective registry of approximately 7000 *de novo* implantable cardioverter-defibrillator patients. Outcomes and costs were ascertained using health administrative databases.

Results: Among patients who underwent VT ablation, the cumulative rates of VA-related hospitalizations were lower in the 2 years after their

RÉSUMÉ

Contexte : L'ablation par cathéter du foyer de tachycardie ventriculaire (TV) peut réduire le fardeau de l'arythmie ventriculaire (AV), mais les effets de cette intervention sur l'utilisation et les coûts des soins de santé ultérieurs sont mal connus. Nous avons voulu comparer les taux d'hospitalisation liée à un problème cardiovasculaire, la survie et les coûts des soins de santé requis chez les patients présentant une TV récidivante ayant été traités soit par une ablation, soit par une prise en charge médicale.

Méthodologie : Cent patients porteurs d'un défibrillateur cardioverteur implantable et atteints d'une cardiopathie structurelle qui avaient subi une ablation de TV ont été inclus dans l'étude. Des patients appariés en fonction de leur coefficient de propension dont la TV récidivante avait été traitée par une prise en charge médicale ont été repérés dans un registre prospectif recensant environ 7000 personnes porteuses d'un défibrillateur cardioverteur implanté *de novo*. Les résultats des

Among patients with structural heart disease and left ventricular dysfunction, catheter-based ablation of ventricular tachycardia (VT) has been shown to effectively reduce the recurrence of VT in this population.[1-4] Despite the positive finding, the effect of VT ablation of clinical outcomes such as mortality, heart failure (HF) events, and health care utilization remains uncertain, because published trials are not specifically designed and powered to assess such end points.[5] To justify the continued growth of VT ablation, it is imperative for researchers to show that it can positively affect outcomes, which have a direct effect on our health care systems. This is particularly pertinent in the current era, because cost containment and cost-effectiveness justification are increasingly demanded and expected by health payers. These issues are germane to VT ablation, an invasive complex therapy with high associated procedural costs and morbidity.[6] It is conceivable that reduction of VT burden via ablation might reduce patients' subsequent downstream health care utilization by reducing hospital admissions or emergency

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ablation procedure compared with the year before (rate ratio, 0.3; 95% confidence interval [CI], 0.22-0.43). Rates of CV-related hospitalization and hospitalization because of VA post index date were similar between the VT ablation and medical therapy groups (hazard ratio [HR], 0.94; 95% CI, 0.57-1.54 and HR, 1.04; 95% CI, 0.57-1.91, respectively). Health care costs in the VT ablation patients were not increased post-ablation compared with the medical management group. The risk of all-cause mortality was lower among patients in the VT ablation group relative to the medical therapy group (HR, 0.64; 95% CI, 0.4-0.99).

Conclusions: Patients who underwent VT ablation experienced a significant reduction in their rate of VA-related hospitalizations. Patients treated with VT ablation had similar rates of CV-related hospitalization compared with those treated with medical therapy without increased health care-related costs.

traitements et les coûts ont été établis à partir de bases de données administratives sur la santé.

Résultats : Parmi les patients dont la TV avait été traitée par ablation, les taux cumulatifs d'hospitalisation liée à l'AV ont été plus bas au cours des 2 années suivant l'ablation que durant l'année précédant cette intervention (rapport des taux, 0,3; intervalle de confiance [IC] à 95 %, 0,22-0,43). Les taux d'hospitalisation liée à un problème cardiovasculaire et d'hospitalisation en raison de l'AV après la date index étaient comparables chez les patients traités par ablation et chez ceux traités par une prise en charge médicale (rapport des risques instantanés [RRI], 0,94; IC à 95 %, 0,57-1,54 et RRI, 1,04; IC à 95 %, 0,57-1,91, respectivement). Les coûts des soins de santé dans le groupe traité par ablation n'ont pas augmenté après l'intervention comparativement au groupe ayant fait l'objet d'une prise en charge médicale. Le risque de mortalité toutes causes confondues était plus faible dans le groupe traité par ablation que chez les patients ayant fait l'objet d'une prise en charge médicale (RRI, 0,64; IC à 95 %, 0,4-0,99).

Conclusions : Chez les patients dont la TV a été traitée par ablation, une réduction marquée du taux d'hospitalisation liée à l'AV a été observée. Les patients traités par ablation ont affiché des taux d'hospitalisation liée à un problème cardiovasculaire comparables à ceux du groupe ayant fait l'objet d'une prise en charge médicale, sans augmentation des coûts en matière de soins de santé.

department (ED) visits. Recent data have suggested that VT ablation could result in a decrease in health care costs but no control arm was present in one of the reports[7] and probably it only applies for patients receiving amiodarone at baseline as per subgroup data from the Ventricular Tachycardia Ablation vs Escalated Antiarrhythmic Drug Therapy in Ischemic Heart Disease (VANISH) trial.[8] As such, better delineation of the relationship between VT ablation and patients' subsequent downstream health care utilization is important, because it might be a strong driver of health policy outcomes for this therapy.[9]

Using clinical and administrative health databases from Ontario, Canada, we sought to examine if VT ablation has a positive effect on patients' subsequent health care utilization by comparing the rates of cardiovascular (CV)-related hospitalizations, CV mortality, all-cause mortality, and costs between VT ablation patients and a propensity score-matched cohort of patients with recurrent VT treated with medical therapy.

Methods

This study was approved by the institutional review board at Sunnybrook Health Sciences Centre (Toronto, Ontario, Canada) as well as by the Review Ethics Board at University Health Network (Toronto, Ontario, Canada).

Study populations

VT ablation cohort. From a single institution (University Health Network, Toronto, Ontario, Canada), 103 consecutive patients with an implantable cardioverter-defibrillator (ICD) and structural heart disease, depressed left ventricular ejection fraction (LVEF) < 40%, recurrent symptomatic VT refractory to antiarrhythmic drug therapy, and with more than 1 appropriate ICD shock who underwent catheter-based VT ablation were identified between April 2008 and September 2015.

Selection of the medical management cohort. VT patients treated with medical therapy alone were obtained from a cohort of approximately 7000 subjects in the ICD database, which prospectively collected data from all 10 ICD implantation centres in Ontario, Canada from February 2007 to May 2012. The design, implementation, and maintenance of the Ontario ICD database have been previously detailed elsewhere.[10] In brief, all patients referred for evaluation in ICD clinics were enrolled into a prospective registry with detailed clinical data collection at enrollment and with subsequent clinical follow-up and documentation of ICD therapies. The Ontario Ministry of Health and Long-Term Care mandated this registry. As a prescribed entity under Ontario's health information privacy legislation, we were able to collect data on all patients in this registry without the need for written informed consent.

All 10 institutions (see the *Participating Centers in the Ontario ICD Database* section of the Supplementary Material) where patients were followed-up are tertiary centres that have the capability of deciding to perform VT ablation procedures and performing guideline-directed treatment thus avoiding clustering effects in the treatment depending on the institution and providing for a similar threshold for VT ablation. For this analysis, selection of subjects into the medical therapy (control) group was restricted to all institutions except University Health Network to mitigate potential selection bias. Inclusion criteria into the control group were the following: presence of structural heart disease, LVEF < 40%, and an ICD; at least 1 appropriate shock with at least 1 subsequent ventricular arrhythmia (VA)-related hospitalization; and without a VT ablation procedure (Table 1).

Propensity score-matching schemes

Propensity score-matching was used to match each subject in the VT ablation cohort with a similar subject in the medical therapy cohort. Variables present and measured at baseline that have been previously shown to affect mortality in ICD patients[10] were used for inclusion in the propensity score model: age, sex, LVEF groups ($\leq$ 20%, 21%-30%, > 30%), diabetes, creatinine levels, and type of cardiomyopathy (ischemic or nonischemic). Subjects were matched on the logit of the propensity score using calipers of width equal to 0.2 of the SD of the logit of the propensity score.[11] We did not include antiarrhythmic drug usage in the main analysis because time points for the collection of these data were different in each group (Table 2).

Additionally, with the objective of better classifying our 2 groups of patients and to account for the variability in the VT burden and the antiarrhythmic drug usage pre-index date a secondary propensity matching scheme was studied by adding those 2 variables to the matching scheme. Antiarrhythmic drug usage was obtained from the Ontario Drug Database (Table 3).

Follow-up of the study population

VT ablation patients. The index date (and time at which follow-up started) for these patients was the date of the VT ablation procedure. Antiarrhythmic drug usage data were collected at the time of the ablation procedure. Follow-up was up to the earliest date of death or March 31, 2017.

Medical management patients. The index date (and time at which follow-up started) for the control patients was the date of the rehospitalization for VA after a first shock had occurred. This date was elected to mitigate lead-time bias because those patients at the time of recurrent VA readmission could have undergone a VT ablation procedure but continued medical therapy according to physician preference. Antiarrhythmic drug usage data were collected at the time of ICD implantation. Follow-up for hospital admissions and ED visits was up to the earliest date of death or March 31, 2017. Causes of death were analyzed until December 2014 according to administrative data availability.

Data sources

Mortality data were collected using each patient's unique, encoded health card number where ICD data were linked to administrative databases for vital statistics, namely the Registered Persons Database for death events. Vital statistics information was ascertained in all study patients. CV death was determined using the Ontario Registrar General Database. Information about CV hospitalizations before and after the procedure or after the recurrent shock was identified via the Canadian Institute for Health Information Discharge Abstract Database using the International Classification of Diseases Tenth Revision, Canada (ICD) coding system. Codes used for HF were I50, for ischemic heart disease (IHD) I20-I25, and for VA I459-I461, I469-I472, I479, I4900, and I4901. Drugs prescribed at the time of index admission were obtained from the Ontario Drug Benefit Database. These data sets were linked using unique encoded identifiers and analyzed at the Institute for Clinical Evaluative Sciences. Accuracy of the most responsible diagnosis for detection of VT was assessed according to ICD logs of VT therapies being the gold standard. The sensitivity of hospitalization for VT to detect ICD-logged VT was calculated to be 95.5% for accurately classifying patients who experienced VT as assessed in the ICD logs.

Outcomes and comparisons

The primary outcome in this study was the occurrence of nonelective hospitalizations and ED visit for CV reasons including HF, VA, or IHD. Secondary outcomes included: all-cause mortality and CV mortality. Those outcomes were compared using 2 strategies: (1) rates of events 1 year pre-VT ablation vs 2 years post-VT ablation among patients who underwent the procedure; and (2) propensity-matched medical management patients vs VT ablation patients followed for 2 years after the index date (Fig. 1).

Cost analysis

For matched patients in the VT ablation cohort and the medical therapy cohort, any health care costs occurred during 1 year before and after the index date were calculated in 2015 Canadian dollars. The health costs included all types of costs, such as hospital services (inpatient, same-day surgery, rehabilitation, complex and continuing care, and long-term care), drug claims recorded in Ontario Drug Benefit, home care services, or health services covered by the Ontario Health Insurance Plan. Those costs were compared: (1) within each cohort; the costs 1 year before and after the index were compared; and (2) the expense occurred in the

Table 1. Baseline characteristics of patients before propensity score matching

	Medical management (n = 211)	Catheter ablation group (n = 103)	Standardized difference
Age	65.39 ± 12.40	62.25 ± 14.05	0.2367
Male sex	178 (84.4)	93 (90.3)	0.179
LVEF groupings			
≤ 20	33 (15.6)	28 (27.2)	0.2843
20%-30%	80 (37.9)	45 (43.7)	0.1177
> 30%	82 (38.9)	30 (29.1)	0.2066
Missing	16 (7.6)	0 (0.0)	0.4051
Diabetes mellitus	41 (19.4)	15 (14.6)	0.1299
Creatinine level, μMol/L	117.81 ± 89.10	112.53 ± 43.32	0.0753
Amiodarone use	63 (29.9)	79 (76.7)	1.0633
Ischemic cardiomyopathy	140 (66.4)	66 (64.1)	0.0477

Data are presented as mean ± SD or n (%).

LVEF, left ventricular ejection fraction.

Table 2. Baseline characteristics of patients after baseline propensity score-matching

	Medical management (n = 100)	Catheter ablation group (n = 100)	Standardized difference
Age	63.18 ± 13.67	62.97 ± 13.43	0.0155
Male sex	92 (92.0)	90 (90.0)	0.0699
LVEF groupings			
≤ 20	27 (27.0)	28 (28.0)	0.0224
20%-30%	40 (40.0)	42 (42.0)	0.0407
> 30%	33 (33.0)	30 (30.0)	0.0646
Diabetes mellitus	11 (11.0)	15 (15.0)	0.1192
Creatinine level, μMol/L	120.17 ± 100.98	113.20 ± 43.60	0.0896
Ischemic cardiomyopathy	68 (68.0)	65 (65.0)	0.0636

Data are presented as mean ± SD or n (%).
LVEF, left ventricular ejection fraction.

same period were compared between matched medical management patients and VT ablation patients.

Statistical analysis

In the intragroup analysis among patients who underwent VT ablation a Poisson regression model estimated using generalized estimating equations methods was applied to compare event rates pre- and post-VT ablation. In the between groups analysis, the similarity of measured baseline covariates was assessed between the VT ablation patients and the medical therapy patients using standardized differences, before and after matching.[12] In the matched sample, the effect of the intervention (VT ablation) was determined by using a cause-specific hazard model to regress the cause-specific hazard of the outcome on an indicator variable denoting treatment status.[13] The time to outcomes was calculated as time to first event. Importantly, a large percentage of ED visits led to unplanned hospital admissions (90% of HF ED visits, 81% of IHD ED visits, and 87% of VA-related ED visits). In these cause-specific models, death was accounted for as a competing risk (in the model in which all-cause mortality was used, a conventional Cox model was used).[14] A robust variance estimator was used to account for the matched nature of the sample.[15] Median costs were compared using a signed rank test. All analyses were performed using SAS version 9.4.5 (SAS Institute, Inc, Cary, NC).

Results

Baseline clinical characteristics and procedural data of the matched cohort

Between April 2008 and September 2015, we identified 100 patients in the VT ablation group. From a cohort of approximately 7000 patients who received *de novo* ICDs, we identified 211 patients for inclusion in the pool of potential controls who received medical management (Table 1). The final cohort consisted of 100 matched pairs of patients and their baseline characteristics are shown in Table 2. Notably, 35% of patients had a nonischemic etiology. The total follow-up duration for patients in the VT ablation and medical management group was 353 person-years and 362 person-years, respectively. See the *Procedural Characteristics of the VT Ablation Treatment* section of the Supplementary Material for details.

Health care utilization rates

VT ablation group. In the year before VT ablation, the overall rate of unplanned CV hospitalizations (because of VA, HF, or IHD) was 144.7 admissions per 100 person-years. It decreased to 48.6 admissions per 100 person-years in the 2 years after VT ablation (rate ratio [RR], 0.35; 95% confidence interval [CI], 0.26-0.47; $P < 0.001$). The cumulative rate of ED visits because of CV causes (because of VA, HF, or IHD)

Table 3. Sensitivity analysis propensity score matching

	Medical management (n = 66)	Catheter ablation group (n = 66)	Standardized difference
Age	63.68 ± 13.58	62.21 ± 14.72	0.1038
Male sex	60 (90.9)	58 (87.9)	0.0985
LVEF grouping			
≤ 20	13 (19.7)	14 (21.2)	0.0376
20%-30%	25 (37.9)	25 (37.9)	0
> 30%	28 (42.2)	27 (40.9)	0.0307
Diabetes mellitus	8 (12.1)	9 (13.6)	0.0452
Creatinine level, μMol/L	111.05 ± 81.0	105.85 ± 31.27	0.0848
Ischemic cardiomyopathy	41 (62.1)	40 (60.6)	0.031
Number of VT hospitalizations within 1 year before the index date	0.76 ± 0.84	0.76 ± 0.8	0
Patients receiving antiarrhythmic drugs on the index date	25 (37.9)	23 (34.8)	0.063

Baseline characteristics of patients after the secondary propensity score matching that included age, etiology of cardiomyopathy, previous diabetes, antiarrhythmic medication use, along with the quadratic term of age, and interaction terms between LVEF group with other variables. Data are presented as mean ± SD or n (%).
LVEF, left ventricular ejection fraction; VT, ventricular tachycardia.

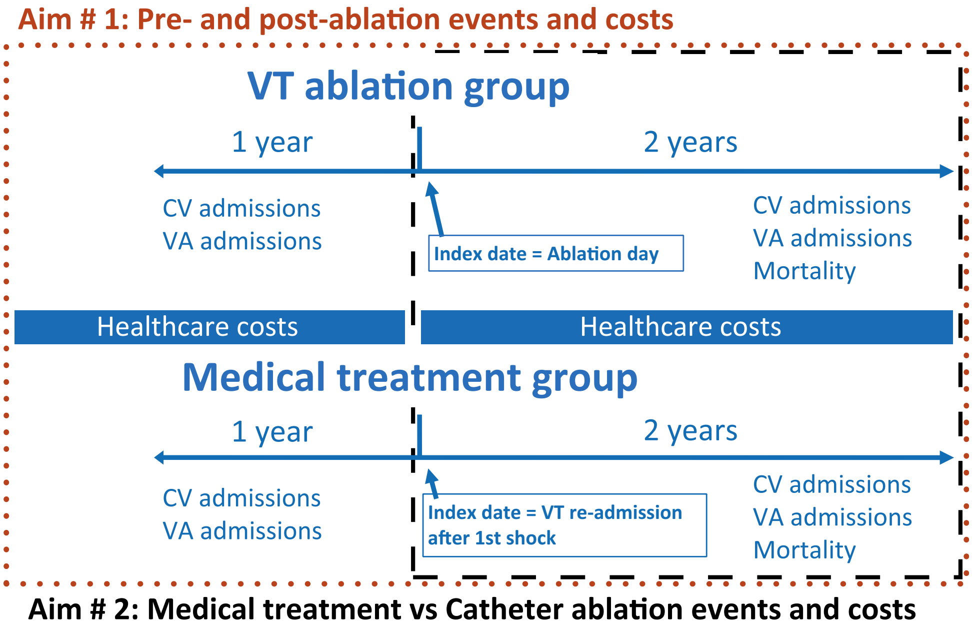

Figure 1. Study design and aims. **Dotted red line** indicates the timeline of the pre- and post-ventricular tachycardia (VT) ablation event rate study. Index time is the day of the VT ablation procedure. **Black interrupted line** indicates the medical treatment vs VT ablation comparison with index time in the medical treatment group being the day of a subsequent readmission for VT after having experienced a previous appropriate implantable cardioverter-defibrillator shock for VT (recurrent VT). CV, cardiovascular; VA, ventricular arrhythmia.

was 139.8 visits per 100 person-years in the year before VT ablation. This rate decreased to 54.6 visits per 100 person-years in the 2 years after VT ablation (RR, 0.41; 95% CI, 0.30-0.56; $P < 0.001$). Reduction in the number of VA-related unplanned hospitalizations and ED visits was the primary driver of the overall reduction in hospitalization and ED visit rates. In the year before VT ablation, the cumulative rate of unplanned CV hospitalizations because of VA was 114.6 admissions per 100 person-years, which decreased to 33.8 admissions per 100 person-years in the 2 years after VT ablation (RR, 0.30; 95% CI, 0.22-0.43; $P < 0.001$). Similarly, the cumulative rate of ED visits because of VA was 95.1 visits per 100 person-years in the year before VT ablation, which decreased to 27.9 visits per 100 person-years in the 2 years after VT ablation (RR, 0.31; 95% CI, 0.21-0.46; $P < 0.001$; Table 4).

Medical management group. In the year before experiencing a recurrent appropriate ICD shock, patients treated medically had an overall rate of unplanned CV hospitalizations (because of VA, HF, or IHD) of 53.0 admissions per 100 person-years. After experiencing the index recurrent shock the rate was 55.9 admissions per 100 person-years (RR, 1.10; 95% CI, 0.76-1.60; $P = 0.597$). The cumulative rate of ED visits because of CV causes (because of VA, HF, or IHD) was 75.0 visits per 100 person-years in the year before a recurrent appropriate ICD shock. This rate was 60.6 visits per 100 person-years in the 2 years after the index

Table 4. Outcomes and measures of association 12 months before VT ablation vs 24 months after VT ablation among patients who underwent the procedure

Outcome	Event rate per 100 person-years: 12 months before VT ablation (reference)	Event rate per 100 person-years: 24 months after VT ablation	Rate ratio (95% CI)	*P*
Unplanned hospital admissions				
HF	20.39	12.46	0.66 (0.33-1.34)	0.2516
VA	114.56	33.81	0.30 (0.22-0.43)	< 0.0001
IHD	9.71	< 5	0.24 (0.08-0.77)	0.016
Cardiovascular hospitalization (HF + VA + IHD)	144.66	48.64	0.35 (0.26-0.47)	< 0.0001
ED visits				
HF	32.04	18.39	0.60 (0.32-1.12)	0.1067
VA	95.15	27.88	0.31 (0.21-0.46)	< 0.0001
IHD	12.62	8.30	0.68 (0.33-1.42)	0.3077
Cardiovascular ED visit (HF + VA + IHD)	139.81	54.58	0.41 (0.30-0.56)	< 0.0001

CI, confidence interval; ED, emergency department; HF, heart failure; IHD, ischemic heart disease; VA, ventricular arrhythmia; VT, ventricular tachycardia.

Canadian Journal of Cardiology
Volume 35 2019

Table 5. Outcomes and measures of association 12 months before recurrent VT vs 24 months after recurrent VT among patients who were medically managed after experiencing recurrent appropriate ICD shocks for VT

	Event rate per 100 person-years			
Outcome	12 Months before earliest recurrent VT arrhythmia (reference)	24 Months after earliest recurrent VT arrhythmia	Rate ratio (95% CI)	*P*
Unplanned hospital admissions				
HF	28.00	26.98	1.02 (0.61-1.70)	0.9514
VA	16.00	23.69	1.52 (0.78-2.95)	0.2175
IHD	9.00	5.27	0.58 (0.21-1.62)	0.3007
Cardiovascular hospitalization (HF + VA + IHD)	53.00	55.94	1.10 (0.76-1.60)	0.597
ED visits				
HF	34.00	32.91	1.07 (0.62-1.84)	0.8081
VA	25.00	20.40	0.81 (0.45-1.47)	0.4926
IHD	16.00	7.24	0.46 (0.22-0.96)	0.0386
Cardiovascular ED visit (HF + VA + IHD)	75.00	60.55	0.83 (0.56-1.22)	0.344

CI, confidence interval; ED, emergency department; HF, heart failure; ICD, implantable cardioverter-defibrillator; IHD, ischemic heart disease; VA, ventricular arrhythmia; VT, ventricular tachycardia.

recurrent shock (RR, 0.83; 95% CI, 0.56-1.22; $P = 0.344$; Table 5).

Comparison of health care utilization of patients treated with medical therapy vs VT ablation

Event rates of first unplanned hospitalization and first ED visit for the VT ablation and medical therapy groups are presented in Table 6. On the basis of the reported hazard ratios (HRs), the instantaneous rates of unplanned hospitalizations, and ED visits because of HF, VA, or IHD were similar between the 2 groups. Notably, during the year before the index date the burden of VA was much higher in the VT ablation group (Table 5).

Costs of health care utilization of patients treated with medical therapy vs VT ablation

Analysis of total health care-related costs is summarized in Table 7. Among patients who underwent VT ablation a significant increase in the median costs was seen in the year after the index procedure. In contrast, patients who continued medical therapy had similar costs after their repeated admission for recurrent appropriate ICD shocks for VT. Patients treated with VT ablation had a baseline 1 year preablation cost that was slightly higher than the medically treated cohort although no statistically significant difference was seen. Post VT ablation costs remained similar for the VT ablation cohort compared with the medical treatment group.

Mortality

Rates of CV mortality were similar between the VT ablation and medical therapy group (HR, 0.75; 95% CI, 0.38-1.48; $P = 0.41$). Patients in the VT ablation group had lower all-cause mortality rates compared with those treated with medical therapy (HR, 0.63; 95% CI, 0.40-0.998; $P = 0.0489$; Table 6).

Sensitivity analysis

In an additional analysis patients were matched according to the number of admissions for VA and the presence of antiarrhythmic drug usage at the time of the index date (sotalol or amiodarone). Sixty-six pairs of patients were found with a well balanced matching scheme (Table 3). In this analysis VT ablation was shown to be linked to a decreased number of visits to the ED for VA during follow-up (HR, 0.53; 95% CI, 0.28-0.97). There were no other differences in the outcomes although a trend toward better survival was also

Table 6. Outcomes (calculated using time to first event) and measures of association between groups (VT ablation vs medical treatment group)

	Event rate per 100 person-years (follow-up person-years)			
Outcome	VT ablation group (n = 100)	Medical treatment group (n = 100)	Hazard ratio (95% CI)	*P*
Unplanned hospital admissions				
HF	5.21 (326)	9.5 (305)	0.68 (0.34-1.33)	0.26
VA	12.63 (253)	12.65 (261)	1.04 (0.57-1.91)	0.89
IHD	1.46 (343)	3.22 (342)	0.31 (0.09-1.11)	0.07
Cardiovascular hospitalization (HF + VA + IHD)	19.14 (230)	22.13 (230)	0.94 (0.57-1.54)	0.79
ED visits				
HF	7.42 (296)	9.41 (298)	0.84 (0.44-1.59)	0.58
VA	10.78 (278)	12.38 (259)	0.88 (0.47-1.62)	0.68
IHD	3.4 (323)	4.18 (335)	0.50 (0.18-1.38)	0.18
Cardiovascular ED visit (HF + VA + IHD)	21.77 (221)	22.37 (223)	0.86 (0.54-1.38)	0.54
Cardiovascular mortality	8.09 (284)	9.14 (328)	0.75 (0.38-1.48)	0.41
All-cause mortality	12.45 (353)	16.84 (362)	0.63 (0.40-0.998)	0.049

CI, confidence interval; ED, emergency department; HF, heart failure; IHD, ischemic heart disease; VA, ventricular arrhythmia; VT, ventricular tachycardia.

Table 7. Analysis of health care-related costs: primary analysis of costs within and between VT ablation and medical treatment patients

	Median (IQR) costs within 1 year before index procedure/admission (in 2015 CAD$)	Median (IQR) costs within 1 year after the index procedure/admission (in 2015 CAD$)	*P* for signed rank test within groups
VT ablation patients (n = 100)	39,600.00 (21,751.50-64,367.50)	40,707.00 (22,240.50-88,830.50)	0.0460
Medical treatment patients (n = 100)	28,376.00 (7345.00-60,108.00)	34,338.50 (15,324.00-67,585.00)	0.2703
P for signed rank test between groups	0.1053	0.0514	

IQR, interquartile range; VT, ventricular tachycardia.

seen (HR, 0.65; 95% CI, 0.39-1.09; *P* = 0.1; Table 8). Further details are shown in Supplemental Table S1.

Discussion

There are 4 major findings in our study. First, patients with structural heart disease and impaired LVEF who underwent VT ablation experienced a significant reduction in their number of unplanned hospital admissions and ED visits because of VA thus indicating the effectiveness of the treatment strategy undertaken. Second, we observed that VT ablation patients had comparable rates of health care utilization and major adverse cardiac events compared with a matched cohort of medically treated patients. Third, our analysis suggests improved survival for patients who underwent VT ablation relative to those treated with medical therapy. Fourth, health care-related costs were not significantly increased after VT ablation compared with medical treatment. Taken together, these results suggest that when VT ablation is performed in a carefully selected population of patients with advanced cardiac dysfunction and VAs, a meaningful reduction in their subsequent health care utilization can be achieved without compromising their safety or survival, however, a decrease in their health care costs is not to be expected.

Effect of VT ablation on VA-related hospitalizations

Previous studies had shown that VT ablation reduces VT burden.[2] However, these studies were neither designed nor powered to address whether reduction of VT burden using ablation could reduce mortality or unplanned hospitalizations/ED visits because of VA. Elucidating the potential effect of VT ablation on such outcomes is critical if the overarching goal is to influence health policy. In this respect, our study is novel because it focuses on the downstream health care utilization effect of VT ablation in a medically compromised population of patients with VT. Among patients in the VT ablation group, we observed high rates of unplanned hospitalizations and ED visits because of VA, at approximately 1.5 admissions and approximately 1.4 ED visits per person-year in the 12 months before ablation. Remarkably, we noted a threefold decrease in the cumulative rates of VA-related hospitalizations and ED visits for these patients within the 2 years after VT ablation.

The favourable findings of VT ablation on health care utilization are restricted to our intragroup analysis. When we compared the rates of unplanned hospitalization and ED visits between patients who underwent VT ablation with a matched cohort of VT patients who were medically treated only (ie, not ablated), we observed comparable outcomes. These findings were consistent with the VANISH trial in terms of cardiac hospitalization outcomes.[5] However, in our study, in the 12 months before the start of study follow-up, the cumulative rates of unplanned VA-related hospitalizations and ED visits were markedly greater in the VT ablation group (10-fold and 5-fold, respectively) than the medical therapy group. This suggested that patients in the VT ablation group might represent a higher arrhythmic risk group than the medical treatment group (more VA-related admissions despite being matched for many other prognostic markers). Our finding that the postprocedural rates of hospital admission and ED visits of patients who underwent VT ablation were similar to a matched cohort of medically treated VT patients actually might favourably reflect the effect of VT ablation on patients' subsequent arrhythmic risk. Moreover, even when matching patients with the same antiarrhythmic drug usage and number of VA-related admissions in the year before the index date we

Table 8. Sensitivity analysis: outcomes (calculated using time to first event) and measures of association between groups (VT ablation vs medical treatment group) using the propensity score that includes AAD usage and number of VA-related admissions

	Event rate per 100 person-years (follow-up in person-years)			
Outcome	VT ablation group (n = 66)	Medical treatment group (n = 66)	Hazard ratio (95% CI)	*P*
Unplanned hospital admissions				
HF	< 5 (235)	5.95 (235)	0.74 (0.33-1.68)	0.471
VA	9.01 (200)	9.26 (194)	0.97 (0.49-1.90)	0.917
IHD	< 5 (249)	< 5 (245)	0.50 (0.18-1.35)	0.170
Cardiovascular hospitalization (HF + VA + IHD)	14.47 (180)	16.34 (184)	0.83 (0.49-1.41)	0.496
ED				
HF	7.06 (213)	6.89 (232)	0.91 (0.43-1.93)	0.811
VA	7.45 (215)	14.5 (172)	0.53 (0.28-0.97)	0.041
IHD	< 5 (244)	< 5 (240)	0.72 (0.28-1.86)	0.495
Cardiovascular ED visit (HF + VA + IHD)	16.67 (174)	22.12 (158)	0.75 (0.47-1.22)	0.246
Cardiovascular mortality	7.44 (202)	10.72 (224)	0.61 (0.30-1.24)	0.171
All-cause mortality	9.78 (256)	14.35 (258)	0.65 (0.39-1.09)	0.099

AAD, antiarrhythmic drug; CI, confidence interval; ED, emergency department; HF, heart failure; IHD, ischemic heart disease; VA, ventricular arrhythmia; VT, ventricular tachycardia.

confirmed very similar results. Notably, a decrease in VA-related visits to the ED in the VT ablation group was seen. This could translate into a decrease of unplanned hospitalizations that is not detected in our model because it is driven by time to first event and patients very frequently visit the ED before having an unplanned hospitalization. Our findings raise the tempting possibility that VT ablation can potentially assuage the risk of a previously highly arrhythmic patient cohort to a more stable clinical state. Larger-scale, prospective, multicentre studies with a focus on the real-world health care utilization outcomes of VT ablation vs medical therapy are required to formally address this hypothesis.

Effect of VT ablation on HF outcomes

A bidirectional relationship exists between HF and VAs, making them two closely linked entities. It is not uncommon for HF to serve as an important trigger for VAs among patients with left ventricular dysfunction. However, onset of sustained VAs can exacerbate HF in some patients. The role of VT ablation in preventing subsequent HF onset is scarcely addressed in published VT ablation trials. Neither VANISH nor Thermocool observed differences in HF event rates between the VT ablation and medical therapy groups.[5,16] No data on HF outcomes were reported by the **S**ubstrate **M**apping and **A**blation in **S**inus Rhythm to **H**alt **V**entricular **T**achycardia (SMASH-VT) and the **V**entricular **T**achycardia **A**blation in **C**oronary **H**eart Disease (VTACH) trials.[17,18] Moreover, there is a theoretical risk that patients' HF status might be worsened by VT ablation when the already-compromised myocardium is ablated and destroyed. This consideration is particularly relevant in the current era when extensive substrate ablation is advocated by some groups worldwide.[19,20] In this respect, our results provide reassurance to clinicians on the effect of VT ablation on patients' subsequent HF outcomes if an activation mapping and late potential elimination strategy is followed.

Effect of VT ablation on mortality

Our results suggest that patients who underwent VT ablation had lower all-cause mortality compared with those who were medically treated. However, no difference in the risk of CV mortality was observed between the two groups. Because of the retrospective and nonrandomized design of our study, these findings are hypothesis-generating and should be interpreted with caution. However, there were recent data suggesting that VT ablation could be associated with improved survival in the sickest HF patients.[21] Without randomized trial data, it is not possible to conclude whether VT ablation can reduce mortality even if it is performed in the sick, high-risk patients at the present juncture. In addition, our sensitivity analysis adding the antiarrhythmic drug usage and the VA burden before the index date did not show a survival benefit for the VT ablation group. Accordingly, clinicians must rely on studies that focus on other clinically relevant outcomes (eg, health care utilization, VT recurrence, quality of life) to decide on whether VT ablation should be offered to their patients.

Effect of VT ablation on health care costs

VT ablation is a procedure with very high costs as it pertains to advanced electroanatomical mapping systems, expensive catheters, multiple physicians, prolonged hospital stay, etc. One could hypothesize that if there were large benefits to be expected in terms of downstream cost savings after the procedure this would be a cost-effective strategy. Interestingly, pre-index date costs showed no significant differences between groups although a trend toward higher costs in the VT ablation group was seen, which could well be a reflection of a higher number of hospitalizations and ED visits in this group. Additionally, our analysis suggests that there was no comparative increase in costs after the VT ablation procedure compared with medically treated patients with recurrent VT. Although the higher VA-related admissions burden in the VT ablation group pre-procedure might suggest that their health care consumption would keep increasing if the procedure was not performed, our analysis was not designed to assess this hypothesis. A large randomized trial with real-world cost analysis would be needed to answer this question and recent data from the VANISH trial have shown that the decrease in health care-related costs might be limited to patients with VT refractory to amiodarone usage.[8]

Limitations

Our study has a number of important limitations. It was a retrospective, single-centre experience of VT ablation outcomes and it is subject to the usual limitations of observational research in terms of selection bias and overall generalizability. Outcomes were ascertained using administrative databases. Our findings need to be validated with larger-scale, preferably prospective studies. Second, although we use 2 propensity scores to match key baseline characteristics of patients treated with ablation vs medical therapy, residual unmeasured confounding might still persist. Yet, even if there was residual confounding that could not be accounted for using our statistical methods, we did incorporate variables that are known to be strongly associated with adverse outcomes in the ICD and HF population in our propensity score.[22] In addition, it should be pointed out that the presence of survival and lead-time bias could exist in the VT ablation group, which would potentially bias our findings away from the null. However, most of our outcomes were similar between the VT ablation and medical therapy groups. Therefore, even if the VT ablation group is affected by survival and lead-time bias, their potential effects on our results is, at best, uncertain. Furthermore, in the 12 months before the start of follow-up, patients in the VT ablation group had considerably higher rates of HF- and VA-related hospitalizations and ED visits than those in the medical therapy group. In this respect, survival and lead-time bias did not appear to be important factors in selecting a subgroup of lower-risk VT ablation patients in our comparative analysis.

Conclusions

After VT ablation, patients experienced a significant decrease in their rates of unplanned hospitalizations and ED visits because of VA relative to their preablation state. Patients who underwent VT ablation had a higher burden of VA-related admissions pre-procedure and experienced comparable health care utilization outcomes and costs after the procedure compared with those who were medically managed. There was no significant difference in costs among the two treatment strategies although patients treated with VT ablation seemed to experience lower overall mortality rates.

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Disclosures

The authors have no conflicts of interest to disclose.

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Supplementary Material

To access the supplementary material accompanying this article, visit the online version of the *Canadian Journal of Cardiology* at www.onlinecjc.ca and at https://doi.org/10.1016/j.cjca.2018.10.011.