Outcomes of Telemedicine Video-Conferencing Clinic Versus In-Person Clinic Follow-Up for Implantable Cardioverter-Defibrillator Recipients

See Editorial by Turakhia

BACKGROUND: Implantable cardioverter-defibrillator (ICD) recipients require close follow-up that can be difficult for patients who have to travel long distances for clinic follow-up. We aimed to compare clinical outcomes between ICD patients followed-up in a telemedicine video-conferencing clinic (TMVC) and a conventional in-person clinic (CIC). We hypothesized that outcomes of patients followed in the TMVC are noninferior to the CIC.

METHODS AND RESULTS: This retrospective study compares time to first appropriate ICD therapy, time to first inappropriate ICD therapy, time to first shock, and overall survival in patients followed in TMVC compared with CIC between 2001 and 2016. Two hundred and eighty-seven patients were followed in the TMVC group and 236 patients in the CIC. The average age of the TMVC and CIC groups was 64.13±9.38 and 65.23±8.57 years, respectively (P=0.164). There was no difference in the modified Seattle heart failure model score between the 2 groups (–0.12±1.0 versus –0.21±0.99; P=0.287). The Charlson comorbidity index score was higher in the CIC group compared with the TMVC group (7.0 versus 6.0; P=0.01). Mean duration of follow-up was 4.8 years. Adjusted and unadjusted tests of noninferiority found TMVC was not inferior to in-person follow-up for the prespecified outcomes.

CONCLUSIONS: Video-conferencing ICD follow-up for patients in areas where electrophysiology subspecialty care is not available leads to outcomes that are noninferior to CIC follow-up.

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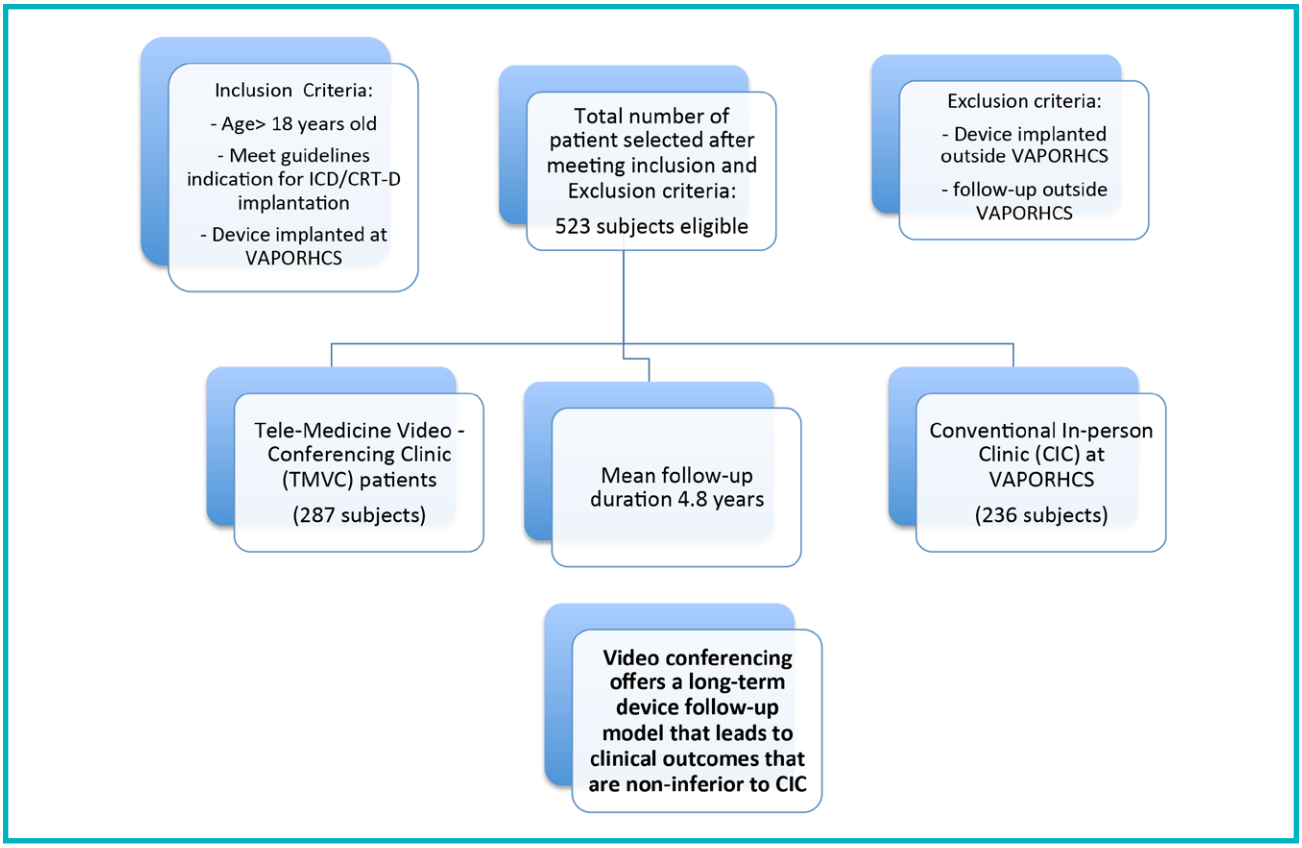

WHAT IS KNOWN

- Implantable cardioverter-defibrillator recipients require close follow-up. The logistics of monitoring these devices place a substantial and increasing burden on the cardiovascular community and implantable cardioverter-defibrillator recipients.
- Follow-up can be difficult for patients and providers who have to travel long distances for their device clinic follow-up appointments.
- Telehealth interventions can improve clinical outcomes.

WHAT THE STUDY ADDS

- Telemedicine implantable cardioverter-defibrillator follow-up using video conferencing offers a long-term device follow-up model that leads to clinical outcomes that are noninferior to the conventional in-person follow-up.
- This model has the potential for cost savings in reducing travel time and cost for patients and providers, as well as a solution for constrained clinic space and resource utilization.

Implantable cardioverter-defibrillators (ICDs) are increasingly used for primary and secondary prevention of sudden cardiac death.[1–5] The estimated number of ICDs and cardiac resynchronization therapy (CRT) devices implanted in North America in 2007 was 234 748 and 148 092, respectively, according to the 2008 Heart Rhythm Society and European Heart Rhythm Association consensus statement on the monitoring of cardiovascular implantable electronic devices.[6,7] The minimum frequency of in-person evaluation or remote interrogation should be every 3 to 6 months for ICD/CRT-defibrillator devices according to practice guidelines.[6,8] The logistics of monitoring these devices have placed a substantial and increasing burden not only on the cardiovascular community but also on ICD recipients who sometimes have to travel long distances for their device clinic follow-up appointments.

Telehealth or telemedicine (TM) uses information technology and telecommunication to provide health care. Several studies have shown that telehealth interventions can improve clinical outcomes in a variety of conditions.[9–12] The veterans administration (VA) has used TM health programs to monitor veterans with diabetes mellitus, spinal cord injuries, pressure ulcers, and in rehabilitation efforts.[13,14]

The primary goal of an ICD follow-up clinic is to monitor the function of the devices and to optimize medical therapy and programming parameters to reduce the burden of arrhythmias, both spontaneous and device induced, and minimize appropriate and inappropriate ICD therapies. The goal of this study is to determine whether outcomes in patients followed via video conferencing using TM are noninferior to those followed in person.

METHODS

Study Population

The Portland veterans affairs healthcare system (VAPORHCS) provides for TM video-conferencing clinic (TMVC) follow-up for patients who reside in Seattle (WA), Roseburg (OR), Boise (ID), Walla Walla (WA), and Anchorage (AK). TMVC visits replace conventional in-person clinic (CIC) visits. Therefore, patients are not required to travel to the VAPORHCS. The TMVC device model includes a registered nurse plus a technical support representative from the ICD companies or a nurse practitioner with expertise in device interrogation on the patient side communicating via an audio and a video link with a physician or nurse practitioner at VAPORHCS. The practitioner in Portland has the option to view a room camera, a direct video feed from the programmer, or a document camera as needed. All providers in the TMVC complete training courses (video and web courses) on various aspects of participating in TM clinics. All clinic data are entered into a prospective database.

The study population included patients who received an ICD/CRT-defibrillator device at the VAPORHCS between January 2001 and January 2013 and were followed-up in either the TMVC via video conferencing or the CIC in Portland, OR. The study proposal was reviewed by the VAPORHCS Institutional Review Board and was granted approval and access to patients' medical records. A priori identified study variables were extracted from the VA electronic medical record and a prospective clinical database with data on ICD implants, follow-up, and therapies. Electronic medical records were systematically reviewed by 3 coinvestigators (K.D., N.G., and M.R.), and the following variables were extracted using a data abstraction form to ensure consistency: demographic information, including age, sex, weight, systolic blood pressure on day of implant, list of comorbidities, medications, and laboratory tests, that will allow calculation of modified Seattle heart failure model score (differential ICD benefit Seattle heart failure model score-D) and Charlson comorbidity index score, relevant echocardiographic data (ejection fraction within 3 months of implant procedure) or other imaging modality that estimated ejection fraction, and baseline electrocardiographic data at the time of device implant. A Seattle heart failure model score heart failure model score-D score was calculated for every patient at the time of device implant, as described by Levy et al, as well as a Charlson comorbidity index, as described by Charlson et al. Seattle heart failure model score-D was chosen because data were missing for variables, such as lymphocyte count and uric acid levels.[15] ICD therapies as adjudicated by the physicians caring for the patients were extracted from the electrophysiology database and electronic medical record. The cohort of eligible veterans was defined as those (1) with ≥18 years of age, (2) who received ICD/CRT-defibrillator devices according to the guidelines current at the time of ICD implantation for primary prevention of sudden cardiac death or secondary prevention of sudden cardiac death, (3) whose devices were implanted at the VAPORHCS. Patients were excluded if devices were implanted outside the VAPORHCS and if routine device follow-up occurred outside the VAPORHCS clinics.

Figure 1 is a flowchart that shows the study profile diagram. Duration of follow-up was defined as the period from the time of implantation to the last device follow-up visit, until death or if they were lost to follow-up or crossed-over from one clinic follow-up model to the other. Loss to follow-up occurred if patients switched to follow-up at a different VA device clinic (other than VAPORHCS) or a different healthcare system. Time intervals beyond crossover points were censored from analysis. Different device companies developed remote interrogation/monitoring capabilities at different times. Both TMVC and CIC patients were enrolled in remote monitoring programs as they became available.

Study End Points

The primary outcome of the study compared time to first appropriate ICD therapy. The secondary outcomes were overall survival, time to first inappropriate ICD therapy, and time to first ICD shock.

Statistical Analysis

The primary noninferiority hypothesis required that the TMVC group preserve ≤10% point difference in cumulative incidence rate of each outcome to prove noninferior to the conventional group. The 10% point difference was arbitrary chosen. Medical and demographic characteristics were summarized using means and SDs for continuous variables and frequencies and percentages for categorical variables. Charlson comorbidity score was summarized with a median and interquartile range because of its semiquantitative nature. Independent *t* tests (modified to use robust standard errors), rank-sum tests, and χ^2 tests were used to compare characteristics between CIC and TMVC groups, with statistical significance set to 0.05. Time to death and time to ICD therapy end points (unadjusted for patient characteristics) was addressed using Kaplan–Meier estimates. Tests of noninferiority (assuming TMVC is inferior to CIC until data demonstrates the opposite) were based on the difference in estimates of survival (or incidence) at 6 months, 1 year, 3 years, 5 years, and 7 years of follow-up, and all tests used a 10% point margin of noninferiority. Formal tests of equivalence were not reported beyond 7 years because of sparseness of data. Analyses used the full data set out to 14.4 years for all tests and inferences, but figures generated have been curtailed to 10 years of follow-up. Cox proportional hazard (PH) models were used to investigate how patient characteristics affected survival and ICD therapies. Continuous and semicontinuous covariates were included in the model using restricted cubic splines with knots (k=4) placed at the 5th, 35th, 65th, and 95th percentile of a given covariate; binary indicator variables were used to model categorical factors. All Cox PH models retained age and treatment group, regardless of significance, but other variables were excluded as needed based on supervised backward elimination from an initial model that included all potential explanatory variables. The final parsimonious multivariable model for each outcome included covariates that were significant at the P≤0.10 and the PHs assumption was assessed through plots of scaled Schoenfeld residuals and the Grambsch–Therneau test. Regression of pseudovalues derived from Kaplan–Meier estimates was used to conduct noninferiority tests adjusted for those characteristics identified through the Cox PH models at the same 5 follow-up times and with the stated margin of noninferiority.[16] Estimated survival (or incidence)

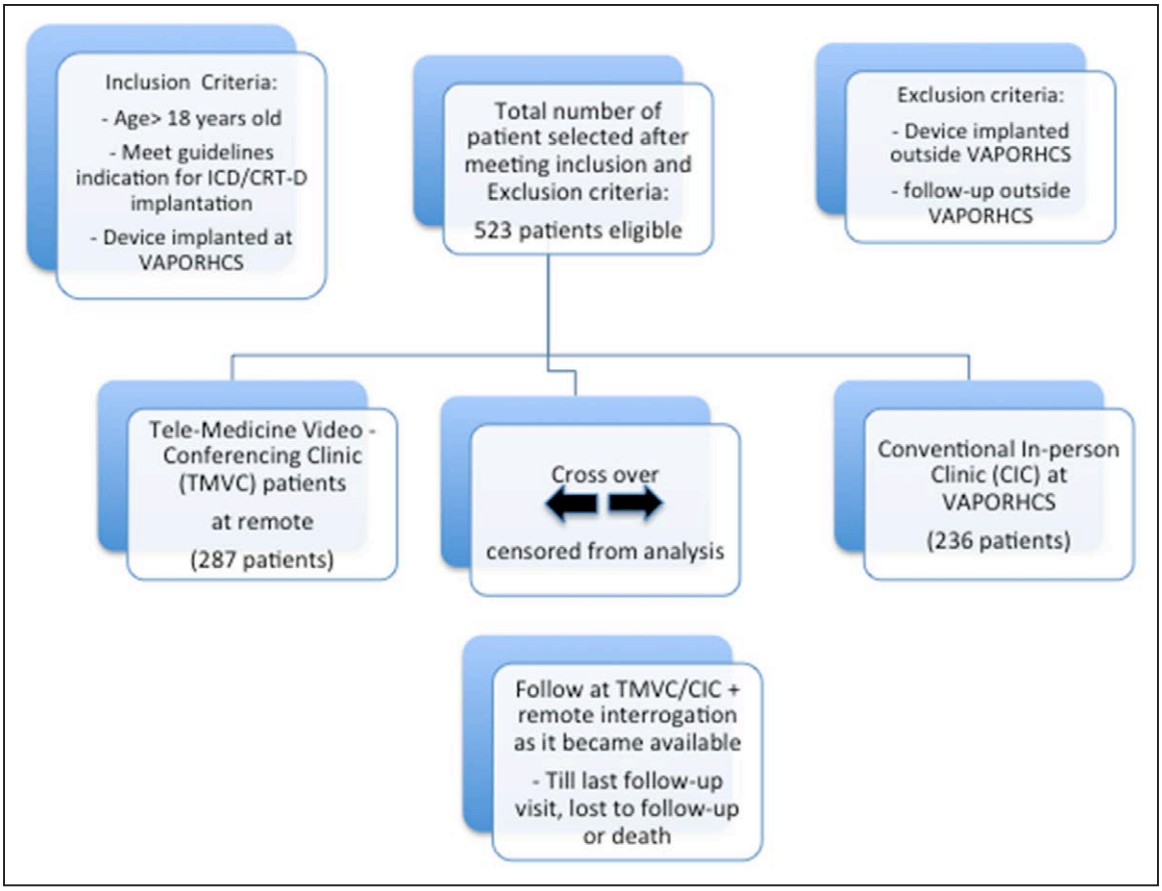

Figure 1. Trial profile diagram.
CIC indicates conventional in-person clinic; CRT-D, cardiac resynchronization therapy defibrillator; and ICD, implantable cardioverter-defibrillator.

corresponds to fitted values from these regression models of pseudovalues when relevant covariates are set to their mean value and factors set to their baseline level. All analyses were performed using Stata (version 14.1; StataCorp, LP, College Station, TX) and the stpsurv module.

RESULTS

Baseline Characteristics

Our analysis included a total of 523 patients of whom 236 patients were followed-up at the CIC, and 287 patients were followed-up at the TMVC. Mean duration of follow-up was 1763.5 days (≈4.8 years), whereas the median and interquartile range was 1623 (811–2394) days (≈4.4 [2.2–6.6] years). Approximately 10% of subjects had >9.3 years of follow-up. Characteristics of the study groups are presented in the Table I in the Data Supplement. The mean age was 64.1 years in the TMVC group and 65.2 years in the CIC group (*P*=0.164). Of 287 patients in the TMVC groups, 286 were men (99.6%), and of the 236 patients in the CIC group, 231 were men (97.6%; *P*=0.096) showing a predominance of men in our study sample of veterans. Charlson scores were higher for those followed in CIC compared with those in the TMVC group (7.0 versus 6.0; *P*=0.01; rank-sum test). History of diabetes mellitus was 10% points higher (95% CI, 1.4–18.3; *P*=0.022) for those followed in the CIC compared with TMVC; likewise, a history of atrial fibrillation was 8.5% points greater for those followed in the CIC group (*P*=0.04; 95% CI, 0.4–16.6). The 2 groups were similar with respect to other baseline characteristics and did not statistically differ.

Primary Outcomes

The median time at risk for the primary outcome of appropriate ICD therapy was 1.61 years (maximum 13.4 years) for 236 persons followed in the CIC model and was 1.74 years (maximum 13.0 years) among 287 individuals followed in the TMVC model. There was no statistically significant difference in cumulative incidence of appropriate ICD therapy between the groups either early (X_1^2=0.18; *P*=0.68; Peto-Peto test) or late during follow-up (X_1^2=0.15; *P*=0.70; log-rank test). Figure 2 shows the Kaplan–Meier curves of the cumulative incidence during time of the primary end point. Tests for noninferiority found patients followed by TM trended to have a lower risk of appropriate ICD

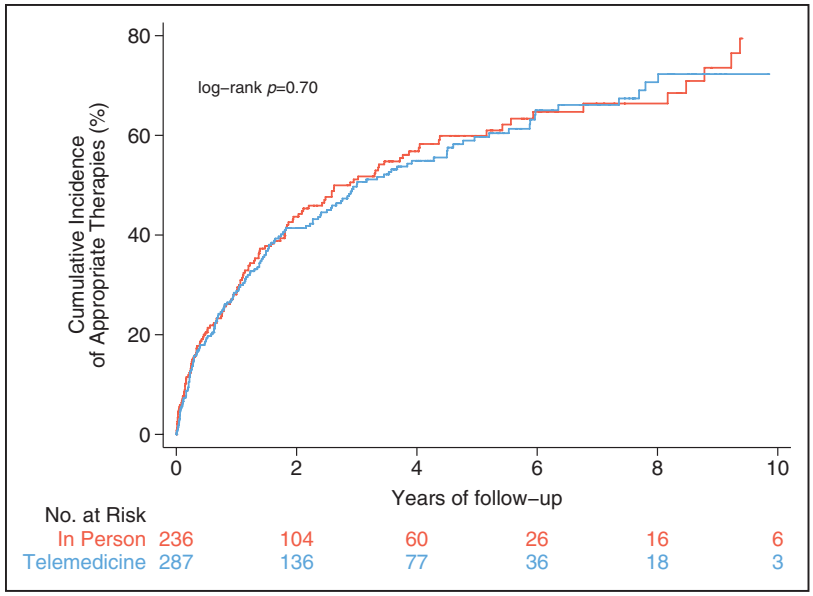

Figure 2. Kaplan–Meier plot of the cumulative incidence over time of adjudicated primary end point of time to first implantable cardioverter-defibrillator therapy.

therapy with the upper limit of the confidence being less than the prespecified 10% difference for noninferiority at all time points (6 months, 1 year, 3 years, 5 years, and 7 years) that were evaluated (Table IIA in the Data Supplement). Multivariable Cox PH models were run that included covariates with a *P* value of ≤0.10 and identified age, ejection fraction, digoxin use, and indication of ICD implantations (primary prevention ICD) as variables significantly associated with appropriate ICD therapies (Table IIB in the Data Supplement). After adjusting for these variables, the noninferiority criterion was still met for all prespecified time points (Table 1).

Secondary Outcomes

Mortality

Kaplan–Meier curves of survival showed no significant difference between groups, either early on (X_1^2=0.90; *P*=0.34; Peto-Peto test) or later during follow-up (X_1^2=0.78; *P*=0.38; log-rank test) as shown in Figure 3. Median time at risk was 4.45 years (maximum of 13.4 years) for 236 people followed in person and was 4.42 years (maximum 14.4 years) among 287 individuals followed in the TMVC group. There were 111 and 125 deaths observed in the CIC and TMVC groups, respectively. Unadjusted specific tests for noninferiority (at 0.5, 1, 3, 5, and 7 years of follow-up) indicated TMVC follow-up is not inferior to CIC follow-up (*P*<0.05). For the first 7 years, survival is noted to trend slightly higher for TMVC than for CIC follow-up and, at worst, survival for those followed via video conferencing is estimated to be at most 5.9% points less (1-sided 95% confidence limit) than survival for those followed in person, which is within the 10% points margin of noninferiority (Table IIIA in the Data Supplement). Multivariable Cox PH models for overall survival identified age, Seattle heart failure model score-D score, Charlson score, use of digoxin, and history of diabetes mellitus as significant risk factors (Table IIIB in the Data Supplement). After adjustment, adjusted specific tests for noninferiority indicated TMVC follow-up is not inferior to CIC follow-up (*P*<0.05) through the first 7 years (Table 2).

Table 1. Adjusted Noninferiority Tests Comparing Appropriate ICD Therapies Between Groups

Follow-Up Duration	Appropriate ICD Therapies, CIC (n=236)	Appropriate ICD Therapies, TMVC (n=287)	*P* Value	Difference, TMVC–CIC (90% CI)
6 mo	0.3295	0.3331	0.003	0.004 (–0.054 to 0.061)
1 y	0.4055	0.4276	0.023	0.022 (–0.042 to 0.086)
3 y	0.6360	0.6410	0.020	0.005 (–0.071 to 0.081)
5 y	0.7241	0.7364	0.036	0.012 (–0.068 to 0.093)
7 y	0.7896	0.8010	0.049	0.011 (–0.077 to 0.100)

Adjusted noninferiority tests comparing incidence of appropriate shocks between CIC and TMVC groups at 6 mo, 1, 3, 5, and 7 y of follow-up. Estimated survival is adjusted to reflect a 64-y-old individual with ejection fraction of 27%, and other drug and medical histories set to reference values. Margin of noninferiority is 10% points, and a significant *P* value implies one can reject the idea of TMVC being inferior to CIC follow-up. CI (2-sided 90% coverage; 1-sided 95% coverage) estimates a reasonable range for the difference in incidence between groups, and the upper limit must be <+0.10 to declare noninferiority. CI indicates confidence interval; CIC, conventional in-person clinic; ICD, implantable cardioverter-defibrillator; and TMVC, telemedicine video-conferencing clinic.

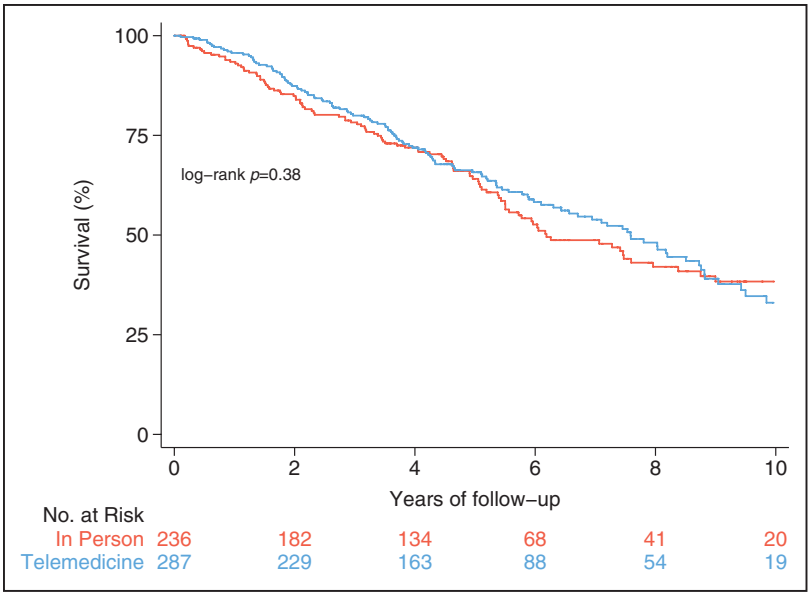

Figure 3. Kaplan–Meier curves showing the probability of event-free survival over time.

Inappropriate Therapies

There were 69 and 82 patients with inappropriate therapies observed in the CIC and TMVC groups, respectively. No statistically significant difference was noted in cumulative incidence rate between groups either early (X_1^2=0.07; *P*=0.79; Peto-Peto test) or at later times during follow-up (X_1^2=0.16; *P*=0.69; log-rank test; Figure 4A). Tests for noninferiority found TMVC is not inferior to CIC follow-up (*P*<0.05) at all of the preselected time points before (Table IVA in the Data Supplement) and after adjustment (Table 3).

Time to First ICD Shock

No statistically significant difference was noted in the cumulative incidence rate of time to first ICD shocks between the groups either early (X_1^2=0.02; *P*=0.88; Peto-Peto test) or late in follow-up (X_1^2=0.04; *P*=0.84; log-rank test; Figure 4B). There were 126 and 159 patients with ICD shocks observed in the CIC and TMVC groups, respectively. In an unadjusted setting, TMVC was noninferior to CIC (*P*<0.05) during the first 4 time points explored (through 5 years of follow-up), but the CIs were wider and noninferiority was not met at 7 years (Table VA in the Data Supplement). Multivariable Cox PH model showed that age, QRS duration, use of digoxin, history of atrial fibrillation, and indication for ICD implantation (primary prevention) were significant risk factors (Table VB in the Data Supplement). After controlling for these important covariables, tests of noninferiority showed that TMVC is not inferior to CIC follow-up (*P*<0.05) only at 1 and 3 years of follow-up (Table 4).

DISCUSSION

We examined clinical outcomes for device follow-up between a unique form of device follow-up using video-conferencing TM and the conventional in-person follow-up model that is routinely used in clinical practice. This is the first chart review study to compare clinical outcomes between the aforementioned device follow-up models with a long duration of follow-up. The main findings of this study were that device follow-up by TMVC, when compared with CIC device follow-up, was noninferior

Table 2. Adjusted Noninferiority Tests Comparing Overall Survival Between Groups

Follow-Up Duration	Survival, CIC (n=236)	Survival, TMVC (n=287)	*P* Value	Difference in Survival, TMVC–CIC (90% CI)
6 mo	0.8980	0.9172	<0.001	0.019 (0.009–0.048)
1 y	0.8757	0.8845	<0.001	0.009 (–0.027 to 0.044)
3 y	0.7237	0.7272	0.002	0.004 (–0.054 to 0.061)
5 y	0.5825	0.5854	0.008	0.003 (–0.067 to 0.073)
7 y	0.4291	0.4669	0.003	0.038 (–0.044 to 0.120)

Adjusted noninferiority tests comparing survival between CIC and TMVC groups at 6 mo, 1, 3, 5, and 7 y of follow-up. Estimated survival is adjusted to reflect a 64-y-old individual with Charlson score of 6, SHFM-D score of 0, not taking digoxin and with history of diabetes mellitus. Margin of noninferiority is 10% points, and a significant *P* value implies one can reject the idea of TMVC being inferior to CIC follow-up. CI (2-sided 90% coverage; 1-sided 95% coverage) estimates a reasonable range for the difference in survival between groups, and the lower limit must be >–0.10 to declare noninferiority. CI indicates confidence interval; CIC, conventional in-person clinic; SHFM-D, Seattle heart failure model score; and TMVC, telemedicine video-conferencing clinic.

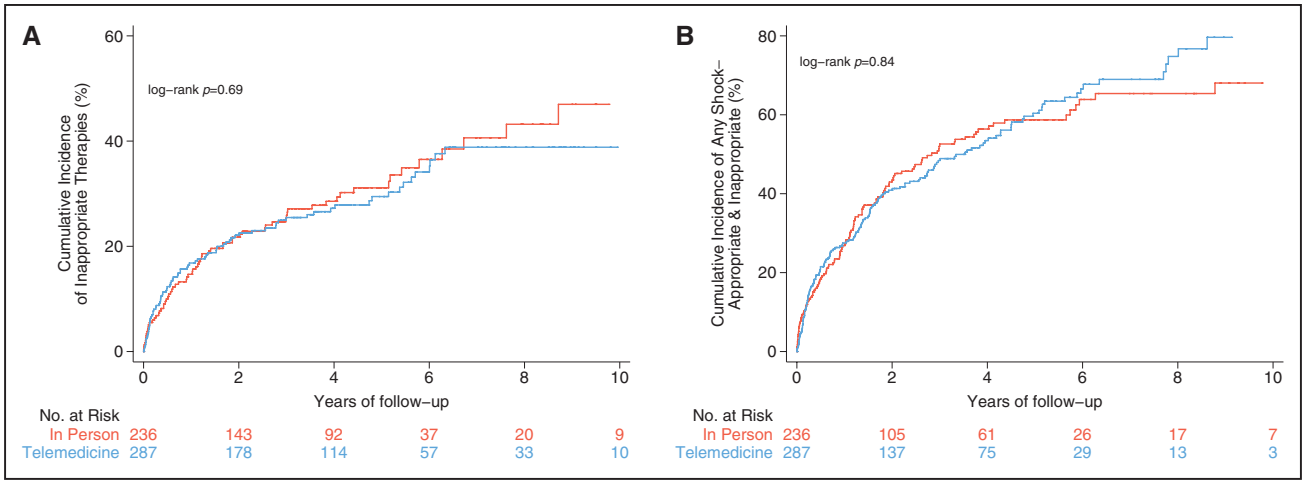

Figure 4. Kaplan–Meier curves of first inappropriate implantable cardioverter-defibrillator (ICD) therapy and time to first ICD shock.

A, Kaplan–Meier curves of the cumulative incidence over time of the time to occurrence of first inappropriate ICD therapies. **B**, Kaplan–Meier curves of the cumulative incidence of time to first ICD shock.

with respect to the primary outcome of appropriate ICD therapies during early and late follow-up, as well as the secondary outcomes of overall survival in the first 7 years of follow-up, incidence of inappropriate therapies, and time to first ICD shock in the first 5 years of follow-up. These end points were chosen because the net effect of the optimization of ICD programming and general cardiology care that occurs in ICD clinics is directly reflected in these outcomes. Optimal programming has been shown to minimize the risk of both appropriate and inappropriate therapy and improve mortality.[17–19] Similarly, the optimization of general cardiology care should minimize the risk of decompensated heart failure that could also lead to a reduction in appropriate and inappropriate ICD therapy. Finally, ICD shocks are a prime driver of patient satisfaction and anxiety, and minimizing the risk of shocks is an important goal of all ICD follow-up programs.

The main observation that there is no difference in clinical outcomes between the 2 models suggests TMVC offers a safe and reliable solution for the delivery of ICD follow-up care to patients who live long distances from electrophysiology specialty centers. Implantation of devices with wireless remote monitoring will allow continuous monitoring, providing daily self-testing, better event notifications for out-of-bound parameters, and earlier detection of actionable events.[8] Although the use of remote interrogation will help reduce the volume of in-person visits,[20–24] the need for in-person follow-up to address recurrent ICD shocks, out-of bound parameters, adjust programming/medication, and clinical evaluation will continue to be required and needed. The TMVC model can offer an alternative to in-person device follow-up for patients in remote areas where electrophysiology subspecialty care is not available.

TMVC device follow-up reduces travel time and travel cost for patients and providers. Reimbursement is the same whether the visit is in-person or telemedicine and is based on individual contracts with the commercial payors. Data for fiscal year 2016 showed that VAPORHCS did a total of 1308 TMVC visits saving an estimated 238 000 miles of patient travel. The large geographic area covered by VAPORHCS leads to

Table 3. Adjusted Noninferiority Tests Comparing Inappropriate Therapies Between Groups

Follow-Up Duration	Inappropriate Therapies, CIC (n=236)	Inappropriate Therapies, TMVC (n=287)	*P* Value	Difference, TMC–CIC (90% CI)
6 mo	0.1894	0.2187	0.006	0.029 (–0.017 to 0.075)
1 y	0.2362	0.2636	0.012	0.027 (–0.026 to 0.080)
3 y	0.3480	0.3499	0.007	0.002 (–0.064 to 0.068)
5 y	0.4003	0.3897	0.007	–0.011 (–0.085 to 0.063)
7 y	0.4944	0.4830	0.032	–0.011 (–0.111 to 0.088)

Adjusted noninferiority tests comparing incidence of inappropriate therapies between CIC and TMVC groups at 6 mo,1, 3, 5, and 7 y of follow-up. Estimated incidence is adjusted to reflect a 64-y-old individual with QRS of 118 ms, ejection fraction of 27%, and other drug and medical histories set to reference values. Margin of noninferiority is 10% points, and a significant *P* value implies one can reject the idea of TMVC being inferior to CIC follow-up. CI (2-sided 90% coverage; 1-sided 95% coverage) estimates a reasonable range for the difference in incidence between groups and the upper limit must be <+0.10 to declare noninferiority. CI indicates confidence interval; CIC, conventional in-person clinic; and TMVC, telemedicine video-conferencing clinic

Table 4. Adjusted Noninferiority Tests Comparing Incidence of Time to First ICD Shock Between Groups

Follow-Up Duration	Incidence of First ICD Shock, CIC (n=236)	Incidence of First ICD Shock, TMVC (n=287)	*P* Value	Difference, TMVC–CIC (90% CI)
6 mo	0.2301	0.2786	0.068	0.049 (–0.008 to 0.105)
1 y	0.3148	0.3385	0.025	0.024 (–0.040 to 0.087)
3 y	0.5708	0.5471	0.005	–0.024 (–0.102 to 0.054)
5 y	0.6311	0.6667	0.099	0.036 (–0.047 to 0.118)
7 y	0.6985	0.7532	0.206	0.055 (–0.036 to 0.146)

Adjusted noninferiority tests comparing incidence of overall shocks between CIC and TMVC groups at 6 mo, 1, 3, 5, and 7 y of follow-up. Estimated incidence is adjusted to reflect a 64-y-old individual with QRS of 118 ms and other characteristics (Digoxin, history of atrial fibrillation, primary prevention implant) set to reference values. Margin of noninferiority is 10% points, and a significant *P* value implies one can reject the idea of TMVC being inferior to CIC follow-up. CI (2-sided 90% coverage; 1-sided 95% coverage) estimates a reasonable range for the difference in incidence between groups; the upper limit must be <+0.10 to declare noninferiority. CI indicates confidence interval; CIC, conventional in-person clinic; ICD, implantable cardioverter-defibrillator; and TMVC, telemedicine video-conferencing clinic.

a larger number of miles saved per patient than other clinics might realize. However, the patient centric value of care and patients' convenience resulting from this type of clinic cannot be underestimated. For providers, TM clinics will save travel time compared with traveling to rural areas to do clinics. TM clinics can also allow some additional benefits at the provider end by providing efficiencies in the use of constrained resources, such as clinic space, nursing staff, and other infrastructure. TM is an example of a flexible model that can overcome constrained resource allocation challenges. In this light, telehealth programs in the VA and non-VA health systems have proven to be cost-effective.[14,25] Potential cost savings from using this model in a wide range of healthcare systems may be significant.

Limitations

The data may not represent veterans or nonveterans in other geographic locations. Few female veterans were represented (<1%); therefore, extrapolation of these results to a female ICD recipient population is precluded. Limitations inherent in retrospective studies, which include but are not limited to incomplete documentation, variation in interpretation of data, and missing data verification, should be considered when interpreting our results. However, previous studies have shown that VA medical data sets are generally reliable.[26] Our study did not investigate the number of heart failure hospitalizations because data for hospitalizations outside the VA system were not available to us. However, one would expect the efficacy of heart failure control to be reflected in virtually all of our end points suggesting that heart failure treatment was noninferior in the patients followed in the TMVC.

Conclusions

TM ICD follow-up, using video conferencing for patients in areas where electrophysiology subspecialty care is not available, offers a long-term device follow-up model that leads to clinical outcomes that are noninferior to the conventional in-person follow-up. This model has potential cost savings in reducing travel time and cost for patients and providers, as well as providing a potential solution for constrained clinic space and resource utilization. Further research in the form of a prospective randomized clinical trial and cost-effectiveness study is needed to confirm or refute the findings in our study.

AFFILIATIONS

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DISCLOSURES

None.

FOOTNOTES

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REFERENCES

1. The Antiarrhythmics Versus Implantable Defibrillators (AVID) Investigators. A comparison of antiarrhythmic-drug therapy with implantable defibrillators in patients resuscitated from near-fatal ventricular arrhythmias. *N Engl J Med*. 1997;337:1576–1583.
2. Bardy GH, Lee KL, Mark DB, Poole JE, Packer DL, Boineau R, Domanski M, Troutman C, Anderson J, Johnson G, McNulty SE, Clapp-Channing N, Davidson-Ray LD, Fraulo ES, Fishbein DP, Luceri RM, Ip JH; Sudden Cardiac Death in Heart Failure Trial (SCD-HeFT) Investigators. Amiodarone or an implantable cardioverter-defibrillator for congestive heart failure. *N Engl J Med*. 2005;352:225–237. doi: 10.1056/NEJMoa043399.
3. Kadish A, Dyer A, Daubert JP, Quigg R, Estes NA, Anderson KP, Calkins H, Hoch D, Goldberger J, Shalaby A, Sanders WE, Schaechter A, Levine JH; Defibrillators in Non-Ischemic Cardiomyopathy Treatment Evaluation (DEFINITE) Investigators. Prophylactic defibrillator implantation in patients with nonischemic dilated cardiomyopathy. *N Engl J Med*. 2004;350:2151–2158. doi: 10.1056/NEJMoa033088.
4. Moss AJ, Hall WJ, Cannom DS, Daubert JP, Higgins SL, Klein H, Levine JH, Saksena S, Waldo AL, Wilber D, Brown MW, Heo M. Improved survival with an implanted defibrillator in patients with coronary disease at high risk for ventricular arrhythmia. Multicenter automatic defibrillator implantation trial investigators. *N Engl J Med*. 1996;335:1933–1940. doi: 10.1056/NEJM199612263352601.
5. Moss AJ, Zareba W, Hall WJ, Klein H, Wilber DJ, Cannom DS, Daubert JP, Higgins SL, Brown MW, Andrews ML; Multicenter Automatic Defibrillator Implantation Trial II Investigators. Prophylactic implantation of a defibrillator in patients with myocardial infarction and reduced ejection fraction. *N Engl J Med*. 2002;346:877–883. doi: 10.1056/NEJMoa013474.
6. Tracy CM, Epstein AE, Darbar D, Dimarco JP, Dunbar SB, Estes NA III, Ferguson TB Jr, Hammill SC, Karasik PE, Link MS, Marine JE, Schoenfeld MH, Shanker AJ, Silka MJ, Stevenson LW, Stevenson WG, Varosy PD. 2012 ACCF/AHA/HRS focused update of the 2008 guidelines for device-based therapy of cardiac rhythm abnormalities: a report of the American College of Cardiology Foundation/American Heart Association task force on practice guidelines. *J Am Coll Cardiol*. 2012;60:1297–1313. doi: 10.1016/j.jacc.2012.07.009.
7. Wilkoff BL, Auricchio A, Brugada J, Cowie M, Ellenbogen KA, Gillis AM, Hayes DL, Howlett JG, Kautzner J, Love CJ, Morgan JM, Priori SG, Reynolds DW, Schoenfeld MH, Vardas PE; Heart Rhythm Society; European Heart Rhythm Association; American College of Cardiology; American Heart Association; European Society of Cardiology; Heart Failure Association of ESC; Heart Failure Society of America. HRS/EHRA expert consensus on the monitoring of cardiovascular implantable electronic devices (CIEDs): description of techniques, indications, personnel, frequency and ethical considerations. *Heart Rhythm*. 2008;5:907–925.
8. Slotwiner D, Varma N, Akar JG, Annas G, Beardsall M, Fogel RI, Galizio NO, Glotzer TV, Leahy RA, Love CJ, McLean RC, Mittal S, Morichelli L, Patton KK, Raitt MH, Ricci RP, Rickard J, Schoenfeld MH, Serwer GA, Shea J, Varosy P, Verma A, Yu CM. HRS expert consensus statement on remote interrogation and monitoring for cardiovascular implantable electronic devices. *Heart Rhythm*. 2015;12:e69–e100. doi: 10.1016/j.hrthm.2015.05.008.
9. Joseph AM. Care coordination and telehealth technology in promoting self-management among chronically ill patients. *Telemed J E Health*. 2006;12:156–159. doi: 10.1089/tmj.2006.12.156.
10. Verhoeven F, van Gemert-Pijnen L, Dijkstra K, Nijland N, Seydel E, Steehouder M. The contribution of teleconsultation and videoconferencing to diabetes care: a systematic literature review. *J Med Internet Res*. 2007;9:e37. doi: 10.2196/jmir.9.5.e37.
11. Whited JD, Datta S, Hall RP, Foy ME, Marbrey LE, Grambow SC, Dudley TK, Simel DL, Oddone EZ. An economic analysis of a store and forward teledermatology consult system. *Telemed J E Health*. 2003;9:351–360. doi: 10.1089/153056203772744671.
12. Khan F, Amatya B, Kesselring J, Galea MP. Telerehabilitation for persons with multiple sclerosis. A cochrane review. *Eur J Phys Rehabil Med*. 2015;51:311–325.
13. Galea M, Tumminia J, Garback LM. Telerehabilitation in spinal cord injury persons: a novel approach. *Telemed J E Health*. 2006;12:160–162. doi: 10.1089/tmj.2006.12.160.
14. Smith MW, Hill ML, Hopkins KL, Kiratli BJ, Cronkite RC. A modeled analysis of telehealth methods for treating pressure ulcers after spinal cord injury. *Int J Telemed Appl*. 2012;2012:729492. doi: 10.1155/2012/729492.
15. Levy WC, Lee KL, Hellkamp AS, Poole JE, Mozaffarian D, Linker DT, Maggioni AP, Anand I, Poole-Wilson PA, Fishbein DP, Johnson G, Anderson J, Mark DB, Bardy GH. Maximizing survival benefit with primary prevention implantable cardioverter-defibrillator therapy in a heart failure population. *Circulation*. 2009;120:835–842. doi: 10.1161/CIRCULATIONAHA.108.816884.
16. Tunes da Silva G, Logan BR, Klein JP. Methods for equivalence and noninferiority testing. *Biol Blood Marrow Transplant*. 2009;15:120–127. doi: 10.1016/j.bbmt.2008.10.004.
17. Moss AJ, Schuger C, Beck CA, Brown MW, Cannom DS, Daubert JP, Estes NA III, Greenberg H, Hall WJ, Huang DT, Kautzner J, Klein H, McNitt S, Olshansky B, Shoda M, Wilber D, Zareba W; MADIT-RIT Trial Investigators. Reduction in inappropriate therapy and mortality through ICD programming. *N Engl J Med*. 2012;367:2275–2283. doi: 10.1056/NEJMoa1211107.
18. Kloppe A, Proclemer A, Arenal A, Lunati M, Martìnez Ferrer JB, Hersi A, Gulaj M, Wijffels MC, Santi E, Manotta L, Mangoni L, Gasparini M. Efficacy of long detection interval implantable cardioverter-defibrillator settings in secondary prevention population: data from the avoid delivering therapies for nonsustained arrhythmias in ICD patients III (ADVANCE III) trial. *Circulation*. 2014;130:308–314. doi: 10.1161/CIRCULATIONAHA.114.009468.
19. Gasparini M, Proclemer A, Klersy C, Kloppe A, Lunati M, Ferrer JB, Hersi A, Gulaj M, Wijfels MC, Santi E, Manotta L, Arenal A. Effect of long-detection interval vs standard-detection interval for implantable cardioverter-defibrillators on antitachycardia pacing and shock delivery: the ADVANCE III randomized clinical trial. *JAMA*. 2013;309:1903–1911. doi: 10.1001/jama.2013.4598.
20. Boriani G, Da Costa A, Ricci RP, Quesada A, Favale S, Iacopino S, Romeo F, Risi A, Mangoni di S Stefano L, Navarro X, Biffi M, Santini M, Burri H; MORE-CARE Investigators. The monitoring resynchronization devices and cardiac patients (MORE-CARE) randomized controlled trial: phase 1 results on dynamics of early intervention with remote monitoring. *J Med Internet Res*. 2013;15:e167. doi: 10.2196/jmir.2608.
21. Crossley GH, Boyle A, Vitense H, Chang Y, Mead RH; CONNECT Investigators. The CONNECT (clinical evaluation of remote notification to reduce time to clinical decision) trial: the value of wireless remote monitoring with automatic clinician alerts. *J Am Coll Cardiol*. 2011;57:1181–1189. doi: 10.1016/j.jacc.2010.12.012.
22. Hindricks G, Elsner C, Piorkowski C, Taborsky M, Geller JC, Schumacher B, Bytesnik J, Kottkamp H. Quarterly vs. yearly clinical follow-up of remotely monitored recipients of prophylactic implantable cardioverter-defibrillators: results of the REFORM trial. *Eur Heart J*. 2014;35:98–105. doi: 10.1093/eurheartj/eht207.
23. Varma N, Epstein AE, Irimpen A, Schweikert R, Love C; TRUST Investigators. Efficacy and safety of automatic remote monitoring for implantable cardioverter-defibrillator follow-up: the lumos-T safely reduces routine office device follow-up (TRUST) trial. *Circulation*. 2010;122:325–332. doi: 10.1161/CIRCULATIONAHA.110.937409.
24. Varma N, Michalski J, Stambler B, Pavri BB; TRUST Investigators. Superiority of automatic remote monitoring compared with in-person evaluation for scheduled ICD follow-up in the TRUST trial - testing execution of the recommendations. *Eur Heart J*. 2014;35:1345–1352. doi: 10.1093/eurheartj/ehu066.
25. Smith MW, An LC, Fu SS, Nelson DB, Joseph AM. Cost-effectiveness of an intensive telephone-based intervention for smoking cessation. *J Telemed Telecare*. 2011;17:437–440. doi: 10.1258/jtt.2011.110303.
26. Kashner TM. Agreement between administrative files and written medical records: a case of the department of veterans affairs. *Med Care*. 1998;36:1324–1336.

Outcomes of Telemedicine Video-Conferencing Clinic Versus In-Person Clinic Follow-Up for Implantable Cardioverter-Defibrillator Recipients

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SUPPLEMENTAL MATERIAL

S-Table 1. Baseline Characteristics of Patients - Tele-Medicine Video-Conferencing Clinic (TMVC) and Conventional -In-person (CIC) groups.

Characteristic	CIC (n = 236)	TMVC (n = 287)	p-value
Age in years (SD)	65.23 (8.57)	64.13 (9.38)	0.164
Sex - Male n (%)	231(97.9)	286 (99.6)	0.096
Creatinine, mg/dl (SD)	1.24 (0.75)	1.23 (0.60)	0.935
Left ventricular Ejection fraction % (SD)	30.86 (12.86)	29.98 (13.32)	0.441
Charlson score median (IQR)	7 (5 - - 8)	6 (5 - - 7)	0.010
QRS Duration milliseconds (SD)	124.5 (30.21)	128.6 (32.59)	0.142
SHFM-D score (SD)	- 0.12 (1.00)	- 0.21 (0.99)	0.287
Primary prevention implant n (%)	129 (54.7)	175 (61.0)	0.145
Beta-blockers n (%)	221(93.6)	276 (96.2)	0.186
Statins n (%)	200 (84.8)	236 (82.2)	0.442
Diuretics n (%)	163 (69.1)	191(66.6)	0.540
ACEI or ARB n (%)	203 (86.0)	256 (89.2)	0.269
Digoxin n (%)	68 (28.8)	84 (29.3)	0.909
Hypertension n (%)	208 (88.1)	238 (82.9)	0.094
Diabetes Mellitus n (%)	114 (48.3)	110 (38.3)	0.022
CAD n (%)	182 (77.1)	226 (78.8)	0.655
CHF n (%)	214 (90.7)	255 (88.8)	0.494
Atrial fibrillation n (%)	90 (38.1)	85 (29.6)	0.040

Values are mean ± SD, or median (interquartile range)
ACEI = angiotensin converting enzyme inhibitor, ARB = angiotensin receptor blocker, CAD = coronary artery disease, CHF = chronic systolic heart failure, CIC = Conventional In-person Clinic, IQR =

interquartile range, SD = standard deviation, SHFM-D = Seattle heart failure model – differential, TMVC = Tele-Medicine Video-Conferencing Clinic.

S-Table 2A. Unadjusted non-inferiority tests comparing appropriate ICD therapies between groups

Follow-up Duration	Appropriate ICD therapies **CIC** (n = 236)	Appropriate ICD therapies **TMVC** (n = 287)	p-value	Difference **TMVC – CIC** (90% CI)
6 months	0.2048	0.1936	0.001	- 0.011 (-0.070, 0.047)
1 year	0.2806	0.2881	0.011	0.008 (-0.059, 0.074)
3 years	0.5116	0.5018	0.011	- 0.010 (-0.088, 0.069)
5 years	0.5990	0.5967	0.020	- 0.002 (-0.084, 0.080)
7 years	0.6639	0.6610	0.030	- 0.003(-0.093, 0.087)

Unadjusted non-inferiority tests comparing incidence of appropriate shocks between CIC and TMVC groups at 6 months,1 year, 3 years, 5 years, and 7 years of follow-up. Margin of non-inferiority is 10 percentage points and a significant p-value implies one can reject the idea of TMVC being inferior to CIC follow-up. Confidence interval (two-sided 90% coverage; one-sided 95% coverage) estimates a reasonable range for the difference in incidence between groups and the upper limit must be less than + 0.10 to declare non-inferiority.

S-Table 2B. Multi-variable Cox proportional hazard model describing time to appropriate ICD therapies.

Variables	**HR (95% CI)**	**p-value**
CIC **TMVC**	-- 0.98 (0.78–1.24)	0.878
Age (59 – 71)	1.11 (0.95–1.30)	0.190
Ejection fraction (20 – 35%)	0.84 (0.73–0.98)	0.030
Primary prevention No Yes	 -- 0.44 (0.34–0.58)	 < 0.001
Digoxin No Yes	 -- 1.27 (0.97–1.66)	 0.088

Effects for continuous and semi-continuous covariates are expressed as a half-sample hazard ratio i.e. the HR spanning the middle 50% of the particular covariate between the 75th and 25th percentile (IQR)

CIC = Conventional In-person Clinic, CI = confidence interval, IQR = interquartile range, TMVC = Tele-Medicine Video-Conferencing Clinic.

S-Table 3A.Unadjusted non-inferiority tests comparing survival between groups.

Follow-up Duration	Survival **CIC** (n = 236)	Survival **TMVC** (n = 287)	p-value	Difference in survival **TMVC – CIC** (90% CI)
6 months	0.9567	0.9894	< 0.001	0.033 (0.009, 0.057)
1 year	0.9344	0.9567	< 0.001	0.022 (-0.011, 0.056)
3 years	0.7825	0.7995	0.001	0.017 (-0.044, 0.078)
5 years	0.6409	0.6574	0.006	0.017 (-0.059, 0.092)
7 years	0.4872	0.5386	0.002	0.051 (-0.036, 0.138)

Unadjusted non-inferiority tests comparing survival between CIC and TMVC groups at 6 months,1 year, 3 years, 5 years, and 7 years of follow-up. Margin of non-inferiority is 10 percentage points and a significant p-value implies one can reject the idea of TMVC being inferior to CIC follow-up. Confidence interval (two-sided 90% coverage; one-sided 95% coverage) estimates a reasonable range for the difference in survival between groups and the lower limit must be above – 0.10 to declare non-inferiority.

S-Table 3B. Multi-variable Cox proportional hazard model for overall survival.

Variables	**HR (95% CI)**	**p-value**
CIC **TMVC**	-- 0.86 (0.67–1.12)	0.273
Age (59 – 71)	1.12 (0.91–1.39)	0.276
SHFM-D (-0.93–0.47)	1.54 (1.06–2.25)	0.025
Charlson Score (5 – 8)	1.63 (1.27–2.11)	< 0.001
Digoxin No Yes	 -- 1.33 (1.00–1.79)	 0.051
History of Diabetes No Yes	 -- 0.75 (0.56–1.02)	 0.070

Effects for continuous and semi-continuous covariates are expressed as a half-sample hazard ratio i.e. the HR spanning the middle 50% of the particular covariate between the 75th and 25th percentile (IQR)

CIC = Conventional In-person Clinic, CI = confidence interval, IQR = interquartile range, SHFM-D = Seattle heart failure model – differential, TMVC = Tele-Medicine Video-Conferencing Clinic.

S-Table 4A. Unadjusted non-inferiority tests comparing inappropriate therapies between groups.

Follow-up Duration	Inappropriate therapies **CIC** (n = 236)	Inappropriate therapies **TMVC** (n = 287)	p-value	Difference **TMVC – CIC** (90% CI)
6 months	0.100	0.1234	0.003	0.023 (-0.022, 0.069)
1 year	0.1468	0.1683	0.008	0.021 (-0.032, 0.075)
3 years	0.2588	0.2547	0.006	- 0.004 (-0.072, 0.064)
5 years	0.3111	0.2946	0.006	- 0.017 (-0.092, 0.059)
7 years	0.4062	0.3884	0.029	- 0.018 (-0.120, 0.084)

Unadjusted non-inferiority tests comparing incidence of inappropriate therapies between CIC and TMVC groups at 6 months,1 year, 3 years, 5 years, and 7 years of follow-up. Margin of non-inferiority is 10 percentage points and a significant p-value implies one can reject the idea of TMVC being inferior to CIC follow-up. Confidence interval (two-sided 90% coverage; one-sided 95% coverage) estimates a reasonable range for the difference in incidence between groups and the upper limit must be below + 0.10 to declare non-inferiority.

S-Table 4B. Multi-variable Cox proportional hazard model describing time to inappropriate therapies.

Variables	**HR (95% CI)**	**p-value**
CIC **TMVC**	-- 0.99 (0.72–1.37)	 0.953
Age (59 – 71)	 0.71 (0.57–0.88)	 0.002
QRS duration (104 – 148)	 0.68 (0.52–0.88)	 0.004
Ejection fraction (20 – 35%)	 0.81 (0.66–0.99)	 0.042
Statins No Yes	 -- 0.68 (0.45–1.02)	 0.060
Diuretics No Yes	 -- 0.73 (0.50–1.05)	 0.087
History of atrial fibrillation No Yes	 -- 1.79 (1.28–2.50)	 0.001

Effects for continuous and semi-continuous covariates are expressed as a half-sample hazard ratio i.e. the HR spanning the middle 50% of the particular covariate between the 75th and 25th percentile (IQR)

CIC = Conventional In-person Clinic, CI = confidence interval, IQR = interquartile range, TMVC = Tele-Medicine Video-Conferencing Clinic.

S-Table 5A. Unadjusted non-inferiority tests comparing incidence of time to first ICD shock between groups.

Follow-up Duration	Incidence of first ICD shock **CIC** (n = 236)	Incidence of first ICD shock **TMVC** (n = 287)	p-value	Difference **TMVC – CIC** (90% CI)
6 months	0.1865	0.2152	0.022	0.029 (-0.030, 0.087)
1 year	0.2715	0.2752	0.008	0.004 (-0.062, 0.070)
3 years	0.5280	0.4841	0.001	- 0.044 (-0.122, 0.034)
5 years	0.5888	0.6039	0.045	0.015 (-0.068, 0.098)
7 years	0.6553	0.6897	0.119	0.034 (-0.057, 0.126)

Unadjusted non-inferiority tests comparing incidence of overall shocks between CIC and TMVC groups at 6 months,1 year, 3 years, 5 years, and 7 years of follow-up. Margin of non-inferiority is 10 percentage points and a significant p-value implies one can reject the idea of TMVC being inferior to CIC follow-up. Confidence interval (two-sided 90% coverage; one-sided 95% coverage) estimates a reasonable range for the difference in incidence between groups and the upper limit must be less than + 0.10 to declare non-inferiority.

S-Table 5B. Multi-variable Cox proportional hazard model describing time to first ICD shock.

Variables	**HR (95% CI)**	**p-value**
CIC **TMVC**	-- 1.07 (0.84-1.35)	0.599
Age (59 – 71)	0.82 (0.70–0.96)	0.014
QRS duration (104 – 148)	0.84 (0.70–0.99)	0.044
Primary prevention implant No Yes	 -- 0.53 (0.41–0.69)	 < 0.001
Digoxin No Yes	 -- 1.45 (1.11–1.91)	 0.007
History of atrial fibrillation No Yes	 -- 1.43 (1.11–1.83)	 0.005

Effects for continuous and semi-continuous covariates are expressed as a half-sample hazard ratio i.e. the HR spanning the middle 50% of the particular covariate between the 75th and 25th percentile (IQR)

CIC = Conventional In-person Clinic, CI = confidence interval, IQR = interquartile range, TMVC = Tele-Medicine Video-Conferencing Clinic.