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

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Background—Monitoring implantable cardiac device function and patient condition is important. The Lumos-T Safely Reduces Routine Office Device Follow-Up (TRUST) trial tested the hypothesis that remote home monitoring with automatic daily surveillance (HM) is safe and effective for implantable cardioverter-defibrillator follow-up for 1 year and enables rapid physician evaluation of significant events.

Methods and Results—In total, 1339 patients were randomized 2:1 to HM or conventional follow-up. Follow-up checks occurred at 3, 6, 9, 12, and 15 months after implantation. HM was used before office visits at 3 and 15 months in the HM group. At 6, 9, and 12 months, HM only was used but was followed by office visits if necessary. Conventional patients were evaluated with office visits only. Scheduled office visits and unscheduled evaluations, incidence of morbidity, and time elapsed from first event occurrence in each patient to physician evaluation were tracked for each group. HM and conventional patients were similar (age, 63.3±12.8 versus 64.0±12.1 years; gender, 72.0% versus 73.1% male; New York Heart Association class II, 55.9% versus 60.4%; pathology: left ventricular ejection fraction, 29.0±10.7% versus 28.5±9.8%; coronary artery disease, 64.8% versus 71.7%; primary prevention indication, 72.2% versus 73.8%; and dual-chamber implants, 57.8% versus 56.6%). HM reduced total in-hospital device evaluations by 45% without affecting morbidity. In the HM group, 85.8% of all 6-, 9-, and 12-month follow-ups were performed remotely only, indicating that HM provided sufficient assessment in the majority. Median time to evaluation was 2 days in the HM group compared with 36 days in the conventional group (P<0.001) for all arrhythmic events.

Conclusions—HM is safe and allows more rapid detection of actionable events compared with conventional monitoring in patients with implantable electronic cardiac devices.


(Circulation. 2010;122:325-332.)

Key Words: defibrillators ■ follow-up ■ patient monitoring ■ pacemaker, artificial ■ remote monitoring

Implantable cardioverter-defibrillators (ICDs) improve survival.1 Postimplantation follow-up is important for monitoring device function and patient condition.2 However, clinical practice is inconsistent. Follow-up schedules vary according to facility, physician preference, and available resources. Expert consensus advocates 3- to 6-month clinic checks with increased frequency in response to product advisories and recalls.2 Efficacy of this schedule with regard to patient safety, adherence, incidence of unscheduled encounters, and rate of problem detection remains untested. A major limitation of conventional follow-up, regardless of frequency, is the absence of monitoring between hospital interrogations, which accounts for the majority of the time. Hence, recorded data remain concealed for extended periods. This is important if clinical intervention based on these data would preempt patient morbidity/mortality, as may be the case with product advisories. Increased frequency of evaluation of a large patient population with a low incidence of problems challenges both patient compliance and clinic follow-up capacity. A mechanism for performing continuous surveillance and rapid problem identification notification, without overburdening device clinics, is desirable.3,4 Remote

Received January 21, 2010; accepted May 10, 2010.

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The online-only Data Supplement is available with this article at http://circ.ahajournals.org/cgi/content/full/CIRCULATIONAHA.110.937409/DC1.

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DOI: 10.1161/CIRCULATIONAHA.110.937409
monitoring may fulfill this task but has not been tested in a large-scale clinical trial.

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Currently available remote technologies differ operationally. Some rely on patient-initiated communication on a scheduled calendar basis.5–7 These risk missing interim asymptomatic problems. In contrast, remote home monitoring (HM) performs daily self-checks with a fully automatic transmission path independent of patient or physician interaction.8–10 Stored ICD data are relayed every 24 hours and delivered as trend data for Web site review. Critical events (eg, arrhythmia onset or compromised device integrity) are transmitted separately and flagged for attention. Technical reliability (preservation of data integrity during transmission and early notification ability) of HM and feasibility for remote follow-up have been demonstrated in preliminary evaluations.8–9 This system offers the advantages of providing nearly continuous arrhythmia and device surveillance and early detection but risks increased unscheduled patient evaluations. The Lumos-T Safely Reduces Routine Office Device Follow-Up (TRUST) study was designed to determine whether HM could safely reduce in-hospital device evaluation yet enable earlier problem discovery.

Methods

TRUST was a prospective, randomized, multicenter clinical trial comparing the safety and usefulness of automatic remote monitoring in ICD recipients with standard in-clinic follow-up. Details of the study protocol have been published previously.11 The study was an investigator-initiated clinical trial designed by a steering committee consisting of physicians (who also served as investigators) in collaboration with the sponsor (Appendices A and B, respectively, of the online-only Data Supplement). The protocol was written by the principal investigator and sponsor. TRUST was conducted in 102 US centers. The institutional review board at each site approved the study, and all patients gave written informed consent. Enrollment of patients began in August 2005 and was completed in February 2008. The follow-up period ended in May 2009.

Design

Recipients of single- and dual-chamber ICDs with HM implanted for class I/II indications who were not pacemaker dependent were eligible.11 HM was based on a low-power wireless transmitter within the pulse generator transmitting stored data daily to a bedside communicator for relay telephonically (cellular and/or landline) to a service center for automatic processing and online review. Critical event data (including silent events) were transmitted immediately and flagged for attention. Eligible patients were enrolled 0 to 45 days after successful device implantation and then randomly assigned in a 2:1 ratio to the HM or conventional group. A block randomization method was used. To prevent bias, the blocks and randomization schedule were predefined before the first study implantation and were generated by an outside consultant. A site-specific randomization schedule was developed for all sites, which each site accessed through the use of a secure randomization Web site.

TRUST evaluated patients’ scheduled and unscheduled device interrogations for 1 year after implantation. In the conventional follow-up arm, HM was disabled, and patients were seen every 3 months with in-clinic device interrogations. Unscheduled interrogations in interim periods resulted from physician or patient initiation. In HM, the following event notifications were activated: out-of-range impedance, elective replacement indicator, inactive ventricular tachycardia/fibrillation (VT/VF) detection, VT, VF, supraventricular tachycardia (SVT), ineffective 30-J shock, mode switch duration >10% of 24 hours, and device transmission failure >3 days. Additional device programming was at investigators’ discretion. HM patients were evaluated in the clinic at 3 months. Subsequent in-clinic follow-up was scheduled 15 months after implantation. Interim 3-month calendar-based checks were performed online. (Thus, both groups adhered to 3 month follow-up.) The protocol prespecified that if online checks were considered insufficient, then investigators were permitted to evaluate patients additionally in the office. These were categorized as in-person evaluations, even if not yielding incremental information to remote interrogation. Incisional checks occurring after enrollment and randomization before the first scheduled office visit were classified as unscheduled evaluations. All unscheduled hospital interrogations initiated by physician or patient resulting from event notifications in HM were tracked in both study groups.

Early detection was assessed by time elapsed from event onset to physician evaluation. In the conventional group, this occurred at an in-office interrogation (scheduled or unscheduled). Evaluation in HM occurred on receipt of event notifications in response to detection of preprogrammed events or in-office interrogation (scheduled or unscheduled). Investigators recorded whether these events were clinically asymptomatic (“silent”).

A device evaluation was defined as actionable if it prompted initiation/uptitration of antiarrhythmic medications or significant ICD reprogramming/system revision (eg, increasing pacing output >1 V, changes in VT/SVT algorithm/settings). Major adverse events, including death, incidence of stroke, and events requiring cardiac surgical interventions (eg, device explantations or lead revision), were recorded.

An independent Clinical Events Committee comprising 3 physicians not participating in the trial and blinded to investigational sites, patient identities, and randomization assignment adjudicated all device and adverse events and disputed classifications of actionable versus nonactionable office device interrogations between the physician and the prespecified protocol definition (Appendix C, online-only Data Supplement). Data collection and management and statistical analysis were performed by the sponsor. The publications committee included investigators from the top-enrolling centers (Appendix D, online-only Data Supplement). The report was written by the principal investigator (an academic author) and subsequently edited by all the authors.

Statistical Analysis

The sample size of the study was based on the safety end point and calculated on a Blackwelder-type test of noninferiority with the standard design criteria: type I error (1-sided), statistical power of 80%, and a 2:1 randomization. Assuming a 1-year attrition rate of 10% in group 1 (HM) and group 2 (control), a sample of 622 HM patients and 311 control patients, resulting in a total of 933, was sufficient to demonstrate noninferiority within a clinically significant difference of 5%. The study met this enrollment objective.

The analysis of the primary efficacy end point was based on the comparison of the average numbers of in-clinic device evaluations in the HM compared with the conventional group and analyzed by Student t test. The evaluation of the primary safety end point was based on an exact binomial noninferiority test comparing the proportions of patients with a major adverse event. A Kaplan-Meier actuarial analysis was also done, comparing the time to first event in the 2 study groups, with the difference evaluated with a log-rank test. A value of P=0.05 was considered evidence of statistical significance for either of the 2 primary end points.

Because statistical significance was achieved for the 2 primary study end points, the cardiac events identified in secondary end point (atrial fibrillation [AF], VT, VF, and SVT) were evaluated in a prespecified hierarchical closed procedure to maintain an
Efficacy and Safety of Remote ICD Follow-Up

Table 1. Patient Characteristics

<table>
<thead>
<tr>
<th></th>
<th>HM (n=908)</th>
<th>Conventional (n=431)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at enrollment, y</td>
<td>63.3±12.8</td>
<td>64.0±12.1</td>
<td>0.365</td>
</tr>
<tr>
<td>Male gender, n (%)</td>
<td>254 (72.0)</td>
<td>315 (73.1)</td>
<td>0.695</td>
</tr>
<tr>
<td>ICD indications, n (%)</td>
<td>656 (72.2)</td>
<td>318 (73.8)</td>
<td>0.599</td>
</tr>
<tr>
<td>Prophylactic</td>
<td>64 (7.0)</td>
<td>33 (7.7)</td>
<td>0.735</td>
</tr>
<tr>
<td>Survived cardiac arrest with documented VT/VF</td>
<td>21 (2.3)</td>
<td>18 (4.2)</td>
<td>0.08</td>
</tr>
<tr>
<td>VT with or without hemodynamic instability</td>
<td>145 (16.0)</td>
<td>68 (15.8)</td>
<td>1.00</td>
</tr>
<tr>
<td>Nonsustained VT after MI and LVEF ≤40%</td>
<td>73 (8.0)</td>
<td>38 (8.8)</td>
<td>0.671</td>
</tr>
<tr>
<td>Syncpe without documented VT and LVEF ≤40%</td>
<td>44 (4.8)</td>
<td>19 (4.4)</td>
<td>0.784</td>
</tr>
<tr>
<td>Positive family history of cardiac death</td>
<td>16 (1.8)</td>
<td>4 (0.9)</td>
<td>0.784</td>
</tr>
<tr>
<td>Other</td>
<td>76 (8.4)</td>
<td>29 (6.7)</td>
<td>0.328</td>
</tr>
<tr>
<td>Underlying heart disease, n (%)</td>
<td>588 (64.8)</td>
<td>309 (71.7)</td>
<td>0.013</td>
</tr>
<tr>
<td>Coronary heart disease</td>
<td>468 (51.5)</td>
<td>234 (54.3)</td>
<td>0.349</td>
</tr>
<tr>
<td>Hypertension</td>
<td>455 (50.1)</td>
<td>222 (51.5)</td>
<td>0.640</td>
</tr>
<tr>
<td>Hypertrophic cardiomyopathy</td>
<td>37 (4.1)</td>
<td>12 (2.8)</td>
<td>0.277</td>
</tr>
<tr>
<td>Valvular heart disease</td>
<td>104 (11.5)</td>
<td>50 (11.6)</td>
<td>0.927</td>
</tr>
<tr>
<td>Congenital heart disease</td>
<td>8 (0.9)</td>
<td>2 (0.5)</td>
<td>0.515</td>
</tr>
<tr>
<td>Other</td>
<td>172 (18.9)</td>
<td>91 (21.1)</td>
<td>0.377</td>
</tr>
<tr>
<td>Cardiovascular status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LVEF (within last 12 mo), %</td>
<td>29.0±10.7</td>
<td>28.5±9.8</td>
<td>0.497</td>
</tr>
<tr>
<td>NYHA class, n (%)</td>
<td>I</td>
<td>124 (13.8)</td>
<td>36 (8.4)</td>
</tr>
<tr>
<td>II</td>
<td>504 (55.9)</td>
<td>258 (60.4)</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>268 (29.7)</td>
<td>129 (30.2)</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>5 (0.4)</td>
<td>4 (0.9)</td>
<td></td>
</tr>
<tr>
<td>Atrial tachyarrhythmia history, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AT in last 3 mo</td>
<td>176 (19.4)</td>
<td>78 (18.1)</td>
<td>0.602</td>
</tr>
<tr>
<td>Atrial fibrillation in last 3 mo</td>
<td>145 (16.0)</td>
<td>66 (15.3)</td>
<td>0.810</td>
</tr>
<tr>
<td>Atrial flutter in last 3 mo</td>
<td>26 (2.9)</td>
<td>10 (2.3)</td>
<td>0.718</td>
</tr>
<tr>
<td>SVT in last 3 mo</td>
<td>3 (0.3)</td>
<td>1 (0.2)</td>
<td>1.000</td>
</tr>
<tr>
<td>AT symptoms</td>
<td>85 (48.3)</td>
<td>35 (44.9)</td>
<td>0.653</td>
</tr>
<tr>
<td>Dual-chamber implants, n (%)</td>
<td>525 (57.8)</td>
<td>244 (56.6)</td>
<td>0.679</td>
</tr>
<tr>
<td>Medications, n (%)</td>
<td>β-Blockers (including carvedilol)</td>
<td>723 (79.6)</td>
<td>329 (76.3)</td>
</tr>
<tr>
<td>Potassium channel blocker</td>
<td>139 (15.3)</td>
<td>72 (16.7)</td>
<td>0.521</td>
</tr>
<tr>
<td>Sodium channel blocker</td>
<td>4 (0.4)</td>
<td>1 (0.2)</td>
<td>1.000</td>
</tr>
<tr>
<td>Calcium channel blocker</td>
<td>96 (10.6)</td>
<td>39 (9.0)</td>
<td>0.437</td>
</tr>
<tr>
<td>Warfarin</td>
<td>154 (21.8)</td>
<td>89 (20.6)</td>
<td>0.111</td>
</tr>
<tr>
<td>Digoxin</td>
<td>198 (21.8)</td>
<td>111 (25.8)</td>
<td>0.111</td>
</tr>
<tr>
<td>Carvedilol</td>
<td>412 (45.4)</td>
<td>200 (46.4)</td>
<td>0.725</td>
</tr>
<tr>
<td>ACE inhibitor</td>
<td>389 (42.8)</td>
<td>200 (46.4)</td>
<td>0.239</td>
</tr>
<tr>
<td>Angiotensin receptor blocker</td>
<td>70 (7.7)</td>
<td>41 (9.5)</td>
<td>0.289</td>
</tr>
<tr>
<td>Other</td>
<td>3 (0.3)</td>
<td>4 (0.9)</td>
<td>0.221</td>
</tr>
</tbody>
</table>

MI indicates myocardial infarction; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; and ACE, angiotensin-converting enzyme.

Results

Patients

TRUST enrolled and randomized 1450 patients (977 HM versus 473 conventional) at 102 continental US centers from November 2005 to February 2008. Of these, 185 (12.8%) were in academic centers, and 1265 (87.2%) were in private hospitals.

One hundred eleven patients exited the study before the first follow-up. Causes were patient withdrawal (40.5%), death (18.9%), loss to follow-up (35.1%), HM transmission failure (7.2%) in HM patients, and other (5.4%). Patient characteristics were similar between the 2 groups (Table 1) except for a slightly higher incidence of coronary artery disease among patients assigned to conventional care.

In total, 908 HM and 431 conventional patients completed at least 1 follow-up (total, 1339; 92.9% versus 91.1% of those randomized, respectively; P=0.246). Mean overall type I error level for the study of 0.05. The statistical tests compared mean times from onset to evaluation for the first detected event of a given type between groups with Student t tests (means) or associated nonparametric Mann-Whitney tests (distributions) for those patients experiencing at least 1 cardiac event of the type examined.

Continuous variables for other study variables were summarized as means, SDs, ranges, medians, and interquartile ranges. Categorical variables were summarized in frequency distributions. Group differences were compared with Student t tests and Mann-Whitney tests or with Fisher exact tests and χ² tests as appropriate to the type of data. P values associated with statistical tests for variables other than prespecified primary and secondary end points are reported as nominal values without adjustment for multiple testing and without declarations about statistical significance.

Adherence to scheduled device interrogations was recorded. Only patients completing at least 1 follow-up visit were included in the analysis. All end points were analyzed according to the intention-to-treat principle; patients who crossed over were analyzed according to their original treatment assignment.

The protocol specified that end-point analyses be performed for patients with data available at 12 months and for those who died, withdrew, or were unable to perform the evaluation at 12 months. All analyses were performed with SPSS (version 14, SPSS, Inc, Chicago, Ill) and StatXact (version 8, Cytel Software, Cambridge, Mass) software.

Study Objectives

The first primary efficacy end point compared the number of total in-hospital device evaluations in HM compared with conventional care. The second primary end point compared the adverse event rate, comprising incidence of death, strokes, and events requiring surgical interventions (eg, device explantations or lead revision), between the 2 groups. Data for all patients were included through the completion of the 12-month scheduled visit if present. In the case of no 12-month visit, data were censored at the time of withdrawal or the last day of the 12-month window (365 days plus the 30-day window), whichever was earlier. Safety data were included through 395 days after implantation for all patients or until a patient withdrew or died, whichever occurred first.

The secondary end point compared detection times of clinically significant problems, assessed by time from event onset (stamped on device diagnostics) to physician evaluation of first occurrence of arrhythmia (AF, VT, VF, and SVT) in individual patients. Asymptomatic events were called silent. In HM patients in whom HM data were not assessed before the in-office interrogation (protocol violation), time from event onset to manual download was used for an intention-to-treat analysis of early detection.

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Follow-up duration was 0.96 ± 0.21 versus 0.94 ± 0.22 years (P = 0.112). Exit reasons are shown in Figure 1. Thirty-one (3.4%) and 21 (4.9%) patients died in the HM and conventional groups, respectively (P = 0.226). At 12 months, analysis could be performed on 328 conventional patients and 757 HM patients. In response to a Sprint Fidelis lead advisory notice (October 15, 2007) recommending remote patient monitoring if available, 4 patients crossed over from conventional to HM. They were analyzed as conventional care.

Analyses

In the HM group, 3099 of 3316 possible follow-ups were completed compared with 1354 of 1526 in the conventional group (93.5% versus 88.7% over 12 months; P < 0.001). Therefore, adherence to 3-month scheduled calendar-based checks was higher and maintained in the HM compared with the conventional care group. Most scheduled HM follow-ups (93.6%) were performed using HM only or HM followed by an office visit (n = 2901). In a minority (n = 198), HM checks were not performed before patient evaluation (protocol violation) largely because of oversight by the following physician/device specialist (n = 133, 67.2%). Actionability of 3 monthly (3, 6, 9 and 12 month) scheduled calendar-based checks was low in both study groups (6.6%). Overall, actionable causes were reprogramming changes (76.2%, including increasing pacing output of >1V; HM versus conventional, 22 versus 10; P = NS), medication changes (24.8%), and lead/system revision (4.0%). These are listed according to treatment group in Table 2.

Adverse Events

No difference in safety was observed between the HM and conventional care groups (Figure 2, bottom). Overall adverse event rate was 10.4% for HM versus 10.4% for conventional care over 12 months (noninferiority P = 0.005, 1 sided; P = 0.010, 2 sided). Causes are listed in Table 3.

Survival

Of 1339 patients, 52 died before the scheduled 12-month follow-up visit (31 [3.4%] in HM versus 21 [4.5%] in conventional; P = 0.226). Cause of death was cardiac (9 versus 7; P = 0.419), noncardiac (14 versus 8; P = 0.652), or unknown (8 versus 6; P = 0.120) in HM versus conventional patients, respectively. At 12 months, Kaplan-Meier cumulative overall survival (not shown) was 96.4% (95% confidence interval, 95.5 to 97.6) in the HM group and 94.2% (95% confidence interval, 91.8 to 96.6) in the conventional groups (P = 0.174 by the log-rank test).

Figure 2 shows primary end points. The mean number of in-clinic and hospital visits (sum of scheduled and unscheduled) was 2.1 per patient-year in the HM group compared with 3.8 per patient-year in the conventional group (P < 0.001). Hence, total in-office visits were reduced 45% in the HM group at 12 months. Scheduled and unscheduled evaluations were assessed. Scheduled 3-month in-clinic device visits were reduced by 60.6% in HM. This was not the 75% rate expected from the study protocol because investigators were permitted to bring patients in for direct device interrogation after online calendar-based scheduled checks if necessary. We found that 85.8% of all HM group 6-, 9-, and 12-month follow-ups were performed using HM only, indicating that HM provided sufficient assessment in these cases.

Unscheduled in-clinic device visits were low in both groups but slightly higher in HM (0.78 versus 0.50 per year; P = 0.009; Figure 3). Causes in the HM versus conventional group (per patient-year) were physician initiated in 0.16 versus 0.15 (P = 0.09) and in HM an additional 0.15 from event notifications, patient initiated in 0.15 versus 0.14 (P = 0.823), and emergency room visits/hospitalization in 0.11 versus 0.13 (P = 0.655).

Table 2. Actionable Evaluations

<table>
<thead>
<tr>
<th>Actionable Evaluations</th>
<th>HM</th>
<th></th>
<th>%</th>
<th>Conventional</th>
<th>%</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinically significant reprogramming changes</td>
<td>247</td>
<td>78.4</td>
<td>135</td>
<td>72.6</td>
<td></td>
<td>0.158</td>
</tr>
<tr>
<td>Initiation or uptitration of antiarrhythmic medications</td>
<td>69</td>
<td>21.9</td>
<td>55</td>
<td>29.6</td>
<td></td>
<td>0.068</td>
</tr>
<tr>
<td>Lead/generator revision</td>
<td>14</td>
<td>4.4</td>
<td>6</td>
<td>3.2</td>
<td></td>
<td>0.639</td>
</tr>
</tbody>
</table>

Note that a single patient follow-up could have >1 classification (eg, reprogramming and drug initiation). Thus, in the HM group, 325 actionable items occurred in 315 follow-up encounters, and in the conventional group, 196 items occurred in 186 encounters.
and VF events in HM was 1 day, dramatically less than the value in conventional care of 35.5 days (HM versus conventional care [days]: AF: median, 5.5 versus 40; interquartile range, 1 to 51.25 versus 15.5 to 59; VT: median, 1 versus 28; interquartile range, 1 to 6 versus 6.5 to 69.25; VF: median, 1 versus 36; interquartile range, 1 to 7 versus 10 to 75; SVT: median, 2 versus 39; interquartile range, 1 to 19.5 versus 8.5 to 69). Clinically asymptomatic (silent) problems were also detected early in HM for combined first AF, VT, VF, or SVT events (median, 1 versus 41.5; interquartile range, 1 to 6 versus 10 to 70.25) (Figure 4, bottom). System-related problems occurred infrequently (14 in the HM group versus 3 in the conventional group). These were elective replacement indicator (1 HM versus 0 conventional patients) and atrial/ventricular lead out-of-range impedance (13 HM versus 2 conventional patients). Low incidence precluded statistical comparison.

Discussion

The TRUST trial is the first large-scale assessment of ICD follow-up either conventionally or with remote monitoring. HM permitted safe extension of face-to-face encounters, improved adherence to scheduled checks, significantly reduced the need for in-hospital device evaluation (without a detrimental effect on safety), yet enabled prompt evaluation of symptomatic or silent problems. These results were obtained from a predominantly community-based setting representing US implant demographics.

Postimplantation management of cardiac implantable electronic devices is based on monitoring of system operation and patient condition. Significant challenges are increasing complexity, patient volume, and prompt problem detection. Current practice generally follows an in-clinic follow-up protocol with retrieval of stored diagnostic data, performed at short intervals because of safety concerns. Recommended 3- to 6-month scheduled evaluations are onerous, yet knowledge of adherence, safety, incidence of additional unscheduled interrogations, or problem detection ability has been lacking until this trial. In TRUST, conventional care resulted in 3.82 in-clinic visits per year comprising 3.32 scheduled checks (ie, demonstrating loss of adherence) and 0.50 unscheduled
evaluations. The adverse event rate was 10.4%. Scheduled checks were predominantly nonactionable and yielded late event detection of >1 month. The data indicate that a follow-up system that relies on patients to present themselves physically to their physician has significant limitations.

HM reduced total hospital encounters for device interrogation by 45%, reaching the first primary study objective (Figure 2, top). Three monthly interval scheduled checks were more consistently maintained compared with conventional care, likely reflecting a mechanism independent of patient compliance. More than 90% of scheduled checks were nonactionable and did not necessitate an in-person device clinic encounter. Because HM patients had an in-person 3-month evaluation after implantation (in common with conventional care) but subsequent 3-month evaluations were scheduled remotely, total office visits in a 12-month time frame could potentially be reduced by 75%, and 6-, 9-, and 12-month checks could be reduced by 100%. The results showed that the former was reduced by 60.6% and the latter by 85.8%, demonstrating that the quality of transmitted data permitted clinical management.

HM system tested here represents a significant advance in remote technology compared with previous generations that demanded patient and clinic coordination on a calendar-based schedule. This is illustrated by event notification and evaluation within 1 day, in striking contrast to >5 months described as “early” detection with patient-activated systems.3,4 Automatic archiving of longitudinally collected data with high temporal (24 hour) definition enables assessment of system performance and detection of sudden parameter deviations from baseline trends. This may facilitate management of device recalls.3,4 In heart failure patients prone to clinical decompensation, early identification of asymptomatic triggers (eg, nonsustained VT or AF8,14) or markers of deterioration may enable preemptive treatment.

Table 3. Adverse Events

<table>
<thead>
<tr>
<th>Adverse Events (Safety Index)</th>
<th>HM (n=908 patients)</th>
<th>Conventional (n=431 patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Death</td>
<td>31</td>
<td>3.4</td>
</tr>
<tr>
<td>Stroke</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>Surgical intervention</td>
<td>60</td>
<td>6.6</td>
</tr>
</tbody>
</table>

Note that a single patient could have >1 classification (eg, death and stroke). Thus, in the HM group, 94 events occurred in 94 patients, but in the conventional group, 47 events occurred in 45 patients.

HM did not increase adverse events (Figure 2), achieving the second primary study objective.

HM enhanced problem discovery (even if asymptomatic) despite less frequent hospital evaluations, achieving the secondary study objective. Detection was advanced by >30 days compared with conventional care (Figure 4) (likely to be greater with 6 or 12 monthly conventional visits). Arrhythmias were the commonest cause for event notifications. The ability for rapid self-reporting of fault detection may be potentially lifesaving, especially for silent problems, eg, lead fracture or device dysfunction.12,13

The HM system tested here represents a significant advance in remote technology compared with previous generations that demanded patient and clinic coordination on a calendar-based schedule. This is illustrated by event notification and evaluation within 1 day, in striking contrast to >5 months described as “early” detection with patient-activated systems.3,4 Automatic archiving of longitudinally collected data with high temporal (24 hour) definition enables assessment of system performance and detection of sudden parameter deviations from baseline trends. This may facilitate management of device recalls.3,4 In heart failure patients prone to clinical decompensation, early identification of asymptomatic triggers (eg, nonsustained VT or AF8,14) or markers of deterioration may enable preemptive treatment.

This study did not directly assess patients’ perspectives on remote evaluation. Reassurance gained from continuous monitoring may have been countered by face-to-face encounters called for by the following facility in response to event notifications received. This increase in unscheduled office visits slightly offsets the benefit of reduced scheduled appointments (Figure 3). Ensuing therapy and its effects on clinical outcome(s) were not determined here and await future studies.

In summary, the TRUST trial demonstrated that automatic HM ensured continuity of follow-up of a large patient volume, avoided unnecessary in-hospital patient
evaluation (thus reducing clinic load), but maintained continuous surveillance to rapidly identify patients requiring attention. The trial results have significant implications for the management of all patients receiving implantable electronic cardiac devices.

Study Limitations

The 12-month postimplantation evaluation period does not address the majority of device and lead problems, which occur during later stages of follow-up. However, their detection is anticipated to be facilitated by the early notification capability of HM. Pacemaker-dependent patients were excluded because devices did not have the ability for automatic threshold assessment. However, current-generation HM devices possess this feature and automatically notify significant threshold changes, permitting remote management of such patients. Patients with resynchronization devices were not assessed, but early detection of parameter deviations (e.g., percentage pacing, AF) by HM may facilitate management.

Acknowledgments

We acknowledge William Hsu, PhD, MBA, for contribution to study concept and design and Richard G. Holcomb, PhD, for statistical analysis.

Source of Funding

The TRUST Study was sponsored by Biotronik Inc.

Disclosures

Dr Varma has received research grants and honoraria from Biotronik, St. Jude, Boston Scientific, Medtronic, Sorin, and Sanofi-Aventis. Dr Epstein has received research grants and honoraria from Biotronik, Boston Scientific, Medtronic, and St. Jude Medical and serves on committees for Boston Scientific and St. Jude Medical. Dr Schweikert has received research grants and honoraria from Boston Scientific, St. Jude Medical, Glaxo-Smith-Kline, and Sanofi-Aventis. Dr Love has received research grants and honoraria from Boston Scientific, Deringer-Ney, H. L. Gore, Medtronic, Spectranetics, St. Jude Medical, and TyRx Pharma. Dr Irimpen reports no conflicts.

References


**CLINICAL PERSPECTIVE**

Cardiac implantable electronic devices are increasing in prevalence. Postimplantation follow-up is important for monitoring both device function and patient condition. Currently, follow-up care follows guidelines that lack supporting data, leading to inconsistent clinical practice. Conventional in-person evaluation, if performed every 3 to 6 months, generates a huge clinical burden, but its efficacy with regard to patient safety, adherence, incidence of unscheduled encounters, and rate of problem detection remains untested. The absence of monitoring between hospital interrogations permits potentially important clinical data to remain concealed. Remote monitoring technology incorporated into devices holds the promise of resolving these problems. The Lumos-T Safely Reduces Routine Office Device Follow-Up (TRUST) trial in patients with defibrillators confirmed significant limitations of conventional care but, in contrast, affirmed the safety, efficacy, and early warning capability (ie, within 24 hours) of automatic remote monitoring. The outcome measure of hospital use was reduced by almost 50% compared with conventional care. The alert capability and archiving power of this remote management system suit it for system performance monitoring and management of devices placed under advisory notices. The results are important for heart failure patients in whom continuous surveillance with the ability to self-declare parameter deviations may permit early clinical intervention. The trial results have significant implications for the management of patients receiving implantable electronic cardiac devices.
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

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Circulation. 2010;122:325-332; originally published online July 12, 2010; doi: 10.1161/CIRCULATIONAHA.110.937409

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/122/4/325

Data Supplement (unedited) at:
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Supplemental Material

Appendices

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Shumel Inbar, MD: Odessa, TX
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