Impact of remote monitoring on clinical events and associated health care utilization: A nationwide assessment @

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16 BACKGROUND Remote monitoring (RM) of cardiac implantable 17 electronic devices (CIEDs) improves patient survival. However, 18 whether RM reduces health care utilization is unknown.

19 **OBJECTIVE** The purpose of this study was to determine whether RM was 20 associated with reduced hospitalization and costs in clinical practice. 21

22 **METHODS** We conducted a nationwide cohort study using the 23 Truven Health Analytics MarketScan database. Patients implanted with a CIED between March 31, 2009, and April 1, 2012, were 24 included. All-cause hospitalization events were compared between 25 those using RM and those not using RM by using Cox proportional 26 hazards methods with Andersen-Gill extension and propensity 27 scoring. We also compared health care costs (payments > 30 days 28 after CIED implantation). 29

RESULTS Overall, there were 92,566 patients (mean age 72 \pm 13 30 years; 63% men) with a mean follow-up of 19 \pm 12 months, 31**Q7** including 54,520 (59%) pacemaker, 27,816 (30%) implantable 32 cardioverter-defibrillator, and 10,230 (11%) cardiac resynchroniza-33 tion therapy patients. Only 37% of patients (34,259) used RM. 34

36 Introduction 37

The current health care environment in the United States 38 emphasizes improvement in patient outcomes together with 39 cost reduction and more efficient care. Information and 40 telecommunication technologies have been promulgated as 41 important tools to achieve these goals.^{1,2} Overall, hospital 42 admissions of patients with cardiovascular diseases such as 43 heart failure (HF) and atrial fibrillation (AF) are potent 44 drivers of health care costs.^{3,4} However, telephone-based 45 remote management failed to improve outcomes and/or 46 decrease readmissions in this group.⁵ In contrast, results 47

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Patients with RM had Charlson Comorbidity Index values similar to those not using RM but had lower adjusted risk of all-cause hospitalization (adjusted hazard ratio 0.82; 95% confidence Q8 interval 0.80–0.84; P < .001) and shorter mean length of hospitalization (5.3 days vs 8.1 days; P < .001) during followup. RM was associated with a 30% reduction in hospitalization costs (\$8720 mean cost per patient-year vs \$12,423 mean cost per patient-year). For every 100,000 patient-years of follow-up, RM was associated with 9810 fewer hospitalizations, 119,000 fewer days in hospital, and \$370,270,000 lower hospital payments.

CONCLUSION RM is associated with reductions in hospitalization and health care utilization. Since only about a third of CIED patients routinely use RM, this represents a major opportunity for Q9 quality improvement.

KEYWORDS Remote monitoring; Hospitalization; Health care utilization; Cost; Comparative effectiveness; ICD; CRT; Pacemakers

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with automatic remote monitoring (RM) using cardiac implantable electronic devices (CIEDs) have been more favorable, demonstrating improved patient outcomes.^{6–8} RM provides several advantages including improved efficiency of outpatient clinical care and earlier detection of device/lead malfunction and/or changes in disease status (eg, HF and arrhythmias), enabling preemptive intervention.^{9,10} This potentially reduces health care utilization and costs, but data are scant. The objective of the present study was to determine whether RM is associated with a decreased risk of hospitalization and lower health care costs in US clinical practice.

Methods

Data source

We conducted a retrospective, nationwide, observational cohort study using the Truven Health Analytics MarketScan Commercial and Medicare Supplemental Claims databases

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74 with data from April 1, 2008, through March 31, 2013. The 75 Truven database includes integrated inpatient, outpatient, 76 and pharmacy data from privately insured and Medicare Advantage (supplemental) patients throughout the United 77010 States, including >150 million enrollees since 1995. The 78 79 database has been used in nationwide health care utilization and outcome studies,^{11,12} including patients with implanted 80 81 cardiac electronic devices and patients undergoing cardiac electrophysiological procedures.^{13,14} 82

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86 Study population

87 Patients implanted with a permanent pacemaker (PM), 88 implantable cardioverter-defibrillator (ICD), or cardiac 89 resynchronization therapy with PM or defibrillator (CRT-P 90 and CRT-D, respectively) from any manufacturer between 91 March 31, 2009, and April 1, 2012, were included. Patients 92 had to be >21 years of age and have >12 months of 9301 enrollment both before and after implant. To ensure fair 94 comparisons, we restricted our analysis to patients maintain-95 ing regular follow-up by excluding patients with no follow-96 up and those without a clinic visit or RM follow-up within 97 120 days of implant (since these patients have worse 98 outcomes¹⁵). RM utilization was identified with Current 99 Procedural Terminology version 4 codes (93294, 93295, and 100 93296). The study was inclusive of all types of RM, 101 including both inductive and wireless systems. The cohort 102_{F1} selection is shown in Figure 1. Device implant procedures, 103 follow-up procedures, and device type were determined from 104 claims data Current Procedural Terminology codes, as 105 shown in Online Supplemental Table S1.

Outcomes

132 The primary outcome of interest in this analysis was allcause hospitalization events and inpatient hospitalization 133 134 payments occurring >30 days after device implantation. 135 Outpatient and pharmacy payments were not evaluated as 136 part of the present study. We prespecified the evaluation of 137 all-cause hospitalization since arrhythmias and other device 138 findings are often triggered by noncardiovascular triggers 139 such as pneumonia. Secondary outcomes included cardio-140 vascular hospitalizations, HF hospitalizations in patients 141 with a previous diagnosis of HF, readmissions for HF, stroke 142 hospitalizations in patients with a previous diagnosis of AF, 143 and stroke hospitalizations in patients with new-onset AF 144 within 1 year after CIED implant. International Classifica-145 tion of Diseases, Ninth Revision, Clinical Modification codes 146 for all diagnoses and outcomes are shown in Online 147 Supplemental Table S1 as described and validated by Quan et al¹⁶ and Birman-Deych et al.¹⁷ 148 149

Statistical analysis

152 Age, sex, and geography (state) were determined from implant event claims data. For descriptive analyses, the 153 154 study population was dichotomized on RM follow-up use: 155 those with clinic follow-up visits and RM constitute the RM 156 group and those with only clinic visits constitute the no RM 157 group. Characteristics of these 2 groups were compared, and data are represented as mean \pm SD or median (quartiles). 1b58 159 Diagnoses for 20 conditions were assessed using claims data 160 from >12 months before CIED implant. 161

The primary end point for this study was hospitalization risk and payments. A Cox regression model for censored

107 164 108 165 **CIED** implant between **CIED** Implant 109 166 4/1/2008 and 3/31/2013 N=279,407 110 167 year enrollment in MS -1 111 prior to/after implant 168 N=124.341 112 169 MS Enrollment 113 N=155,066 170 First clinic FU > 120 days 114 171 st implant or no clinic FU 115 172 RM N=12,440 (26%) No RM N=47,921 (45%) 116 173 Follow-up N=94,705 117 174 Adherence Patients <21 years old o 118 175 missing data 119 176 BM N=1.832 (5%) No RM N=307 (<1%) 120 177 Study Cohort Age 121 178 N=92,566 122 179 123 180 124 **Clinic Visits &** 181 Remote Clinic Visits Only Remote Monitor 125 Monitoring N=58,307 182 N=34,259 126 183 127 184 No RM RM 128 185 (% indicates the proportion excluded from each group) 129 186 13018 187 Figure 1 Flowchart of cohort selection. CIED = cardiac implantable electronic device; FU = follow-up; MS = XXXX; RM = remote monitoring.

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