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Cardiac Ambulatory Monitoring and Hospital Quality (CAMELOT IQ): Strategies for Reducing Length of Stay and Readmissions

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Abstract

Importance: Early and accurate detection of cardiac arrhythmias via Ambulatory Cardiac Monitoring (ACM) may reduce hospital Length Of Stay (LOS) and 30-day readmissions, yet the differences in monitoring modality on key inpatient quality indicators remains poorly characterized.

Objective: To evaluate variation in hospital LOS and 30-day readmission rates among Medicare fee-for-service beneficiaries undergoing first-time ACM, comparing different monitor types and manufacturers.

Design: Retrospective cohort analysis of administrative claims data. We compared absolute values and adjusted Incidence Rate Ratios (aIRRs) for acute inpatient days and 30-day readmissions during a 12-month baseline period vs. annualized follow-up, using generalized linear models with log-link and negative-binomial distribution.

Settings: U.S. Medicare fee-for-service claims, 2016–2023.

Participants: 287,789 diagnostic-naïve Medicare beneficiaries aged ≥65 years receiving a first ACM, categorized by monitor type: Holter (53.8%), mobile continuous telemetry (MCT; 22.5%), long-term continuous monitor (LTCM; 13.3%), and external event monitor (AEM; 10.3%). The largest manufacturer-specific cohort was an LTCM device (10.8%).

Exposures: First-time use of ACM, stratified by monitoring modality and manufacturer; iRhythm LTCM served as the reference.

Main outcome: (1) Hospital LOS in days; (2) 30-day readmission counts. Secondary economic implications were estimated, assuming $3,000 per hospital day and $16,037 per readmission.

Conclusions and relevance: Hospital length of stay and 30-day readmission rates differed significantly across monitoring modalities and manufacturers. Use of iRhythm Long-Term Continuous Monitoring (LTCM) was associated with shorter hospitalizations and fewer readmissions compared with other ACM strategies. These findings suggest that strategic selection of ACM may influence inpatient quality outcomes. Value-based care programs and guideline committees should consider incorporating such real-world evidence when developing recommendations for arrhythmia monitoring.

Keywords: Ambulatory cardiac monitoring; Length of stay; Readmissions; Medicare; Real-world evidence; Value-based care.

Introduction

Acute care hospitalizations are among the costliest healthcare services, particularly for Medicare patients [1]. Efforts to prevent inpatient admissions, reduce hospital Length-Of-Stay (LOS), and lower 30-day readmissions rates are critical for improving care quality and reducing expenditures [2,3]. These efforts are particularly pertinent for cardiac conditions, which represent a major cause of hospitalizations. Heart Failure (HF) and acute Myocardial Infarction (MI) are especially prevalent indications for hospitalizations [4] and both conditions are frequently associated with underlying arrhythmias that can precipitate or exacerbate these clinical events [5]. Early detection and management of arrhythmias may prevent or mitigate the progression of cardiac conditions that lead to hospitalization [6].

Ambulatory Cardiac Monitoring (ACM) is an essential tool for capturing intermittent arrhythmia frequently missed during brief in-clinic evaluations with standard Electrocardiograms (ECGs) [7]. ACMs vary in form factor, monitoring duration, whether they collect continuously or episodically, and the quality of information in curated reports. ACMs with higher diagnostic yield can provide critical information to clinicians in a complete and timely manner so that therapeutic interventions, including antiarrhythmic medications, rate control strategies, or anticoagulation, can be administered and acute clinical events can be avoided.

Recent evidence suggests that monitoring strategies with higher diagnostic yields are associated with fewer emergency department visits and inpatient admissions, indicating that superior arrhythmia detection may contribute to improved clinical outcomes and reduced healthcare utilization [8] however, it remains unclear if this effect remains for inpatient quality measures used in value-based purchasing programs. This study evaluates the variation in first-time ACM use on hospital LOS and 30-day readmission rates among Medicare beneficiaries. Our findings aim not only to inform clinical practice but also to guide payers and policy makers in identifying the most efficient and effective ACM strategies that will reduce the financial burden of acute care hospitalizations and enhance value-based care initiatives.

Methods

This study is part of a larger and previously reported investigation on the comparative effectiveness and healthcare utilization associated with ACM strategies, with detailed procedures and main outcomes previously described [8]. In this analyses, we assessed the average LOS in days Medicare beneficiaries spent in acute inpatient hospital settings and the average number of 30-day readmissions during baseline (12-months prior) and follow-up (annualized variable follow-up). The average incidence rate per person per year (PPPY) was reported by ACM category as absolute values, and adjusted Incidence Rate Ratios (aIRR) assessed relative differences.

Descriptive statistics include the mean and standard deviation for count variables and used one-way ANOVA with Tukey's range to compare count variables across ACM cohorts. Generalized linear models (GLM) with log-link and negative-binomial distribution were used to determine adjusted Incident Rate Ratios (aIRR) for post-index bed days and 30-day readmission counts. The manufacturer with the largest sample was used as the reference. Adjustments were made for differences in age groups, sex, race/ethnicity, geographic region, baseline comorbid conditions, and baseline all-cause inpatient hospitalizations. The log of follow-up years was added as an offset to the GLM model to adjust for variable patient follow-up lengths. For all outcomes, a p-value < 0.05 was considered statistically significant. All analyses were conducted using SAS Enterprise Guide 8.3 (SAS Institute; Cary, North Carolina).

Results

Of the 287,789 diagnostic-naïve subjects who had a first time ACM, the majority received Holter Monitors (53.8%), followed by MCT (22.5%), LTCM (13.3%), and AEM (10.3%). iRhythm LTCM (10.8%) was the largest cohort identified with an NPI linked to a particular manufacturer. Among these cohorts, inpatient hospitalizations were greatest at follow-up among the AEM (range: 39.4%-40.1%) and MCT (range: 37.4%-40.0%) cohorts, with LTCM (range: 26.8%-31.3%) cohorts having the least. The change from baseline to follow-up was also the least among the LTCM cohorts (range: 10.8%-12.5%) compared to AEM (range: 17.1%-17.5%), MCT (range: 14.4%-15.5%), and Holter monitors (21.9%) (Table 1).

Length-of-stay

There was significant variation in the average number of days that patients stayed in the hospital by monitoring modality and manufacturer. The average LOS during follow-up was greatest among the MCT (range: 3.99-4.28 days) and AEM (range: 3.61-4.09 days) cohorts, and least among the LTCM (range: 2.76-3.52 days) cohorts. The trend remained where the change from baseline to follow-up was greatest among the MCT (range: 2.47-2.82 days) and AEM (range: 2.27-2.64 days) cohorts, and least among the LTCM (range: 1.69-2.51 days) cohorts. Similarly in the fully adjusted analysis incorporating differences in baseline characteristics, when compared to iRhythm LTCM there were significantly greater LOS among all other modalities and most manufacturers (aIRR range: 1.12-1.39) (Table 2).

30-Day readmission

Additionally, there was significant variation in the number of 30-day readmissions patients had by monitoring modality and manufacturer. The average 30-day readmission rate during follow-up was greatest among the AEM (range: 0.13-0.14) and MCT (range: 0.11-0.13) cohorts, and the least among the LTCM (range: 0.07-0.09) and Holter (0.07) cohorts. The trend remained where the change from baseline to follow-up was greatest among the AEM (range: 0.11-0.12) and MCT (range: 0.09-0.11) cohorts, and least among the LTCM (range: 0.05-0.09) and Holter (0.06) cohorts. In a fully adjusted analysis accounting for baseline differences and when compared to iRhythm LTCM, other monitoring modalities and most manufacturers had significantly greater rates of 30-day readmissions (aIRR range: 1.15-1.44).

Table 1. Inpatient hospital stays, length-of-stay, and readmissions by ambulatory cardiac monitor.

Characteristic		LTCM iRhythm (n=30,994)	LTCM Second Brand (n=2,798)	LTCM Third Brand (n=157)	Holter Monitor (n=154,970)	AEM Second Brand (n=10,382)	AEM Third Brand (n=7,157)	MCT Second Brand (n=29,042)	MCT Third Brand (n=11,675)	Overall p-value
Inpatient Hospital Stays	Baseline	5,814 (18.8%)	427 (15.3%)	25 (15.9%)	18,676 (12.1%)	2,316 (22.3%)	1,623 (22.7%)	7,115 (24.5%)	2,681 (23.0%)	<0.001
	Follow-up	9,701 (31.3%)	865 (30.9%)	42 (26.8%)	52,662 (34.0%)	4,089 (39.4%)	2,873 (40.1%)	11,608 (40.0%)	4,382 (37.5%)	<0.001
Length of Stay, mean days (SD) PPPY	Baseline	1.07 (3.41)	0.90 (3.23)	1.01 (3.04)	0.72 (3.45)	1.34 (3.88)	1.45 (4.07)	1.52 (4.17)	1.46 (4.33)	<0.001
	Follow-up	2.76 (18.70)	2.69 (11.33)	3.52 (13.72)	2.77 (11.96)	3.61 (15.33)	4.09 (18.04)	3.99 (19.72)	4.28 (22.06)	<0.001
30-day Readmissions, mean count (SD) PPPY	Baseline	0.02 (0.14)	0.02 (0.15)	0.00 (0.00)	0.01 (0.11)	0.02 (0.17)	0.02 (0.16)	0.02 (0.17)	0.02 (0.17)	<0.001
	Follow-up	0.07 (0.56)	0.08 (0.60)	0.09 (0.49)	0.07 (0.70)	0.14 (1.52)	0.13 (1.12)	0.11 (0.96)	0.13 (1.09)	<0.001

LTCM, long-term continuous monitor; AEM, ambulatory event monitor; MCT, mobile cardiac telemetry; CI, confidence interval; Second Brand, BioTelemetry Inc (Malvern, PA); Third Brand, Preventice Inc (Rochester, MN); PPPY, per-person per-year.

Table 2 Multivariable models of outcomes by ambulatory cardiac monitor type.

Characteristic		Length Of Stay		30-Day Readmission	
Cohort	Count	aIRR (95% CI)	p-value	aIRR (95% CI)	p-value
LTCM iRhythm (ref.)	30,994	-	-	-	-
LTCM Second Brand*	2,798	1.12 (1.00-1.25)	0.046	1.24 (1.02-1.52)	0.030
LTCM Third Brand+	157	1.47 (0.93-2.32)	0.098	1.82 (0.80-4.12)	0.153
LTCM other/unknown	4,369	1.14 (1.05-1.25)	0.003	1.30 (1.11-1.53)	0.001
Holter	154,970	1.13 (1.09-1.17)	<0.001	1.15 (1.08-1.23)	<0.001
AEM Second Brand*	10,382	1.22 (1.14-1.30)	<0.001	1.44 (1.29-1.60)	<0.001
AEM Third Brand+	7,157	1.32 (1.22-1.42)	<0.001	1.41 (1.25-1.59)	<0.001
AEM other/unknown	12,185	1.19 (1.11-1.26)	<0.001	1.35 (1.22-1.50)	<0.001
MCT Second Brand*	29,042	1.32 (1.22-1.42)	<0.001	1.28 (1.18-1.39)	<0.001
MCT Third Brand+	11,675	1.39 (1.30-1.48)	<0.001	1.30 (1.17-1.45)	<0.001
MCT other/unknown	24,060	1.21 (1.15-1.27)	<0.001	1.18 (1.09-1.29)	<0.001

LTCM, long-term continuous monitor; AEM, ambulatory event monitor; MCT, mobile cardiac telemetry;
CI, confidence interval; aIRR, adjusted rate ratio; *BioTelemetry Inc (Malvern, PA); +Preventice Inc (Rochester, MN);
ref, reference category.

Discussion

Our study demonstrates that the modality and manufacturer of ACM used prior to hospitalization are significantly associated with inpatient quality measures used in value-based purchasing programs. Patients monitored with a specific LTCM experienced the shortest hospital stays and the lowest 30-day readmission rates compared to those monitored with most other LTCM manufacturers, Holter monitors, MCT, or AEM. The comprehensive data and higher diagnostic yield provided by LTCM appears to facilitate earlier and more accurate arrhythmia detection, enabling clinicians to develop effective treatment plans prior to hospital admission. This early detection is likely to reduce the need for additional hospital diagnostics, thereby shortening the overall length of stay. In contrast, patients monitored with MCT and AEM exhibited significantly longer hospitalizations and higher 30-day readmission rates even while receiving a longer duration of monitoring.

The intermittent or less detailed data from these monitors may not be capturing the quality of information necessary to construct adequate treatment plans, leading to further hospital evaluations and resulting in prolonged hospital stays. Consequently, patients monitored by these strategies may be at a higher risk of unresolved cardiac issues after discharge, leading to an increased likelihood of readmission. These findings carry important implications for clinical practice, health services, and policy. Clinicians should carefully consider the performance and reliability of ACM when selecting a monitoring strategy, as not all strategies or manufacturers provide equivalent diagnostic yields. From a policy perspective, our study underscores the potential effectiveness of investing in high-performance ACM technologies on improving inpatient quality measures used in value-based purchasing programs.

From a financial standpoint, given that an average cost for a day in the hospital is $3,000, [9] there would be $360-$1,170

greater costs per day associated with all other modalities and manufacturers compared to iRhythm LTCM. If an average cost for a 30-day readmission is $16,037 in unreimbursed expenses [10] there would be $2,406-7,056 greater costs associated with all other modalities and manufacturers compared to iRhythm LTCM. Given the substantial financial burden of prolonged hospitalizations and frequent readmissions, payers and policymakers may benefit from supporting targeted investments in certain monitoring strategies. Such investments could align with the goals of value-based care initiatives by reducing costly healthcare services.

Future research should explore the underlying factors contributing to these differences, including signal quality; algorithm accuracy, recording duration, and patient adherence, to further optimize ACM usage. Ultimately, our study provides evidence that strategic selection in ACM can improve healthcare service outcomes while also offering a pathway for health policy reforms aimed at enhancing cost-effectiveness in the management of cardiac arrhythmia.

Conclusion

In a sample of diagnostic-naïve Medicare beneficiaries receiving ACM, inpatient quality measures used in value-based purchasing programs varied by monitoring strategy and manufacturer. A specific LTCM was associated with lower adjusted hospital LOS and 30-day readmission rates. This suggests monitoring strategies produce different results and value-based care initiatives may benefit by selecting specific ones based on evidence.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, as a retrospective claims-based analysis, the study is subject to inherent biases related to coding accuracy and completeness, which may impact the classification of monitoring modalities and patient outcomes. Additionally, the use of administrative data limits the ability to capture nuanced clinical details, such as the severity of arrhythmia or adherence to prescribed monitoring durations, which could influence outcomes like LOS and 30-day readmissions. Another limitation is the generalizability of findings, as the study population consisted solely of Medicare fee-for-service beneficiaries aged 65 and older, which may not reflect younger populations or those with different insurance coverage. The observational nature of the study precludes any causal inferences, and despite adjustments for confounders, residual confounding cannot be ruled out. Finally, device-related factors such as algorithm sophistication, patient experience, or clinician interpretation, which may influence outcomes, were not directly measured, warranting further investigation into these aspects in future research.

Conflicts of Interest

EH, BW, and KB are employees of iRhythm Technologies and hold equity in the company. No other potential conflicts of interest relevant to this article were reported.

Author Contributions

EH, BW, and KB contributed to conception and design of the study. IM were involved in the data acquisition and analysis. EH drafted the manuscript. All authors critically reviewed the manuscript for important intellectual content and approved the final version. IM conducted the statistical analysis. EH, BW, and KB obtained funding and provided administrative, technical, or material support. EH supervised the project and is the guarantor of the work. IM had full access to all the data and responsibility for the integrity of the data and accuracy of the analysis.

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Role of Funder/Sponsor

IRhythm Technologies, as the study sponsor, had no role in the conduct of the study; collection, management, analysis, or interpretation of the data; preparation of the manuscript; and decision to submit the manuscript for publication. Certain authors (BW, BK, and EH), as employees of iRhythm Technologies, were involved in the study's conception and design, drafting and critical review of the manuscript, and approved the final version as detailed in the Author Contributions section.

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