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ORIGINAL ARTICLE

Reduction in 90 day readmission rates utilizing ambulatory pulmonary pressure monitoring

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Abstract

Aims In the CHAMPION (CardioMEMS Heart Sensor Allows Monitoring of Pressure to Improve Outcomes in New York Heart Association Functional Class III Heart Failure Patients) trial, heart failure hospitalization (HFH) rates were lower in patients with ambulatory pulmonary artery pressure (PAP) monitoring guidance. We investigated the effect of ambulatory haemodynamic monitoring on 90 day readmission rates after HFH.

Methods and results We retrospectively analysed patients across the Advocate Aurora Health hospital network who had undergone PAP sensor implantation between 1 October 2015 and 31 October 2019. Patients with a ventricular assist device (VAD) or transplant prior to implantation were excluded. Rates of total HFH and 30 and 90 day all-cause readmission up to 12 months after implantation were collected, while censoring for an endpoint of heart transplantation, VAD, or death. Event rates were compared using Poisson regression. Of 459 patients included, there were 404 HFHs before and 179 after implantation. Compared with pre-implantation, 30 day all-cause readmission [incidence rate ratio (IRR): 0.55 (0.39–0.77), $P = 0.0006$] and 90 day all cause readmission rates were lower post-implantation [IRR: 0.45 (0.35–0.58), $P < 0.0001$]. The effect of PAP sensor implantation on 90 day all-cause readmission incidence rates was consistent across multiple subgroups.

Conclusions Across a large hospital network, ambulatory haemodynamic monitoring was associated with lower HFH rates, as well as 30 and 90 day all-cause readmission rates. This supports the utility of ambulatory PAP monitoring to improve HF management in the era of value-based medicine.

Keywords 30 day readmission; 90 day readmission; Heart failure hospitalization; Heart failure readmission; Pulmonary artery pressure monitoring

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Introduction

Heart failure (HF)[1] hospitalizations (HFHs) remain a significant burden on the healthcare system. In the United States alone, more than 1 million people are hospitalized for a primary diagnosis of HF annually.[2] The Hospital Readmission Reduction Program was introduced in 2012 as a Medicare value-based programme to improve quality of care by holding providers accountable for excess HF hospital readmissions. The focus of this programme has largely been on 30 day readmission reduction for HF. However, 30 day readmissions are often directly impacted by acute care management strategies during the index hospitalization and are not always reflective of ambulatory chronic management practices for HF. In fact, the vulnerability phase of HF patients after discharge appears to extend beyond 90 days.[3–5] Assessment of outcomes at 90 days may be more helpful in evaluating the efficacy of chronic care management strategies in the ambulatory setting.[6,7]

Ambulatory pulmonary artery pressure (PAP) monitoring has become a therapeutic strategy for reducing HFH in symptomatic HF patients. A sub-analysis of Medicare recipients in the CHAMPION [CardioMEMS Heart Sensor Allows Monitoring of Pressure to Improve Outcomes in New York Heart Association (NYHA) Functional Class III Heart Failure Patients] trial showed that PAP sensor monitoring as compared with

standard of care reduced all-cause 30 day readmission rates as well as total HFH.[8,9] However, the utility of PAP sensor monitoring for 90 day readmission reduction after a primary HFH event has not been previously studied. We sought to review PAP monitoring data in a large, contemporary healthcare network to assess the impact on 90 day readmission rates.

Methods

Study population

We conducted a retrospective analysis using an electronic medical record (EMR) database from the Advocate Aurora Health network. Patients who underwent ambulatory PAP monitor implantation with a CardioMEMS (Abbott, Chicago, IL, USA) sensor between 1 October 2015 and 31 October 2019 were included if sufficient hospitalization records were available within our EMR database for 1 year prior to and 1 year after implantation. Patients were included regardless of left ventricular ejection fraction or aetiology of HF diagnosis. Patients who had a ventricular assist device (VAD) or heart transplant prior to PAP sensor implantation were excluded, as were those who were part of an active clinical trial involving PAP sensor management during the study time frame. This investigation conforms with the principles outlined in the Declaration of Helsinki. The study protocol was reviewed and approved by the Aurora Institutional Review Board, and the requirement for informed consent was waived due to minimal risk associated with the study design.

Definitions

Hospitalization data 1 year prior to and 1 year after implantation were extracted from hospital billing encounters via the EMR database. The aetiology for hospitalization was determined by the final-coded primary diagnosis listed on the hospital billing encounter. The primary diagnosis was prospectively adjudicated by chart review by the study team in cases in which data were insufficient for EMR extraction. The PAP sensor implantation date was defined as the anchor point, separating pre- and post-implantation hospitalization events. HFH events were defined as any hospitalization with the final-coded primary diagnosis of HF. Readmission events were defined as occurring within either 30 or 90 days of discharge from an index HFH event when analysing for 30 and 90 day readmission, respectively. HFHs in which the patient was discharged against medical advice or died in-hospital were excluded from both 30 and 90 day readmission examination. All-cause hospitalizations were defined as hospitalization for any cause as determined by the primary coding diagnosis. Hospitalizations occurring for or after a VAD implantation or heart transplantation were excluded. Hospitalization event rates were compared 1 year prior to and 1 year after implantation for the study population, adjusting for patient days.

Statistical analysis

Patient demographics and medical history were analysed. Continuous variables were presented as mean ± standard deviation. Categorical variables were summarized as frequencies and percentages. Rates of total HFH, 30 day all-cause readmission, and 90 day all-cause readmission after an index HFH event were collected for the 12 months before implantation and subsequently for a total of 12 months after implantation, while censoring at the time of an event of heart transplantation, VAD implantation, or death. Event rates were calculated pre- and post-implantation separately. The total number of events over the course of the 12 months before implantation was summed for each patient. The total number of events identified over each individual patient's cumulative follow-up time frame after implantation was also summed. Incidence rates were defined as hospitalization events per patient per 180 days after adjusting for specific post-implantation follow-up time frames. Poisson regression analysis was utilized for statistical modelling of HFH event rates, 30 day readmissions, and 90 day readmissions comparing pre-implantation event rates within the patient population to post-implantation event rates. For all statistical analysis, significance levels were two-sided with a P value < 0.05.

Results

Of the 488 patients screened, 459 were included in the analysis (*Figure 1*). Six patients were excluded due to ongoing involvement with a PAP sensor management study. Twenty-three patients were excluded due to a history of VAD or heart transplantation prior to PAP sensor implantation. The baseline demographics and medical history of the study population is shown in *Table 1*. Of importance, the mean ejection fraction of the study cohort was 40.3 ± 17.3%. Of the 459 patients, 48% had an ejection fraction $>$ 40%. Background medical history of diabetes, hypertension, and pre-existing chronic kidney disease (CKD) was common (60.8%, 87.6%, and 68.3% of patients indicated, respectively). The overall mean follow-up after implantation was 337 ± 76 days. Ten patients went on to receive a VAD or heart transplant within 1 year of their implant, and follow-up time was censored at the time of hospital event. There were 58 mortalities within the first 1 year after implantation. The overall survival free of VAD, transplantation, and death at 3, 6, 9, and 12 months after implantation was 97.2%, 94.3%, 90.8%, and 87.2%, respectively.

Figure 1 CONSORT diagram of total patients screened. Patients who were in an active clinical study involving PAP sensor implantation were excluded, as were patients with a pre-existing VAD or HTx. HTx, heart transplant; PAP, pulmonary artery pressure; VAD, ventricular assist device.

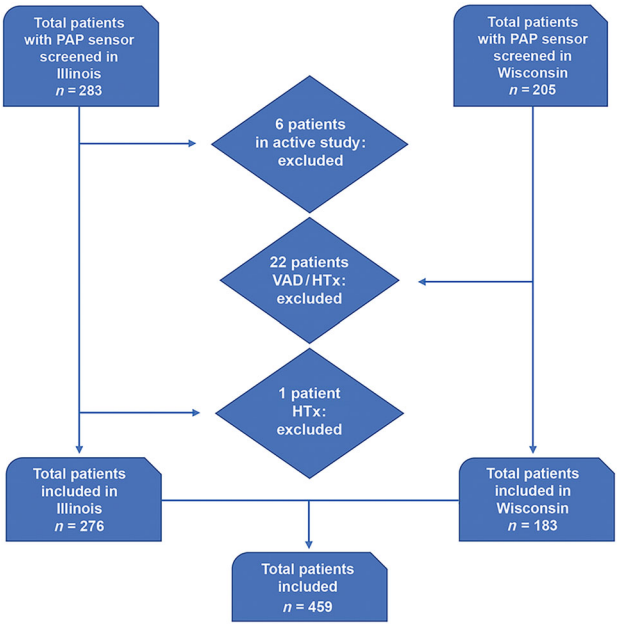

Table 1 Baseline characteristics

Characteristics	*n*	Frequency (%) or mean ± standard deviation (minimum–maximum)
Age at implantation, years	459	70.8 ± 11.8 (30–93)
Age = 75 years	459	198 (43.1)
Prior EF	448	40.3 ± 17.3 (5–75)
Prior EF > 40%	448	215 (48)
Male sex	459	279 (60.8)
Prior GFR	397	49.3 ± 20 (13–90)
GFR ≤ 60	397	291 (73.3)
GFR ≤ 30	397	67 (16.9)
Race		
Caucasian	459	375 (81.7)
African-American	459	51 (11.1)
Asian/Pacific Islander	459	10 (2.2)
Unknown	459	21 (4.6)
Ethnicity		
Hispanic	459	15 (3.3)
Unknown	459	66 (14.4)
Comorbidities		
Ischaemic cardiomyopathy	459	203 (44.2)
Diabetes	459	279 (60.8)
Hypertension	459	402 (87.6)
COPD	459	208 (45.3)
Chronic kidney disease	423	289 (68.3)
CAD	459	335 (73)
Prior CRT/CRT-D	450	150 (33.3)

CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; CRT/CRT-D, cardiac resynchronization therapy/CRT-defibrillator; EF, ejection fraction; GFR, glomerular filtration rate.

In the entire patient cohort, 404 total HFH events occurred before implantation, compared with 179 HFH events after implantation. There was a statistically significant reduction in inpatient HFH events following PAP sensor implantation [0.43 events per patient per 180 days vs. 0.21 events per patient per 180 days; incidence rate ratio (IRR): 0.48 (0.40–0.57), $P < 0.0001$]. Compared with pre-implantation, there was a lower rate of 30 day all-cause readmission post-index HFH [0.11 events per patient per 180 days vs. 0.06 events per patient per 180 days; IRR: 0.55 (0.39–0.77), $P = 0.0006$]. Similarly, compared with pre-implantation, there was a statistically significant reduction in the 90 day all-cause readmission rate post-implantation [0.21 events per patient per 180 days vs. 0.10 events per patient per 180 days; IRR: 0.45 (0.35–0.58), $P < 0.0001$; *Figure 2*]. The effect of PAP sensor implantation on 90 day all-cause readmission was consistent across multiple subgroups (*Figure 3*).

Discussion

Ambulatory pulmonary pressure monitoring has gained traction as a functional diagnostic tool to aid in therapeutic adjustments in HF patients. In the randomized CHAMPION trial, HF treatment guided by PAP sensor data reduced HFH compared with standard of care.[10] These benefits were consistent across patients with both preserved and reduced ejection fraction.[11] The outcomes were closely associated with a reduction in PAP over time with guided adjustments in medical therapy.[12] In a single-arm trial of 1200 patients, the CardioMEMS Post Approval Study revealed sustained benefits of lowered PAP, lower rates of HFH events, and lower all-cause hospitalization following PAP sensor implantation.[13] In a real-world analysis of 1114 patients using Medicare claims data, Desai *et al*. were able to further confirm a consistent benefit of HFH event reduction post-sensor implantation.[14] Our study expands on this benefit by showing a significant reduction in all-cause 90 day readmission in a large contemporary network of HF patients. In a pre-specified pre-COVID-19 impact analysis of the Haemodynamic-GUIDEed management of Heart Failure (GUIDE-HF) trial, a similar statistical reduction of HFH events was observed in the intervention group over that of the control.[15] These cumulative data continue to support the benefits of PAP sensor-guided HF management strategies.

Previous studies on Medicare beneficiaries suggest that all-cause 90 day readmissions following an index HF event average as high as 40% across healthcare systems.[6] These findings suggest that the vulnerable phase of HF extends well beyond the 30 day cut-off. In fact, 90 day readmission remains an independent predictor of mortality in HF patients.[16] However, temporal trends in 90 day HF readmission rates after implementation of the Hospital Readmission Reduction

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Figure 2 Mean event rates per patient per 180 days pre- and post-PAP sensor implantation. HFH, heart failure hospitalization; IRR, incidence rate ratio.

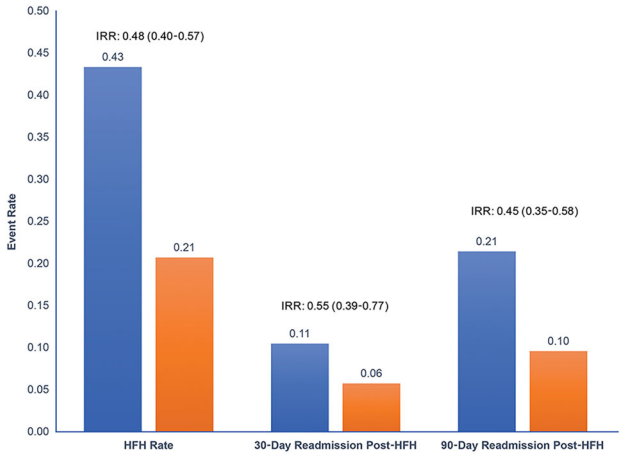
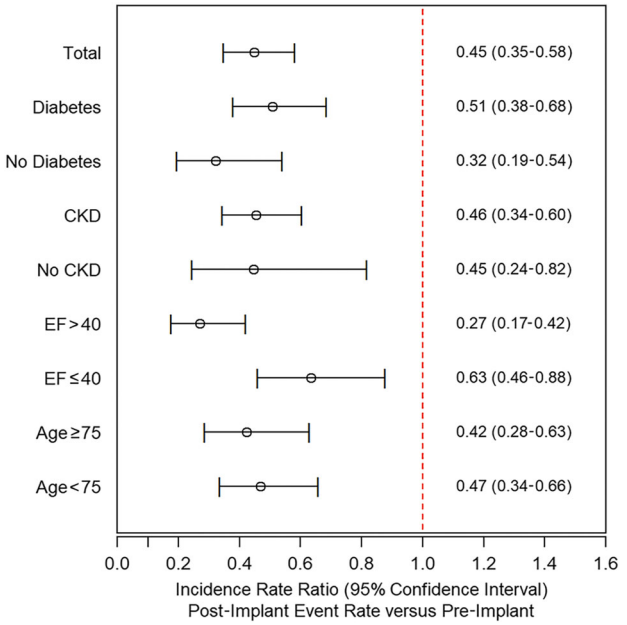


Figure 3 Ninety-day readmission after heart failure hospitalization reduction in incidence rate post- vs. pre-implantation. CKD for modelling purposes was defined as either documented comorbidity of CKD or glomerular filtration rate at implantation ≤ 30. Non-CKD was defined as absence of documented CKD and if documentation was missing glomerular filtration rate > 30. CKD, chronic kidney disease; EF, ejection fraction.



Program penalty phase have not shown substantial improvement, suggesting that our current ambulatory chronic care strategies remain inadequate.[7] The traditional methods of tracking ambulatory weight changes and frequent telephonic assessment are found to be suboptimal, as these methods often fail to accurately predict congestion.[17–20] Dilated inferior vena cava size as a surrogate for elevated intracardiac pressure continues to remain a potent echocardiographic predictor of 90 day readmission rates, suggesting that persistent congestion correlates closely with recurrent hospitalizations.[21] Strategies to effectively track ambulatory congestion in HF patients can therefore provide timely treatment of decompensation and prevent hospitalization over a vulnerable phase. Our study expands on the known benefits of PAP monitoring and suggests sensor-guided therapy correlates to a reduction in 90 day all-cause readmission rates for HF. Incorporating PAP sensor-guided chronic care management strategies may decrease hospital utilization and improve value-based care.

In this study, the use of ambulatory PAP sensor monitoring was shown to be effective across patient subgroups. Previously, a sub-analysis of the CHAMPION trial showed the effectiveness of PAP monitoring to reduce 30 day readmission in a Medicare-eligible (age ≥ 65 years of age) cohort.[9] Our study showed expanded efficacy of PAP monitoring on both 30 and 90 day readmissions in all age cohorts. The effect remained consistent independent of ejection fraction measurement or presence of a comorbid disease state such as diabetes or CKD. In previous studies, PAP sensor monitoring has been proven to be efficacious in reducing HFH in patients with CKD.[22] Laboratory values such as elevated blood urea nitrogen have consistently remained a strong predictor of all-cause 90 day readmission.[21] Utilization of PAP sensor monitoring in this study strongly correlated to reduction in 90 day readmission rates even in HF patients with established CKD.

Study limitations

This study was a retrospective analysis utilizing an EMR database for data extraction. Accordingly, limitations of availability of hospitalization data from other centres outside the hospital network are inherent. Background medical therapy, therapeutic adjustments, and adherence to PAP monitoring were not evaluated in this study. This study evaluated treatment effect across multiple implanting centres within a network, and therapeutic strategies were not standardized across the system. As this was a comparison of outcomes pre- and post-implantation, using individual patients as their own historical control, one cannot exclude post-implantation enhanced provider scrutiny, increased frequency of contact, and more aggressive chronic care management strategies as also contributing to the noted decrease in HFH events. However, the strategy of PAP sensor-guided management has been compared with intensely managed control arms in randomized controlled trials previously, negating the perceived effect of these confounding factors.

Conclusions

In a large contemporary hospital network setting, post-PAP sensor implantation led to a reduction in all-cause 90 day re-admission rates from an index HFH event. This benefit was consistent across all patient subgroups. This study suggests that the use of ambulatory haemodynamic monitoring to guide therapeutic adjustments can be helpful in reducing hospital utilization and improving value-based medicine. This approach may aid in the development of more comprehensive chronic care management strategies to provide long-term benefit and risk reduction to HF patients.

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Conflict of interest

Ali Valika, MD, is on the speaker bureau for Abbott Medical, Inc. No other authors report conflicts pertaining to this manuscript.

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