The role of remote monitoring in preventing readmissions after acute heart failure

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Despite advances in medical therapies to treat heart failure, the hospitalization rate has not changed significantly from 2000. As a result, heart failure continues to be a MAJOR DRIVER OF OVERALL HEALTH CARE COSTS.

*Study projections assumes HF prevalence remains constant and continuation of current hospitalization practices

HF-Hospitalization is a Significant Event

Progressive decrease in survival with each subsequent HF admission

Congestion status at discharge

A  Discharge
   - High-grade orthoedema 16%
   - Low-grade orthoedema 32%
   - No orthoedema 52%

B  60-day Follow up
   - High-grade orthoedema 38%
   - Low-grade orthoedema 27%
   - No orthoedema 35%

52% No Congestion  35% No Congestion

Table 2. Orthoedema Scores

<table>
<thead>
<tr>
<th>Score Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild edema, no orthopnea</td>
<td>0</td>
</tr>
<tr>
<td>Moderate edema, no orthopnea</td>
<td>1</td>
</tr>
<tr>
<td>Severe edema OR orthopnea</td>
<td>2</td>
</tr>
<tr>
<td>Moderate edema and orthopnea</td>
<td>3</td>
</tr>
<tr>
<td>Severe edema and orthopnea</td>
<td>4</td>
</tr>
</tbody>
</table>
60 day Event Rates Based on congestion status at discharge

“Weight loss did not consistently correlate congestion status as measured by orthodema”

Figure 3. Sixty-day event rates based on discharge orthodema score to represent congestion (P=0.038).
Weight Gain

<table>
<thead>
<tr>
<th>Weight Gain</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 kg weight gain over 48-72 hrs²</td>
<td>9%</td>
<td>97%</td>
</tr>
<tr>
<td>2% weight gain over 48-72 hrs²</td>
<td>17%</td>
<td>94%</td>
</tr>
<tr>
<td>3 lbs in 1 day or 5 lbs in 3 days³</td>
<td>22.5%</td>
<td>-</td>
</tr>
</tbody>
</table>

**NO CORRELATION**
Daily weights do not correlate with filling pressures.

Clinical Examination

N = 366 Advanced Chronic HF patients, mean LVEF 25%±7

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate of</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JVP Edema</td>
<td>RAP</td>
<td>48</td>
<td>78</td>
<td>60</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>94</td>
<td>55</td>
<td>60</td>
</tr>
<tr>
<td>Pulse Press</td>
<td>Cardiac Index</td>
<td>27</td>
<td>69</td>
<td>52</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>36</td>
<td>81</td>
<td>69</td>
<td>54</td>
</tr>
<tr>
<td>S3 Dyspnea</td>
<td>PCWP</td>
<td>50</td>
<td>73</td>
<td>67</td>
<td>57</td>
</tr>
<tr>
<td>Rales</td>
<td></td>
<td>13</td>
<td>90</td>
<td>60</td>
<td>48</td>
</tr>
</tbody>
</table>

RESULTS

Data from clinical evaluations has poor sensitivity and predictive value in determining hemodynamic profile.

Clinical examination has LIMITED RELIABILITY in assessing filling pressures.

# Clinical Surrogates of Rising Filling Pressures

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Surrogate for:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptoms (PND, orthopnea, etc.)</td>
<td>( LVEDP, RAP )</td>
</tr>
<tr>
<td>JVP</td>
<td>( RAP )</td>
</tr>
<tr>
<td>HJR</td>
<td>( RAP )</td>
</tr>
<tr>
<td>S3</td>
<td>( LVEDP )</td>
</tr>
<tr>
<td>Rales</td>
<td>( LVEDP )</td>
</tr>
<tr>
<td>Daily weight</td>
<td><em>Body volume (LVEDP, RAP)</em></td>
</tr>
<tr>
<td>BNP</td>
<td>( PCWP )</td>
</tr>
<tr>
<td>Intrathoracic impedance</td>
<td>( PCWP )</td>
</tr>
<tr>
<td>Heart rate variability</td>
<td><em>Cardiac autonomic control</em></td>
</tr>
</tbody>
</table>

**THE GOAL:** Predict gradual decompensation leading to acute decompensation.
## Impact of Clinical Surrogates on Hospitalizations

<table>
<thead>
<tr>
<th>Trial</th>
<th>N</th>
<th>Parameter Monitored/ Clinician Interaction</th>
<th>Impact on HF Hospitalization</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TELE-HF¹</td>
<td>1,653</td>
<td>Signs/symptoms, daily weights</td>
<td>None</td>
<td>2010</td>
</tr>
<tr>
<td>TIM-HF²</td>
<td>710</td>
<td>Signs/symptoms, daily weights</td>
<td>None</td>
<td>2011</td>
</tr>
<tr>
<td>TEN-HMS³</td>
<td>426</td>
<td>Signs/symptoms, daily weights, BP, nurse telephone support</td>
<td>None</td>
<td>2005</td>
</tr>
<tr>
<td>BEAT-HF⁴</td>
<td>1,437</td>
<td>Signs/symptoms, daily weights, nurse communications</td>
<td>None</td>
<td>2015 Abstract</td>
</tr>
<tr>
<td>INH⁵</td>
<td>715</td>
<td>Signs/symptoms, telemonitoring, nurse coordinated DM</td>
<td>None</td>
<td>2012</td>
</tr>
<tr>
<td>DOT-HF⁶</td>
<td>335</td>
<td>Intrathoracic impedance with patient alert</td>
<td>Increased</td>
<td>2011</td>
</tr>
<tr>
<td>Optilink⁷</td>
<td>1,002</td>
<td>Intrathoracic impedance</td>
<td>None</td>
<td>2011</td>
</tr>
<tr>
<td>REM-HF⁸</td>
<td>1,650</td>
<td>Remote monitoring via ICD, CRT-D, or CRT-P</td>
<td>None</td>
<td>2016 Abstract</td>
</tr>
<tr>
<td>MORE CARE⁹</td>
<td>865</td>
<td>Remote monitoring of advanced diagnostics via CRT-D</td>
<td>None</td>
<td>2016</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8,793</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Multiple trials studying > 8,500 patients have demonstrated that current markers have **NO IMPACT ON HF HOSPITALIZATION.**

4. Ong MK, AHA 2015 LBCT.
Why Are These Parameters Ineffective?

REACTIVE AND INEXACT
Traditional physiologic markers, such as patient weight, symptoms, and blood pressure, occur late in the decompensation process and leave little time to react before hospitalization.\(^7\)

Progressive Rise in Filling Pressures Leads to Hospitalization

Transition from Chronic Compensated to Acute Decompensated HF

Hemodynamic-Guided HF Management

Table 1 Characteristics of the five studies identified using implantable haemodynamic monitoring technology to guide heart failure management

<table>
<thead>
<tr>
<th>Study details</th>
<th>Chronicle Feasibility (n = 32)</th>
<th>HOMEO STASIS (n = 40)</th>
<th>CHAMPION (n = 550)</th>
<th>COMPASS-HF (n = 274)</th>
<th>REDUCEhf (n = 400)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years of study Study type</td>
<td>Published 2003 Prospective, observational, historic control</td>
<td>2005–2008 Prospective, observational, open label</td>
<td>2007–2009 Prospective, single-blinded, randomized control</td>
<td>2003–2004 Prospective, single-blinded, randomized control</td>
<td>Published 2011 Prospective, single-blinded, randomized control</td>
</tr>
</tbody>
</table>
| 5 Trials, 1296 Chronic HF patients, permanently implanted sensors SIGNIFICANT IMPACT ON HF HOSPITALIZATIONS 38% [HR 0.62] reduction in HF events

Adamson et al. Eur J Heart Fail (2017) 19, 426-433
COMPASS-HF (n=274 [n=134 device, n=140 control])

Did not significantly reduce total HF-related events but was associated with a 36% RRR in HF-hospitalization

Bourge et al. J Am Coll Cardiol 2008;51:1073-1079
Hemodynamic-Guided HF Management

PURPOSE
Evaluate the safety and efficacy of the CardioMEMS™ HF System in reducing HF related hospitalizations in NYHA class III heart failure patients.

Treatment group managed to target PA pressures:
- Systolic 15 – 35 mmHg
- Diastolic 8 – 20 mmHg
- Mean 10 – 25 mmHg

CHAMPION (n=550)

CardioMEMS™ PA Sensor Implanted
n = 550

Treatment Group
n = 270
Traditional HF management guided by PA pressures

Control Group
n = 280
Traditional HF management

Primary Endpoint: Rate of HF hospitalization

Secondary Endpoints:
- Change in PA pressure at 6 months
- No. of pts admitted to hospital for HF
- Days alive outside of hospital
- QOL (MLHFQ)

Study exits < 6 mos.:
26 (9.3%) Total
15 (5.6%) Death
11 (4.0%) Other

Study exits < 6 mos.:
20 (7.1%) Death
6 (2.2%) Other

Hemodynamic-Guided HF Management

Cardiomems™ HF System

Target location for PA pressure sensor

Pulmonary Artery Pressure Sensor

Patient Electronics System

Merlin.net™ PCN

Hemodynamic-Guided HF Management

CHAMPION (n=550)

Hemodynamic-Guided HF Management

CHAMPION (n=550)

By targeting PA pressure ranges and titrating medications, mean PA pressure was significantly reduced over time.

Systolic 15 – 35 mmHg
Diastolic 8 – 20 mmHg
Mean 10 – 25 mmHg

P=0.0077

## Hemodynamic-Guided HF Management

### CHAMPION (n=550)

<table>
<thead>
<tr>
<th>Endpoint</th>
<th>Treatment (n = 270)</th>
<th>Control (n = 280)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Safety Endpoints</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Device-related or system-related complications</td>
<td>3 (1%)</td>
<td>3 (1%)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Total</td>
<td>8 (1%)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure-sensor failures</td>
<td>0</td>
<td>0</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td><strong>Secondary Endpoints</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change from baseline in PA mean pressure (mean AUC [mm Hg x days])</td>
<td>-156</td>
<td>33</td>
<td>0.008</td>
</tr>
<tr>
<td>Number and proportion of patients hospitalized for HF (%)</td>
<td>55 (20%)</td>
<td>80 (29%)</td>
<td>0.03</td>
</tr>
<tr>
<td>Days alive and out of hospital for HF (mean ± SD)</td>
<td>174.4 ± 31.1</td>
<td>172.1 ± 37.8</td>
<td>0.02</td>
</tr>
<tr>
<td>Quality of life (Minnesota Living with Heart Failure Questionnaire, mean ± SD)</td>
<td>45 ± 26</td>
<td>51±25</td>
<td>0.02</td>
</tr>
</tbody>
</table>

**ALL ENDPOINTS MET.**

Both primary safety endpoints and all secondary endpoints were met at 6 months

Analyze medical therapy data from the CHAMPION trial to determine which interventions were linked to decreases in HF hospitalizations during PA pressure guided management.

**PURPOSE**

Medication changes based on PA pressure information were more effective in reducing HF hospitalizations than using signs & symptoms alone.

**RESULTS**

- Significantly more changes in medication doses in the Treatment Group than in the Control Group.
- Diuretics were the most frequently adjusted medication and the changes were significantly higher in the Treatment Group.

Costanzo et al., J Am Coll Cardiol HF 2016;4:333-44
Evaluate the effect of PA pressure-guided therapy with the CardioMEMS™ HF System in patients with preserved ejection fraction (EF ≥ 40%), a group with no clinically proven therapies.

**PURPOSE**

HFpEF pts made up 22% of the trial cohort

**HFpEF**

**HF Hospitalization Reduction (18 mo follow-up)**

- RRR 46% (HR 0.54, CI 0.38-0.70)

**HFrEF**

- RRR 24% (HR 0.76, CI 0.61-0.91)

Incremental Cost-Effectiveness of Guideline-Directed Medical Therapies for Heart Failure

Gaurav Banka, MD,* Paul A. Heidenreich, MD,† Gregg C. Fonarow, MD*

Los Angeles and Palo Alto, California

Our analysis demonstrates that medical treatment of HFrEF is highly cost-effective and may even result in cost-savings. Greater efforts to ensure optimal adherence to guideline-directed medical therapy for HFrEF are warranted. (J Am Coll Cardiol 2013;61:1440–6) © 2013 by the American College of Cardiology Foundation
PARADIGM-HF: Cardiovascular Death or Heart Failure Hospitalization (Primary Endpoint)

Hazard ratio, 0.80 (95% CI, 0.73–0.87)
P<0.001

CV death HR ,80
HF hosp HR .79

3.7% age
20% relative reduction

No. at Risk
LCZ696  4187  3922  3663  3018  2257  1544  896  249
Enalapril  4212  3883  3579  2922  2123  1488  853  236

Pulmonary Artery Pressure Guided Management of HF rEF Incremental Benefit with GDMT

Need to Validate Strategy of Optimal Neurohormonal Antagonists COMBINED with PA Pressure Guided Treatment

Givertz et al.
PA Pressure-Guided HF Management on Top of GDMT

JACC Vol. 70, No. 15, 2017
October 10, 2017:1875–86
Summary

• Congestion is a key predictor of HF events
• Typical clinical parameters do not accurately assess congestion
• Hemodynamic Guided treatment is the only remote monitoring technique shown to reduce HF admissions
• GDMT and PA pressure guided therapy appear to have a synergistic impact on HF outcomes
• Validation studies demonstrating the clinical impact of PA pressure guided therapy and BEST GDMT are necessary
• The VALUE added impact of PA guided treatment will be essential to demonstrate