Sleep disordered breathing (SDB) is a common medical condition affecting up to 24% of men and 9% of women in the middle-aged population. There is growing evidence that untreated SDB is associated with a spectrum of adverse health outcomes, most notably those related to cardiovascular health. SDB is an independent risk factor for the development of systemic hypertension and is associated with congestive heart failure, coronary artery disease, atrial fibrillation, and stroke.

Sleep apnea has significant adverse consequences on cardiac function. Obstructive apneas cause episodes of hypoxia, exaggerated negative intrathoracic pressure, and increased sympathetic activity. In response to these disruptions, there are abnormal elevations in blood pressure and heart rate during sleep that may worsen heart failure and promote arrhythmias. Heart failure further increases sympathetic activity and also can cause central sleep apnea. Thus sleep apnea can have a significant negative impact on heart failure.

Heart failure is one of the leading causes of morbidity and mortality in the United States. According to the 2011 American Heart Association statistics, at age 40, the lifetime risk of developing heart failure is 1 in 5 for both men and women. Forty-three percent of these patients in the United States are hospitalized four or more times for heart failure over their lifetime, and 20% of patients admitted for heart failure will be rehospitalized within 30 days. This is the highest nonsurgical cause for readmission among Medicare recipients and leads to a large economic burden on society. As a result, identifying and treating conditions that negatively affect heart failure, such...
as SDB, could potentially help reduce health care spending if readmission rates are decreased.

Sleep disordered breathing occurs in 50% to 80% of patients with heart failure.16 Symptoms of SDB, snoring, apneas, and hypoxia, are frequently observed in the inpatient setting. Unfortunately, many hospitalized patients with observed symptoms of SDB remain undiagnosed and untreated.17,18 One reason for this may be that SDB is primarily considered a disorder that is managed in an outpatient setting. However, performing outpatient sleep studies in hospitalized cardiac patients is limited by the wait time and cost for an outpatient polysomnogram (PSG).19 Moreover, many of these patients never follow up with their outpatient sleep study. Performing diagnostic studies and providing treatment for SDB in the hospital could address this issue.

Treating SDB with continuous positive airway pressure (CPAP) has been shown to improve serum markers of cardiovascular and vascular injury, decrease sympathetic activity during sleep, and increase plasma levels of nitric oxide derivatives, all which positively affect patients with cardiovascular disease.20,21 Patients using CPAP for SDB who undergo electrical cardioversion for atrial fibrillation have a 50% reduction in recurrence rate for atrial fibrillation after one year compared to those who are not treated.22 Moreover in heart failure patients, treating SDB with CPAP increases left ventricular ejection fraction by 2% to 8%.23-25 The 2013 report from the American College of Cardiac Foundation/American Heart Association Task Force on practice guidelines for the management of heart failure supports the use of CPAP in patients with heart failure.26 This report indicated that PAP has been shown to increase ejection fraction and improve functional status in patients with heart failure and sleep apnea.26

In our study, we designed a new paradigm to diagnose and manage OSA in cardiac inpatients by performing sleep studies and positive airway pressure (PAP) initiation for hospitalized patients with observed SDB symptoms using portable sleep monitoring systems and auto-PAP. These patients were then monitored for PAP adherence using modem and data card tracking. We hypothesized that (1) this paradigm would effectively identify SDB patients in cardiac hospitalized patients with SDB related symptoms but no previous SDB diagnosis; and (2) PAP initiation would reduce 30-day hospital readmission rates in patients adherent to prescribed PAP treatment.

METHODS

Patients

Between January 2012 and March 2013, all patients who were hospitalized at the Hospital of the University of Pennsylvania (HUP) for a cardiac condition in the cardiac intermediate care unit (CICU) and underwent a sleep study were approached for this study. Cardiac conditions included heart failure, arrhythmias, and myocardial infarction. Not all patients admitted for cardiovascular conditions were tested. However, all cardiac patients who underwent an inpatient sleep study were approached to be in the study. Sleep studies were ordered (after the subjects were evaluated by the sleep consult team) if the subject had a clinical presentation consistent with sleep apnea. The study was approved by the Institutional Review Board (IRB) at the University of Pennsylvania (#816517). Informed consent was waived for retrospective review of patients who were evaluated and treated prior to the IRB approval. The clinical protocol to perform in-hospital sleep studies on cardiac patients was established before IRB submission and is still ongoing.

Study Protocol

Routine clinical care at the Hospital of the University of Pennsylvania (HUP) included sleep studies performed on hemodynamically stable patients who were identified by the cardiology and sleep medicine team as likely to have SDB by clinical history (loud snoring, excessive daytime sleepiness, or witnessed apneas), physical examination (body habitus—obesity, large neck size, crowded pharyngeal airway, retrognathia) and/or nocturnal hypoxia. All patients undergoing an inpatient sleep study were screened for the research study by one of the investigators (SK). Patients with SDB, defined by an apnea-hypopnea index (AHI) ≥ 5 events/h, in whom PAP was prescribed, were started on auto-titrating PAP (5-20 cm of water) as an inpatient and discharged from the hospital with their own auto-PAP. The decision to prescribe PAP was ultimately at the discretion of the attending physician on the sleep medicine consult service. Patients were excluded from the study if they had a preexistent diagnosis of SDB and were on PAP prior to the hospital admission.

Medical records were reviewed to obtain baseline demographic data, admission diagnoses, comorbid illnesses, echocardiogram results, sleep study results, decision for treatment, and readmission data. Patients who were discharged with PAP were monitored for adherence data using modem or data card technology.

Procedures

In-Hospital Sleep Study and CPAP/Bilevel Treatment

In-hospital sleep studies were performed with a type III sleep study, which is classified according to the American Academy of Sleep Medicine.27 This unattended cardiorespiratory monitor (Embletta Gold) measures nasal pressure, respiratory effort, oxygen saturation, electrocardiogram, and body position. The sleep study was set up by a previously trained sleep technician who explained the study to the patient. The next morning, data on the time the patient fell asleep and awoke were collected by the sleep technician and the study recordings were downloaded and transmitted via the hospital network for interpretation by a sleep specialist.

Based on the results of the study, if the patient had SDB and the sleep specialist believed the best treatment was PAP, patients were offered a trial of therapy. If they agreed, they were treated with auto-CPAP or auto-bilevel (Phillips Respironics REMstar Auto 550P A-Flex and BiPAP Auto 750P Bi-Flex), monitored by overnight oximetry (Embletta Gold), and fitted for a mask by the sleep technician. The next morning, treatment data were collected using the data card from the PAP unit. If adequately treated, an auto-PAP unit and mask were ordered for the patient to be delivered in the hospital or at home depending on the patient’s date of discharge.

Interpretation of Sleep Studies

SDB was defined as AHI ≥ 5 events/h. Apnea was scored when there was ≥ 90% cessation of airflow detected through the nasal pressure sensor. Hypopnea was scored when there...
was ≥ 50% reduction in airflow with an associated ≥ 3% oxy-
hemoglobin desaturation. Central apnea was scored when there
was ≥ 90% cessation of airflow detected through the nasal pres-
sure sensor and no effort in the thorax and abdomen. Each of
these events needed ≥ 10 s duration to be scored.27 An AHI cut-
off ≥ 5 events/h was selected to account for the potential over-
estimation of sleep time in the inpatient setting compared to a
conventional in laboratory sleep study where EEG is obtained,
which would lead to an underestimation of the AHI. If > 50% of
the apneas were central, the SDB was classified as central sleep
apnea (CSA). If > 50% of the apneas were obstructive in nature,
it was considered obstructive sleep apnea (OSA).

PAP Compliance Data
PAP compliance data were collected via modem or data card.
If a modem was not supplied by the durable medical supply
company or the modem was not working, data were collected
from the data card in the PAP unit. Based on the data available,
patients were classified as non-users, partial users, or full users.
Full users were classified based on Centers of Medicare and
Medicaid Services (CMS) guidelines defined as use of PAP ≥ 4
h/night on 70% of nights during 30 consecutive days in the
first 90 days of PAP treatment.28 Partial users were those with
some usage who did not meet the criteria for full usage, and
non-users were those with no PAP usage recorded or who could
have been prescribed PAP treatment but refused or were not
discharged with it. As a sensitivity analysis, we also used addi-
tional methods for calculating PAP usage group for patients
who were readmitted during the first 30 days. First, 30-day PAP
use was recalculated after removing the days in which the pa-
tients were in the hospital. Second, we calculated their PAP us-
age group using only the days before readmission. In both cases,
the PAP usage group remained the same for all patients.

Determining 30-Day Hospital Readmission
Thirty-day hospital readmission was defined as a hospitaliza-
tion or visit to the emergency department (ED) for a cardiac
cause ≥ 48 h after discharge. Hospitalizations and ED visits at
the primary hospital and other hospitals in the tri-state region
(Pennsylvania, New Jersey, and Delaware) were included. Data
were collected from clinical records or by speaking with the pa-
tient if records did not clearly reference readmissions. Elective
admissions were not included in the definition of readmission.
However, only one patient studied had an elective admission,
and this was for a heart transplant as a heart became available
during follow-up. The 30-day readmission rate was specifically
examined in light of the CMS regulations which withhold hos-
pital reimbursement for the care of patients readmitted within
30 days after hospital discharge.29 Readmission rates were com-
pared between the 3 different PAP user groups (non-users, par-
tial users, and full users). Eleven patients who had refused PAP,
and 3 CSA patients who could have been given PAP but were
not, were included in the non-user group for further analysis of
the impact of PAP use on hospital 30-day readmission.

Statistical Analysis
Demographic and clinical characteristics were summarized
using means and standard deviations for continuous variables
and frequencies and percentages for categorical variables.
Continuous variables were compared among groups using t-
tests or analysis of variance (ANOVA), where appropriate, and
categorical variables using χ² or Fisher exact tests. To further
examine the relationship between 30-day readmission and PAP
usage, we performed a Kaplan-Meier survival analysis, com-
paring the resulting survival curves among the PAP groups us-
ing a log-rank test. Statistical analyses were performed using
Stata Version 12 (StataCorp, College Station, TX) or SAS Soft-
ware, Version 9.3 (SAS Institute, Cary, NC).

RESULTS

Patient Characteristics
During the study period (January 2012 through March 2013),
106 cardiac patients were identified as patients currently not
 treated with PAP at home who underwent evaluation with a type
III sleep study while hospitalized. One hundred four (98.1%)
patients had conclusive diagnostic studies. The 2 patients with
inconclusive studies were secondary to multiple channel fail-
ure on the recording and insufficient time during the patient’s
hospital stay to repeat the study. The mean ± standard deviation
(SD) length of stay for all patients tested was 12.8 ± 8.7 days,
and the mean ± SD percent of the stay that was completed at the
time of the sleep study was 53.9% ± 22.5%.

Clinical characteristics of the patients with conclusive di-
agnostic studies (n = 104) are shown in Table 1. Sixty-five
(62.5%) of the patients were male; they had a mean ± SD age
of 58.7 ± 14.7 years and body mass index (BMI) of 34.1 ± 8.9
kg/m². The majority of the patients (87.4%) in the study carried

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>(n) mean ± SD or (n) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>(104) 58.7 ± 14.7</td>
</tr>
<tr>
<td>Male</td>
<td>(65) 62.5%</td>
</tr>
<tr>
<td>Body mass index</td>
<td>(104) 34.1 ± 8.9</td>
</tr>
<tr>
<td>LVEF</td>
<td>(101) 36.3 ± 21.2</td>
</tr>
<tr>
<td>Ischemic cardiomyopathy</td>
<td>(31) 33.7%</td>
</tr>
<tr>
<td>Heart failure</td>
<td>(90) 87.4%</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>(49) 47.1%</td>
</tr>
<tr>
<td>Hypertension</td>
<td>(85) 81.7%</td>
</tr>
<tr>
<td>Diabetes</td>
<td>(53) 51.0%</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>(70) 67.3%</td>
</tr>
<tr>
<td>Stroke</td>
<td>(18) 17.3%</td>
</tr>
</tbody>
</table>

NYHA, New York Heart Association Class; ED, emergency department.

| Total admission days | (103) 13.0 ± 8.7 |
| % of visit complete at study | (103) 53.7 ± 22.6 |
| 30 day readmission/ED visit | (16) 16.2% |

SD, standard deviation; LVEF, left ventricular ejection fraction; NYHA,
the diagnosis of heart failure (based on medical record data) with a mean ± SD left ventricular ejection fraction (LVEF) of 32.7 ± 19.8. Forty-nine (47.1%) patients had atrial fibrillation and 44 (42.3%) of these patients also had heart failure. There were only 8 (7.7%) patients who were not admitted for either of these causes; they were primarily admitted for chest pain and myocardial infarction.

### Classification and Characteristics of SDB

Eighty-one (77.9%) patients studied had SDB (AHI ≥ 5 events/h). Of those with SDB, 65 (80.2%) were classified having as obstructive sleep apnea (OSA) and 16 (19.8%) with central sleep apnea (CSA). Many of these patients had a combination of both obstructive and central sleep apnea. Of the 16 patients with CSA, 9 had 30% to 49% obstructive events/h. Of those with SDB, 65 (80.2%) were classified having as obstructive sleep apnea (OSA) and 16 (19.8%) with central sleep apnea (CSA). Many of these patients had a combination of both obstructive and central sleep apnea. Of the 16 patients with CSA, 9 had 30% to 49% obstructive events/h.

When patients with SDB were compared to those without SDB in this population (Table 2), there was no difference in age, gender, BMI, 30-day hospital readmission/emergency department visit, or left ventricular ejection fraction. The only a difference noted was a history of a prior stroke, which was more common in patients with SDB (p = 0.011).

In the comparison of OSA patients to CSA patients (Table 3), patients with CSA were more likely to be male, have a lower LVEF, and have a higher AHI than OSA patients. OSA patients had a higher BMI than CSA patients.

### Inpatient Model for Diagnosis and Treatment of SDB: Classification and Characteristics Based on PAP Use

For the majority of patients, data from the type III sleep study and auto-PAP trial provided sufficient information to prescribe treatment. Fifty (61.7%) patients with SDB were prescribed PAP at the time of discharge (Figure 1). Five of these 50 patients had CSA. Patients with SDB who were not discharged with PAP included those who refused treatment (n = 11 [13.6%]), had CSA/Cheyne Stokes Respirations in the setting of incomplete heart failure management optimization (n = 3 [3.7%]), died while hospitalized (n = 1 [1.2%]) or needed further testing with an in-laboratory sleep study to determine the best treatment (n = 16 [17.8%]).

PAP usage data from either a modem or data card were available for 42 (84.0%) patients discharged with a PAP unit. Nineteen (45.2%) patients were classified as full PAP users. On average, these patients used PAP on 94.9% ± 6.9% of nights in a 30 day period for 6.4 ± 1.4 h/night used. In the partial use group (n = 20 [47.6%]), the mean ± SD percent of days used was 59.9% ± 28.7% and the mean ± SD number of treatment hours on the days used was 5.3 ± 3.2 (Table 4).

### Adequate PAP Use Decreases 30-Day Hospital Readmission Rate

In the comparison of the 3 PAP usage groups (Table 5), the most notable finding was a difference in the 30-day readmission among the PAP groups (p = 0.025). Specifically, PAP compliant patients (full-users) were significantly less likely to be readmitted within 30 days from discharge when compared to both partial (p = 0.045) and non-users (p = 0.022). Partial PAP use did not affect the readmission rate, as they were not significantly different from non-users. None of the full users were readmitted within 30 days. Six (30%) of the partial users and 5 (29.4%) of the non-users were readmitted. This is also seen in our Kaplan-Meier analysis, where compliant patients performed better than those who were not fully compliant (Figure 2, p = 0.048).

### Table 2—Comparison of demographic and clinical characteristics between SDB and non-SDB patients.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Non-SDB (n = 23)</th>
<th>SDB (n = 81)</th>
<th>p *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>(23) 57.4 ± 15.8</td>
<td>(81) 59.1 ± 14.4</td>
<td>0.6200</td>
</tr>
<tr>
<td>Male</td>
<td>(12) 52.2%</td>
<td>(53) 65.4%</td>
<td>0.2464</td>
</tr>
<tr>
<td>Body mass index</td>
<td>(23) 31.7 ± 9.9</td>
<td>(81) 34.9 ± 8.5</td>
<td>0.1280</td>
</tr>
<tr>
<td>LVEF</td>
<td>(21) 35.1 ± 21.2</td>
<td>(80) 36.6 ± 21.4</td>
<td>0.7727</td>
</tr>
<tr>
<td>Ischemic cardiomyopathy</td>
<td>(8) 44.4%</td>
<td>(23) 31.1%</td>
<td>0.2820</td>
</tr>
<tr>
<td>Heart failure</td>
<td>(18) 78.3%</td>
<td>(72) 90.0%</td>
<td>0.1586</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>(9) 39.1%</td>
<td>(40) 49.4%</td>
<td>0.3847</td>
</tr>
<tr>
<td>Hypertension</td>
<td>(16) 69.5%</td>
<td>(69) 85.2%</td>
<td>0.1237</td>
</tr>
<tr>
<td>Diabetes</td>
<td>(10) 43.5%</td>
<td>(43) 53.1%</td>
<td>0.4160</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>(15) 65.2%</td>
<td>(55) 67.9%</td>
<td>0.8087</td>
</tr>
<tr>
<td>Stroke</td>
<td>(0) 0.0%</td>
<td>(18) 22.2%</td>
<td>0.0107</td>
</tr>
<tr>
<td>AHI</td>
<td>(23) 2.5 ± 1.9</td>
<td>(81) 29.0 ± 21.5</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>NYHA = 4</td>
<td>(9) 50.0%</td>
<td>(28) 38.9%</td>
<td>0.4306</td>
</tr>
<tr>
<td>Total admission days</td>
<td>(23) 13.5 ± 8.5</td>
<td>(80) 12.8 ± 8.9</td>
<td>0.7320</td>
</tr>
<tr>
<td>% of visit complete at study</td>
<td>(23) 57.0 ± 26.3</td>
<td>(80) 52.8 ± 21.5</td>
<td>0.4405</td>
</tr>
<tr>
<td>30 day readmission/ED visit</td>
<td>(4) 17.4%</td>
<td>(12) 15.8%</td>
<td>&gt; 0.999</td>
</tr>
</tbody>
</table>

Results presented as (n) mean ± standard deviation or (n) %. SDB, sleep disordered breathing; LVEF, left ventricular ejection fraction; AHI, apnea-hypopnea index; NYHA, New York Heart Association Class; ED, emergency department. *p-value from t-test (for continuous variables) and χ² or Fisher exact tests (for categorical variables).
Table 3—Comparison of demographic and clinical characteristics between CSA and OSA patients.

<table>
<thead>
<tr>
<th>Variable</th>
<th>CSA (n = 16)</th>
<th>OSA (n = 65)</th>
<th>p*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (16)</td>
<td>(16) 60.6 ± 11.9</td>
<td>(65) 58.8 ± 15.1</td>
<td>0.6453</td>
</tr>
<tr>
<td>Male (14)</td>
<td>87.5%</td>
<td>60.0%</td>
<td>0.0383</td>
</tr>
<tr>
<td>Body mass index (16)</td>
<td>30.3 ± 5.4</td>
<td>36.0 ± 8.8</td>
<td>0.0024</td>
</tr>
<tr>
<td>LVEF (16)</td>
<td>27.8 ± 16.3</td>
<td>38.8 ± 22.0</td>
<td>0.0665</td>
</tr>
<tr>
<td>Ischemic cardiomyopathy (4)</td>
<td>25.0%</td>
<td>32.8%</td>
<td>0.7617</td>
</tr>
<tr>
<td>Heart failure (16)</td>
<td>100.0%</td>
<td>87.5%</td>
<td>0.3467</td>
</tr>
<tr>
<td>Atrial fibrillation (8)</td>
<td>50.0%</td>
<td>49.2%</td>
<td>0.9560</td>
</tr>
<tr>
<td>Hypertension (15)</td>
<td>93.8%</td>
<td>83.1%</td>
<td>0.4431</td>
</tr>
<tr>
<td>Diabetes (13)</td>
<td>81.3%</td>
<td>64.6%</td>
<td>0.2017</td>
</tr>
<tr>
<td>Stroke (6)</td>
<td>37.5%</td>
<td>18.5%</td>
<td>0.1753</td>
</tr>
<tr>
<td>AHI (16)</td>
<td>46.1 ± 21.1</td>
<td>24.7 ± 19.5</td>
<td>0.0002</td>
</tr>
<tr>
<td>NYHA = 4 (3)</td>
<td>20.0%</td>
<td>43.9%</td>
<td>0.091</td>
</tr>
<tr>
<td>Total admission days (16)</td>
<td>12.0 ± 7.0</td>
<td>13.0 ± 9.2</td>
<td>0.6818</td>
</tr>
<tr>
<td>% of visit complete at study (16)</td>
<td>55.2 ± 27.3</td>
<td>52.2 ± 20.1</td>
<td>0.6239</td>
</tr>
<tr>
<td>30 day readmission/ED visit (2)</td>
<td>12.5%</td>
<td>&gt; 0.999</td>
<td></td>
</tr>
</tbody>
</table>

Results presented as (n) mean ± standard deviation or (n) %. CSA, central sleep apnea; OSA, obstructive sleep apnea; LVEF, left ventricular ejection fraction; AHI, apnea-hypopnea index; NYHA, New York Heart Association Class; ED, emergency department. *p-value from t-test (for continuous variables) and χ² or Fisher exact tests (for categorical variables).

Figure 1—Disposition of the 106 consecutive cardiac patients who underwent an in-hospital sleep study between January 2012 and March 2013.

There were 31 patients who were discharged without PAP due to patient refusal of treatment, further in-lab testing, heart failure optimization required for treatment prescription, or death before discharge. Insufficient compliance data were secondary to 1 death and 1 patient requiring a tracheostomy within 30 days from discharge. Full PAP use was defined as use of PAP ≥ 4 h per night on 70% of nights during a consecutive 30-day period in the first 90 days of PAP treatment. SDB, sleep disordered breathing; OSA, obstructive sleep apnea; CSA, central sleep apnea; PAP, positive airway pressure.
None of the CSA patients discharged with PAP were readmitted within 30 days.

As a sensitivity analysis, we explored additional methods for classifying PAP use relative to hospital readmission. We reanalyzed our data for the n = 6 patients with partial PAP use in 2 ways: (1) excluding days they were admitted to the hospital; and (2) using only the days prior to hospital admission or ED visit to classify their PAP usage group. All 6 patients who were readmitted remained in the partial PAP use classification based on either of these methods. Therefore, the association between hospital readmission and PAP usage remains the same for each potential classification method.

To further evaluate the various factors affecting readmission, the association between readmission and several variables (age, BMI, LVEF, NYHA Class; ED, emergency department) was studied in bivariate analyses (Table 6). These analyses only identified LVEF as a predictor of readmission (p = 0.037). Patients with a lower LVEF during the initial hospital admission (before the sleep study was performed) were more likely to be readmitted within 30 days from discharge. Fifteen (93.8%) of 16 patients who were readmitted had heart failure.

Given that LVEF and CPAP adherence were the only variables significantly (p < 0.05) associated with readmission, we performed analyses including both variables in a single model within the subset (N = 53) of patients with both CPAP adherence and LVEF data. In this analysis, CPAP adherence remained significantly associated with readmission (p = 0.048), while LVEF was no longer significant (p = 0.295). We note that in bivariate analyses restricted to this sample of patients with CPAP adherence, LVEF was not significantly associated with readmission (p = 0.182), as it was in the overall sample.

**DISCUSSION**

Using a new paradigm, we have shown that approximately 80% of hospitalized cardiac patients with sleep disordered breathing related symptoms, but no previous SDB diagnosis, have OSA or CSA. Moreover, our data indicate that PAP adherence for SDB in these cardiac patients leads to a reduction in 30-day readmission rates. We were able to demonstrate this by implementing a protocol to diagnose and treat SDB in hospitalized patients using unattended studies and PAP units with modems and data cards for monitoring treatment adherence.
the first to investigate the impact of PAP treatment on 30-day hospital readmission rates. None of the patients (n = 19) who were compliant with CPAP based on CMS guidelines were readmitted to the hospital or had an ED visit within 48 hours to 30 days after discharge. In comparison, patients with no PAP use or partial use had readmission rates of 29.4% and 30.0%, respectively. Of note, this is a higher readmission rate than the general readmission rate for patients admitted to our institution’s cardiac intermediate care unit, which ranges from 12% to 18%. This variation in the rates may be due to a number of factors, including patients with cardiac disease and SDB being more likely to be readmitted to the hospital than cardiac patients without SDB. Furthermore, in order to be comprehensive, our study included emergency department visits as well as admissions to other institutions.

The difference in 30-day readmission rates between the PAP usage groups is noteworthy, as it can affect hospital reimbursement based on the current Medicare guidelines, which both withhold payment and charge additional fees to hospitals when patients are readmitted within 30 days from discharge. Our data support prior findings of Kasai et al., which showed heart failure patients with untreated or inadequately treated SDB are more likely to die or be hospitalized than patients who were compliant (average PAP use of 6 h/night). In a larger scale study using Medicare claims, Javaheri et al. found that patients with newly diagnosed heart failure and SDB who were started on PAP treatment had a better 2-year survival rate than those who were not treated. However, this study was not able to document the effect of PAP compliance on survival or hospital readmission.

The average total cost per heart failure hospitalization ranges from $13,000 to $18,000. The cost of running an inpatient sleep consult program that provides a sleep physician consult, sleep study set up by sleep technician, and trial of auto-PAP is variable, based on staffing and the number of patients tested. However, using our data, we estimate the cost to range from $40,000-$60,000 annually. Based on these numbers, decreasing 30-day hospital readmission rates by 3-5 patients per year would offset the cost of funding an inpatient sleep consult service. Our preliminary data suggest that this is possible; however, more data and a closer financial analysis on the cost of hospital readmissions are necessary.

Studies performed by Khayat et al. introduced the concept of inpatient sleep studies as a method of diagnosing OSA. They performed type III attended studies on hospitalized patients with heart failure and were able to validate the results of OSA in a subset of 62 patients who had a follow-up in-lab polysomnography 6-8 weeks after discharge. We did not repeat sleep studies in the outpatient setting, but we used a similar model of inpatient evaluation and found that 78% of the patients studied had SDB. The majority of these patients had primarily obstructive apnea (80%) and a smaller percentage of patients (20%) had primarily central apnea. These results were consistent with the findings of Khayat and those from a study performed by Egea et al.

PAP compliance data were available for 42 of the 50 (84%) patients who were discharged from the hospital with PAP. Studies have shown a variety of results for PAP compliance in the outpatient setting, ranging from 29% to 85%. Nineteen (45%) of the patients in our study with available compliance data showed adequate use; however, for this population of patients with significant cardiac disease we had a higher goal for adherence. Sin et al. found a compliance rate > 85% when patients with

![Figure 2—Kaplan-Meier analysis and curves for readmission demonstrating the difference in readmission rates between the 3 PAP usage groups.](image)

Non-Readmission Probability

<table>
<thead>
<tr>
<th>Readmission Kaplan-Meier Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Users</td>
</tr>
<tr>
<td>Days</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td>30</td>
</tr>
</tbody>
</table>

Full users were defined as patients with use of PAP ≥ 4 h per night on 70% of nights during a consecutive 30-day period in the first 90 days of PAP treatment. Readmission was defined as hospitalization or visit to the emergency department from 48 h to 30 days after discharge. PAP, positive airway pressure.

### Table 6—Comparison of demographic and clinical characteristics between patients not readmitted and those readmitted within 30 days.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Not Readmitted † (n = 85)</th>
<th>Readmitted † (n = 16)</th>
<th>p *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>(85) 60.3 ± 14.3</td>
<td>(16) 53.7 ± 15.3</td>
<td>0.0940</td>
</tr>
<tr>
<td>Body mass index</td>
<td>(85) 33.8 ± 8.3</td>
<td>(16) 35.2 ± 11.9</td>
<td>0.6636</td>
</tr>
<tr>
<td>LVEF</td>
<td>(82) 39.5 ± 21.8</td>
<td>(16) 27.3 ± 17.3</td>
<td>0.0370</td>
</tr>
<tr>
<td>Heart failure</td>
<td>(71) 84.5%</td>
<td>(15) 93.6%</td>
<td>0.4577</td>
</tr>
<tr>
<td>AHI</td>
<td>(83) 23.8 ± 22.5</td>
<td>(16) 22.3 ± 22.0</td>
<td>0.7970</td>
</tr>
<tr>
<td>NYHA = 4</td>
<td>(27) 37.5%</td>
<td>(5) 35.7%</td>
<td>0.8994</td>
</tr>
</tbody>
</table>

Results presented as (n) mean ± standard deviation or (n) %. LVEF, left ventricular ejection fraction; AHI, apnea-hypopnea index; NYHA, New York Heart Association Class. 30-day hospital readmission was defined as a hospitalization or visit to the emergency department for a cardiac cause > 48 h after discharge. * p-value from t-test (for continuous variables) and χ² or Fisher exact tests (for categorical variables).
moderate to severe SDB were closely followed after initial PAP treatment. This included a daily telephone call during the first week of treatment followed by clinic visits at 2 weeks, 4 weeks, 3 months, and 6 months. This model may be difficult to follow due to the staff needed to maintain such close monitoring; however, with modern tracking technology a modified version of this model could be established. Another option includes incorporating SDB follow-up into other routine visits. Many patients are closely followed by their cardiiology team specifically for heart failure after discharge from the hospital. Thus the cardiologist could address PAP use to improve compliance.

Limitations to our study include the potential that reduced readmission rates may be affected by the fact that patients who are adherent to their other medical regimens may also be compliant with PAP and as a result reduce their risk for readmission. However, no data were collected on medication history and lifestyle changes, and as a result these factors were not controlled for as possible confounders. Another limitation was there were too few patients with follow-up echocardiogram results to evaluate the potential benefits of PAP use specifically on cardiac function. Due to limitations in PAP usage data and variations in patient PAP use, 4 patients were classified on PAP usage based on their use in the 30-90 day period. When the data were reanalyzed after excluding these patients, the differences in 30-day readmission among the PAP groups remained significant (p = 0.033). While our results suggest a relationship between CPAP use in cardiac patients with SDB and a reduction in 30-day readmissions, given the relatively small sample size and observational nature of the study, results should be replicated in future randomized trials. Moreover, given the relatively small sample size in this study, negative results (for outcomes other than CPAP adherence and readmission rates) should be interpreted with caution, as there is limited power to observe small effect sizes. Furthermore, in general, it is not a recommended practice to prescribe auto-CPAP to patients with CSA. However, there are not a lot of data to support this recommendation. Moreover, studies using auto-CPAP have shown that it improves left ventricular ejection fraction in patients with heart failure. In addition, most of the subjects in this study had obstructive sleep apnea, and auto-CPAP is indicated in those patients.

In conclusion, our study showed that (1) SDB is common in hospitalized cardiac patients with symptoms but no previous SDB diagnosis, and (2) that cardiac patients with SDB who are adherent to treatment with PAP therapy have a lower 30-day hospital readmission rate than similar subjects who are not adherent to PAP. This potential benefit is important in the setting of new Medicare regulations for withholding payment and penalties for 30-day hospital readmissions for heart failure and myocardial infarction. We believe there are a number of cardiac patients with SDB who are hospitalized all over the world and who remain undiagnosed and untreated. Identifying these patients and promoting compliance with prescribed PAP treatment appear to be critical elements in their overall medical management.

REFERENCES


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SUBMISSION & CORRESPONDENCE INFORMATION

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