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SCIENTIFIC INVESTIGATIONS

The prevalence of sleep-disordered breathing and associated risk factors in patients with decompensated congestive heart failure in Mozambique

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Study Objectives: Sleep-disordered breathing (SDB) is common in patients with congestive heart failure and has important implications regarding symptoms and prognosis. However, the burden of SDB on those with heart failure has not been well characterized in developing countries, including Mozambique in sub-Saharan Africa. Diagnosing SDB in individuals with congestive heart failure is important because treatment of SDB may improve outcomes.

Methods: Between September 2014 and April 2017, patients hospitalized in a specialized cardiology unit in Maputo, Mozambique with decompensated congestive heart failure were recruited using convenience sampling. We determined the prevalence of SDB and associated risk factors.

Results: A total of 165 patients were recruited, of which 145 had evaluable sleep study data. The overall prevalence of SDB in patients with decompensated congestive heart failure was 72%, and of these 46% had Cheyne–Stokes respirations. Male sex, higher body mass index, and lower left ventricular ejection fraction were all associated with a higher likelihood of SDB and more severe SDB. Cheyne–Stokes respirations were associated with male sex, lower ejection fraction, and larger left atrial size.

Conclusions: We conclude that in sub-Saharan Africa SDB is common in decompensated congestive heart failure and strongly predicted by demographic and echocardiographic parameters. This study highlights the need for the development of diagnostic tools and management strategies for patients with severe heart failure in resource-limited settings.

Keywords: breathing, sleep, heart failure, apnea, breath, sleep disorder, decompensated, congestive, Mozambique

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BRIEF SUMMARY

Current Knowledge/Study Rationale: The burden of sleep-disordered breathing on those patients with heart failure has not been well-characterized in Mozambique. We believe this is the first article of its kind to evaluate sleep-disordered breathing in patients with acute congestive heart failure and address an important risk factor and disease in an underserved and disadvantaged population.

Study Impact: We hope that the results from this study may help influence physician care and health policy in this field. Specifically, we hope that our study may encourage the development of diagnostic tools and management strategies for patients with severe heart failure in resource-limited settings.

INTRODUCTION

Congestive heart failure (CHF) is a common condition that is rising in global prevalence due in part to the aging of the population and accumulation of cardiovascular risk factors and other comorbidities.[1,2] With the help of increased medical understanding and new therapies, patients with CHF are surviving longer but thus experiencing associated health complications as well. In the United States alone, over 6 million adults have CHF. Although CHF has been well-studied in affluent countries, there is a paucity of data in developing countries. The Sub-Saharan Africa Survey of Heart Failure (THESUS–HF) was a prospective observational study of 1,006 patients with decompensated heart failure admitted to 12 university hospitals in 9 sub-Saharan African countries, including Mozambique.[3] In this study, hospital and 6-month mortality rates were, respectively, 4.2% and 17.8%, much higher than values reported in developed countries. Another study indicated that in sub-Saharan Africa 42.5% of hospital admissions are due to heart failure complications, with a 3-year mortality rate of up to 70%.[4] This considerable disease burden contributes to a high number of health complications, health care costs, and mortality rates.

Of particular importance, research has suggested that up to 80% of patients with decompensated CHF may have evidence of sleep-disordered breathing (SDB) (ie, obstructive or Cheyne–Stokes breathing).[5] Studies indicate that the presence of SDB is associated with worse outcomes in those with CHF, although whether SDB is simply a marker of CHF severity or a causal factor toward outcomes remains unclear.[6–9] Patients with SDB have a higher body mass index (BMI) and prevalence of snoring compared to those who do not.[10] Furthermore, old age, male sex, atrial fibrillation, and hypocapnia are established risk factors for

SDB in patients with CHF in North America.[10] Importantly, SDB in those with CHF might include both obstructive and central sleep apnea; in the developed world these appear to occur in approximately equal proportions.[11] The classic breathing pattern in heart failure of Cheyne–Stokes respirations (CSR) may be seen in some but not all, likely reflecting individual patient physiology. These differences in physiology have important implications, because treatments for obstructive and central apneas may differ. Given the differences in demographic profiles and heart failure (including etiologies, severity, and treatments), one might expect important differences in SDB in the developing vs developed world.

Given the strong association with adverse outcomes, SDB may be an important therapeutic target in patients with CHF. To our knowledge, there are some efforts to provide low-cost treatment equipment and machines, but even these are not readily available in most of Africa.[11] Although therapeutic options might be limited by availability in developing areas, generic drugs such as acetazolamide and other low-cost treatment options might be effective and feasible.[12] Overall, there is a need for research to understand SDB better as a potential target for intervention for CHF patients in the developing world.

Our primary objective was to define the prevalence of SDB in decompensated CHF in our Mozambique patient population and identify potential risk factors for its occurrence. Our secondary objective was to separate SDB by type and identify potential predictors of SDB type in such patients. Our overarching goal was to highlight the importance and need of diagnosing and addressing SDB in patients with CHF in the developing world and, further, to prompt the development of potential strategies for targeted intervention in this vulnerable population.

METHODS

This cross-sectional observational study was conducted at the Maputo Central Hospital in Maputo, Mozambique between September 2014 and April 2017. This hospital receives a referral population from around Mozambique. Using a convenience sampling method, all patients who were admitted to a specialized cardiology unit (tertiary referral center) by the emergency department or by a transfer from another hospital center and subsequently diagnosed with CHF were contacted and invited to participate in the study. Patients were eligible if they were ages 18 years or older and diagnosed with decompensated CHF within 48 hours of hospitalization. Decompensated CHF was defined by clinical criteria via physical examination based on The Sub-Saharan Africa Survey on Heart Failure (THESUS-HF).[3] Patients with CHF had acute dyspnea with two or more signs, measured through a clinical exam, including crackles, limb edema, elevated jugular venous pressure, hepatomegaly, and ascites, as assessed by the study physician. Participants were excluded if they were currently pregnant, had a history of cardiac surgery prior to study initiation, or were diagnosed with any serious mental disorders. Based on these criteria, 198 patients were screened and invited to participate. Of these, 165 patients with CHF who met our eligibility criteria and agreed to participate were included in the study. Of these 165 patients, 20 were later excluded because of technical reasons (artifact on flow and belts, no pulse oximeters, and incomplete data). Thus, 145 patients were included in the final study analysis.

A trained research coordinator was designated as the overseer of the study procedures in Mozambique, though very limited resources precluded comprehensive documentation of all procedures. All participants provided written informed consent, which was approved by the Maputo Central Hospital Ethics Committee, Faculty of Medicine of Eduardo Mondlane University Ethics Committee, and by the Mozambican National Bioethics Committee.

Participants provided demographic information and clinical sleep information in a self-report demographics questionnaire and Epworth questionnaire conducted by their physician. HIV status was classified as either HIV-positive, -negative, or unknown. A physical examination was performed including measurement of height and weight to calculate BMI. Neck circumference, systolic and diastolic blood pressure, and heart rate were also measured. A medication history was also gathered for each patient. In addition, all enrolled patients had a 12-lead electrocardiogram and an echocardiogram, according to European Society of Cardiology Guidelines of Echocardiography (echo machine: Philips HD7 XE, Eindhoven, Netherlands).[13] These data were acquired and interpreted by a licensed cardiologist who was blinded to the sleep study results. Heart failure in patients was diagnosed and confirmed by echocardiogram in the appropriate clinical context by an experienced Maputo cardiologist. Apnea-hypopnea index (AHI) severity was defined as mild (5–15 events/h), moderate (15–30 events/h), and severe (> 30 events/h). Sleep testing was recorded by a trained blinded nurse and was measured using the Apnea Link device (Resmed, Inc., San Diego, California).[14] Nurses at the cardiology ward started the recording at 7:00 PM and stopped it at 6:00 AM the following day. All data were deidentified and sent via Health Insurance Portability and Accountability Act–compliant transmission to an experienced blinded registered polysomnographic technologist (P.D.) under the supervision of an American Academy of Sleep Medicine professional board-certified sleep medicine physician (A.M.). We used a modified Chicago criteria whereby apneas were defined based on 10-second cessation of airflow and hypopnea was defined based on a discernible decrement in airflow with evidence of a 3% or more desaturation.[15] Cheyne– Stokes breathing was defined based on a waxing and waning breathing pattern characteristic of this condition. AHI cutoff value of above 5 events/h was used a priori to define the presence of SDB.[16] Data were entered on a spreadsheet and sent securely to research staff at the University of California San Diego, where the data were verified and stored in a RedCap database. Data analysis was conducted by a trained investigator.

Univariable and multivariable regression methods were performed to determine and analyze the relationship between the candidate variables and SDB. Linear regression was used to determine associations with AHI, and logistic regression was used to determine the probability of SDB and Cheyne–Stokes respiration. Multivariable models were built with standard backward selection: A univariable screen was performed and

any variable with a P value < .10 was included in the initial multivariable model. Subsequently, any variable with a P value < .05 was removed sequentially (starting with the highest P value) to determine the final model, where all parameters had a P value of < .05. All data were analyzed with R software modules (R v4.1.1, RStudio v1.4, package ggplot2 v3.3.5; R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

A total of 165 patients enrolled in the study, and sleep study data were available for 145 of them (20 were excluded due to missing or inadequate recordings). Characteristics of the study participants separated by SDB status are shown in **Table 1**. Participants were relatively young and a higher percentage were women.

Table 1—Study population characteristics by SDB status.

Characteristic	No SDB (n = 40)[a]	SDB (n = 105)[a]	P[b]
Age (years)	32 (25, 41)	36 (25, 52)	.2
Sex (n)			.008
Male	9 (23%)	50 (48%)	
Female	30 (77%)	55 (52%)	
HIV (n)			.2
No	23 (59%)	68 (66%)	
Yes	14 (36%)	23 (22%)	
Unknown	3 (7.5%)	14 (13.3%)	
BMI (kg/m^2)	20.1 (18.1, 21.9)	23.1 (20.4, 26.4)	<.001
Weight class (n)			.014
Normal	35 (90%)	68 (65%)	
Overweight	2 (5.1%)	22 (21%)	
Obese	2 (5.1%)	15 (14%)	
Epworth score	8.0 (6.0, 9.0)	7.0 (4.5, 10.0)	.4
Structural heart disease (n)			
Dilated cardiomyopathy	9 (22%)	37 (35%)	.14
Endomyocardial fibrosis	4 (10%)	8 (7.6%)	.7
Rheumatic heart disease	21 (52%)	26 (25%)	.001
Peripartum cardiomyopathy	5 (12%)	15 (14%)	.8
Hypertensive heart disease	1 (2.5%)	15 (14%)	.071
Other	1 (2.5%)	0 (0%)	.3
AHI (events/h)	2 (1, 3)	23 (11, 36)	<.001
OAI (n)	0.00 (0.00, 0.12)	0.60 (0.10, 2.00)	<.001
CAI (n/hour)	0 (0, 0)	7 (1, 18)	<.001
Cheyne–Stokes respirations (n)	3 (7.5%)	64 (61%)	<.001
% Time SpO_2 < 90%	0 (0, 5)	6 (1, 17)	<.001
Nadir SpO_2	92 (90, 94)	85 (81, 88)	<.001
SDB severity (n)			<.001
None	40 (100%)		
Mild		37 (35%)	
Moderate		32 (30%)	
Severe		36 (35%)	
LVEF (%)	47 (24, 56)	29 (17, 41)	.002
RVSP (mm Hg)	67 (31, 100)	63 (27, 96)	.6
Unknown — missing values	27	44	
Left atrial size (mm)	50 (42, 58)	50 (45, 58)	.6
Unknown — missing values	2	3	

[a]Median (interquartile range); n (%). [b]Wilcoxon rank sum test; Pearson's chi-squared test; Fisher's exact test. AHI = apnea-hypopnea index, BMI = body mass index, CAI = central apnea index, LVEF = left ventricular ejection fraction, OAI = obstructive apnea index, RVSP = right ventricular systolic pressure, SDB = sleep-disordered breathing, SpO_2 = saturation of peripheral oxygen.

Over 60% of the patients were not overweight or obese, and a minority reported excessive daytime sleepiness based on the average Epworth score. Fewer than half of the patients had HIV. The etiology of heart failure was varied, with more than half having rheumatic heart disease among those without SDB and over 30% having dilated cardiomyopathy among those with SDB. Most patients had a low left ventricular ejection fraction (LVEF); 82% of patients with HFrEF (LVEF ≤ 45%) had SDB vs 52% of those with HFpEF (LVEF > 45%) ($P < .001$) (**Table S1** in the supplemental material). Among patients with SDB, the average obstructive apnea index and central apnea index was 0.60 and 7, respectively. Seventy-two percent of participants had SDB, as defined by an AHI ≥ 5 events/h, with approximately equal proportions of mild, moderate, and severe cases. Among those who had SDB, over 60% of the patients had evidence of CSR during their sleep study. Among those who had SDB its severity varied. Average right ventricular systolic pressure and left atrial size were similar across both groups.

Risk factors for SDB are displayed in **Table 2**. The univariate analysis showed the variables sex, BMI, heart failure etiology, and ejection fraction to be significant. In backward multivariable selection initially including these variables the final model included sex, BMI, and LVEF as predictors of the presence of SDB.

Variables associated with AHI are shown in **Table 3**. In univariable analysis, significant associations with increasing AHI included male sex, higher BMI, heart failure etiology, and LVEF. The final backward selection model determined that independent predictors of elevated AHI included male sex, BMI, and LVEF. The final model showed significant ($P < .001$) but modest ability to explain variability in AHI (adjusted $R^2 = .266$). The strength of the relationship between LVEF and AHI is shown in **Figure 1**.

From **Figure 1**, the AHI increased with decreasing LVEF in both univariable analyses, along with multivariable analysis accounting for the significant effects of male sex and increasing BMI. The central apnea index is shown in color, revealing the relationship with the higher central apnea index and increasing AHI and lower LVEF.

The variables associated with the presence vs absence of CSR are shown in **Table 4**. The univariate analysis (cutoff of 0.1) resulted in the variables age, sex, ejection fraction, and left atrial size being included in multivariable analysis. In the final multivariate analysis model there was a higher probability of CSR in those with male sex, lower ejection fraction, and larger left atrial size. In contrast to the model of SDB, higher BMI was not independently associated with increased probability of CSR.

DISCUSSION

To our knowledge, this is the first study conducted to evaluate the prevalence of SDB in patients with CHF in the sub-Saharan Africa community. Based on the analysis of our study participants, the overall prevalence of SDB in patients with decompensated CHF was 72%, with 46% of them having CSR. Being of male sex and having a higher BMI and lower LVEF were significantly associated with a higher likelihood of SDB. In addition, being of male sex and having a lower ejection fraction and a larger left atrial size were associated with increased probability of CSR. The study's findings add to the current body of literature regarding SDB breathing in patients with decompensated CHF, primarily addressing a gap of research present in the Mozambique population. In the study participants, the proportion of SDB in patients with CHF was over 70%. This percentage is comparable to values observed in North America but it

Table 2—Univariable and multivariable associations with the presence of SDB.

	Univariable		Multivariable	
Variable	**Log OR (95% CI)**	***P***	**Log OR (95% CI)**	***P***
Age	0.0 (0, 0.0)	.80		
Sex (male)	1.1 (0.30, 2.0)	.009	1.2 (0.3, 2.2)	.01
HIV (yes)	−0.6 (−1.4, 0.2)	.2		
BMI	0.1 (0.0, 0.2)	.018	0.1 (0.0 0.2)	.02
HF etiology				
Dilated	Reference			
EMF	−0.7 (−2.1, 0.8)	.3		
Hypertensive	1.3 (−0.5, 4.3)	.2		
Peripartum	−0.4 (−1.6, 1.0)	.5		
Rheumatic	−1.2 (−2.2, −0.3)	.011		
LVEF	−0.03 (−0.1,0)	.001	−0.03 (−0.06, −0.01)	.002
Left atrial size	0.0 (0.0, 0.1)	.5		
RVSP	0.0 (0.0, 0.0)	.5		

BMI = body mass index, CI = confidence interval, EMF = endomyocardial fibrosis, HF = heart failure, LVEF = left ventricular ejection fraction, OR = odds ratio, RVSP = right ventricular systolic pressure, SDB = sleep-disordered breathing.

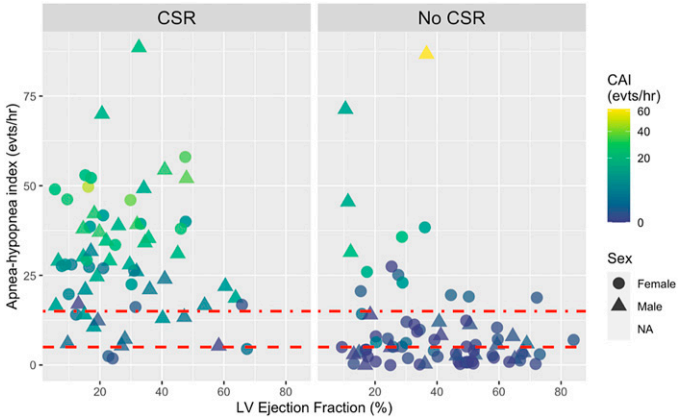
Table 3—Univariable and multivariable associations with AHI.

	Univariable		Multivariable	
Variable	**Beta (95% CI)**	***P***	**Beta (95% CI)**	***P***
Age	0.0 (0, 0.1)	.80		
Sex (male)	9 (3, 15)	.005	8 (3, 13)	.004
HIV (yes)	0 (−7, 7)	>.9		
BMI	1.0 (0.6, 1.4)	<.001	1.0 (0.6, 1.4)	<.001
HF etiology				
Dilated	Reference			
EMF	−19 (−30, −8)	<.001		
Hypertensive	8 (−2, 17)	.13		
Peripartum	−9 (−18, 0)	.058		
Rheumatic	−14 (−21, −7)	<.001		
LVEF	−0.3 (−0.5, −0.2)	<.001	−0.3 (−0.4, −0.2)	<.001
Left atrial size	0.0 (−0.3, 0.3)	>.9		
RVSP	0.0 (−0.1, 0.1)	.5		

AHI = apnea-hypopnea index, BMI = body mass index, CI = confidence interval, EMF = endomyocardial fibrosis, HF = heart failure, LVEF = left ventricular ejection fraction, RVSP = right ventricular systolic pressure.

was higher than anticipated, given the lack of substantial obesity, the younger age of the participants, and other major risk factors in this population. In addition, there was a high prevalence of Cheyne–Stokes breathing in patients with decompensated CHF, even though this breathing pattern is generally uncommon in females and young adults.[17] Our results likely reflect the high severity of heart failure in this population and might reflect the observed heart failure etiologies and medical heart failure therapies available for use. Studying differences across populations is important because the etiology of CHF conditions appears to vary by country (eg, coronary artery disease, which is one possible condition of CHF, is relatively uncommon in sub-Saharan Africa).[11,12] In contrast, other diseases that may be related to CHF, such as HIV, rheumatic heart disease, hypertensive heart disease, peripartum cardiomyopathy, and idiopathic dilated cardiomyopathy, are quite common in Mozambique.[18–20] Many of these sub-Saharan African patients are fairly lean and young; thus, their respiratory function (eg, SDB), a possible indicator of CHF, is predicted to be quite different from that of patients with CHF in the United States or other well-resourced countries. Indeed, there are major epidemiological differences between Mozambique and the United States. To the best of our knowledge, we are not aware of access to sleep studies in most parts of sub-Saharan Africa, thus making our data unique in this field. Previous studies focused on regions such as the United States or Europe. This study's setting is Mozambique, yet we still find similar rates of SDB in patients with CHF even though the demographics and behaviors of this population are vastly different from those in the United States and Europe (eg, our cohort is younger and leaner than typical CHF cohorts that have been studied). Our present findings highlight the potential importance of diagnosing SDB in patients with CHF.

Figure 1—Relationship between LVEF and apnea-hypopnea index among all participants by CSR status.



CAI = central apnea index, CSR = Cheyne–Stokes respirations, LVEF = left ventricular ejection fraction, NA = not available.

In the United States, prior studies have reported a high prevalence of SDB in patients with decompensated and chronic CHF.[9] Current research has indicated that continuous positive airway pressure, which is a common intervention in the United States, can improve outcomes in decompensated CHF.[21,22] In those with chronic stable CHF, continuous positive airway pressure has been shown to improve cardiac physiology including arrhythmias, LVEF, and possibly long-term survival.[7] However, continuous positive airway pressure therapy is not currently available in Mozambique, hence the study team was unable to assess the impact of such an intervention to help these patients with CHF. We view obstructive sleep apnea and central

Table 4—Univariable and multivariable associations with probability of CSR.

	Univariable		Multivariable	
Variable	**Log OR (95% CI)**	***P***	**Log OR (95% CI)**	***P***
Age	0.0 (−0.0, 0.0)	.60		
Sex (male)	1.4 (0.7, 2.1)	<.001	1.3 (0.5, 2.1)	<.001
HIV (yes)	−0.1 (−0.9, 0.7)	.8		
BMI	0.0 (0.0, 0.1)	.11		
HF etiology				
Dilated	Reference			
EMF	−1.6 (−3.2, −0.3)	.026		
Hypertensive	0.3 (−1.4, 0.9)	.6		
Peripartum	−1.1 (−2.2, 0.0)	.058		
Rheumatic	−1.1 (−2.0, −0.3)	.010		
LVEF	−0.04 (−0.06, −0.02)	<.001	−0.05 (−0.07, −0.02)	<.001
Left atrial size	0.03 (0.0, 0.036)	.061	0.04 (0.01, 0.08)	.016
RVSP	0.0 (−0.1, 0.1)	>.9		

BMI = body mass index, CI = confidence interval, CSR = Cheyne–Stokes respirations, EMF = endomyocardial fibrosis, HF = heart failure, LVEF = left ventricular ejection fraction, OR = odds ratio, RVSP = right ventricular systolic pressure.

sleep apnea as a spectrum of disease rather than dichotomous conditions, based on the spectrum of underlying traits (eg, upper airway collapse and loop gain) seen across individuals. Underscoring this idea is the observation that treatment with continuous positive airway pressure can be successful in central sleep apnea and can fail in obstructive sleep apnea.[23–25] Treatment for SDB in heart failure remains an area of uncertainty. Overall, we acknowledge that treatment options remain uncertain and many devices are unavailable in most of Africa. We hope that our findings help to raise awareness sufficiently to facilitate advocacy for proper treatments for everyone. Similarly, other interventions such as supplemental oxygen or pharmacotherapy (eg, acetazolamide) appear to have some role in treating SDB in those with CHF, although long-term outcome data are lacking and feasibility of these interventions in developing countries is unknown. Nonetheless, the data from this study should help raise awareness regarding this important issue in this vulnerable population; we hope that this study highlights the importance of data collection from developing countries where demographics and patient characteristics may differ from those in the United States. In addition, we encourage efforts to prompt and motivate stakeholders, both in the developed world and Mozambique, to use the results from this study to assess optimal strategies of screening and diagnosing SDB conditions in patients with CHF in that patient population.

Due to logistical and resource constraints, our sample was modest; the SDB and risk factor result estimates represent the patients with CHF in the Maputo Central Hospital but may not accurately reflect all patients with CHF in Mozambique. This situation may be the result of Maputo Central Hospital's use of a patient referral method. Although we attempted to enroll a consecutive series of patients with CHF, we used a convenience sampling method because equipment and personnel were limited, despite our best efforts. Thus, similar studies using larger sample sizes are recommended. The demographics of this study suggest a skewed sample; there is a known prevalence toward younger female patients in sub-Saharan Africa. The different etiology and demographics of heart failure in our study contributes new findings to the literature that includes study populations of older, predominantly male, more economically advantaged patients with coronary artery disease. This study recruited a convenience sample of patients presenting to a heart failure unit in Maputo, and thus the recruited population may differ from that in community-based epidemiological studies. Therefore, although the prevalence of SDB may be similar to that in studies with different demographic profiles, there are likely important differences in the phenotypes of SDB (eg, degree of hypoxemia, event lengths, central vs obstructive physiology). (Specifically, we do distinguish obstructive sleep apnea from central sleep apnea based on the presence or absence of respiratory effort during the cessation of airflow. The classification of hypopneas into obstructive vs central is more controversial and thus we typically do not distinguish type of hypopnea in CHF without esophageal manometry.) A future comparative study would be best to address how different demographic groups might drive different SDB manifestations and potential differences in SDB-related outcomes. Instead, these results seek to highlight the need to screen and address SDB conditions in patients with CHF in the Mozambique population and provide a case for increased investment in understanding this health issue in Mozambique.

Despite the potential strength and novelty of our study, we acknowledge a number of limitations as well. First, many patients with prolonged apneas had profound desaturations which were difficult to quantify accurately; in addition, in regard to the scoring criteria, CSR was scored by a blinded

registered polysomnographic technologist given there were a minimum of three consecutive central apneas and/or hypopneas separated by crescendo–decrescendo breathing with a cycle length of a minimum of 40 seconds. However, such technological limitations (eg, pulse oximetry issues) are common to many studies in this field. Second, because the studies were performed on a level III home sleep apnea test, the hypopnea scoring is not reliable to distinguish central from obstructive hypopneas. Because many events are hypopneas, most patients would not meet criteria for *International Classification of Sleep Disorders* criteria for central sleep apnea (> 50% central apneas + hypopneas) without making a clear distinction and decision about central vs obstructive hypopneas. Thus, in our view, it is more relevant to report the indices rather than try to classify patients. The presence of CSR was quantified, which may be a more reliable measure of classic central sleep apnea in heart failure. We recognize the classification of hypopneas is controversial, but we believe esophageal manometry is required to draw rigorous conclusions in CHF. Third, in line with current research, we agree that SDB increases in those with decompensated HF. As such, we chose a priori a sensitive cutoff because AHI > 5 events/h is the formal criterion for SDB diagnosis, although whether a higher cutoff may find more clinically important SDB diagnoses still remains unclear. Furthermore, interventions may not function similarly across different populations due to various social, economic, and cultural forces that could heavily influence sleep behaviors. This concern is important in the Mozambique population with its vast and diverse behavioral patterns; hence, further research should explore how these effects may differ across varying populations. Moreover, we acknowledge the limitation of a lack of retesting postdischarge phase and also having access to any information on the persistence of the SDB rates in this population in the postdischarge phase. Rigorous postdischarge follow-up and comparisons to the United States are not readily available in Mozambique. Therefore, we hope that subsequent studies will focus on some aspect of follow-up data. Given the substantial baseline data presented herein, and that follow-up data will also require substantial discussion related to issues such as loss to follow-up and death, we feel separate research studies and papers are important. Maputo is the capital and has the only hospital able to handle these patients, many of whom travel long hours by bus and car when possible; this is a main reason why retesting certain variables and factors in this patient population, in many cases, is not feasible for these patients. Our main focus for this study was on inpatient prevalence and thus persistence of disease, hence retesting is outside of the scope for this research study. Additionally, despite the research team's best efforts, there remained missing data including incomplete Doppler information on some of the echocardiograms performed. Nonetheless, we believe that our study was quite rigorous given the local conditions and the data we obtained were robust, particularly given the constraints of performing research in underresourced countries. In regard to participant exclusion, cardiac surgery is not readily available in Mozambique and thus we did not believe we would be able to enroll enough patients in this category to draw any important conclusions. We were also concerned about selection bias because only a very small (and not representative) subset of people in Mozambique have access to cardiac surgery (eg, the most affluent individuals). Of note, we excluded roughly 10% of recordings due to technical issues (eg, no pulse oximeter reading or artifacts), which is consistent with our clinical experience with home sleep testing in the United States. We also note the challenges with the use of pulse oximetry based on skin color and thus support further research to assess arterial blood gases and to develop new technology that is reliable for all patients.[26–29] Furthermore, we acknowledge that our study population is not clearly representative of the population with heart failure in sub-Saharan Africa and may have limited relevance to other regions of the world. However, our study is not meant to be a comprehensive evaluation of heart failure in sub-Saharan Africa but instead an important starting point toward understanding the potential importance of SDB among patients with heart failure outside of the Western world.

In this study, validated questionnaires, which were previously translated into Portuguese, were used to conduct the assessments. Hence, the data provide reassurance that these questionnaires may be effective for the purposes and objectives described in this study. Of particular note, though, many of the Epworth questions do not pertain to the Mozambique population because a large number of them do not have a television or drive a vehicle, minimizing the relevance of the questionnaire in this local population.[30,31] Nevertheless, due to high cost and lack of technology readily available in developing countries such as Mozambique, using questionnaires may be helpful because it could provide a low-cost and low-burden screening assessment tool for breathing issues among patients with CHF as long as it is specifically designed and constructed for this patient population and ensures both cultural appropriateness and clinical accuracy. Such instruments may be used to stratify patients' needs and to prioritize further objective testing procedures. The knowledge about the likelihood of developing SDB could also help to guide both patient and physician disease management (eg, aggressiveness of diuretic therapy).[32,33]

In summary, the present study demonstrates that in patients with CHF there is a high likelihood of SDB comorbidity. Furthermore, there are various risk factors correlated with CHF that may differ for Cheyne–Stokes breathing vs non-Cheyne–Stokes breathing. These observations are in line with the concept that these 2 conditions have different underlying pathogenesis. Due to the alarming prevalence rate of SDB in patients with CHF, we encourage further research and rapid development of a systematic screening guideline for evaluation and management SDB in these patients.

ABBREVIATIONS

AHI, apnea-hypopnea index
BMI, body mass index
CHF, congestive heart failure
CSR, Cheyne–Stokes respirations
LVEF, left ventricular ejection fraction
SDB, sleep-disordered breathing
THESUS-HF, The Sub-Saharan Africa Survey of Heart Failure

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