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Prevalence of sleep apnea in unselected patients with atrial fibrillation by a home-monitoring device: The DAN-APNO study

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ABSTRACT

Background: Sleep apnea (SA), a modifiable risk factor in - atrial fibrillation (AF), is associated with worse outcomes in AF. We aimed to assess the prevalence and severity of SA in patients with AF, and, subsequently, to assess the positive predictive value (PPV) of moderate to severe SA by a home-monitoring device in comparison to cardio-respiratory monitoring (CRM) in consecutive patients with AF.

Methods: This cross-sectional study recruited unselected patients with AF without known SA from an out-patient clinic at Department of Cardiology, Herlev-Gentofte University Hospital. Participants underwent four consecutive nights of sleep-recording with the home-monitoring device NightOwl™ (NO). Moderate SA was defined as an Apnea-Hypopnea Index (AHI) of 15–29 and severe SA as ≥ 30 AHI. Participants with moderate to severe SA was offered CRM for validation of the diagnosis.

Results: We included 126 patients with AF with a median age of 68 (interquartile range: 60–75) years, 42 (33 %) women, 70 (56 %) hypertension, 61 (48 %) hyperlipidemia and 49 (39 %) heart failure. NO detected severe SA in 36 (29 %) of patients with AF, moderate SA in 35 (28 %), mild SA in 45 (36 %) and no SA in 10 (8 %). Of 71 patients with moderate to severe SA by NO, 38 patients underwent CRM and the PPV of NO was 0.82 (31/38) to diagnose moderate SA and 0.92 (22/24) to diagnose severe SA by CRM.

Conclusion: Moderate to severe SA by NO was highly prevalent in patients with AF without known SA. A home-monitoring device such as NO could be an easy and feasible SA screening tool in patients with AF.

1. Introduction

In recent years co-existing conditions have gained increased interest in management of patients with atrial fibrillation (AF) [1–3]. Sleep apnea (SA) has recently been established as an important modifiable risk factors in relation to AF [4]. SA is characterized by episodical reductions of airflow and is accompanied by hypoxia, hypercapnia and hemodynamic changes resulting in frequent interruption of respiration and sleep [5]. The severity of SA is determined with Apnea-Hypopnea-Index (AHI) which is the number of apnea and hypopnea episodes per hour of sleep. This index categorizes SA as mild (5–14 AHI), moderate (15–29 AHI) or severe (≥30 AHI). The presence of both AF and SA has in various studies shown to be related to poorer treatment outcomes hence diagnosing SA in patients with AF is clinically important [4,6,7]. Notably, the magnitude of co-existing SA further emphasizes the gravity of undetected SA with prevalences of moderate to severe SA ranging between 21 % and 74 % compared to population-based prevalence of 17 % in males and 10 % in females aged between 50 and 70 years [4,8–12]. Several methods are used to detect presence of SA and gold standard is considered to be polysomnography (PSG) which requires an in-patient, overnight stay in a specialized sleep laboratory [13]. The procedure is time-consuming and inconvenient for patients and not widely available. An often-used alternative is cardiorespiratory monitoring (CRM) that could be performed at home but requires instructions by staff.

A different approach is to screen patients using questionnaires to identify high-risk subjects that could benefit from a sleep study. These

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questionnaires include scoring of symptom burden and focus on excessive daytime sleepiness. However, studies have shown that patients with AF report low levels of daytime sleepiness although subsequently PSG analysis found SA present [14]. As such, optimal screening and management of SA in patients with AF requires new and more conveniently assessment tools. Miniaturized home-monitoring devices and development of accurate algorithms may be a new approach for clinical SA evaluation in patients with AF. One of such devices is NightOwl™ (NO) which has been validated against PSG in the general population [15].

We aimed to assess the prevalence and severity of SA by the home-monitoring device NO in consecutive patients with AF. Subsequently, we aimed to determine whether the home-monitoring device could be an easy and feasible screening method for SA in patients with AF by calculating its positive predictive value in comparison to moderate to severe SA by a clinical CRM.

2. Methods

2.1. Population and clinical data

This was a cross-sectional study. Patients with documented AF without known SA age below 90 and >18 years were included from the out-patient clinic at the Department of Cardiology, Herlev-Gentofte University Hospital. Exclusion criteria were secondary AF, professional drivers, severe heart failure (NYHA class III or IV) and severe chronic obstructive pulmonary disease (COPD). Patients visited the clinic due to planned management of their AF including anticoagulation control appointments and rhythm/rate-control appointments. The patients' primary reason for visit was AF. Clinical data was obtained at the day of inclusion including age, sex, body mass index (BMI), neck circumference and blood pressure. The participants' clinical records were systemically evaluated to obtain latest blood samples, comorbidities, prior procedures performed such as electrocardiogram (ECG) and echocardiography, and prior procedures related to AF such as electrical cardioversion and ablation. Duration of AF was calculated as days since the date of AF diagnosis. Thromboembolic events are defined as either an event of deep vein thrombosis or pulmonary embolism. Moderate or severe LA dilatation was categorized in accordance with the recommendations of the American Society of Echocardiography (left atrial diameter > 4.7 cm in men and > 4.3 cm in women) [16]. At the initial visit participants received thorough verbal instruction on how to use the NO. Written instructions on how to use NO were also available for the participants together with instructions provided through the NO application. After the initial visit the participants underwent four consecutive nights of recording with NO at home. The four nights of SA screening with NO were followed by an online clinical feasibility questionnaire and a telephone consultation with the project coordinator. The telephone consultation included information about test results and possibly referral to CRM. All participants with moderate or severe SA (mean AHI $\geq$ 15) by the home-test were offered one night of SA assessment by CRM at the Department of Pulmonology, Herlev-Gentofte University Hospital. The CRM quantified the frequency, duration, and type of SA (obstructive or potential central/mixed type) by assessing AHI, oxygen desaturation index, respiration rates, oximetry distribution and heart rates for one night.

The potential initiation of CPAP treatment for SA were at the discretion of the attending SA physician. The start of treatment was based on a clinical examination including parameters derived from the CRM and a symptomatic score of SA using Epworth Sleepiness Scale.

2.2. The device

The NO system consists of a miniaturized sensor device and the NO software which is a smartphone application coupled to an encrypted cloud-based analytics platform. The NO sensor obtains its data from reflectance based photoplethysmography (PPG) from which it acquires actigraphy, saturation of peripheral oxygen (SpO_2), peripheral artery tone (PAT) and heart rate, amongst other features [15]. From these PPG-derived parameters the NO system derives all diagnostic variables recommended by The American Academy of Sleep Medicine Manual for the Scoring of Sleep and Associated Events for home SA testing [17]. A full description of the methods has been published previously [18].

2.3. Questionnaire

After four nights of NO recording all participants were sent an online clinical feasibility questionnaire to their e-mail. The clinical feasibility questionnaire was constructed using Copenhagen Center for Health Technology unified method for assessment of clinical feasibility (CUMACF) [19]. The CUMACF method focuses on assessing three things; usage adoption, perceived usefulness and usability, and health efficacy.

2.4. Statistical analysis

Prevalence of SA was calculated by the proportion of participants with moderate to severe SA out of all study participants. Baseline was defined at the time of inclusion. Baseline characteristics were compared between subjects with and without moderate to severe SA. Differences between none and mild SA and moderate to severe SA was assessed by the independent sample *t* test to compare means of continuous variables and the χ^2 test was used to compare proportions of categorical variables. Differences in medication between none and mild SA and moderate to severe SA was assessed by the $\chi 2$ test to compare proportions of the categorical medication variables. Correlation assessment was conducted between CRM vs NO by scatter plots based on AHI. The positive predictive value (PPV) was calculated as the proportion of moderate to severe and only severe AHI by NO confirmed by CRM. All statistics were computed using R (version 4.0.4 for Mac, R Foundation for Statistical Computing).

2.5. Ethics

The project was approved by The Committees on Health Research Ethics in the Capital Region of Denmark (H-20047552) and the Danish Data Protection Agency (P-2021-57).

3. Results

A total of 146 patients were eligible for inclusion and 126 accepted participation (Fig. 1). 12 participants dropped out of the study due to sudden worsening of their disease (n = 2), lack of capability to undergo the home-monitoring (n = 3) or changed their mind about participation (n = 6). 8 participants had unsuccessful measurements due to wrong placement of the device or not enough recording time to generate a SA report.

3.1. Participants' characteristics

Participant characteristics with and without moderate to severe SA are shown in Table 1. Of the 126 participants recruited 33 % were women and median age was 68.0 (IQR 60.0–75.0) years. The most prevalent comorbidities in the total cohort were hypertension (56 %), hyperlipidemia (48.4 %) and congestive heart failure (38.9 %). The most prevalent type of AF was paroxysmal AF (50.0 %), 12.7 % had persistent AF, 6.3 % had permanent AF and some were unclassified (31.0 %). The use of medications is presented in Table 2, which shows 90 (71.4 %) participants used beta-blockers, 79 (63 %) participants were on direct-acting oral anticoagulants and 58 (46.0 %) participants used renin-angiotensin-system inhibitors.

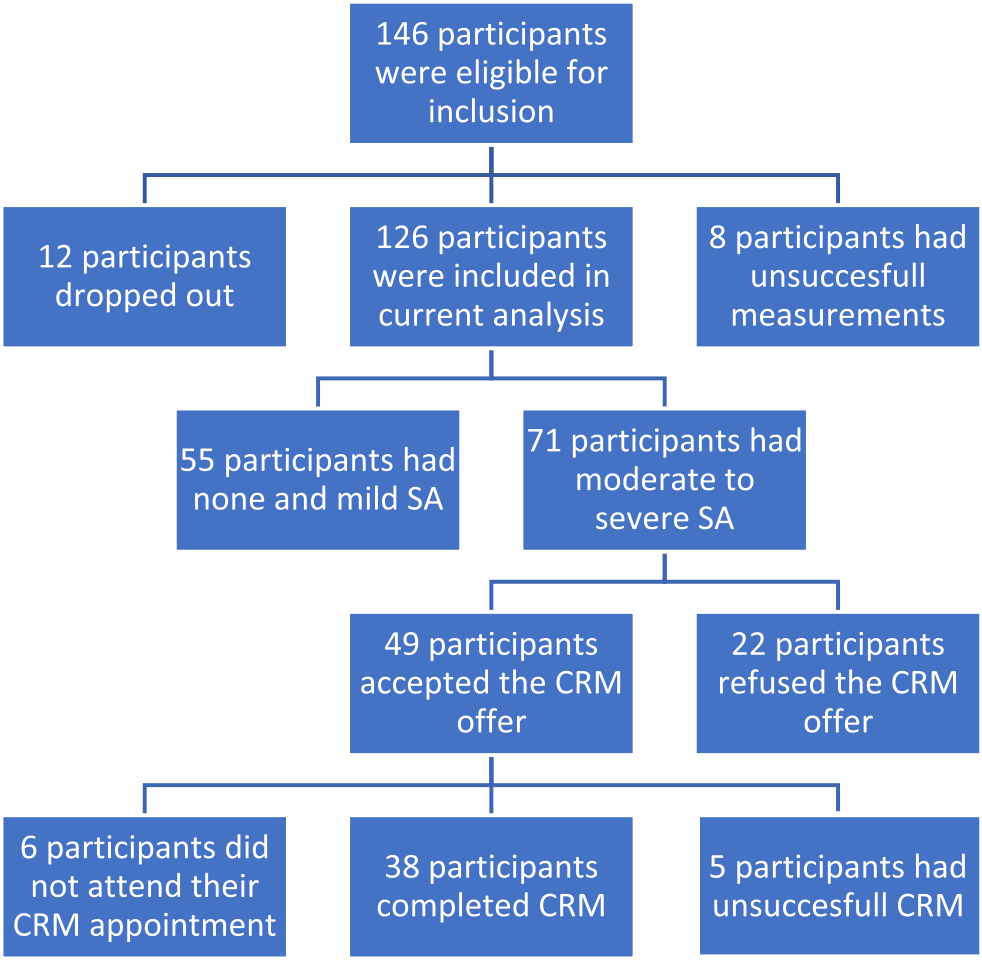

Fig. 1. Selection of population. Legend: SA = sleep apnea; CRM = cardio-respiratory monitoring.

3.2. Prevalence of sleep apnea using NO

In all participants, median AHI was 17/h (interquartile range (IQR) 9.0/h–32.0/h). Mild SA (AHI between 5 and 15) was detected in 45 of participants (36 %), moderate SA (AHI 15–30) in 35 of participants (28 %) and severe SA (AHI > 30) in 36 of participants (29 %). Moderate to severe SA (AHI > 15) were detected in 71 (56 %) of participants (Fig. 2).

Moderate to severe SA was more prevalent in participants older than 70 years of age (68 %) compared to those below 70 years of age (40 %). Similar prevalence was found between males and females.

3.3. Characteristics associated with moderate to severe SA by NO

In the group with moderate to severe SA, participants were significantly older (70 vs 64 years, p = 0.006), had a significantly higher BMI (28.1 vs 25.8, p = 0.024) and a significantly larger neck circumference (41.0 cm vs 39.0 cm, p = <0.001) compared to the none or mild SA participants. Difference in CHA_2DSC_2-VASc score were significant between the two groups (p = <0.001) along with significant differences between CHA_2DSC_2-VASc score in both males and females in the two groups (p = 0.002 and p = 0.013 respectively). The only main difference between the two groups in medication use were the use of benzodiazepines (12.7 % vs 1.8 %, p = 0.025) and opioids (11.3 % vs 5.5 % p = 0.049).

3.4. NO compared with CRM

The 71 participants with moderate to severe SA by NO were offered a CRM, 49 (69 %) participants accepted the offer. Finally, 38 (54 %) participants underwent CRM as 6 participants did not attend their CRM appointment and 5 participants had unsuccessful CRM measurements.

The correlation between the mean AHI assessed by the four consecutive nights of recording by NO and the AHI assessed by one night of recording by CRM is illustrated as a scatter plot in Fig. 3**.** Of the 38 participants undergoing CRM, 31 (82 %) participants were also assessed to have moderate to severe SA by the CRM analysis (positive predictive value (PPV) 0.82). As such, NO over diagnosed 7 participants in the none to mild SA category (15 < AHI) with two of these 7 participants having AHI = 14 on their CRM analysis (Table 3).

Of the 38 participants who underwent CRM, NO found 24 of these to have severe SA. Of these 24 participants the CRM assessed 22 (92 %) participants to have moderate to severe SA. As such, the PPV for NO to predict moderate to severe SA in the CRM assessment when NO found severe SA (mean AHI ≥ 30) was 0.92.

3.5. Questionnaire

85 participants answered the online clinical feasibility questionnaire and a selection of questions with mean values are presented in Supplemental Fig. 1. Overall, the participants associated the use of NO with ease and had a good perceived usability of the device and application.

4. Discussion

In this study of >100 patients with AF undergoing screening for SA with NO we found that 1) a high prevalence of SA, 2) NO have a high

Table 1
Demographic and clinical characteristics of the study population with comparisons between patients with none-and-mild SA and moderate-to-severe SA.

Characteristics	Total (n = 126)	None- and-mild SA (n = 55)	Moderate-to-severe SA (n = 71)	P-value
Age, years, median (IQR)	68 (60.0–75.0)	64 (56.5–72.5)	70 (63.0–76.0)*	0,006
Women	42 (33.3)	19 (34.6)	23 (32.3)	0,799
BMI, median (IQR)	27.1 (24.6–30.0)	25.8 (23.2–28.6)	28.1 (25.8–30.9)*	0,024
Neck Circumference, cm, median (IQR)	39.0 (37.0–43.0)	39.0 (36.0–41.0)	41.0 (38.3–44.0)*	<0.001
SBP, mm Hg, median (IQR)	134.0 (121.5–146.0)	132.5 (122.5–142.0)	135.0 (120.5–147.0)	0,173
DBP, mm Hg, median (IQR)	78.0 (72.8–88.0)	77.0 (72.3–88.5)	79.5 (74.3–88.0)	0,382
HR, beats per min, median (IQR)	61.0 (54.0–69.3)	59.0 (52.0–67.0)	65.0 (59.5–70.5)*	0,026
Atrial Fibrillation Type				
Paroxysmal	63 (50.0)	32 (58.2)	31 (43.4)	0,106
Persistent	16 (12.7)	7 (12.7)	9 (12.7)	0,277
Permanent	8 (6.3)	0 (0)	8 (11.3)*	0,010
Unclassified	39 (31.0)	16 (29.1)	23 (32.3)	0,691
Previous cardioversion	40 (31.7)	16 (29.1)	24 (33.8)	0,573
Previous RFA	24 (19.0)	14 (25.5)	10 (14.1)	0,107
Duration of AF, days, median (IQR)	850 (673.5–1926.5)	831 (667.5–1667.5)	959 (675.0–1995.0)	0,123
Medical History				
CHA2DS2-VASc, median (IQR)				
Women	3.0 (2.0–3.0)	2.0 (1.0–3.0)	3.0 (2.0–4.0)*	0,013
Men	2.0 (1.0–3.0)	1.0 (0.0–2.3)	3.0 (1.0–4.0)*	0,002
Overall	2.0 (1.0–3.0)	2.0 (1.0–3.0)	3.0 (2.0–4.0)*	<0.001
Hypertension	70 (55.6)	22 (40)	48 (67.6)*	0,002
Heart Failure	49 (38.9)	20 (36.4)	29 (40.8)	0,609
Diabetes	13 (10.3)	3 (5.5)	10 (14.1)	0,114
Thromboembolic events	9 (7.1)	1 (1.8)	8 (11.3)*	0,041
Hypercholestorelaemia	61 (48.4)	23 (41.8)	38 (53.5)	0,192
Stroke/TIA	10 (7.9)	4 (7.3)	6 (8.5)	0,808
Ischaemic heart disease	24 (19.0)	8 (14.5)	16 (22.5)	0,257
COPD	12 (9.5)	3 (5.5)	9 (12.7)	0,171
Echocardiographic parameters				
LA moderate or severe dilated	51 (40.5)	18 (32.7)	33 (46.5)	0,119
LVEF, %, median (IQR)	55.0 (50.0–60.0)	55.0 (55.0–60.0)	55.0 (50.0–60.0)*	0,016
NightOwl parameters, median (IQR)				
AHI, events/hour	17.0 (9.0–32.0)	7.0 (5.0–11.4)	30.0 (20.0–38.0)*	<0.001
ODI < 3 %, events/hour	16.0 (8.0–29.0)	8.0 (6.0–11.0)	27.0 (17.0–35.0)*	<0.001
ODI < 4 %, events/hour	8.0 (4.3–21.0)	4.0 (3.0–6.0)	18.0 (10.6–26.5)*	<0.001
Minimum oxygen SAT, %	83.0 (76.0–86.0)	85.0 (78.0–87.0)	79.0 (74.0–84.0)*	<0.001

Values are counts (column percentages) unless stated otherwise. The independent sample *t* test was used to compare means of continuous variables. The χ^2 test was used to compare proportions of categorical variables.
AHI = apnea-hypopnea index; BMI = body mass index; COPD = chronic obstructive pulmonary disease; DBP = diastolic blood pressure; HR = heart rate; IQR = interquartile range; LA = left atrial; LVEF = left ventricular ejection fraction; ODI = oxygen desaturation index; RFA = radiofrequency ablation; SAT = saturation; SBP = systolic blood pressure; SD = standard deviation; TIA = transient ischemic attack.
* Significant *P* value; *P* values indicate differences between patients with none-and-mild SA and moderate-to-severe SA.

validity compared to CRM and hence 3) NO might be an easy and feasible SA screening tool in patients with AF.

4.1. Prevalence of sleep apnea

We found a prevalence of 56 % of moderate to severe SA in unselected patients with AF using 4 nights of recording with a home-monitoring device. This prevalence is similar to previously published literature in patients with AF and highlights SA as a markedly unrecognized condition [8,12]. A study by Abumuamar et al. found a prevalence of moderate to severe SA of 55 % in 123 patients with AF referred to an arrythmia clinic [12]. The prevalence in that study was also assessed by home sleep recording but included PSG data such as electroencephalogram, electro-oculogram, electromyogram and ECG. In this study, the mean patient age was 64 years, 31 % were women, the mean BMI was 28,7 and 50 % had hypertension. As such, the characteristics of this study's population are very similar to those found in our current study. With a similar population, patient setting, and proportion with significant SA, a miniaturized home-monitoring device for SA diagnostics could gather sufficient data on a larger scale as replacement for PSG investigations. Despite studies finding consistently high proportions of AF patients with SA some important differences on setting and diagnostic methods also need to be considered. A study by Gami et al. found a similar prevalence of SA (49 %) in 151 patients with AF referred for cardioversion [8]. This study assessed SA by the Berlin Questionnaire which means the investigators have a selected population of symptomatic SA patients. This is a noteworthy difference to our evaluation of SA, as our study reports objective data based on home-monitoring data and do not take the symptomatic burden of SA into account. However, other studies have shown patients with AF report low SA symptom burden on questionnaires which suggests that presence of potential and clinically relevant SA is not captured easily with only the use of screening questionnaires [4,14,20]. The limited value and the many patients with AF at risk for SA that may be missed when using questionnaires as diagnostic tool could suggest a home-monitoring device such as NO may be useful as a replacement. Large-scale registry studies have also investigated the prevalence of SA, one of these is the ORBIT-AF which found a substantially lower prevalence of moderate to severe SA (18 %) in 10,132 patients with AF [6]. The lower prevalence of SA could reflect the fact that the ORBIT-AF diagnosis of SA was based entirely on a history of previously SA and not based on specific SA evaluation. As such, the true prevalence may have been higher. Lastly, the prevalence studies mentioned above, along with most other data related to the prevalence of SA in patients with AF originate from North America, which restricts the generalizability of the findings and emphasizes the importance of the present study's results.

4.2. Correlation of NO and CRM

One other study has analyzed the correlation between NO and a

Table 2
Medications on study population with comparison between patients with non and mild SA vs moderate to severe SA.

Medication	Entire Cohort (n = 126)	None and mild OSA (n = 55)	Moderate-to-severe OSA (n = 71)	P-value
Beta-blockers	71.4 % (n = 90)	67.3 % (n = 37)	77.6 % (n = 53)	0.36
Digitalis	5.6 % (n = 7)	7.2 % (n = 4)	4.2 % (n = 3)	0.46
Antiarrhythmic drugs	7.9 % (n = 10)	7.2 % (n = 4)	8.5 % (n = 6)	0.81
RAS inhibitors	46.0 % (n = 58)	43.6 % (n = 24)	47.9 % (n = 34)	0.50
MRA	19.8 % (n = 25)	20.0 % (n = 11)	19.7 % (n = 14)	0.97
Diuretics	38.9 % (n = 49)	30.9 % (n = 17)	45.1 % (n = 32)	0.11
CCB	18.3 % (n = 23)	14.5 % (n = 8)	21.1 % (n = 15)	0.34
Statins	46.0 % (n = 58)	40.0 % (n = 22)	50.7 % (n = 36)	0.23
Vasodilators (Angina Pectoris)	13.5 % (n = 7)	11.0 % (n = 6)	15.5 % (n = 11)	0.46
LMWH	5.6 % (n = 7)	5.5 % (n = 3)	5.6 % (n = 4)	0.97
Marevan	16.7 % (n = 21)	11.0 % (n = 6)	21.1 % (n = 15)	0.13
DOAC	63.0 % (n = 79)	63.6 % (n = 35)	62.0 % (n = 44)	0.85
Opiods	8.7 % (n = 11)	5.5 % (n = 3)	11.3 % (n = 8)	0.25
Benzodiazepin	7.9 % (n = 10)	1.8 % (n = 1)	12.7 % (n = 9)*	0.03*
Steroid	11.9 % (n = 15)	5.5 % (n = 3)	16.9 % (n = 12)*	0.05*
Inhaled medicine (COPD & Asthma)	19.0 % (n = 24)	18.2 % (n = 10)	19.7 % (n = 14)	0.83

Data are presented as % of total. The χ^2 test was used to compare proportions of categorical variables.
RAS = renin-angiotensin-system; MRA = mineralocorticoid receptor antagonists; CCB = calcium channel blocker; LMWH = low-molecular-weight heparins; DOAC = direct oral anticoagulants; COPD = chronic obstructive pulmonary disease.
* Significant *P* value; *P* values indicate differences between patients with none-and-mild SA and moderate-to-severe SA.

standardized SA assessment tool. Massie et al. showed the correlation between NO and PSG in a general population of 101 participants in a single-night in-laboratory setting [15]. The study found a PPV for moderate SA of 0.89 and a PPV for severe SA of 0.94. Furthermore, the study also found NO to sometimes overscore the AHI of participants, in this case in the mild SA category (5 to <15) with a total of 7 participants out of 31 participants being re-classified to the moderate SA category. Our study found a PPV for moderate to severe SA of 0.82 and a PPV for moderate to severe SA when NO found severe SA to be 0.92. This suggest NO to be a valid screening tool compared to CRM for determining moderate to severe SA in patients with AF especially when severe SA is found. Notably, the consistent findings in unselective AF patients in an out-patients setting is reassuringly, and NO could be a valid alternative to CRM. However, caution should be taken when relying solely on NO for initiating treatment for SA as NO may overestimate the AHI for some patients with AF.

4.3. Under-recognition of SA in patients with AF

The high prevalence of moderate to severe SA found in this study may suggest that SA is underreported in patients with AF. Several factors could explain the under-recognition of SA in patients with AF. One of them being that patients with AF report low daytime sleepiness hence mask the presence of SA and as a result never gets a referral to a sleep specialist for examination [14]. In addition, no tool for routine workup and screening for SA in patients with AF exists and the challenges related to obtaining PSG does not make it suitable for routine management in this population. Consequently, home-monitoring devices is gaining considerable interest in identifying, managing, and treating SA in relation to AF. Another advantage supporting the increased interest in home-monitoring devices is the potential cost-effectiveness they provide. Using devices such as NO instead of in-hospital testing can free up resources and reduce the overall cost for the healthcare system. Additionally, home-monitoring testing is often more convenient for patients, less time-consuming for health care staff, and could be more widely available for the patients. However, cost-effective analysis was not part of the study protocol.

This care of co-existing risk factors to AF has been acknowledged as equally beneficial as anticoagulation control, rhythm control, and rate control in the management of AF patients to improve outcomes [4,21]. Several valid reasons to consider SA screening as part of AF management have been showed in previous studies and the 2020 European Society of Cardiology (ESC) guidelines for management of AF also advocates for the reasonableness in screening for SA in AF patients [1]. A previous study has showed that AF patients with untreated SA have a higher risk of recurrence of AF after an initially successful cardioversion than patients without SA [22]. Similar results have been demonstrated after catheter ablation, exemplified in a meta-analysis where AF patients with SA had a 25 % increased risk of AF recurrence after catheter ablation compared to non-SA patients [23]. Furthermore, evidence has also suggested SA reduce the effectiveness of rhythm drug therapy [24]. This underlines the potential positive effect SA treatment could have on the AF management. However, patients with AF rarely undergo sleep evaluation mainly due to the screening for SA is not widely available, cumbersome, and not routinely implemented in AF management. A possible solution to the overlooked sleep evaluation could be a home-monitoring device such as NO. A home-use device can easily and accurately identify which patients with AF who might benefit from a more comprehensive clinical evaluation of SA to potentially start treatment for SA and improve AF management.

4.4. Study limitations

Patients with AF were included from a single outpatient clinic which may limit the generalizability of our results. On the other hand, the participants were unselected with a profile matching typical AF patients. Furthermore, not all participants with moderate to severe SA accepted the referral to CRM which could limit the correlation analysis of NO and CRM as an unintended selected group may have been created. Another limitation is that the study did not refer all participants to the CRM analysis and the study could not answer if NO underscored AHI in the none and mild SA category. However, to determine the validity of NO as a diagnostic screening tool the PPV is more important. A limitation of NO is the difficulty in distinguishing OSA and central SA, but subclassification of hypopneas is not recommended by ASSM guidelines for classification and scoring of sleep events [25]. This study did not assess SA by gold-standard of PSG but instead by CRM, but CRM has been tested against PSG in several randomized trials with good diagnostic accuracy although not in patients with AF [26,27]. Finally, the lack of data on AF burden in the study represents a limitation that hinders an understanding of the possible correlation between the degree of SA and the burden of AF.

5. Clinical implications/perspectives

Although current guidelines and evidence suggest a more integrated role for SA testing and treatment in AF management, the need for large scale prospective studies in this area are required. This includes large scale studies determining easy identification strategies for SA in patients with AF e.g., by assessing the feasibility and accuracy of home

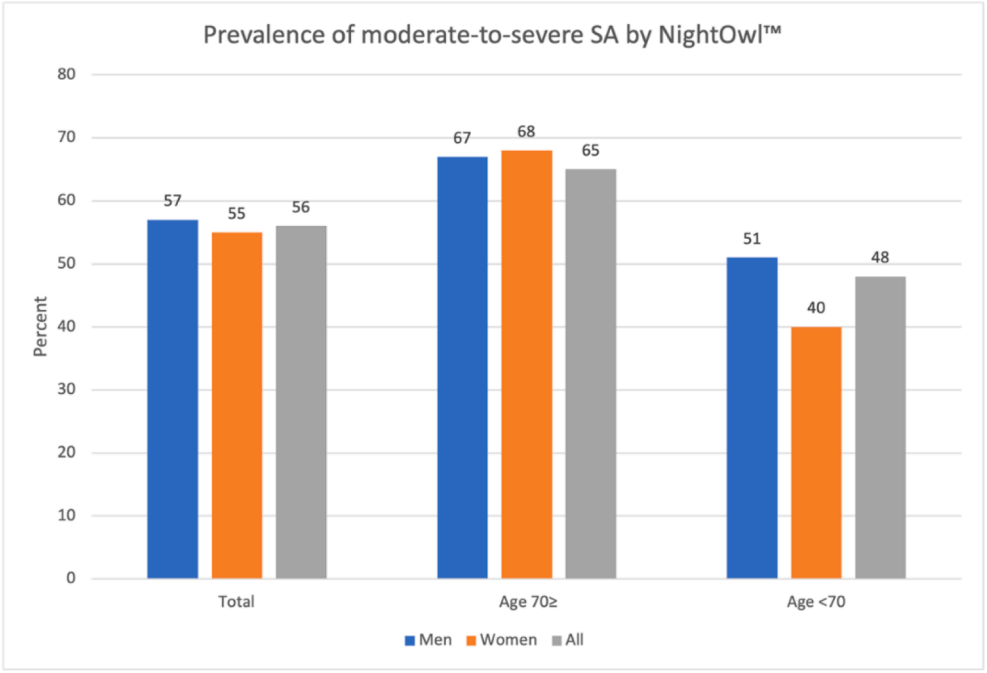

Fig. 2. Prevalence of moderate to severe sleep apnea by NightOwl™. Legend: The prevalence of moderate to severe sleep apnea in study participants. Presence of moderate to severe sleep apnea is determined by AHI ≥ 15 via NightOwl™.

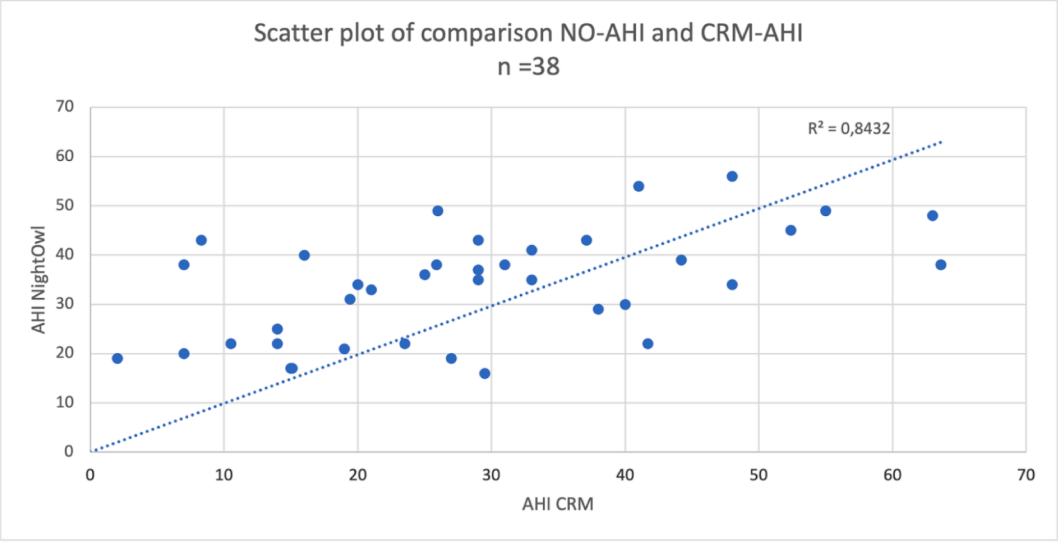

Fig. 3. Title: Scatter plot of comparison AHI by NO vs AHI by CRM. Legend: The dotted line represents the points for which the x-axis values equal the y-axis values of the graph (identity line). The values are mean. Participants included are those with moderate-to-severe SA determined by NO (n = 38). AHI = apnea-hypopnea index; NO = NightOwl™; CRM = cardio-respiratory monitoring.

Table 3
Error matrix of AHI category by CRM vs AHI category by NO.

n = 38	AHI Category by NO	
AHI Category by CRM	Moderate	Severe
Normal	1	0
Mild	4	2
Moderate	6	10
Severe	3	12

AHI = apnea-hypopnea index; NO = NightOwl™; CRM = cardio-respiratory monitoring.

monitoring test devices for SA and how these devices may be implemented in a clinical AF care and management pathway the same way as ambulatory ECG Holter and blood pressure monitoring is included. In this study, low-cost home-monitoring SA evaluation was feasible and could potentially be integrated in an AF outpatient clinic. This method has the potential for significant patient involvement and furthermore to empower patients with AF to self-manage their condition thus potentially encouraging the patients to play a considerable role in the decision-making process regarding their screening and treatment of SA. However, whether structured screening of SA in patients with AF is cost-effective needs to be investigated further. This includes randomized controlled studies determining the effect of SA treatment on different AF outcomes such as major cardiovascular events, AF burden, and quality of

life.

6. Conclusion

Moderate to severe SA was highly prevalent in patients with AF without known SA. Using a home monitoring device was an easy and feasible screening tool for SA in patients with AF and the device showed good correlation with CRM for determining moderate to severe SA.

Author's contributions

MHJ, FD and ML designed the study. ML and FD conceived the original idea. ML supervises the project. MHJ, ML, RRL and VG carried out the implementation. MHJ, FD, ML, RRL, VG, MLH, OV and JH all contributed to the final version of the manuscript and approved the content of the article.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcha.2023.101219.

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