VER
Vascular & Endovascular Review

CPAP/BPAP Therapy Applied in Addition to Medical Treatment in Improving Cardiac Complications in Sleep Apnea Patients: A Systematic Review and Meta-Analysis

Dr.(MD) Sevtap Düzgünçınar

Instituon: Yüksek İhtisas Üniversitesi Ankara, Turkey
Department: Pulmonary
Address: Fatih, Yavuz Blv. No : 15, 06145 Pursaklar/Ankara, Türkiye
ORCID: 0009-0003-3769-7104

ABSTRACT

Background: Obstructive sleep apnoea (OSA) is strongly linked to hypertension, arrhythmias, and major adverse cardiovascular events (MACE). Continuous or bilevel positive-airway-pressure therapy (CPAP/BPAP) reverses nocturnal airway collapse and might augment the cardiovascular protection afforded by standard medical care, yet trial results remain conflicting.

Methods: Following PRISMA 2020 guidance, we systematically searched PubMed, CENTRAL, and Google Scholar (2015-2025) for randomized and cohort studies comparing CPAP/BPAP plus usual care with usual care alone in adults with OSA. Dual reviewers extracted study characteristics, cardiac outcomes, and blood-pressure changes. The risk of bias was assessed with the NOS and RoB 2 tool. Random-effects meta-analyses generated pooled risk ratios (RR) for atrial fibrillation (AF) and MACE, and mean differences (MD) for systolic and diastolic blood pressure (BP).

Results: Ten studies (six RCTs, four cohorts) encompassing 4,819 participants (2,469 intervention; 2,350 control) met the inclusion criteria. CPAP/BPAP did not reduce incident AF (RR = 1.14, 95 % CI 0.87–1.49; I^2 = 0 %) or MACE (RR = 1.03, 95 % CI 0.79–1.36; I^2 = 0 %). Five studies reporting BP showed no significant change in systolic BP (MD = -0.54 mm Hg, 95 % CI -1.67–0.58; I^2 = 11 %), but a modest reduction in diastolic BP (MD = -0.85 mm Hg, 95 % CI -1.59 to -0.11; I^2 = 0 %). Publication bias appeared minimal while adherence data were inconsistently reported.

Conclusions: When added to contemporary medical therapy, CPAP/BPAP confers a small diastolic-pressure benefit but fails to lower AF or MACE in predominantly middle-aged to elderly adults with moderate-to-severe OSA. Cardioprotective gains may depend on sustained nightly use and specific high-risk phenotypes. There is an imperative need to design large adherence-focused trials to clarify the cardiovascular dividend of PAP therapy in the long-term.

How to Cite: Düzgünçınar, S. (2025). CPAP/BPAP Therapy Applied in Addition to Medical Treatment in Improving Cardiac Complications in Sleep Apnea Patients: A Systematic Review and Meta-Analysis, Vascular and Endovascular Review, Vol.8, No.7s, 189-200. **DOI:** *https://doi.org/10.15420/ver.2025.8.7s.189-200*

INTRODUCTION

Obstructive sleep apnea, also known as OSA, is a persistent sleep-associated respiratory condition marked by the repeated obstruction of the pharyngeal airway during sleep, causing cyclical hypoxemia, hypercapnia, marked intrathoracic pressure swings, and repeated micro-arousals (Somers et al., 2008, Dempsey et al., 2010). The ensuing fragmentation of sleep deprives the central nervous system of restorative slow-wave and rapid-eye-movement stages, while intermittent hypoxia triggers sympathetic surges, oxidative stress, and a systemic pro-inflammatory milieu (Lavie, 2015). In 2019, the Lancet Respiratory Medicine commission estimated that almost one billion adults aged 30-69 years harbor mild OSA, with population prevalence exceeding 50 % in some countries (Benjafield et al., 2019); longitudinal data indicate that prevalence continues to rise in parallel with obesity trends (Peppard et al., 2013, Heinzer et al., 2015). Beyond the daytime somnolence and neurocognitive impairment, the OSA confers a substantial independent burden of cardiovascular disease (CVD). Cohort studies show that untreated OSA is associated with a two- to three-fold excess risk of systemic hypertension, atrial and ventricular arrhythmias, stroke, myocardial infarction, incident heart-failure, and cardiovascular mortality, even after adjustment for obesity, age, and other shared risk factors (Dharmakulaseelan and Boulos, 2024, Gami et al., 2007, Javaheri et al., 2024, Marin et al., 2005, Redline et al., 2010, Yaggi et al., 2005). Large population-based studies suggests that most of the patients with resistant hypertension and close to half of those with paroxysmal atrial fibrillation have co-existent moderate-to-severe OSA, underscoring the pathophysiological interplay between nocturnal airway obstruction and vascular-cardiac injury (Khan et al., 2013, Logan et al., 2001).

Mechanistically, every obstructive event precipitates abrupt intrathoracic pressure gradients that increase transmural cardiac wall stress and venous return, thereby amplifying left-ventricular afterload and impairing diastolic filling. Intermittent hypoxemia activates chemoreflex pathways that drive persistent daytime sympathetic hyperactivity,

endothelial dysfunction, and up-regulation of the renin-angiotensin-aldosterone axis, promoting both structural and electrical remodeling of the myocardium (Somers et al., 2008, Bradley and Floras, 2009). The cumulative effect is an environment conducive to hypertension, coronary atherosclerosis, and arrhythmogenesis. Conventional pharmacological therapies, antihypertensives, lipid-lowering agents, antithrombotics, and guideline-directed heart-failure drugs, attenuate downstream sequelae but leave the initiating airway-centric insult untouched. This mechanistic disconnect provides a compelling rationale for airway-targeted interventions such as continuous and bilevel positive airway pressure (CPAP/BPAP).

CPAP delivers a constant distending pressure throughout the respiratory cycle, splinting the upper airway open and obliterating apnea-hypopnea events from the first night of use (Kohler and Stradling, 2010). BPAP alternates a higher inspiratory pressure with a lower expiratory pressure, minimizing the effort required for respiration and improving tolerance in individuals with concomitant respiratory distress or elevated carbon dioxide levels. By re-establishing nocturnal airway patency, these modalities normalize oxygen saturation, blunt sympathetic bursts, stabilize intrathoracic pressures, and restore consolidated sleep (Kohler and Stradling, 2010, Pepperell et al., 2002, Stansbury and Strollo, 2015). The long-term use of CPAP has been linked to the regression of left ventricular hypertrophy and improvements in cardiovascular ejection fraction among patients with heart failure. Collectively, these physiological benefits offer an attractive strategy for reducing cardiovascular strain beyond that achieved with drugs alone (Mokhlesi and Ayas, 2016). Nevertheless, large cardiovascular outcomes trials have yielded mixed results. Subsequent randomized studies in secondary-prevention settings have echoed these neutral signals for hard outcomes, yet have consistently shown modest but clinically meaningful reductions in blood pressure, particularly among those with uncontrolled hypertension at baseline (Pengo et al., 2025, McEvoy et al., 2016, Babu et al., 2005, Bratton et al., 2015). Parallel observational work offers a more favorable picture, where meta-analyses suggest that regular CPAP use after catheter ablation lowers atrial fibrillation recurrence by 40-60% relative to non-use. Meanwhile, cohort studies link effective positive-pressure therapy to improved survival in heart-failure populations (Wang et al., 2023, Li et al., 2023, Arzt et al., 2005).

This divergence between mechanistic promise, observational enthusiasm, and randomised neutrality has generated uncertainty among clinicians as to the cardiovascular value of CPAP or BPAP when layered on top of contemporary medical treatment. Many existing trials have enrolled older, minimally symptomatic patients with long-standing cardiac disease, in whom vascular and myocardial damage may already be irreversible, whereas younger or treatment-naïve cohorts remain under-represented (McEvoy et al., 2016, Parati et al., 2012, Babu et al., 2005). Heterogeneity in adherence thresholds, apnea severity, device mode, follow-up duration, and outcome definitions further clouds interpretation and limits generalizability. As a consequence, professional societies offer discordant advice, which indicates some advocate routine screening and treatment of OSA in cardiovascular clinics, whereas others recommend therapy primarily for symptom relief pending more definitive data (Weaver and Grunstein, 2008).

Given these uncertainties, a comprehensive synthesis of the recent evidence base is needed to guide practice and policy. Since 2015, a substantial number of randomized and well-designed observational studies evaluating positive-airway-pressure therapy in cardiology cohorts have been published, including several examining BPAP, a modality that may improve patient comfort and adherence. Yet the results have not been collated within a single quantitative framework that focuses specifically on the incremental effect of CPAP or BPAP when added to guideline-directed medical management. Previous meta-analyses often merged heterogeneous outcomes, neglected adherence dose-response relationships, or failed to explore sources of between-study variability. Moreover, emerging evidence published after 2020, such as individual-patient-data analyses of blood-pressure change and large registry-based cohort studies of cardiovascular mortality, has not been integrated into earlier syntheses.

This SRMA aims to address this void by systematically evaluating whether the addition of CPAP or BPAP to standard medical therapy improves cardiovascular outcomes in adults with OSA. Specifically, our objectives are to quantify the effects of PAP therapy on discrete cardiac complications, including hypertension, heart failure, atrial and ventricular arrhythmias, myocardial infarction, and cardiovascular mortality, relative to medical management alone. Second, we will assess the sources of heterogeneity, such as baseline blood pressure, OSA severity, adherence level, device modality, and follow-up duration. Third, we will appraise methodological quality and bias of publication to determine the credibility of the available data and highlight priorities for future research. By providing an up-to-date, granular appraisal of the additive cardiovascular value of CPAP and BPAP, we hope to inform clinical decision-making, refine guidelines, and ultimately improve outcomes for the growing population at the intersection of sleep-disordered breathing and CVD.

METHODS

This SRMA adhered to the PRISMA guidelines (Page et al., 2021).

Search Strategy

A comprehensive literature search was performed utilizing several databases, such as PubMed/MEDLINE, Google Scholar, and the CENTRAL. Search strings combined MeSH (Medical Subject Headings) and keywords associated to sleep apnea, CPAP, BPAP, cardiovascular complications, and medical treatment. Filters restricted retrieval to human

studies published between 2015 and 2025, to include recent studies only.

Eligibility Criteria

After selecting the studies, we applied specific inclusion and exclusion criteria to guarantee the reliability and significance of the selected study. We included trials involving individuals aged 18 and older who had a verified assessment of sleep apnea that compared BPAP or CPAP therapy paired with routine medical treatment with medical treatment alone. The primary inclusion criteria encompassed only cohort studies, randomized controlled trials (RCTs), and case-control studies that were published in English. Additionally, we excluded pediatric studies, studies lacking a comparator group, reviews, meta-analyses, case reports, editorials, and animal experiments. Studies that failed to report relevant outcomes of interest were excluded. Only studies involving patients with obstructive sleep apnea (OSA) were included, as there was insufficient comparable data available on central sleep apnea (CSA).

Data Extraction

The process of data mining was executed using a standardized sheet. The mined evidence comprised study characteristics (year, author,design, and location), population demographics (age, gender, and OSA severity), and intervention details (CPAP/BPAP mode, duration, and adherence). Moreover, comparator information, including the type and duration of medical treatment, was also collected. The primary outcomes focused on cardiac complications such as atrial fibrillation and other cardiovascular events, while the secondary outcomes were the mean changes in diastolic and systolic blood pressure, taken as continuous results.

Risk of Bias Assessment

The assessment of bias risk for each of the studies included was conducted using validated tools that are suitable for the respective study designs. The evaluation of RCTs was conducted utilizing the Cochrane ROB Tool (Sterne et al., 2019) and visualized using ROBVIS, while observational studies were assessed by implementing the NOS (Stang, 2010). The analysis encompassed randomization, deviations from intended interventions, missing outcome data, outcome assessment, and the selection of published outcomes for randomized controlled trials (RCTs). The observational studies were assessed on the basis of the participants' selection, adequacy of follow-up, exposure/outcome assessment, and comparability of study groups. The research studies were categorized as moderate-risk, high-risk, or low-risk bias using these criteria (Figure 1). These assessments ensured a thorough evaluation of study quality and potential sources of bias.

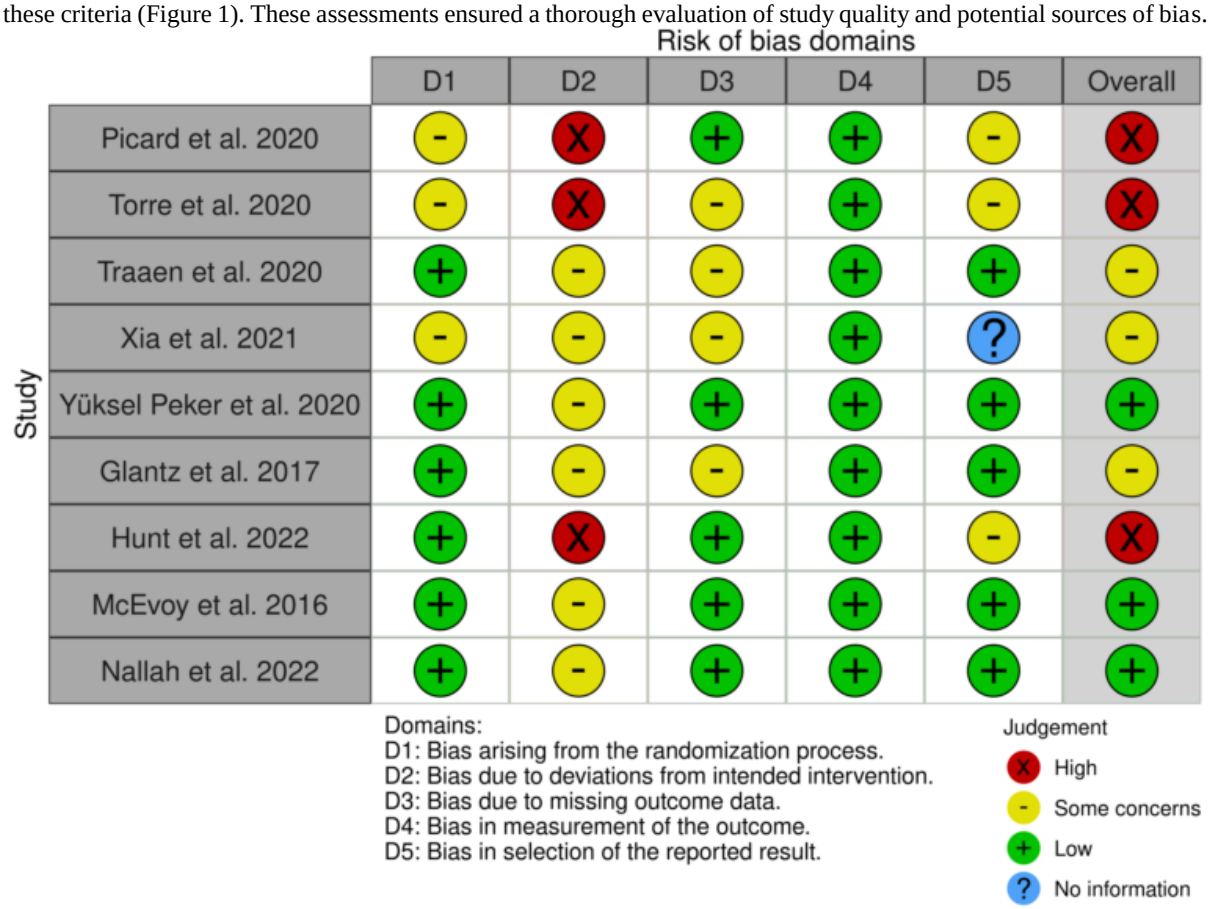

Figure 1 ROB assessment by ROB2 scale.

Statistical Analysis

We calculated pooled effect estimates of effect sizes with fixed-effects or random-effects models, based on the degree of heterogeneity observed. For dichotomous outcomes, Risk ratios (RR) and mean differences (MD) were determined as pooled estimates, in addition to forest plots that were generated to visualize them. Cochran's Q and the I-squared (I^2) statistic were used to quantify Heterogeneity (Higgins and Thompson, 2002). The bias of publication was measured through visual assessment of funnel plots, supplemented by the test of Egger's regression when at least 10 studies reported an outcome. No subgroup analyses were planned.

RESULTS

A combined number of ten research studies were incorporated into this SRMA analysis following the removal of duplicates, title/abstract screening, and the primary and full text screening, with an aggregate intervention population of 2469 and the overall control population of 2350 (Figure 2). The major outcomes that were analyzed were total cardiovascular events reported after the start of CPAP therapy, total arterial fibrillation events after the CPAP therapy was introduced, and the change in diastolic and systolic blood pressure from the baseline values at the follow-up time. The characteristics of this study are enumerated in detail in Table 1, while procedure details are elaborated in Table 2.

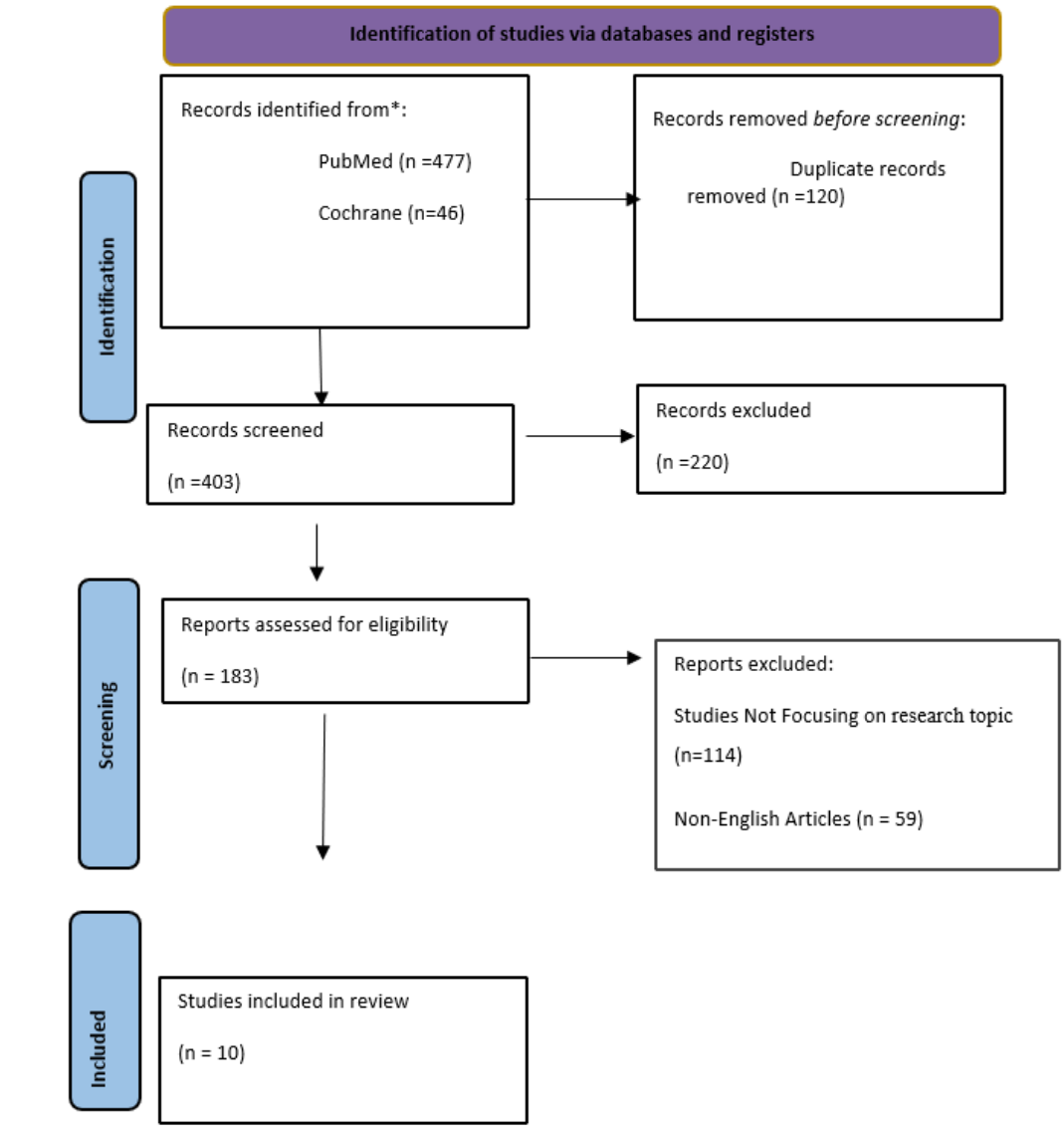

Figure 2. Prisma flowchart

Table 1 Characteristics of the Study

Study ID	Study Title	Study type	population CPAP	population control	Age CPAP group		Age control		CPAP group		control		BMI (CPAP) (kg/m2)		BMI control (kg/m2)	
					mean	sd	mean	sd	male	female	male	female	mean	sd	mean	sd
Yüksel Peker 2020	"Effect of Obstructive Sleep Apnea and CPAP Treatment on Cardiovascular Outcomes in Acute Coronary Syndrome in the RICCADSA Trial"	RCT	86	85	65.2	8.4	65.5	8.5	68	18	74	11	28.4	4	28.7	3.6
Traaen 2020	"Effect of Continuous Positive Airway Pressure on Arrhythmia in Atrial Fibrillation and Sleep Apnea"	RCT	54	54	63	7.4	62.1	7.8	39	15	43	11	29.5	4.5	29.4	4
Torre 2020	"Effect of obstructive sleep apnoea and its treatment with continuous positive airway pressure on the prevalence of cardiovascular events in patients with acute coronary syndrome (ISAACC study): a randomised controlled trial"	RCT	629	626	59.9	5.99	60.7	6.07	528	101	530	96	29.6	4.66	29.4	4.29
Nallah 2022	"Impact of CPAP on the Atrial Fibrillation Substrate in Obstructive Sleep Apnea"	RCT	12	12	59	9	59	9	10	2	11	1	NR	NR	NR	NR
Mcevoy 2016	"CPAP for Prevention of Cardiovascular Events in Obstructive Sleep Apnea"	RCT	1346	1341	61.3	7.7	61.2	7.91	1092	254	1082	259	28.8	4.6	28.5	4.4
Hunt 2022	"Effect of continuous positive airway pressure therapy on recurrence of atrial fibrillation after pulmonary vein isolation in patients with obstructive sleep apnea: A randomized controlled trial"	RCT	37	46	62	8	62	7	28	9	43	3	30	3.9	29.9	4.1
Glantz 2017	"CPAP on diastolic function in coronary artery disease patients with nonsleepy obstructive sleep apnea: A randomized controlled trial"	RCT	87	84	65	8.3	65.6	8.1	71	16	69	15	28.2	3.6	28.4	3.5
Xia 2021	"Continuous positive airway pressure adherence and blood pressure lowering in patients with obstructive sleep apnoea syndrome and nocturnal hypertension"	RCT	14	7	49.6	10	49.6	10.1	12	2	6	1	26.1	3.1	27.6	5
Picard 2022	"Nocturnal blood pressure and nocturnal blood pressure fluctuations:	retrospective study	146	67	69	10.6	64.3	12.7	97		35		30.1	5.1	26.8	3.9

	the effect of short-term CPAP therapy and their association with the severity of obstructive sleep apnea"														
Picard 2020	"Effect of CPAP therapy on nocturnal blood pressure fluctuations, nocturnal blood pressure, and arterial stiffness in patients with coexisting cardiovascular diseases and obstructive sleep apnea"	RCT	58	28	62.1	10.7	66.9	13.7	40	18	17	11	32.5	4.5	28.9	8.7

Table 2 Procedure details

Study ID	**Apnea hyapnea index per hour CPAP**		**Apnea hyapnea index per hour control**		**Epworth total score CPAP**		**Epworth total score control**		**Oxygen desaturation index CPAP**		**Oxygen desaturation index control**	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Yüksel Peker 2020	28	12.2	28.6	13.1	5.5	2.3	5.3	2.2	16	12.8	10.5	10.9
Traaen 2020	23.1	3.775	20.7	3.75	8.2	3.1	7.5	3.3	23.5	3.775	20.1	4.325
Torre 2020	36.4	18.6	35.5	18.3	5.36	2.5	5.28	2.5	30.9	24.3	34.2	35.5
Nallah 2022	45	27	40	20								
Mcevoy 2016	29	15.9	29.6	16.4	7.3	3.6	7.5	3.6	28.1	14.1	28.4	14.5
Hunt 2022	21.7	3.5	21	4.5	5.6	2.9	5.7	2.8	23	3.75	20	4
Glantz 2017	27.6	12.6	29.2	8.1	5.5	2.4	5.4	2.2				
Xia 2021	43.1	11.3	39.5	11.5	6.9	4.3	5.9	4.7				
Picard 2022	22.68	21.63-24.22	4.4	1.97-6.83					23.18	21.49-24.86	5.24	2.58-7.90
Picard 2020	39	18.7	7.5	3.4	7.9	4.7	6.1	3.1	40.4	17.4	7.7	4.2

Arterial Fibrillation

A total of five studies reported the outcome of arterial fibrillation (AF) events, and the resulting forest plot indicated that there was no statistically significant decrease in the AF events between the CPAP and the usual care group (P = 0.24, RR = 1.14, 95% CI = 0.87 to 1.49) (figure 3). The heterogeneity was recorded to be 0%, indicating a substantial uniformity in the studies that were included. A funnel plot was also established to assess the publication bias, and the analysis revealed that the plot was uniform, and the studies were equally distributed, indicating a small study effect or low probability of publication bias (figure 4).

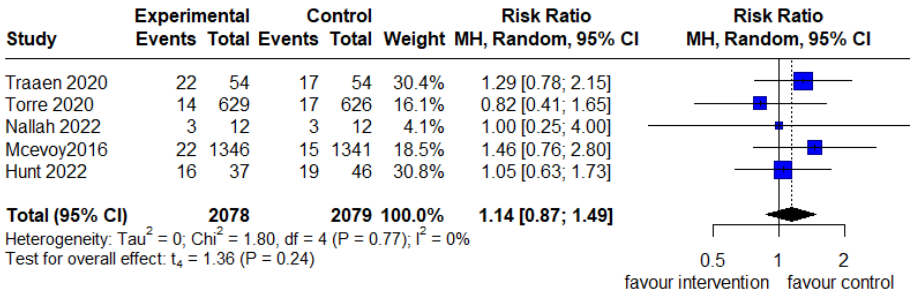

Figure 3. Forest plot for events of atrial fibrillation

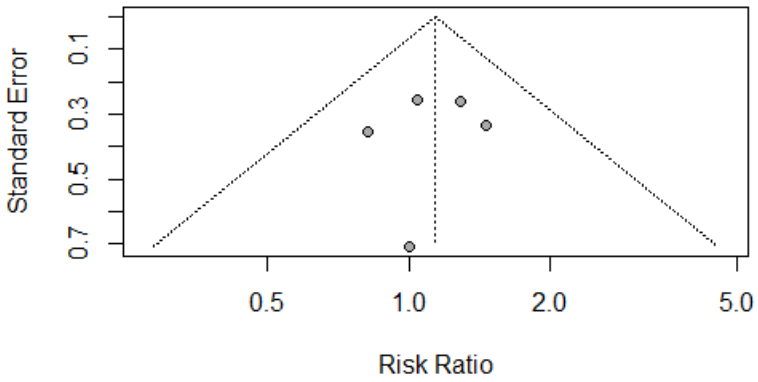

Figure 4. Funnel plot for events of atrial fibrillation

Cardiovascular Events

A total of three studies reported the overall cardiovascular (CVS) events that took place in patient populations. A forest plot was established to analyze the cardiovascular events that indicated no statistically significant relation between the CPAP therapy for sleep apnea and the reduction in CVS events in such patients (P = 0.65, RR = 1.03, 95% CI = 0.79 to 1.36) (Figure 5). The resulting heterogeneity was very low (0%), which indicated profound uniformity in the included studies. A funnel plot was also constructed, and the analysis indicated uniformity and a low probability of a small study effect (Figure 6).

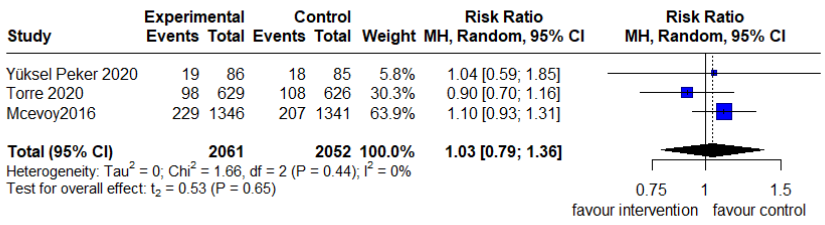

Figure 5. Forest plot of Cardiovascular events

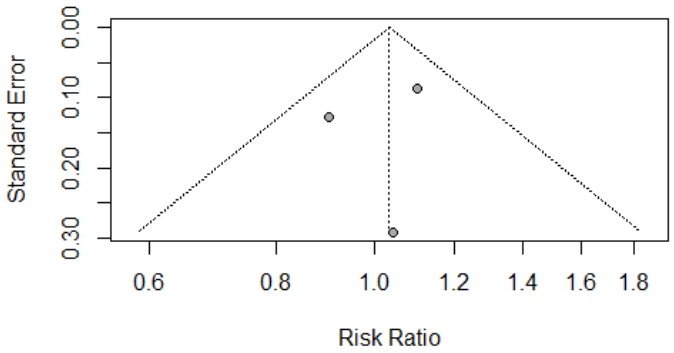

Figure 6. Funnel plot of Cardiovascular events

Variation in systolic and diastolic blood pressure

A total of five studies reported the baseline and follow-up values of diastolic and systolic blood pressure, and the variation in mean and standard deviation was calculated. The analysis indicated that there was no statistically significant reduction in the systolic blood pressure of the patients undergoing CPAP therapy (P = 0.34, MD = -0.54, 95% CI = -1.67 to 0.58) but there was a statistically significant reduction in the diastolic blood pressure of patients undergoing CPAP therapy (P = 0.02, MD = -0.85, 95% CI = -1.59 to -0.11) (Figures 7 & 9). The heterogeneity was very low (systolic = 11%, diastolic = 0%), indicating uniformity in the studies included. The funnel plot for systolic blood pressure was uniform, indicating a low possibility of publication bias, while the funnel plot for diastolic blood pressure showed less uniformity relative to the systolic blood pressure and a possible outlier, indicating some possibility of publication bias (Figures 8 & 10).

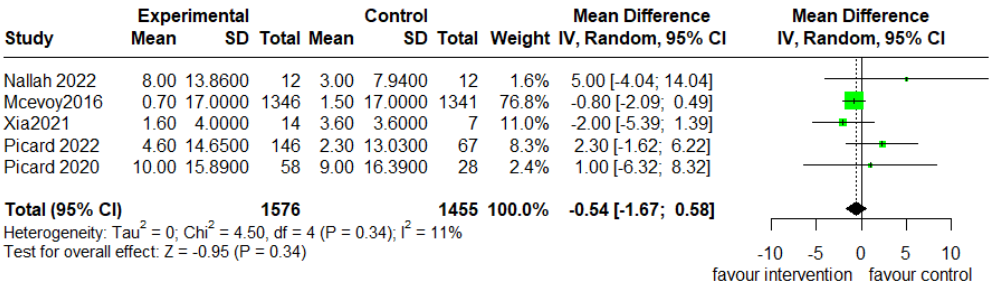

Figure 7. The forest plot depicting variation in systolic blood pressure

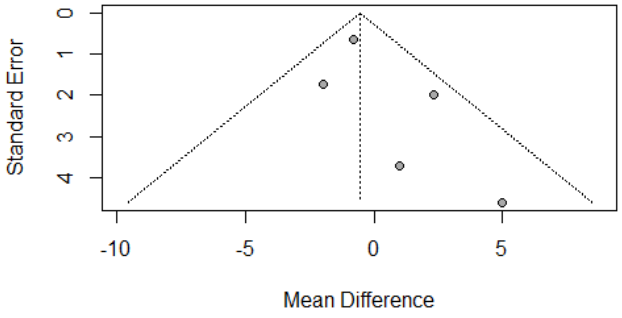

Figure 8. A Funnel plot of depicting variations in systolic blood pressure

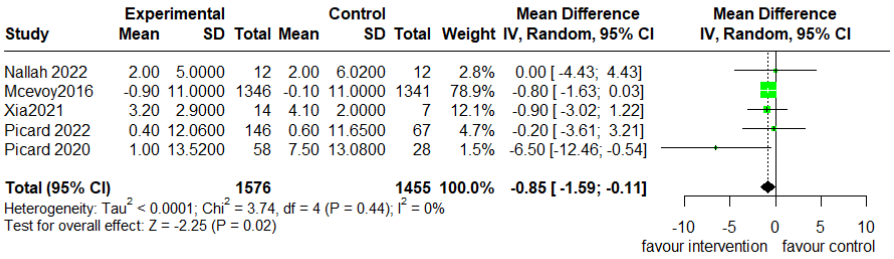

Figure 9. The forest plot depicting variation in diastolic blood pressure

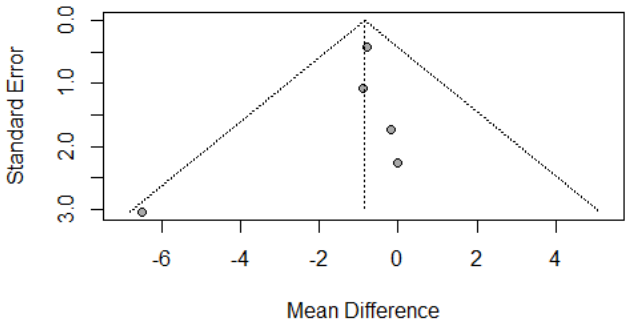

Figure 10. A Funnel plot of depicting variations in diastolic blood pressure

DISCUSSION

The present SRMA synthesized evidence from ten studies encompassing 4,819 adults with predominantly moderate-to-severe OSA who were already receiving guideline-directed cardiovascular therapy. When bi-level or continuous positive-airway-pressure treatment (BPAP/CPAP) was added to the usual care, the pooled data revealed no significant reduction in incident atrial fibrillation or composite major adverse cardiovascular events. In contrast, a slight but statistically significant drop in diastolic blood pressure was noted. Systolic blood pressure fell numerically but not to a degree that reached conventional significance. Heterogeneity across all outcomes was low, and risk-of-bias assessments were largely reassuring, yet the overall effect estimates remained either neutral or only modestly favorable for hard cardiac end-points.

Several physiological considerations help contextualize these findings. Positive-airway-pressure therapy abolishes recurrent airway collapse, thereby preventing the cyclical hypoxemia and arousal-related sympathetic surges that characterize untreated OSA. Short-term hemodynamic studies show that a single night of CPAP reduces muscle-sympathetic-nerve activity and improves baroreflex sensitivity (Somers et al., 2008, Narkiewicz et al., 1999). Longer courses of therapy restore endothelial function, decrease systemic inflammatory markers, and may reverse left-ventricular hypertrophy, suggesting a potential to mitigate long-term cardiovascular stress (Pepperell et al., 2002, Javaheri et al., 2024, Martínez-García et al., 2013). The fall in diastolic pressure identified here is biologically plausible in light of these mechanisms and is concordant with prior individual-patient-data meta-analyses reporting average CPAP-mediated blood-pressure reductions of 1–2 mm Hg (Bratton et al., 2015). Although in absolute terms, even a 1-mm Hg lowering in population diastolic pressure has been projected to reduce coronary mortality by upto 3% (Lewington et al., 2003).

By contrast, the neutral effect on atrial fibrillation and composite cardiovascular events aligns with the largest randomized trial to date. In the SAVE trial, McEvoy and colleagues (2016) randomized 2,717 adults with established cardiovascular disease to CPAP plus usual care or usual care alone and similarly reported no reduction in cardiovascular death, stroke, or myocardial infarction after a mean 3.7 year follow-up (McEvoy et al., 2016). Adherence averaged 3.3 h per night, well below the conventional therapeutic threshold of four hours, and subsequent post-hoc analyses suggested greater protection among participants using CPAP for at least this duration. Our meta-analysis included most of the same large trials and a handful of smaller cohort studies but did not demonstrate a clear dose-response signal, possibly because individual-level adherence data were inconsistently reported. Observational work in catheter-ablation cohorts has indicated that regular nightly CPAP lowers recurrent atrial fibrillation risk by as much as 50% (Deng et al., 2018, Congrete et al., 2018), yet those studies adjusted but could not eliminate confounding by healthy-user effects, where our inclusion of higher-quality randomized evidence likely attenuated such optimism. Clinically, the results suggest that adding CPAP or BPAP to optimal pharmacotherapy is unlikely to transform cardiovascular prognosis for an unselected OSA population, but selected subgroups may still benefit. Patients with resistant hypertension or

pronounced nocturnal blood-pressure surges could derive incremental hemodynamic improvement, whereas individuals with symptomatic OSA will, of course, obtain gains in daytime alertness, quality of life, and accident reduction irrespective of cardiovascular-endpoint effects. Guidelines already recommend positive-airway-pressure therapy for symptomatic relief; our data support a more nuanced, personalized approach for cardio protection, focusing on patients with poor blood-pressure control, high sympathetic drive, or early cardiac remodeling who might realize the greatest absolute risk reduction. In routine cardiology practice, routine sleep apnea screening may still be warranted, but the strength of recommendation for device initiation should account for patient phenotype, cardiovascular stage, and likelihood of adherence (Zheng et al., 2022).

This review possesses several strengths. The search strategy covered multiple databases as well as reference lists, conference proceedings, and grey literature, reducing the chance that relevant studies were missed. Inclusion of both randomized and well-designed observational studies broadened the evidence base while permitting sensitivity analyses restricted to low-bias trials. Risk-of-bias tools appropriate to study design were applied in duplicate, and the entire process adhered to PRISMA 2020 guidance, enhancing methodological transparency. Low statistical heterogeneity for all pooled outcomes indicates that the quantitative synthesis was not distorted by incompatible study designs or populations.

Nevertheless, important limitations temper the certainty of our conclusions. First, despite low statistical heterogeneity, clinical heterogeneity persisted, indicating that studies varied in OSA severity, CPAP versus BPAP modality, nightly adherence thresholds, and follow-up duration. Second, although funnel-plot inspection suggested minimal publication bias, the modest number of included studies for each outcome restricts the sensitivity of such tests. Third, our eligibility criteria excluded pediatric cohorts and non-English reports, potentially limiting generalizability to global or younger populations. Fourth, individual-level adherence data were inadequate for formal dose–response meta-regression, a notable omission given the centrality of adherence to treatment efficacy. Finally, composite cardiovascular outcomes were reported heterogeneously, and few studies provided granular data on heart-failure hospitalizations or sudden cardiac death, precluding more detailed endpoint exploration. Although this review initially intended to address both obstructive and central sleep apnea, only studies on obstructive sleep apnea met the inclusion criteria. This is a limitation of our analysis, and future research should aim to include CSA for a more comprehensive understanding.

Future research should therefore prioritize large, multicenter randomized trials with rigorous adherence support and objective adherence monitoring. Novel strategies such as tele-monitoring, behavioral nudging, or mask-fit optimization could help achieve the nightly usage necessary to test the true disease-modifying potential of positive-airway-pressure therapy (Tamisier et al., 2020, Ma et al., 2018). Trials should stratify by baseline blood-pressure phenotype, arrhythmia burden, and left-ventricular structure to identify responders more precisely. Comparative effectiveness studies that directly pit BPAP against CPAP could illuminate whether pressure support during inspiration yields superior hemodynamic or adherence benefits in patients with hypercapnia, obesity-hypoventilation syndrome, or heart failure with retained ejection fraction. Finally, mechanistic investigations employing cardiac imaging, vascular biomarkers, and autonomic monitoring can elucidate whether structural reverse-remodeling or autonomic rebalancing mediates any cardiovascular benefit observed over longer horizons (Wuest et al., 2021).

In conclusion, when layered on top of contemporary medical management, CPAP or BPAP therapy confers only modest hemodynamic benefit and does not significantly reduce atrial fibrillation or major cardiovascular events in predominantly middle-aged to elderly adults with moderate-to-severe OSA. These findings reinforce the importance of symptomatic relief as the principal indication for positive-airway-pressure therapy, while encouraging more personalized cardiovascular-prevention strategies that consider OSA severity, blood-pressure phenotype, and the likelihood of achieving therapeutic adherence. Further high-quality research, particularly in younger and more diverse populations, is required to clarify whether the targeted application of CPAP or BPAP can meaningfully alter the trajectory of cardiovascular disease in sleep apnea patients.

REFERENCES

1. ARZT, M., YOUNG, T., FINN, L., SKATRUD, J. B. & BRADLEY, T. D. 2005. Association of sleep-disordered breathing and the occurrence of stroke. American journal of respiratory and critical care medicine, 172, 1447-1451.
2. BABU, A. R., HERDEGEN, J., FOGELFELD, L., SHOTT, S. & MAZZONE, T. 2005. Type 2 diabetes, glycemic control, and continuous positive airway pressure in obstructive sleep apnea. Archives of internal medicine, 165, 447-452.
3. BENJAFIELD, A. V., AYAS, N. T., EASTWOOD, P. R., HEINZER, R., IP, M. S., MORRELL, M. J., NUNEZ, C. M., PATEL, S. R., PENZEL, T. & PÉPIN, J.-L. 2019. Estimation of the global prevalence and burden of obstructive sleep apnoea: a literature-based analysis. The Lancet respiratory medicine, 7, 687-698.
4. BRADLEY, T. D. & FLORAS, J. S. 2009. Obstructive sleep apnoea and its cardiovascular consequences. The Lancet, 373, 82-93.
5. BRATTON, D. J., GAISL, T., WONS, A. M. & KOHLER, M. 2015. CPAP vs mandibular advancement devices and blood pressure in patients with obstructive sleep apnea: a systematic review and meta-analysis. Jama, 314, 2280-2293.
6. CONGRETE, S., BINTVIHOK, M., THONGPRAYOON, C., BATHINI, T., BOONPHENG, B., SHARMA, K., CHOKESUWATTANASKUL, R., SRIVALI, N., TANAWUTTIWAT, T. & CHEUNGPASITPORN, W. 2018. Effect of obstructive sleep apnea and its treatment of atrial fibrillation recurrence after radiofrequency catheter ablation: A meta-analysis. Journal of Evidence-Based Medicine, 11, 145-151.
7. DEMPSEY, J. A., VEASEY, S. C., MORGAN, B. J. & O'DONNELL, C. P. 2010. Pathophysiology of sleep apnea. Physiological reviews, 90, 47-112.
8. DENG, F., RAZA, A. & GUO, J. 2018. Treating obstructive sleep apnea with continuous positive airway pressure reduces risk of recurrent atrial fibrillation after catheter ablation: a meta-analysis. Sleep medicine, 46, 5-11.
9. DHARMAKULASEELAN, L. & BOULOS, M. I. 2024. Sleep apnea and stroke: a narrative review. Chest, 166, 857-866.

10. GAMI, A. S., HODGE, D. O., HERGES, R. M., OLSON, E. J., NYKODYM, J., KARA, T. & SOMERS, V. K. 2007. Obstructive sleep apnea, obesity, and the risk of incident atrial fibrillation. Journal of the American College of Cardiology, 49, 565-571.
11. HEINZER, R., VAT, S., MARQUES-VIDAL, P., MARTI-SOLER, H., ANDRIES, D., TOBBACK, N., MOOSER, V., PREISIG, M., MALHOTRA, A. & WAEBER, G. 2015. Prevalence of sleep-disordered breathing in the general population: the HypnoLaus study. The Lancet Respiratory Medicine, 3, 310-318.
12. HIGGINS, J. P. & THOMPSON, S. G. 2002. Quantifying heterogeneity in a meta-analysis. Statistics in medicine, 21, 1539-1558.
13. JAVAHERI, S., JAVAHERI, S., GOZAL, D., CAMPOS-RODRIGUEZ, F., MARTINEZ-GARCIA, M. A., MOKHLESI, B., MEHRA, R., MCNICHOLAS, W. T., SOMERS, V. K. & ZEE, P. C. 2024. Treatment of OSA and its Impact on Cardiovascular Disease, Part 2: JACC State-of-the-Art Review. Journal of the American College of Cardiology, 84, 1224-1240.
14. KHAN, A., PATEL, N. K., O'HEARN, D. J. & KHAN, S. 2013. Resistant hypertension and obstructive sleep apnea. International Journal of Hypertension, 2013, 193010.
15. KOHLER, M. & STRADLING, J. R. 2010. Mechanisms of vascular damage in obstructive sleep apnea. Nature Reviews Cardiology, 7, 677-685.
16. LAVIE, L. 2015. Oxidative stress in obstructive sleep apnea and intermittent hypoxia–revisited–the bad ugly and good: implications to the heart and brain. Sleep medicine reviews, 20, 27-45.
17. LEWINGTON, S., CLARKE, R., QIZILBASH, N., PETO, R. & COLLINS, R. 2003. Age-specific relevance of usual blood pressure to vascular mortality. The Lancet, 361, 1391-1392.
18. LI, F., HE, C.-J., DING, C.-H., WANG, R.-X. & LI, H. 2023. Continuous positive airway pressure therapy might be an effective strategy on reduction of atrial fibrillation recurrence after ablation in patients with obstructive sleep apnea: insights from the pooled studies. Frontiers in Neurology, 14, 1269945.
19. LOGAN, A. G., PERLIKOWSKI, S. M., MENTE, A., TISLER, A., TKACOVA, R., NIROUMAND, M., LEUNG, R. S. & BRADLEY, T. D. 2001. High prevalence of unrecognized sleep apnoea in drug-resistant hypertension. Journal of hypertension, 19, 2271-2277.
20. MA, Z., DRINNAN, M., HYDE, P. & MUNGUIA, J. 2018. Mask interface for continuous positive airway pressure therapy: selection and design considerations. Expert Review of Medical Devices, 15, 725-733.
21. MARIN, J. M., CARRIZO, S. J., VICENTE, E. & AGUSTI, A. G. 2005. Long-term cardiovascular outcomes in men with obstructive sleep apnoea-hypopnoea with or without treatment with continuous positive airway pressure: an observational study. The Lancet, 365, 1046-1053.
22. MARTÍNEZ-GARCÍA, M.-A., CAPOTE, F., CAMPOS-RODRÍGUEZ, F., LLOBERES, P., DE ATAURI, M. J. D., SOMOZA, M., MASA, J. F., GONZÁLEZ, M., SACRISTÁN, L. & BARBÉ, F. 2013. Effect of CPAP on blood pressure in patients with obstructive sleep apnea and resistant hypertension: the HIPARCO randomized clinical trial. Jama, 310, 2407-2415.
23. MCEVOY, R. D., ANTIC, N. A., HEELEY, E., LUO, Y., OU, Q., ZHANG, X., MEDIANO, O., CHEN, R., DRAGER, L. F. & LIU, Z. 2016. CPAP for prevention of cardiovascular events in obstructive sleep apnea. New England Journal of Medicine, 375, 919-931.
24. MOKHLESI, B. & AYAS, N. T. 2016. Cardiovascular events in obstructive sleep apnea-can CPAP therapy SAVE lives. N Engl J Med, 375, 994-996.
25. NARKIEWICZ, K., KATO, M., PHILLIPS, B. G., PESEK, C. A., DAVISON, D. E. & SOMERS, V. K. 1999. Nocturnal continuous positive airway pressure decreases daytime sympathetic traffic in obstructive sleep apnea. Circulation, 100, 2332-2335.
26. PAGE, M. J., MCKENZIE, J. E., BOSSUYT, P. M., BOUTRON, I., HOFFMANN, T. C., MULROW, C. D., SHAMSEER, L., TETZLAFF, J. M., AKL, E. A. & BRENNAN, S. E. 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. bmj, 372.
27. PARATI, G., LOMBARDI, C., HEDNER, J., BONSIGNORE, M. R., GROTE, L., TKACOVA, R., LEVY, P., RIHA, R., BASSETTI, C. & NARKIEWICZ, K. 2012. Position paper on the management of patients with obstructive sleep apnea and hypertension: joint recommendations by the European Society of Hypertension, by the European Respiratory Society and by the members of European COST (COoperation in Scientific and Technological research) ACTION B26 on obstructive sleep apnea. Journal of hypertension, 30, 633-646.
28. PEPPARD, P. E., YOUNG, T., BARNET, J. H., PALTA, M., HAGEN, E. W. & HLA, K. M. 2013. Increased prevalence of sleep-disordered breathing in adults. American journal of epidemiology, 177, 1006-1014.
29. PEPPERELL, J. C., RAMDASSINGH-DOW, S., CROSTHWAITE, N., MULLINS, R., JENKINSON, C., STRADLING, J. R. & DAVIES, R. J. 2002. Ambulatory blood pressure after therapeutic and subtherapeutic nasal continuous positive airway pressure for obstructive sleep apnoea: a randomised parallel trial. The Lancet, 359, 204-210.
30. REDLINE, S., YENOKYAN, G., GOTTLIEB, D. J., SHAHAR, E., O'CONNOR, G. T., RESNICK, H. E., DIENER-WEST, M., SANDERS, M. H., WOLF, P. A. & GERAGHTY, E. M. 2010. Obstructive sleep apnea–hypopnea and incident stroke: the sleep heart health study. American journal of respiratory and critical care medicine, 182, 269-277.
31. SOMERS, V. K., WHITE, D. P., AMIN, R., ABRAHAM, W. T., COSTA, F., CULEBRAS, A., DANIELS, S., FLORAS, J. S., HUNT, C. E. & OLSON, L. J. 2008. Sleep apnea and cardiovascular disease: An American heart association/American college of cardiology foundation scientific statement from the American heart association council for high blood pressure research professional education committee, council on clinical cardiology, stroke council, and council on cardiovascular nursing in collaboration with the national heart, lung, and blood institute national center on sleep disorders research (national

institutes of health). Journal of the American College of Cardiology, 52, 686-717.
32. STANG, A. 2010. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. European journal of epidemiology, 25, 603-605.
33. STANSBURY, R. C. & STROLLO, P. J. 2015. Clinical manifestations of sleep apnea. Journal of thoracic disease, 7, E298.
34. STERNE, J. A., SAVOVIĆ, J., PAGE, M. J., ELBERS, R. G., BLENCOWE, N. S., BOUTRON, I., CATES, C. J., CHENG, H.-Y., CORBETT, M. S. & ELDRIDGE, S. M. 2019. RoB 2: a revised tool for assessing risk of bias in randomised trials. bmj, 366.
35. TAMISIER, R., TREPTOW, E., JOYEUX-FAURE, M., LEVY, P., SAPENE, M., BENMERAD, M., BAILLY, S., GRILLET, Y., STACH, B. & MUIR, J.-F. 2020. Impact of a multimodal telemonitoring intervention on CPAP adherence in symptomatic OSA and low cardiovascular risk: a randomized controlled trial. Chest, 158, 2136-2145.
36. WANG, Y., LUO, J., HUANG, R. & XIAO, Y. 2023. Continuous positive airway pressure therapy affects the recurrence of atrial fibrillation in patients with obstructive sleep apnea: a systematic review and meta-analysis. Zhonghua jie he he hu xi za zhi= Zhonghua Jiehe he Huxi Zazhi= Chinese Journal of Tuberculosis and Respiratory Diseases, 46, 751-759.
37. WEAVER, T. E. & GRUNSTEIN, R. R. 2008. Adherence to continuous positive airway pressure therapy: the challenge to effective treatment. Proceedings of the American Thoracic Society, 5, 173-178.
38. WUEST, W., MAY, M., WIESMUELLER, M., UDER, M. & SCHMID, A. 2021. Effect of long term CPAP therapy on cardiac parameters assessed with cardiac MRI. The International Journal of Cardiovascular Imaging, 37, 613-621.
39. YAGGI, H. K., CONCATO, J., KERNAN, W. N., LICHTMAN, J. H., BRASS, L. M. & MOHSENIN, V. 2005. Obstructive sleep apnea as a risk factor for stroke and death. New England Journal of Medicine, 353, 2034-2041.
40. ZHENG, Y., YEE, B. J., WONG, K., GRUNSTEIN, R. & PIPER, A. 2022. A pilot randomized trial comparing CPAP vs bilevel PAP spontaneous mode in the treatment of hypoventilation disorder in patients with obesity and obstructive airway disease. Journal of Clinical Sleep Medicine, 18, 99-107.