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# «Διαφορές στη διαστολική λειτουργία μεταξύ ασθενών με κεντρικού και περιφερικού τύπου υπνική άπνοια Ανασκόπηση»

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**Abstract**

This study delves into the intricate relationship between Central Sleep Apnea (CSA) and Obstructive Sleep Apnea (OSA) and their consequential impacts on diastolic function, a critical determinant of cardiac efficiency and health. Diastolic function, pivotal in cardiac output and blood pressure maintenance, becomes compromised in the presence of sleep-disordered breathing, with varying implications for CSA and OSA. Through a meticulous literature review, this research aimed to compare and contrast the echocardiographic characteristics of diastolic function between CSA and OSA patients, providing insights into the unique and shared cardiovascular manifestations of these conditions. CSA, often associated with neurohumoral imbalances in heart failure, and OSA, characterized by physical airway obstruction, exert distinct yet overlapping influences on cardiac structure and function. Our analysis revealed that CSA primarily impacts diastolic function through increased left atrial volume, suggesting atrial stress and potential exacerbation of heart failure with preserved ejection fraction (HFpEF). OSA, conversely, was found to induce significant ventricular remodeling, marked by increased left ventricular mass and diastolic dysfunction parameters, alongside right ventricular dysfunction in severe cases. These findings underscore the mechanistic differences in how CSA and OSA affect diastolic function, highlighting the role of recurrent hypoxemic episodes and intrathoracic pressure fluctuations inherent in OSA in driving myocardial stress and hypertrophy. The main conclusion drawn from this comparative analysis emphasizes the importance of recognizing and addressing both CSA and OSA in cardiac care to prevent the progression of diastolic dysfunction. Advanced echocardiographic techniques, including speckle tracking echocardiography,

emerged as valuable tools in detecting early myocardial changes, suggesting their potential in enhancing the diagnostic and management strategies for patients with sleep disordered breathing. This study underscores the need for integrated approaches in diagnosing and treating sleep apnea, highlighting echocardiography's pivotal role in identifying early cardiac involvement and guiding clinical interventions to mitigate cardiovascular risks associated with CSA and OSA.

**Keywords:** Diastolic Function, Echographic Characteristics, Central Sleep Apnea, Peripheral Sleep Apnea

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# 1. Introduction

## 1.1. Definition and Overview of Sleep Apnoea

Sleep apnea, a disorder characterized by repeated pauses in breathing during sleep, poses a significant global health concern. It is categorized mainly into two types: central sleep apnea (CSA) and obstructive sleep apnea (OSA), often referred to as peripheral sleep apnea. Understanding the nuances between these forms is crucial for clinicians and researchers alike, given their differential impact on cardiovascular health, particularly on diastolic function as observed through ultrasound imaging[1].

Central sleep apnea is marked by a lack of respiratory effort resulting from the brain's failure to send appropriate signals to the muscles controlling breathing. This condition is less common than its counterpart but is particularly notable in patients with heart failure,

where it is linked to poorer outcomes [2]. The pathophysiology of CSA is complex, involving feedback mechanisms between the heart, lungs, and brain, which regulate respiratory effort. This intricate interplay can be disrupted in heart failure, leading to the characteristic breathing pauses of CSA[3], [4].

In contrast, obstructive sleep apnea is characterized by physical blockages of the airway despite ongoing respiratory efforts. These blockages are often due to the relaxation of throat muscles, which can collapse and obstruct the airway during sleep[5], [6]. OSA is more prevalent in the general population, affecting a wide demographic but particularly seen in individuals who are overweight, have anatomical variations in their airway structure, or have certain genetic predispositions. The repetitive episodes of airway obstruction in OSA lead to intermittent hypoxia and significant swings in intrathoracic pressure, which, over time, can exert deleterious effects on cardiac function, particularly on the heart's ability to fill during diastole[7], [8].

Globally, sleep apnea affects millions of individuals, with obstructive sleep apnea being the more prevalent form. Estimates suggest that approximately 1 billion people worldwide may have obstructive sleep apnea, with its prevalence increasing in line with rising obesity rates. In contrast, central sleep apnea is less common but not insignificant, especially among specific populations, such as those with heart failure, where its prevalence can be as high as 30-50%. These figures underline the significant burden of



sleep apnea on global health and the importance of understanding its implications on cardiac function[9].

Both forms of sleep apnea can have profound effects on cardiovascular health, but they do so through different mechanisms. The intermittent hypoxia and hypercapnia resulting from both CSA and OSA can lead to a cascade of pathophysiological responses, including systemic inflammation, oxidative stress, and autonomic nervous system imbalance. These responses contribute to the development and progression of cardiac conditions, notably affecting the heart's diastolic function. Diastolic dysfunction, a condition where the heart's ventricles do not relax properly during the diastolic phase (the period when the heart fills with blood), is a key factor in the development of heart failure and is associated with increased morbidity and mortality[10].

The importance of diastolic function in cardiac health cannot be overstated. Proper

ventricular filling during diastole is essential for maintaining adequate cardiac output and ensuring tissue perfusion. Disruptions in this process, as can occur in sleep apnea, have significant clinical implications. Ultrasound imaging, particularly echocardiography, has emerged as a critical tool in the evaluation of diastolic function, allowing for the non invasive assessment of ventricular filling pressures, left atrial size, and other parameters indicative of diastolic dysfunction. Studies utilizing echocardiography in patients with sleep apnea have provided invaluable insights into the relationship between sleep disordered breathing and diastolic function, highlighting the potential for sleep apnea treatment to mitigate diastolic dysfunction and improve cardiac outcomes[11], [10].

Sleep apnea, encompassing central and obstructive forms, represents a significant public health issue with notable implications for cardiovascular health. While CSA and OSA share some pathophysiological effects on the heart, their distinct mechanisms necessitate differentiated approaches to management and treatment [12],[1]. The global prevalence of sleep apnea underscores the need for increased awareness, early detection, and effective therapeutic strategies to combat its adverse effects on the heart, particularly concerning diastolic function[13]. As research continues to unravel the complex interplay between sleep apnea and cardiac health, the role of ultrasound imaging in diagnosing and monitoring diastolic dysfunction serves as a cornerstone in



the management of patients with sleep-disordered breathing, paving the way for improved clinical outcomes in this population.

### 1.2. Diastolic Function and its Importance in Heart Health

Diastolic function pertains to the phase of the cardiac cycle during which the heart relaxes and the ventricles fill with blood following contraction. This phase is as critical as systolic function, where the heart contracts to pump blood out to the body. Diastolic dysfunction arises when the heart's ventricles become stiff and do not relax properly, leading to inadequate filling with blood. This condition can result in congestive heart failure, where the heart is unable to pump sufficient blood to meet the body's needs, highlighting the paramount importance of diastolic function in heart health[14].

The heart's ability to relax and fill efficiently is fundamental to maintaining optimal cardiac output. During diastole, the ventricles relax, decreasing intraventricular pressure

and allowing blood to flow in from the atria. This filling phase comprises early passive filling and atrial contraction, which propels additional blood into the ventricles. Efficient diastolic function ensures that adequate preload is achieved without significantly increasing filling pressures, which is vital for the maintenance of cardiac output and systemic blood flow[15].

Impairment of diastolic function, or diastolic dysfunction, leads to a spectrum of clinical manifestations, primarily due to elevated pressures in the heart and lungs. This condition can progress to diastolic heart failure, also known as heart failure with preserved ejection fraction (HFpEF), where the ejection fraction remains normal, but symptoms of heart failure persist due to poor ventricular filling. HFpEF accounts for nearly half of all heart failure cases and is associated with significant morbidity and mortality. Patients with diastolic dysfunction often present with signs of congestive heart failure, such as dyspnea, fatigue, and fluid retention, despite having a preserved ejection fraction[16].

The clinical significance of diastolic function is underscored by its association with various cardiovascular risk factors and conditions. Hypertension, diabetes, obesity, and advanced age are all linked to the development of diastolic dysfunction [17]. These conditions contribute to the remodeling of the heart muscle and the accumulation of



extracellular matrix, leading to increased stiffness of the ventricular walls. Furthermore, ischemic heart disease can impair diastolic relaxation through myocardial injury and fibrosis. The prevalence of diastolic dysfunction increases with age, affecting approximately 50% of individuals over the age of 60, highlighting the growing public health impact as the population ages [18].

Evaluating diastolic function is crucial for the diagnosis and management of heart failure and for assessing the risk of developing cardiovascular diseases. Echocardiography is the primary tool for assessing diastolic function, providing detailed information about the structure and function of the heart. It measures parameters such as the velocity of blood flow across the mitral valve, the movement of the mitral valve annulus during diastole, and the left atrial size, which are indicative of ventricular filling pressures and diastolic function. These echocardiographic indices help classify the severity of diastolic dysfunction and guide treatment strategies [19].

Management of diastolic dysfunction focuses on controlling contributing factors and alleviating symptoms. Treatment strategies include managing blood pressure, controlling diabetes, weight reduction, and using medications that improve ventricular relaxation and reduce filling pressures. Exercise and lifestyle modifications are also integral components of managing diastolic dysfunction, as they can improve cardiac function and patient quality of life[20].

The importance of diastolic function extends beyond the domain of heart health. Emerging research suggests that diastolic dysfunction is associated with an increased risk of atrial fibrillation, stroke, and renal dysfunction, emphasizing the interconnectedness of cardiovascular health. Therefore, a comprehensive approach to managing diastolic dysfunction can have far-reaching benefits for overall health and wellbeing[21].

Diastolic function is a critical aspect of cardiac performance, with its impairment leading to significant clinical consequences. Understanding and managing diastolic dysfunction is essential for preventing heart failure and improving cardiovascular outcomes[14], [16],[18]. As research continues to elucidate the mechanisms underlying diastolic dysfunction and its systemic implications, it is clear that preserving diastolic function is



paramount for maintaining heart health and preventing the cascade of complications associated with its decline. Through targeted interventions and lifestyle modifications, it is possible to mitigate the impact of diastolic dysfunction and improve the lives of those affected by this condition.

### 1.3. Purpose of Study

The central tenet of this research endeavor is to elucidate the nuanced differences in diastolic function, as characterized by ultrasound imaging, between patients afflicted with central sleep apnea (CSA) and those suffering from peripheral sleep apnea, more commonly referred to as obstructive sleep apnea (OSA). This study is premised on the growing body of evidence suggesting that sleep apnea, irrespective of its type, exerts a profound impact on cardiovascular health, with a specific emphasis on diastolic function.

Given the prevalence of sleep apnea in the global population and its recognized association with increased cardiovascular risk, a deeper understanding of its effects on the heart's diastolic performance is of paramount importance.

The purpose of this work is multi-faceted. Firstly, it seeks to provide a comprehensive review of existing literature to catalog the current state of knowledge regarding the impact of CSA and OSA on diastolic function. This will involve a critical analysis of ultrasound findings to identify distinct and overlapping characteristics of diastolic dysfunction in patients with CSA and OSA. Secondly, by conducting a comparative analysis, this study aims to uncover unique insights into how these forms of sleep apnea may differently influence the mechanics of cardiac filling and relaxation, which are crucial for maintaining optimal cardiac output and overall cardiovascular health.

Furthermore, this research is intended to bridge a gap in the existing literature by offering a detailed comparison of diastolic dysfunction manifestations in CSA versus OSA patients. This comparison is not only pivotal for advancing our understanding of the pathophysiological mechanisms underpinning these relationships but also holds the potential to inform clinical practice by enhancing the precision of diagnostic criteria and tailoring therapeutic interventions more effectively.



The overarching goal of this study is to augment the knowledge base surrounding the cardiovascular consequences of sleep apnea, with a special focus on diastolic function. Through meticulous investigation and analysis, this work aspires to contribute significantly to the field of cardiovascular medicine, ultimately aiding in the optimization of outcomes for patients suffering from the wide spectrum of sleep apnea disorders.

# 2. Literature Review

## 2.1. Overview of Diastolic Function Characteristics in Patients with Central Sleep Apnea

In their study, Calvin et al. [22] embarked on an exploration to ascertain the relationship between left atrial size, chemosensitivity to CO2, and the occurrence of central sleep

apnea (CSA) in patients suffering from heart failure (HF). Utilizing a comprehensive methodology that incorporated polysomnography, echocardiography, and CO2 chemosensitivity measurements, the research was aimed at delineating how the physiological attributes measured via ultrasound, specifically left atrial volume index (LAVI), could serve as predictors for CSA in this patient demographic.The study sample comprised 46 patients with HF, characterized by a left ventricular ejection fraction (LVEF) ≤ 35%, who did not have obstructive sleep apnea (OSA). These participants were subjected to a detailed echocardiographic examination, wherein several parameters were meticulously measured, including LVEF, left ventricular end diastolic diameter (LVEDD), right ventricular systolic pressure (RVSP), and notably, LAVI. The LAVI measurements were particularly significant, given their role in the study's conclusions about diastolic function characteristics and their predictive value for CSA.Calvin et al.'s [22]findings illuminated a compelling correlation between increased LAVI and elevated CO2 chemosensitivity, which, in turn, was associated with a greater frequency of CSA. Specifically, they found that LAVI was significantly higher in patients with CSA compared to those without (59.2 mL/m² vs. 36.4 mL/m², P < .001). Moreover, LAVI showed a significant correlation with the log-transformed apnea-hypopnea index (AHI) (r = 0.46, P = .001), reinforcing its association with the severity of sleep-disordered breathing in the context of HF.The analysis also revealed that LAVI stood out as the best predictor of CSA, with an area under the curve (AUC) of 0.83, indicating its robustness as a diagnostic tool. The study proposed specific LAVI thresholds to gauge CSA risk, suggesting that a LAVI ≥ 53 mL/m² was associated with a 92% risk for CSA, whereas a LAVI < 33 mL/m² correlated with a 22% risk.

The implications of Calvin et al.'s [22]work extend beyond the academic, offering practical insights into the management of HF patients. Their findings suggest that



echocardiographic assessment of left atrial size, particularly through LAVI measurements, could serve as an efficient screening tool to guide clinicians in referring patients for polysomnography, thus potentially improving the diagnosis and management of CSA in the HF population.Calvin et al. [22] provide compelling evidence that enhanced LAVI is not only associated with increased CO2 chemosensitivity but also with a higher prevalence of CSA among patients with HF. Their study underscores the

importance of ultrasound characteristics, specifically LAVI, in understanding the pathophysiological link between diastolic function and sleep-disordered breathing, highlighting its utility in identifying patients at risk for CSA.

In the study conducted by Heider et al. [23], the impact of adaptive servo-ventilation (ASV) on diastolic function characteristics in patients with heart disease and preserved ejection fraction (pEF) who suffer from treatment emergent central sleep apnea (TECSA) and central sleep apnea (CSA) was rigorously examined. This retrospective, bi-centric analysis spanned five years and included 114 patients who were introduced to ASV therapy. These patients were meticulously stratified into two groups based on their sleep apnea type—TECSA or CSA—allowing for a nuanced exploration of ASV therapy's efficacy in improving not just sleep quality but also cardiac diastolic function.The methodology employed by Heider et al. [23]involved a thorough review of patient records, diagnostic polysomnography (PSG), CPAP initiation monitoring, and crucially, echocardiography results. Echocardiography, a pivotal tool for assessing diastolic function, was used to measure indicators of heart health such as left ventricular hypertrophy (LVH), left atrial enlargement, and the extent of diastolic dysfunction. Diastolic dysfunction was non-invasively assessed through tissue Doppler imaging, with a particular focus on the E/E′ ratio, a well-regarded index for evaluating left ventricular filling pressures and diastolic function.

The findings of the Heider et al. [23]study were significant, demonstrating that ASV therapy led to a marked reduction in the apnea-hypopnea index (AHI) and arousal index across both patient groups, thereby indicating an improvement in sleep quality that could indirectly benefit cardiac health by reducing the stress on the cardiovascular system associated with frequent night-time awakenings and oxygen desaturation events. More importantly, for the context of diastolic function, the study highlighted the utility of ASV



therapy in improving parameters related to heart disease in patients with pEF. Although the primary focus was on sleep quality improvements, the underlying implications for diastolic function—given the integral role of good sleep in cardiovascular health—cannot be understated.

Heider et al. [23]concluded that ASV therapy significantly enhances sleep efficiency and structure by increasing the proportions of N3 and REM sleep, which are essential for

restorative sleep. While direct measures of diastolic function improvements were not the study's focus, the significant increase in sleep efficiency and reduction in arousal and AHI indirectly suggest a positive impact on cardiac health. Given the complex interplay between sleep quality and cardiovascular function, these findings imply that ASV therapy not only aids in mitigating the symptoms of CSA and TECSA but may also have beneficial effects on the cardiac diastolic function in patients with pEF by promoting a more stable and restorative sleep pattern. Heider et al. [23]study is pivotal in understanding the broader impacts of sleep apnea treatment on cardiac health, particularly in the realm of diastolic function. By demonstrating that ASV therapy can improve sleep quality in patients with CSA and TECSA, Heider et al. [23]contribute to the growing body of evidence suggesting that effective management of sleep apnea can have significant cardioprotective effects, especially in patients with heart disease and preserved ejection fraction, where maintaining optimal diastolic function is crucial for preventing heart failure and improving overall cardiovascular outcomes.

In their study, Lanfranchi et al. [24] sought to unravel the complexities of central sleep apnea (CSA) in patients with left ventricular (LV) dysfunction without overt heart failure, delving into the prevalence, hemodynamic implications, and arrhythmic risks associated with the condition. Their research comprised a thorough investigation of 47 patients, demonstrating a remarkable prevalence of CSA—55% within this cohort—with a notable distinction between those with severe CSA (36% with an apnea-hypopnea index [AHI] >30/h) and those with less pronounced conditions. This delineation is crucial as it underscores the varied manifestation of CSA severity among individuals with asymptomatic LV dysfunction.The methodology employed by Lanfranchi et al. [24]was rigorous, encompassing a comprehensive array of diagnostic tools including Doppler echocardiography, which played a pivotal role in evaluating systolic and diastolic



function, as well as heart rate variability (HRV) measurements and sleep studies. The use of echocardiography was particularly enlightening in this context, providing valuable insights into the cardiac structure and function that remained comparable across patients regardless of CSA severity. This key finding implies that the presence and intensity of CSA in patients with LV dysfunction may not directly correlate with the degree of hemodynamic compromise, challenging preconceived notions about the pathophysiological link between CSA and cardiac function.One of the most significant

revelations from Lanfranchi et al.’s [24]study was the marked impairment in cardiac autonomic control among patients with severe CSA, evidenced by a significant reduction in HRV. This aspect is critical as HRV is a well-acknowledged predictor of cardiac morbidity and mortality, reflecting the heart's ability to respond to a variety of physiological and environmental stimuli. The study further identified a heightened incidence of nonsustained ventricular tachycardia in patients with severe CSA, illuminating the arrhythmic risk posed by CSA in the context of LV dysfunction.

Despite the lack of overt heart failure in the study cohort, the high prevalence of CSA and its association with impaired cardiac autonomic control and increased arrhythmic risk emphasize the clinical significance of recognizing and addressing CSA in patients with asymptomatic LV dysfunction. Lanfranchi et al.’s [24]work also suggests that the mechanisms underlying CSA in this patient population might not solely hinge on the degree of hemodynamic impairment but could involve a complex interplay of factors affecting respiratory and autonomic regulation.Lanfranchi et al. [24]not only illuminated the high prevalence of CSA among patients with LV dysfunction without overt heart failure but also highlighted its potential implications for arrhythmic risk and cardiac autonomic dysfunction. Their findings underscore the importance of vigilant screening for CSA in this patient group, as its identification and subsequent management may have significant implications for preventing arrhythmic complications and optimizing cardiac function. Through their meticulous approach, combining echocardiographic assessment with detailed sleep studies, Lanfranchi et al.[24]contributed valuable insights into the nuanced relationship between CSA, cardiac autonomic control, and diastolic function, paving the way for future research in this domain.



In the study conducted by Haruki et al. [25], a focused investigation was undertaken to explore the nuances of left atrial (LA) phasic function among patients suffering from heart failure with reduced ejection fraction (HFrEF), particularly differentiating between those affected by obstructive sleep apnea (OSA) and central sleep apnea (CSA). The study forms part of the broader Adaptive Servo Ventilation for Therapy of Sleep Apnea in Heart Failure (ADVENT-HF) trial, aiming to discern the impact of adaptive servo ventilation in treating sleep apnea to potentially reduce cardiovascular mortality and

hospitalizations in HFrEF patients. This particular segment of the ADVENT-HF trial scrutinized the echocardiographic data of 132 patients in sinus rhythm, distinguishing between those predominantly suffering from OSA and those with CSA, to evaluate LA functions categorized into reservoir (expansion index), conduit (passive emptying index), and booster (active emptying index) phases.The methodology integrated comprehensive echocardiographic evaluation with polysomnography, providing a robust framework for assessing the intricate relationship between sleep apnea types and LA function. Notably, the study meticulously quantified LA volumes at different cardiac cycle stages to compute the indices reflective of the various LA phasic functions. Such an approach is pivotal, as it offers insights into the mechanical efficiency of the LA, which plays a crucial role in modulating ventricular filling and overall cardiac performance, especially under the stress of HFrEF.

Haruki et al. [25]uncovered that all phasic components of LA function were significantly diminished in patients with CSA compared to those with OSA. This divergence highlights a unique aspect of CSA's impact on cardiac mechanics, underscoring the condition's potential to exacerbate the cardiac dysfunction inherent in HFrEF. Intriguingly, the study revealed that the central apnea-hypopnea index (CAHI), but not the obstructive counterpart (OAHI), exhibited a significant correlation with the impairment of LA expansion and passive emptying indices. Such findings underscore the distinct pathophysiological pathways through which CSA affects cardiac structure and function, differentiating it from OSA.

This investigation contributes critically to the understanding of the cardiac implications of sleep apnea in HFrEF. By demonstrating the differential effects of CSA and OSA on LA phasic function, Haruki et al. [25]provide compelling evidence of the former's deleterious



impact on cardiac mechanics beyond the generalized strain imposed by HFrEF. The findings underscore the necessity of identifying and appropriately managing CSA in patients with HFrEF to mitigate its adverse effects on LA function and, by extension, on overall cardiac health.Haruki et al. [25] deliver essential insights into the complex interplay between sleep apnea types and LA function in HFrEF patients. Their work elucidates the specific challenges posed by CSA, offering a foundation for future research and clinical strategies aimed at optimizing the management of HFrEF patients

afflicted by this form of sleep-disordered breathing. Through detailed echocardiographic analysis aligned with sleep study data, this study significantly advances the understanding of how CSA uniquely compromises LA phasic function, contributing to the broader discourse on the cardiovascular consequences of sleep apnea.

In the study conducted by Pelaia et al. [26], a comprehensive examination was carried out to uncover the potential association between sleep apnea (SA) and valvular heart diseases (VHD) among patients referred to a sleep disorder unit. This study, unique in its endeavor, recruited a sizable cohort of 411 patients, with 371 exhibiting SA, of which 93 had concurrent VHD. Utilizing a cross-sectional analysis approach, the study meticulously assessed the prevalence of VHD in relation to the severity of SA, measured by the apnea-hypopnea index (AHI), alongside other clinical, echocardiographic, and laboratory parameters.The findings from Pelaia et al.'s [26]investigation revealed a significant correlation between the severity of SA, as quantified by AHI values, and the incidence of VHD, highlighting a noteworthy increase in VHD prevalence with higher AHI scores. Interestingly, while obstructive sleep apnea (OSA) was predominant in SA patients without VHD, central and mixed sleep apneas were more frequently observed in those suffering from SA alongside VHD. This distinction is critical, as it not only underscores the differential pathophysiological implications of SA subtypes but also emphasizes the heightened cardiovascular risk associated with central sleep apnea (CSA) in the context of VHD.A notable aspect of the study was its reliance on comprehensive echocardiographic assessments to document and evaluate cardiac function and structure. Through these echocardiographic examinations, Pelaia et al. [26]identified a direct correlation between AHI and several key cardiovascular risk markers, including body mass index (BMI), serum uric acid



levels, high sensitivity C-reactive protein, and indexed left ventricular end-diastolic volume. These findings suggest that the impact of SA, particularly CSA, on cardiovascular health may extend beyond the traditional risk factors, implicating valvular function as a critical area of concern.Furthermore, the study posited that, after BMI, VHD emerged as a principal predictor of AHI values, illustrating the significant role VHD plays in the exacerbation and progression of SA. This relationship between SA and VHD, particularly in the context of CSA, highlights the complex interplay between respiratory

and cardiovascular systems and the importance of integrating cardiac evaluation in the management of patients with sleep-disordered breathing. The investigation by Pelaia et al., [26] sheds light on the intricate association between SA and VHD, with a particular focus on the echocardiographic characteristics and cardiovascular implications of SA in patients with valvular pathology. The study's findings underscore the necessity for clinicians to be vigilant in assessing for VHD in patients with SA, especially those presenting with central or mixed apneas, to tailor more comprehensive and effective management strategies aimed at mitigating the compounded cardiovascular risk posed by the coexistence of these conditions.

### 2.2. Overview of Diastolic Function Characteristics in Patients with Obstructive Sleep Apnea

In their study, Korcarz et al. [27] embarked on a comprehensive exploration of the long term impact of obstructive sleep apnea (OSA) on cardiac structure and function, leveraging data from the Wisconsin Sleep Cohort Study. This prospective observational study meticulously followed 601 participants over a mean span of 18 years, employing overnight polysomnography and subsequent transthoracic echocardiography to assess a range of cardiac parameters. The study's objective was to delineate the prospective associations between OSA, characterized by the apnea-hypopnea index (AHI), and subsequent echocardiographic manifestations of adverse cardiac remodeling, including assessments of left ventricular (LV) and right ventricular (RV) function and morphology.Key findings from this study underscore the significant, independent association of OSA with several critical markers of cardiac health. After adjusting for age, sex, and body mass index (BMI), higher baseline AHI levels were significantly linked to future reductions in LV ejection fraction and an increased likelihood of



diminished RV function, as indicated by tricuspid annular plane systolic excursion (TAPSE) ≤ 15 mm. These associations persisted even after further adjustments for cardiovascular risk factors, highlighting the intrinsic relationship between OSA and cardiac remodeling.The study also conducted secondary analyses examining the relationship between oxygen desaturation indices and future echocardiographic findings. These analyses revealed that nocturnal hypoxia, as indicated by SaO2 desaturation, was independently associated with increased LV mass, LV wall thickness, and RV area.

Such findings suggest that the hypoxic stress associated with OSA may act as a stimulus for cardiac hypertrophy, further implicating OSA as a significant factor in the pathogenesis of cardiac remodeling.

Korcarz et al.'s [27]investigation into the long-term cardiac consequences of OSA provides valuable insights into how OSA contributes to adverse changes in cardiac structure and function. The study's longitudinal design, combined with its comprehensive echocardiographic evaluations, offers robust evidence of OSA's role in promoting cardiac remodeling. By demonstrating the independent effects of OSA, beyond the confounding influences of obesity, on markers of cardiac health, this research underscores the necessity of recognizing and addressing OSA as a significant risk factor for cardiac dysfunction.Korcarz et al. [27]have contributed significantly to our understanding of OSA's impact on the heart. Their findings illustrate the detrimental effects of OSA on both LV and RV function and structure, independent of traditional cardiovascular risk factors. This study emphasizes the critical need for early detection and effective management of OSA to mitigate its potential to induce or exacerbate cardiac remodeling, offering a compelling case for considering OSA in the broader context of cardiovascular disease risk assessment and management.

In the study conducted by Papanikolaou et al. [28], the researchers embarked on an investigative journey to understand the impact of severe obstructive sleep apnea syndrome (OSAS) on left ventricular (LV) diastolic dysfunction, focusing on a cohort without any cardiovascular or oxidative stress-related comorbidities. Their work is significant, delving into a relatively unexplored territory where the direct effects of OSAS on cardiac function are isolated from the confounding influence of other comorbid conditions. The study analyzed 42 men diagnosed with severe OSAS, defined by an



apnea-hypopnea index (AHI) greater than 30, compared to 25 control subjects with an AHI less than 5, providing a clear demarcation between affected individuals and healthy controls.A key strength of Papanikolaou et al.’s [28]methodology lies in its comprehensive assessment protocol, which included detailed echocardiographic evaluations alongside polysomnographic, clinical, and laboratory analyses. This allowed for a nuanced exploration of diastolic function through conventional and Tissue Doppler Imaging (TDI) parameters, thereby shedding light on subtle cardiac dysfunctions not

attributable to comorbidities but rather to OSAS itself.The study's findings reveal a significant association between severe OSAS and LV diastolic dysfunction. Notably, it was observed that the severity of OSAS, as quantified by the AHI, independently contributes to the likelihood of diastolic dysfunction. This suggests that the mechanical and hypoxic stressors inherent in OSAS may lead to cardiac remodeling and impaired diastolic function, a conclusion further substantiated by the study's logistic regression analysis, which identified advanced age and AHI as independent predictors of diastolic dysfunction in the OSAS group.

Furthermore, Papanikolaou et al. [28]provided valuable insights into the pathophysiological mechanisms underpinning this association. By evaluating biomarkers of oxidative stress and hypoxia-induced angiogenesis, they illuminated the complex interplay between systemic inflammation, oxidative stress, and cardiac dysfunction in OSAS patients. Their findings suggest that OSAS severity, marked by nocturnal hypoxemia and repetitive apneic events, may incite oxidative stress pathways, contributing to the onset and progression of diastolic dysfunction.Papanikolaou et al.'s [28]study enriches the current understanding of the cardiovascular implications of severe OSAS, highlighting its independent role in precipitating LV diastolic dysfunction. By focusing on a cohort devoid of traditional cardiovascular risk factors, the study underscores the intrinsic impact of OSAS on cardiac health and stresses the importance of early detection and management of diastolic dysfunction in patients with severe OSAS. This work lays a foundation for future investigations into therapeutic strategies aimed at mitigating the cardiac sequelae of OSAS, thereby potentially improving outcomes for this patient population.



In their study, Touil et al., [29] embarked on elucidating the impacts of obstructive sleep apnea (OSA) on cardiac structure and function through detailed echocardiographic analysis. This cross-sectional study uniquely focused on patients with polygraphy confirmed OSA, devoid of cardiovascular or pulmonary comorbidities, to isolate the effects of OSA on the heart. The cohort consisted of 93 patients, divided based on the severity of OSA as determined by the apnea-hypopnea index (AHI), into mild to moderate (AHI<30) and severe (AHI≥30) groups.Key findings from this study pointed

towards a more pronounced incidence of left ventricular (LV) diastolic dysfunction, alongside increased right ventricular internal diameter (RVID) and systolic pulmonary artery pressure (sPAP) in patients with severe OSA. Notably, the study established that RVID was independently associated with the severity of OSA, a revelation that underscores the systemic impact of OSA on cardiac dimensions and pressures.Despite the absence of statistically significant differences in left ventricular end-systolic (LVES) and end-diastolic (LVED) diameters, and interventricular septum (IVS) thickness between the severe and mild to moderate OSA groups, the observed trend towards higher measurements in the severe OSA group hints at the potential for OSA to induce cardiac remodeling. The lack of significant difference, particularly in the LVES and LVED diameters, could be attributed to the small sample size or the study's cross-sectional nature, which may mask subtler changes in cardiac geometry over time.Furthermore, Touil et al., [29]provided valuable insights into the relationship between OSA severity and pulmonary hypertension. Their findings corroborate the theory that OSA, through mechanisms of nocturnal hypoxemia and increased venous return during apneic events, may contribute to elevated pulmonary pressures, a precursor to more deleterious cardiovascular outcomes.The study's focus on a population without cardiovascular or pulmonary comorbidities enhances its significance, as it isolates OSA as a potential independent factor in the pathogenesis of cardiac alterations. This methodological choice enables a clearer interpretation of the direct effects of OSA on cardiac structure and function, free from the confounding influences of pre-existing cardiac or pulmonary conditions. The study by Touil et al. [29] advances the understanding of OSA's impact on the heart, highlighting its role in the development of LV diastolic dysfunction and alterations in right ventricular dimensions and pulmonary pressures. These findings



underscore the critical need for early detection and management of OSA to mitigate its cardiovascular sequelae, offering a compelling argument for the inclusion of echocardiographic assessment in the diagnostic workup of patients with suspected or confirmed OSA.

In the study conducted by Chetan et al. [30], the researchers delved into the intricacies of obstructive sleep apnea (OSA) and its effects on right ventricular (RV) subclinical myocardial dysfunction, emphasizing the role of advanced echocardiographic

techniques like speckle tracking echocardiography (STE) for early detection. Their investigation underscores OSA's significant cardiovascular disease risk factor, potentially leading to pulmonary hypertension, heart failure, and cardiovascular death if left unchecked.The core of their analysis rested on the premise that while standard echocardiographic parameters are traditionally employed to assess the consequences of OSA on the heart, these methods falter in early RV dysfunction detection due to the RV's complex geometry and the significant impact of pre- and afterload. To bridge this gap, Chetan and colleagues [30]proposed the utilization of speckle tracking echocardiography for its superior sensitivity in unveiling RV functional alterations when conventional echocardiographic methods fall short.The significance of this study lies in its focus on identifying patients with OSA who exhibit subclinical myocardial dysfunction, posing a heightened risk for developing heart failure and subsequent adverse events. The researchers argue for the pivotal role of STE in detecting early stages of RV dysfunction, thereby facilitating improved risk stratification and timely therapeutic intervention.

Through their comprehensive review, Chetan et al.,[30]highlight the utility of advanced echocardiographic parameters beyond the routine assessment, providing a deeper insight into the subclinical myocardial dysfunction in OSA patients. This approach aligns with the growing recognition of OSA's role in cardiovascular morbidity and mortality, as acknowledged by authoritative bodies like the American Heart Association.Moreover, the study brings to light the limitations of standard echocardiographic measurements in capturing the full extent of RV dysfunction in OSA patients, thus reinforcing the necessity for innovative techniques such as STE in the cardiac evaluation of this population. The authors advocate for a more nuanced and detailed examination of the



RV, leveraging the advantages of 3D echocardiography and STE to surpass the conventional methods' constraints. The work of Chetan et al., [30] contributes significantly to the understanding of OSA's impact on the heart, particularly on the right ventricle, by employing advanced echocardiographic techniques for early detection and management of subclinical myocardial dysfunction. This study underscores the critical need for an integrated approach in diagnosing and treating OSA patients, highlighting the importance of echocardiography in preempting cardiovascular complications.

In their comprehensive review, Sascau et al. [31] delved into the echocardiographic manifestations of obstructive sleep apnea (OSA) and underscored the condition's complex interplay with cardiovascular health. They aimed to elucidate how moderate and severe forms of OSA contribute to atrial enlargement and impact left ventricular diastolic function, progressing towards systolic dysfunction. Their focus on the utility of advanced echocardiographic techniques, such as three-dimensional echocardiography for right ventricular ejection fraction assessment, highlights the limitations of bidimensional imaging and traditional measures in capturing the full scope of myocardial impairment.The review accentuates tissue Doppler imaging's sensitivity in detecting ventricular functional impairments, albeit with its limitations, including angle dependency and the impact of tethering forces. Speckle tracking echocardiography emerges as a superior modality for assessing ventricular function, capable of differentiating between active and passive wall motion and identifying subclinical myocardial dysfunction through abnormal strain values. This is particularly noteworthy in patients with normal ejection fraction and chamber volumes, where left ventricular longitudinal strain is more adversely affected by OSA than circumferential strain values.

Sascau et al., [31] underscore the subtlety of OSA-induced changes in cardiac function and structure, advocating for detailed echocardiographic screening to identify early signs of heart failure in OSA patients. This approach could potentially improve therapy adherence and outcomes, emphasizing the need for further research to establish the clinical benefit of such screenings.Their findings suggest a significant correlation between severe OSA and alterations in left ventricular diastolic function, right ventricular internal diameter (RVID), and systolic pulmonary artery pressure (sPAP), underscoring the independent association of RVID with OSA severity. The nuanced understanding



provided by Sascau et al. [31]about OSA's impact on diastolic function and the value of advanced echocardiographic techniques in detecting early myocardial dysfunction underscores the importance of incorporating these modalities into the routine assessment of patients with OSA. This insight is crucial for clinicians aiming to mitigate cardiovascular risks in this patient population, highlighting the importance of early detection and intervention to prevent the progression to heart failure and other adverse cardiovascular outcomes.

In the study conducted by Moro et al. [32], the focus was on elucidating the echocardiographic changes associated with Sleep Apnea-Hypopnea Syndrome (SAHS) and understanding how these changes are influenced by hypertension, a common comorbidity. The researchers undertook a comprehensive examination of 103 consecutive patients diagnosed with SAHS, of which 49 had high blood pressure (HBP) and 54 did not, in comparison to 24 control subjects matched for age and body mass index (BMI). Employing Doppler echocardiography, they meticulously assessed both the morphological and functional aspects of the heart, including wall thickness, diameters, ejection fraction, peak E and A wave velocities, mitral deceleration time, and Tei index.The findings revealed significant morphological changes indicative of left ventricular hypertrophy in hypertensive SAHS patients compared to their non hypertensive counterparts, with increased septal and posterior wall thicknesses. Furthermore, both groups of SAHS patients, regardless of their blood pressure status, exhibited larger changes than the control group, suggesting that SAHS independently contributes to left ventricular remodeling. Importantly, there were notable differences in ventricular filling patterns, with a significantly higher prevalence of impaired biventricular filling in the SAHS groups, particularly among those with concomitant HBP.An intriguing trend towards an enlarged left ventricular Tei index in the SAHS group, although not reaching statistical significance, hints at a subtle deterioration in myocardial performance possibly attributable to SAHS. The study's results underscore the significant cardiac involvement in SAHS, characterized by left ventricular hypertrophy and diastolic dysfunction, which is further exacerbated by the presence of hypertension.Moro et al.'s [32]investigation provides critical insights into the cardiac implications of SAHS, independent of hypertension, reinforcing the importance of early



cardiac evaluation in SAHS patients. The association between SAHS and structural as well as functional cardiac alterations highlights the necessity for a multidisciplinary approach to managing patients with SAHS, incorporating cardiovascular assessment and monitoring to preemptively address the heightened risk of cardiac morbidity. This study contributes to the growing body of evidence linking SAHS with adverse cardiac outcomes and underscores the potential benefits of integrating echocardiographic screening into the routine evaluation of patients diagnosed with SAHS.

In their study, Cunha et al. [33] explored the relationship between obstructive sleep apnea (OSA) and left ventricular diastolic function, emphasizing the utilization of echocardiography as a diagnostic tool. They focused on a cohort of 354 individuals assessed for OSA risk using the Berlin Questionnaire, with 63% identified as high-risk. This approach underscores the practical challenges in diagnosing OSA, where the reliance on questionnaires or clinical prediction algorithms, despite their accessibility, often results in low diagnostic accuracy compared to the gold standard of polysomnography. The study reflects on the broader context of OSA's cardiovascular implications, notably its association with left ventricular diastolic dysfunction, highlighted through increased left atrial volume and altered mitral flow indices.Cunha et al.'s[33] (2019) findings resonate with the existing literature that associates moderate to severe OSA with significant cardiovascular alterations, including left atrial dilation, left ventricular hypertrophy, and diastolic function impairment. This correlation emphasizes OSA's role in precipitating or exacerbating cardiac structural changes, which could potentially progress to heart failure if left unaddressed. The study also points to the potential benefits of OSA treatment in preserving left ventricular structure and function, indicating a need for timely diagnosis and intervention.Furthermore, the study brings to light the evolving echocardiographic techniques that enhance the understanding of OSA's cardiovascular impact. Advanced methods like three-dimensional echocardiography and speckle-tracking echocardiography offer superior insights into myocardial dysfunction, enabling the detection of subclinical alterations even in patients with normal ejection fraction and chamber volumes. The longitudinal strain of the left ventricle, in particular, is identified as significantly impacted by OSA, marking a critical area for further research and clinical assessment. The study by Cunha et al.



[33]underscores the significant interplay between OSA and left ventricular diastolic function, highlighting echocardiography's pivotal role in identifying early cardiac involvement. Their work contributes to a growing body of evidence that stresses the importance of comprehensive cardiovascular evaluation in patients with OSA. It also underscores the need for integrating advanced echocardiographic techniques in the clinical workflow, to improve the detection, risk stratification, and management of patients suffering from this widespread but often underdiagnosed condition.

In their study, Arias et al. [34]investigated the impact of obstructive sleep apnea syndrome (OSAS) on left ventricular diastolic function and the potential therapeutic effects of nasal continuous positive airway pressure (nCPAP). The study involved 27 middle-aged men newly diagnosed with OSAS, who were free from other factors that could affect diastolic function, and 15 healthy control subjects. This prospective, randomized, placebo-controlled, double-blind crossover study aimed to determine if OSAS acts as an independent risk factor for left ventricular diastolic abnormalities and whether nCPAP could ameliorate such alterations by eliminating apneic events.At the outset, an abnormal left ventricular filling pattern was significantly more prevalent among OSAS patients compared to the control group, indicating impaired relaxation as the predominant abnormal pattern. The introduction of effective nCPAP for 12 weeks resulted in notable improvements in diastolic function among the OSAS patients, evidenced by a significant increase in the E/A ratio and reductions in both mitral deceleration and isovolumic relaxation times.These findings support the hypothesis that OSAS independently affects left ventricular diastolic function. More importantly, they demonstrate the potential for nCPAP therapy to not only halt the progression of diastolic abnormalities in OSAS patients but possibly reverse these changes, particularly in the early stages before severe structural adaptations occur. This study is pivotal as it underscores the importance of recognizing and treating OSAS not only to alleviate respiratory symptoms but also to address its cardiovascular implications, specifically regarding diastolic dysfunction.Arias et al.'s [34]work adds significant value to the existing body of research on the cardiovascular consequences of OSAS and the therapeutic benefits of nCPAP. By showing that nCPAP therapy can improve diastolic function in OSAS patients, this study highlights a crucial intervention strategy that could



prevent the progression to heart failure in this high-risk population. The study's rigorous design and conclusive findings underscore the need for early diagnosis and treatment of OSAS to mitigate its cardiovascular sequelae, marking a significant step forward in the management of patients with this common but often underdiagnosed condition.

## 3. Comparative Analysis of Findings

### 3.1. Comparison of Diastolic Function Characteristics Between CSA and OSA

The comparative analysis of diastolic function between patients with Central Sleep Apnea (CSA) and Obstructive Sleep Apnea (OSA) through ultrasound characteristics

reveals a nuanced landscape of cardiovascular involvement across these conditions. Utilizing echocardiography, researchers have delineated distinct impacts on cardiac structure and function, with implications for the pathophysiological understanding and clinical management of sleep apnea.

CSA, characterized by a cessation of airflow without respiratory effort due to neurological instability, has shown unique echocardiographic findings. Calvin et al. [22] highlighted the predictive value of the left atrial volume index (LAVI) in CSA, noting significantly higher LAVI in patients with CSA than those without. This correlation underscores the influence of CSA on atrial enlargement, a surrogate marker for diastolic dysfunction, reflecting increased left atrial pressure and volume due to impaired ventricular filling. Furthermore, Lanfranchi et al. [24]explored CSA in patients with left ventricular (LV) dysfunction, finding a high prevalence of CSA without overt heart failure. Their echocardiographic analysis did not directly correlate CSA severity with hemodynamic compromise, suggesting that CSA's impact on cardiac structure might be independent of ventricular dysfunction severity.

Conversely, OSA is marked by repetitive upper airway collapses leading to nocturnal hypoxemia and intrathoracic pressure swings, impacting cardiac function differently. Korcarz et al. [27], through the Wisconsin Sleep Cohort Study, elucidated OSA's long term cardiac consequences, finding an independent association between baseline apnea-hypopnea index (AHI) and future reductions in LV ejection fraction. This longitudinal insight into OSA's role in promoting cardiac remodeling—particularly LV systolic and diastolic dysfunction—highlights the cumulative burden of recurrent hypoxic events on cardiac health. Similarly, Papanikolaou et al. [28] focused on severe OSA and its linkage to LV diastolic dysfunction, demonstrating that severe OSA, devoid of



cardiovascular comorbidities, independently contributes to diastolic dysfunction, as evidenced by alterations in Tissue Doppler Imaging parameters.

The critical comparison between CSA and OSA unveils both shared and distinct ultrasound characteristics of diastolic function. While CSA's impact is subtly marked by an association with atrial enlargement, reflecting direct effects on diastolic pressures and

volumes, OSA predominantly manifests through ventricular remodeling—evidenced by decreased ejection fraction and diastolic dysfunction. This divergence possibly stems from the pathophysiological mechanisms underlying each condition; CSA's impact is closely tied to neurohumoral imbalances affecting cardiac preload and afterload, whereas OSA exerts its influence through recurrent hypoxemic insults and increased intrathoracic pressure variability, leading to myocardial stress and eventual remodeling.

Moreover, the echocardiographic observation of RV dysfunction and increased pulmonary pressures in severe OSA cases, as highlighted by Touil et al. [29], contrasts with the CSA findings, where such direct correlations are less pronounced. This distinction emphasizes the broader cardiovascular impact of OSA, extending beyond LV diastolic dysfunction to encompass RV impairment and pulmonary hypertension, likely due to the added burden of intrathoracic pressure swings and hypoxia-reoxygenation cycles inherent in OSA.

Furthermore, advanced echocardiographic techniques, such as speckle tracking echocardiography, have refined our understanding of myocardial dysfunction in sleep apnea. Studies like that of Chetan et al. [30] and Sascau et al. [31] underscore the utility of these methods in detecting subclinical myocardial dysfunction, offering insights into the early stages of cardiac involvement that traditional measures might miss. This advanced imaging capability reveals the intricate details of ventricular strain patterns, augmenting the detection of diastolic dysfunction in both CSA and OSA, albeit with nuanced differences reflective of each condition's unique pathophysiological impact on cardiac function.

The comparative analysis of CSA and OSA through echocardiographic lenses reveals critical insights into how these conditions differentially impact cardiac diastolic function.



While CSA is predominantly associated with atrial enlargement and subtle ventricular changes, OSA exerts a more pronounced effect on both ventricular remodeling and pulmonary pressures. These distinctions underscore the importance of tailored screening and management strategies for patients with sleep apnea, emphasizing the role of advanced echocardiographic techniques in unveiling the complex cardiovascular sequelae of these conditions. Future research should further elucidate these differences,

guiding clinical practice towards more personalized approaches in the diagnosis, monitoring, and treatment of sleep apnea-related cardiac dysfunction.

### 3.2. Discussion of Unique and Overlapping Features

The intersection of central sleep apnea (CSA) and obstructive sleep apnea (OSA) with cardiac diastolic function, as delineated through ultrasound characteristics, reveals a complex array of unique and overlapping features that underscore the nuanced interplay between sleep-disordered breathing and cardiovascular health. Echocardiographic evaluations provide a window into the cardiac alterations influenced by these distinct sleep apnea syndromes, highlighting their differential impacts on the heart's diastolic phase.

CSA, primarily characterized by a lack of respiratory effort during sleep, manifests unique echocardiographic characteristics, particularly concerning left atrial size and function. Studies such as Calvin et al. [22] have shown that left atrial volume index (LAVI) is significantly increased in patients with CSA, suggesting an augmented left atrial size that is closely associated with the severity of CSA. This increase in LAVI underscores a predisposition towards atrial stretch and strain, which may precipitate atrial fibrillation or contribute to heart failure with preserved ejection fraction (HFpEF), conditions closely linked with diastolic dysfunction. Furthermore, Lanfranchi et al. [24]observed that despite the presence of CSA in patients with left ventricular dysfunction, echocardiographic parameters of cardiac structure and function remained comparable to those without CSA, suggesting that CSA’s impact on diastolic function might be mediated through mechanisms independent of direct cardiac structural changes.



In contrast, OSA is marked by repetitive episodes of airway obstruction, leading to distinctive echocardiographic findings related to ventricular structure and function. Korcarz et al. [27]and Papanikolaou et al. [28] highlighted the association of OSA with increased left ventricular mass and alterations in diastolic function parameters, such as the E/e' ratio, indicative of elevated left ventricular filling pressures. These changes reflect the direct impact of OSA-induced intrathoracic pressure swings and nocturnal

hypoxemia on the myocardium, fostering ventricular hypertrophy and diastolic dysfunction. Moreover, the presence of right ventricular dilation and altered systolic pulmonary artery pressures, as demonstrated by Touil et al. [29], points to the broader cardiovascular ramifications of OSA, encompassing pulmonary hypertension and right heart strain, which further complicates the diastolic dysfunction landscape.

The overlap between CSA and OSA in terms of diastolic dysfunction is notable in their shared propensity to exacerbate left ventricular filling pressures and impair diastolic relaxation, albeit via different pathophysiological pathways. While CSA's influence on diastolic function might predominantly arise from its association with conditions like HFpEF, wherein diastolic dysfunction is a hallmark feature, OSA directly contributes to diastolic dysfunction through mechanisms such as myocardial ischemia, hypoxemia induced oxidative stress, and systemic inflammation. These shared outcomes underscore the critical role of echocardiography in identifying diastolic dysfunction early in patients with sleep-disordered breathing, facilitating timely intervention.

Advanced echocardiographic techniques such as speckle tracking echocardiography (STE), as discussed by Chetan et al. [30], offer further insights into the myocardial strain patterns uniquely affected by OSA and CSA. STE's ability to detect subtle myocardial dysfunction that traditional echocardiographic parameters may miss illuminates the early myocardial changes induced by sleep apnea, providing a more nuanced understanding of its impact on diastolic function.

In summary, the distinct and overlapping echocardiographic characteristics of diastolic function in CSA and OSA highlight the intricate relationship between sleep-disordered breathing and cardiovascular health. CSA's association with increased left atrial size



and potential for atrial fibrillation contrasts with OSA's direct impact on ventricular hypertrophy, diastolic dysfunction, and pulmonary hypertension. Yet, both conditions converge in their capacity to detrimentally affect diastolic relaxation and filling pressures, underscoring the importance of comprehensive echocardiographic evaluation in patients with sleep apnea. Through advanced imaging techniques and a deeper understanding of these relationships, clinicians can better tailor interventions to mitigate the

cardiovascular consequences of sleep-disordered breathing, enhancing patient outcomes in this complex interplay between respiratory and cardiovascular systems.

## 4. Conclusions

The complex interplay between Central Sleep Apnea (CSA) and Obstructive Sleep Apnea (OSA) and their implications for cardiac health, particularly diastolic function, has emerged as a focal point in cardiovascular and sleep medicine research. This concluding chapter synthesizes our current understanding, drawing on a comparative analysis of findings to highlight the nuanced impacts of these sleep disorders on diastolic function and the overarching implications for clinical practice.

CSA and OSA represent two spectrums of sleep-disordered breathing, each with distinct pathophysiological underpinnings. CSA, characterized by the cessation of airflow despite respiratory effort, is often associated with conditions like heart failure, where it exacerbates cardiovascular stress through mechanisms tied to neurohumoral imbalances. OSA, on the other hand, results from physical obstruction of the airway, leading to repeated episodes of nocturnal hypoxemia and intrathoracic pressure fluctuations. These episodes impose significant mechanical stress on the cardiac structure, promoting hypertrophy and impairing myocardial relaxation.

Diastolic function, the heart's capacity to relax and fill during the diastolic phase, is crucial for maintaining adequate cardiac output and blood pressure. It is modulated by complex interactions between myocardial compliance, preload, afterload, and ventricular relaxation efficiency. Echocardiography, through parameters such as E/A ratio, left atrial



size, and tissue Doppler imaging, serves as a cornerstone for assessing diastolic function, offering insights into the early detection of diastolic dysfunction—a precursor to heart failure with preserved ejection fraction (HFpEF) and atrial fibrillation.

The comparative analysis underscored distinct echocardiographic characteristics associated with CSA and OSA, highlighting their differential impacts on cardiac structure and diastolic function. In CSA, the key findings revolved around increased left atrial

volume index (LAVI), signifying atrial enlargement and heightened atrial stress, which correlate with the severity of apnea. Such changes underscore the direct impact of CSA on the atrial chamber, potentially exacerbating conditions like HFpEF.

Conversely, OSA's influence on diastolic function is marked by more pronounced ventricular remodeling, evidenced by increased left ventricular mass, alterations in diastolic function parameters like the E/e' ratio, and the emergence of right ventricular dysfunction in severe cases. These alterations reflect the cumulative burden of OSA on the ventricular myocardium, driven by hypoxic stress and intrathoracic pressure swings, which precipitate myocardial hypertrophy and compromise diastolic relaxation.

The overlay of CSA and OSA effects reveals a shared propensity to impair diastolic function, albeit via distinct mechanisms. CSA's association with conditions fostering diastolic dysfunction, like HFpEF, contrasts with OSA's direct induction of cardiac remodeling and dysfunction. Nonetheless, both conditions converge in their potential to detrimentally affect myocardial relaxation and filling pressures, underscoring the imperative for comprehensive cardiovascular evaluation in patients with sleep disordered breathing.

The findings from the comparative analysis not only highlight the unique and overlapping echocardiographic features of CSA and OSA but also underscore the importance of recognizing and addressing these sleep disorders within the cardiac care continuum. Advanced echocardiographic techniques, such as speckle tracking echocardiography, have enhanced our capacity to detect subtle myocardial dysfunction early, offering a more nuanced understanding of the cardiovascular sequelae of sleep apnea.



The intricate relationship between CSA, OSA, and diastolic function underscores the complexity of sleep-disordered breathing as a cardiovascular risk factor. This analysis highlights the critical need for integrated approaches in the diagnosis and management of sleep apnea, emphasizing the role of echocardiography in uncovering the early signs of cardiac involvement. Future research should aim to further elucidate these relationships, guiding clinical strategies towards personalized management of sleep apnea, with an eye toward mitigating its cardiovascular implications and enhancing

patient outcomes.

### 3.3. Limitations

The study's reliance on existing literature to draw conclusions about the impact of sleep apnea on diastolic function brings forth several limitations that are crucial for the interpretation and application of the findings.Firstly, the heterogeneity in study designs across the analyzed literature poses a significant limitation. The included studies vary in their methodologies, including differences in sample sizes, demographic characteristics of the populations studied (such as age, sex, and presence of comorbid conditions), and the severity of sleep apnea. Such variability can introduce biases and confounders that may influence the generalizability of the findings. Moreover, differences in the echocardiographic techniques and parameters used to assess diastolic function across studies add another layer of complexity, potentially affecting the consistency and comparability of the results.Another critical limitation is the observational nature of many studies included in this review. While observational studies provide valuable insights into associations between sleep apnea and diastolic function, they cannot establish causality. This limitation is particularly pertinent given the multifactorial etiology of diastolic dysfunction, which can be influenced by various factors beyond sleep apnea, such as hypertension, diabetes, and obesity. Without the ability to control for all these variables, the extent to which sleep apnea independently contributes to diastolic dysfunction remains uncertain.

The retrospective design of some studies further limits the ability to ascertain temporal relationships between sleep apnea and changes in diastolic function. Retrospective



analyses are inherently constrained by the accuracy and completeness of the recorded data, which may not always capture the dynamic nature of sleep apnea and its long term impact on cardiac structure and function.Additionally, the majority of the reviewed literature focuses on populations with either CSA or OSA, with fewer studies examining the effects of mixed sleep apnea or the comparative impacts of these conditions on diastolic function. This gap in the literature restricts a comprehensive understanding of how different forms of sleep apnea might uniquely or collectively influence cardiac

diastolic function.Lastly, the reliance on published studies introduces a publication bias, where studies reporting significant findings are more likely to be published than those with null or negative results. This bias could skew the overall understanding of the relationship between sleep apnea and diastolic function, emphasizing the need for cautious interpretation of the review's findings.While this literature study provides valuable insights into the effects of CSA and OSA on diastolic function, the aforementioned limitations highlight the challenges in drawing definitive conclusions. These constraints underscore the importance of interpreting the findings within the context of the existing literature's methodological diversity, observational nature, and potential biases.

### 3.4. Future Research

The exploration of diastolic function in patients with Central and Obstructive Sleep Apnea (CSA and OSA) through the lens of echocardiography has opened new avenues for understanding the cardiovascular implications of sleep-disordered breathing. However, the limitations inherent in the current body of literature underscore the necessity for future research to address these gaps and refine our understanding.Firstly, prospective longitudinal studies are critically needed to establish causal relationships between sleep apnea (both CSA and OSA) and diastolic dysfunction. Such studies should aim to follow cohorts over time to assess how the initiation and progression of sleep apnea impact cardiac structure and function, controlling for potential confounders like hypertension, obesity, and diabetes. This approach would allow for a clearer delineation of the temporal sequence and causality, providing stronger evidence for sleep apnea’s role in the development of diastolic dysfunction.Secondly, there is a



pressing need for research employing uniform and standardized echocardiographic techniques and parameters to assess diastolic function. The adoption of standardized protocols across studies would facilitate more consistent and comparable results, enhancing the reliability and generalizability of findings. Future studies should also leverage advanced echocardiographic techniques, such as speckle tracking echocardiography, to uncover subtle myocardial changes that conventional methods may overlook. This detailed analysis could reveal early markers of diastolic dysfunction

in sleep apnea patients, aiding in the timely identification and management of at-risk individuals.

Moreover, the impact of therapeutic interventions for sleep apnea on diastolic function warrants further exploration. Randomized controlled trials comparing the efficacy of various treatments (e.g., CPAP, dental appliances, weight loss interventions) in improving or reversing diastolic dysfunction among sleep apnea patients would provide valuable insights into optimal management strategies. Additionally, the exploration of the differential effects of CSA and OSA treatment on cardiac outcomes could guide more personalized therapeutic approaches.Furthermore, future research should aim to explore the mechanisms underlying the relationship between sleep apnea and diastolic dysfunction. Investigating the role of inflammation, oxidative stress, and neurohormonal activation in this context could elucidate the pathophysiological pathways involved, offering targets for novel therapeutic interventions.

Lastly, studies examining the effects of mixed sleep apnea on diastolic function are scarce. Given the potential for unique or additive impacts of mixed sleep apnea on the heart, this represents an important area for future investigation. Understanding the cardiovascular consequences of combined CSA and OSA would fill a significant gap in the literature and inform comprehensive patient care.Addressing these areas in future research would significantly enhance our understanding of the complex interplay between sleep apnea and diastolic dysfunction. By overcoming the current limitations and expanding our knowledge base, we can move closer to effective screening, prevention, and treatment strategies for the cardiovascular manifestations of sleep disordered breathing.

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