Evaluation of the Relationship between Left Atrium Volume and Myocardial Ischemia: A Systematic Review

Abstract

Introduction: The pathophysiology of ischemia involves the cellular effect of myocardial ischemia, reactive oxygen species, and Reactive inflammatory enzymes to form cascade. Left atrial (LA) ischemia has been shown to have several possible mechanisms through which it can lead to abnormalities in left ventricular filling in early diastole and thus reduce LA passive functional reserve. In this review study, we evaluated the physiological mechanisms of LA during myocardial ischemia, as previously demonstrated in experimental and clinical studies.

Methods: Several databases were searched in order to find related articles. The outcome of interest included LA function measurements (measurement of left atrial volume) during ischemia. By applying a standardized protocol, reviewers independently abstracted and assessed the studies.

Results: The literature review indicated 50 publications, among which 15 studies were eligible for analysis. Articles reporting outcomes from the same study were included once in the analysis.

Discussion: Assessment of LA dimension and function is essential for clinical evaluation and prognostic purposes. In the present article, it was revealed that LA passive emptying volume and LA emptying volume significantly increased in myocardial ischemic patients.

Conclusion: Further research could provide a better understanding of pathophysiological mechanisms behind LA enlargement and help predict clinical outcomes in many cardiovascular disorders.

Keywords: myocardial ischemia, left atrium, Atrium Volume
Introduction

Ischemia occurs when an organ is deprived of blood flow, resulting in inadequate oxygen and nutrient supply (1). Ischemia has been implicated in the pathology of peripheral vascular insufficiency (1), angina, myocardial infarction and stroke (2).

Ischemic preconditioning (with brief intermittent periods of ischemia, followed by reperfusion prior to prolonged ischemia) and ischemic postconditioning (immediately after a period of ischemia before the onset of reperfusion) have been shown to reduce myocardial ischemic injury (3). Myocardial reperfusion injury has been postulated to partially explain these outcomes. However, the ischemic myocardium reduces its metabolic needs and tends to adopt itself to survive with minimal requirements by reducing its own contractility and the mechanisms responsible for the development of myocardial hibernation in which the heart reduces the contractile function in proportion to reduced blood flow are yet to be identified (1).

Several recent studies have assessed the structure and function of left atrium (LA). Particular attention has been paid to LA and changes of LA structure, caused by a wide range of pathologies (4). LA function has been traditionally described in three phases: reservoir (the filling phase during ventricular systole), conduit (passive emptying phase during early diastole), and contraction (the pumping phase in late diastole) (5). Moreover, LA impairment has been associated with heart failure, Aging, and other cardiovascular disorders such as atrial fibrillation, hypertension, and hypertrophic cardiomyopathy (6).

LA ischemia has been shown to have several possible mechanisms through which it can lead to abnormalities in left ventricular filling in early diastole and thus reduce passive LA functional reserve (7). Myocardial relaxation is an exquisitely energy-dependent process, which is highly sensitive to the effects of ischemia; moreover, subendocardial longitudinal fibers are particularly
sensitive to ischemia. This leads to incoordination or asynchronicity between circumferential and longitudinal fibers in ischemic areas, as well as a reduction in longitudinal contractile function that may not be initially detectable but could lead to diminished ventricular suction (8).

The present systematic review aimed to discuss the pathophysiological mechanisms of LA during myocardial ischemia, as demonstrated by previous experimental and clinical studies.

**Methods**

*Data sources and search strategy*

The present systematic review was carried out in accordance with the preferred reporting items for systematic reviews and analysis guidelines (9). We searched the literature using the method of keyword search in databases including PubMed, Scopus, Web of Science (WOS), and Google Scholar.

The following Mesh, EMTREE, and keyword search terms were used in combination: ischemia, myocardial infarction, and left atrium (LA). To identify further articles, we searched through citations in review articles and commentaries, which discussed the results in previous studies.

*Data extraction*

The reviewers independently extracted the data on the evaluated populations, patient characteristics, and relevant measured outcomes. We did not specify the definitions of prior outcomes, and they were accepted as defined in individual studies. The measured outcomes were markers of ischemia, myocardial ischemia, and indices of regional LA function. Regional atrial functions were determined by LA function during myocardial ischemia.

*Quality assessment*

A significant body of animal and human experimental data has shown that during an ischemic insult, changes in diastolic left ventricle (LV) function occur before any changes in systolic wall
motion. Thus, relying on detection of systolic wall motion abnormalities alone may result in missing some patients with early ischemia. Similarly, changes in LA function during angioplasty have been shown to precede changes in LV systolic function (8). Nowadays, area and volume measurements are preferred for assessing LA dimensions, as they were shown to correlate better with an increased risk for cardiovascular events (10). Several methods may be used to derive LA volumes such as the cube method, the area length method, the ellipsoid method or Simpson’s modified rule, with the latter being preferred by most physicians, as it relies on fewer geometrical assumptions when compared to the previous methods, particularly the ellipsoid method (8).

Results
The literature review identified 50 publications, among which 15 studies were eligible for analysis. Articles reporting the outcomes of the same study were included once in the analysis. The figure 1 shows the PRISMA flowchart of the study. Overall five systematic reviews were included (5, 8).

Discussion
LA has a complex morphology (11) and current echocardiographic techniques, which allow surface and volume assessment of LA, are not entirely accurate (10). Moreover, the close coupling between left ventricular (LV) pressure and LA volume (LAV) highlights the somewhat artificial distinction between these 2 properties (12).
As a consequence of LA behavior, the flow through the mitral valve during a cardiac cycle exhibits a biphasic behavior; when the ventricles are relaxed (before the contraction of the atrium); the transmitral flow is nearly zero (13). During LV systole, the downward movement of the mitral annulus stretches the atrium so that the atrial and ventricular volumes reciprocate. This
is also the case during early diastolic LA emptying, when ventricular relaxation and elastic recoil move the mitral annulus upward, contributing to LV filling. This has led some to suggest that these LA functional properties should be considered as LV properties (5). Therefore, LA physiology and physiopathology is highly dependent on LV function, as the atrium is exposed to intraventricular pressure, particularly during diastole. As a consequence, any change in intraventricular pressure or volume is reflected on LA function pathophysiological mechanisms of LV during ischemia leads to abnormalities of ventricular filling early in diastole and thus to a diminution of LA passive functional reserve (7).

Based on the previously discussed volumetric measurements, several indices corresponding to the three basic functions of the LA can be derived:

1. LA reservoir function: LA total emptying volume= LAVmax – LAVmin LA total emptying fraction = (LAVmax – LAVmin)/LAV- max.

2. LA conduit function: LA passive emptying volume = LAVmax – LAVpreA LA passive emptying fraction= (LAVmax – LAVpreA) /LAV- max Conduit Volume= stroke volume – total emptying volume.

3. LA booster pump function: LA active emptying volume = LAVpreA – LAVmin LA active emptying fraction = (LAVpreA – LAVmin)/ LAV preA (8).

Clinical characteristics, demonstrated in previous studies indicated the median level of absolute percent increase in LA passive emptying fraction (ΔLAPEF) (8, 14, 15). Some studies reported that LAPEF deteriorated with stress, resulting in a negative value for ΔLAPEF. In fact, patients with ΔLAPEF below the median value had lower baseline LV ejection fraction at rest and larger LV end-diastolic and end-systolic volume indices (16,17). These results showed the increasing deterioration of inducible wall motion during progressive dobutamine stress.
A significant body of animal and human experimental studies has shown that during an ischemic insult, changes in LV diastolic function occur before any changes in systolic wall motion (18). Thus, relying on the detection of abnormalities in systolic wall motion alone may result in missing some patients with early ischemia. Similarly, changes in LA function during angioplasty have been shown to precede changes in LV systolic function (9).

Today, LA area and volume measurements are preferred for assessing LA dimensions, as they are shown to have a better correlation with the increased risk of cardiovascular events (19). Several methods can be applied to measure LAV such as the cube method, the area-length method, the ellipsoid method, and the modified Simpson’s rule. The Simpson’s rule is preferred by most physicians, since it depends on fewer geometrical assumptions, compared to previous methods, particularly the ellipsoid method (20). Therefore, for reporting LA function during ischemia, cardiovascular magnetic resonance imaging (CMR), dobutamine stress evaluation of myocardial ischemia, and quantification of LA emptying function have been applied in previous studies (21-22).

There are several possible mechanisms through which ischemia can lead to abnormalities in ventricular filling in early diastole and thus reduce LA passive functional reserve (7). These mechanisms have been described as follows:

1) Myocardial relaxation is an exquisitely energy-dependent process and is highly sensitive to the effects of ischemia, since adenosine triphosphate hydrolysis is required for the release of tightly bound actin-myosin bonds and calcium reuptake into the sarcoplasmic reticulum.

2) Subendocardial longitudinal fibers are particularly sensitive to ischemia. This leads to incoordination or asynchronicity between circumferential and longitudinal fibers in ischemic areas, as well as a reduction in longitudinal contractility that may not be initially detectable but
could lead to diminished ventricular suction (8). It would be of interest to know if LA functional parameters (such as ΔLAPEF) are more sensitive to LV ischemia than classical diastolic markers.

Resting LAV and LA function are important parameters in healthy subjects and myocardial ischemic patients. As Farzaneh-Far et al. indicated, Bland-Altman analysis of interobserver variability for $V_{\text{OL-max}}$ (left atrial volume at end-systole), $V_{\text{OL-bac}}$ (left atrial volume before atrial contraction) (53 ± 10 ml/m2), and $V_{\text{OL-min}}$ (left atrial volume at end-diastole) had biases (±95% limit of agreement) of 1.5±7.9 ml, 1.0±7.8 ml, and 3.2±7.6 ml, respectively. In addition, kappa values were calculated to assess interobserver agreement in detecting abnormally low LA function parameters (8).

In a study by Pritchett et al. on a population with no cardiovascular diseases and normal systolic and diastolic functions, Doppler echocardiography, along with LA dimension (LAD) and LAV assessments, showed that the median normal value of LAD/body surface area (BSA) was 22 ml/m² in men and 21 ml/m² in women (23); these findings were consistent with the results obtained by Tsang and colleagues (10). Based on the criteria presented by the Standards Committee and the Chamber Quantification Writing Group, LA values may be used to describe LA enlargement as mild (29–33 mL/m²), moderate (34–39 mL/m²), and severe (>40 mL/m²) (24).

As Abhayaratna et al. reported an LA value of ≥ 34 mL/m² could be an independent predictor of death, heart failure, atrial fibrillation, and ischemia (25). Messika-Zeitoun et al. (26) and Rossi et al. (27) also indicated that cardiovascular events are more likely to occur in patients undergoing cardiovascular surgeries for mitral regurgitation in the presence of LA enlargement. However, a
complete assessment of LA size and function may not rely on maximum LA alone, as LA dimensions vary widely during the cardiac cycle.

An electrocardiogram-guided echocardiography allows an accurate quantification of LA functions by measuring LAV at different times during the cardiac cycle. Measurements are usually performed as follows:

1) At the end of systole, just before the opening of the mitral valve (at the end of T-wave on ECG) – LAV$_{\text{max}}$ (Figure 2);
2) At the end of diastole, just before mitral valve closure (at the beginning of QRS complex on ECG) – LAV$_{\text{min}}$ (Figure 3); and
3) At the middle of diastole, just before atrial contraction (at the beginning of P-wave on ECG) – preatrial contraction volume (LAV$_{\text{preA}}$) (Figure 4).

In the present review study, we demonstrated that passive LA emptying volume and total LA emptying volume significantly increased in myocardial ischemic patients. Ischemia without a well-defined etiology is labeled as cryptogenic and accounts for 30-40% of all ischemic cases (15).

It has been suggested that cardiac embolism constitutes a major causative mechanism of myocardial ischemia (28). A recent multicenter study demonstrated that almost 20% of patients with myocardial ischemia had occult paroxysmal atrial fibrillation, detected on outpatient cardiac telemetry over a 21-day period (29).

Conclusion

Myocardial ischemic has the drawback of intermittent cross clamping of artery, which may be cause of severe artery disorders in patients. Assessment of LA function is essential for clinical evaluation and prognostic purposes. Augmentation of LA passive emptying fraction is a
predictor of cardiovascular prognosis, independent of major clinical or LV imaging predictors. LAV measurement may facilitate atrial remodeling assessment in various pathological conditions, as well as reverse remodeling after medical or invasive therapies (such as cardiac resynchronization therapy or ablation for atrial fibrillation). Although previous studies have demonstrated the clinical and prognostic value of LA assessment, further research could provide a better understanding of pathophysiological mechanisms behind LA enlargement and help predict clinical outcomes in many cardiovascular disorders. Moreover, a close relationship was detected between LA passive emptying function and myocardial ischemia. However, the mechanisms linking stress-induced changes in LA function to adverse outcomes require further evaluation.

References


17. Lang RM, Bierig M, Devereux RB, et al. Recommendations for chamber quantification: a report from the American Society of Echocardiography’s Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr 2005; 18:1440–63.


Figure 1: PRISMA flowchart of the study
Potentially relevant in the first search n=50

Studies excluded by initial screening of titles and abstracts n=35

Studies evaluated in detail n=20

Studies excluded due to being narrative review article, letter to editors, and original articles n=16

Studies included in the meta-analysis n=16