Algorithms of Relationships between Left Ventricle Dysfunction and Atrial Fibrillation

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Abstract

Atrial fibrillation (AF) is the most common cardiac arrhythmia. Many studies have investigated the cause for the development of AF in the left ventricle dysfunction. Recently the hypothesis was proposed that atrial fibrillation is a protective physiological mechanism, based on the termination of atrial mechanical systole. This reduces the end-diastolic pressure in the left ventricle by excluding the component of systolic left atrial pressure from the total end-diastolic pressure and, respectively, in the system of the pulmonary veins and alveolar capillaries in situation of the left ventricle dysfunction, and thus reduces the likelihood for development of pulmonary congestion. First of all this hypothesis explains relationship between left ventricle dysfunction and AF. The hypothesis helps to build algorithms of the development AF in the cases of the left ventricle dysfunction in the various diseases and conditions.

Keywords: Atrial fibrillation; Left ventricle dysfunction; End-diastolic pressure; Algorithms

Introduction

Atrial fibrillation (AF) is the most common cardiac arrhythmia in clinical practice and is most often associated with left ventricle (LV) dysfunction/heart failure (HF). The prevalence of AF in patients with heart failure increases in parallel with the severity of the disease, ranging from 5% in patients with mild, from 10% to 26% among patients with moderate, and up to 50% in patients with severe heart failure [1]. Many studies have investigated the cause for the development of AF, however, the question remains unanswered. The causative relationship between the two conditions has not been fully determined. Many studies on the subject: “AF – a cause or consequence?” have been carried out, however the question remain unanswered. Last year the hypothesis was proposed, that atrial fibrillation acts as a protective pathophysiological mechanism, based on the termination of atrial mechanical systole [2,3]. The reasoning of the hypothesis is as follows. The left atrial (LA) systole begins 0.12-0.2 s before the ending of the LV diastole, thus compressing the atrial volume and increasing its internal pressure. An algebraic addition therefore occurs by combining the “positive” pressure of LA systole (atrial kick) with the “negative” pressure of the LV diastole, resulting in the end-diastolic pressure (EDP). At the end of the LV diastole, while the MV is still open, the EDP is immediately transmitted and equalized through the communicating system of the LV, LA, pulmonary veins (PV), and alveolar capillaries (AC), as there are no obstacles to spread of the EDP wave. EDP is thus equal to pulmonary wedge pressure (PWP), with a normal range of ~ 8-12 mm Hg.

AF stops mechanical systole of the LA excluding the component of systolic LA pressure from total pressure in the LA-PV-AC system, thus leading to reduced EDP and PWP. The right atrium (RA) is also involved in AF. As is in the case with the LA, there is a termination of the mechanical systole of the right atrium (RA), and a reduction in end-diastolic pressure in the right ventricle (RV). Thus at the end of diastole of the RV when the tricuspid valve is still open, pressure of systemic venous inflow to the heart is decreased, resulting in a reduction of the preload. Thus, AF leads to a synergy in the hydrodynamic effect, due to the termination of a mechanical systole in both the LA and RA. This reduces the pressure in the system of the pulmonary veins and alveolar capillaries in pathological situations, and thus reduces the likelihood for development of pulmonary congestion and edema. The hypothesis is well correlated with the known facts and phenomenon’s associated with AF, and explains the causes of the onset of AF in different conditions and diseases (Table 1).

It is known that the main manifestation of LV dysfunction (systolic and diastolic) is a significant increase of EDP which is transmitted through the entire intercommunicated system (LV-LA-PV-AC), causing increased PWP with increased likelihood for development of pulmonary congestion and edema. Pulmonary edema is usually present when PWP increases to 20 mm Hg. It is logical to assume that the termination of both left and right side mechanical atrial systole, as a result of the development of the AF, creates more favorable, more optimal hydrodynamic conditions for the heart in a status of LV dysfunction, which is a manifestation of many cardiovascular diseases.

This HYPOTHESIS was proposed that AF acts as the physiological protective mechanism. The main purpose of AF is to eliminate the mechanical systole of the LA in order to reduce the intercommunicated pressure in the system (LV-PV-AC), and of the RA with the effect of reducing preload, and thus prevent pulmonary congestion and edema in the conditions and the diseases which cause to increase this pressure. By means of this hypothesis it is possible to present an algorithm of relationships between AF and LV dysfunction (Figures 1-5).

<table>
<thead>
<tr>
<th>Sinus Rhythm</th>
<th>Atrial Fibrillation</th>
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<tr>
<td>EDP = DPlv + Akp</td>
<td>EDP = DPlv</td>
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EDP – total end diastolic pressure of left ventricle, DPlv – diastolic pressure of left ventricle at the end of diastole, Akp – systolic left atrial pressure (atrial kick pressure).

Table 1: The causes of the onset of AF in different conditions and diseases.

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Development of LV dysfunction / heart failure

EDP increases by increasing left ventricle diastolic pressure

\[ EDP = DP_{lv} + AK_p \]

Increasing EDP immediately transmitted (mitral valve is still open) through the system of the LA-PV-AC with a threat to transudation of fluid into the lung interstitium with the development of pulmonary congestion and edema

DANGER!!!

When the pressure in the LA-PV-AC system increased to a certain critical value, the AF mechanism is activated

Termination of the left atrial mechanical systole

Termination of the right atrial mechanical systole

Excluding the component of systolic left atrial pressure from the total EDP, thus leading to reduce the pressure in the LA-PV-AC system

\[ EDP = DP_{lv} + AK_p \]

Reduction in EDP in the right ventricle with decreasing of systemic venous inflow, resulting in a reduction of the preload

Reduction of the threats of development of pulmonary congestion and edema !!!

Figure 1: LV dysfunction and AF – algorithm of relationship.
Similarly, we can imagine algorithms of the development AF in various diseases [4-6].

1. Hypertension and AF - algorithm of relationship

**HYPERTENSION** – increasing of peripheral vascular resistance

Elevated systemic arterial pressure

Pressure overload of left ventricle against elevated systemic arterial pressure

Development of compensatory hypertrophy of left ventricle (concentric)

Development of diastolic dysfunction with decrease of relaxation function

EDP increases by increasing left ventricle diastolic pressure

\[ EDP = DPlv + AKp \]

Increasing EDP immediately transmitted (mitral valve is still open) through the system of the LA-PV-AC with a threat to transudation of fluid into the lung interstitium with the development of pulmonary congestion and edema

DANGER !!!!
**MITRAL STENOSIS** – obstruction to LV inflow at the level of the mitral valve

The resting diastolic mitral valve gradient, and hence LA pressure, increases

Retrograde transmission of the increased LA pressure to the PV-AC system

When the pressure in the LA-PV-AC system increased to a certain critical value, the AF mechanism is activated

Termination of left atrial mechanical systole

Excluding the component of systolic LA pressure from the total EDP, thus leading to reduce the pressure in the LA-PV-AC system

\[ EDP = DPlv + (A\lambda k) \]

Termination of right atrial mechanical systole

Reduction in EDP in the right ventricle with decreasing of systemic venous inflow, resulting in a reduction of the preload

Reduction of threats of development of pulmonary congestion and edema

Figure 2: Hypertension and AF.
HYPERTHYROIDISM –

a disorder that involves excess synthesis and secretion of thyroid hormones by thyroid gland

It leads to a hypermetabolic condition of thyrotoxicosis

One important symptom in this condition is TACHYCARDIA

Prolonged tachycardia leads to TACHYCARDIA – MEDIATED CARDIOMYOPATHY

LV dysfunction

Increasing end diastolic pressure of LV

DANGER !!!

See the continuation in the algorithm of HYPERTENSION and AF

Figure 3: Mitral stenosis and AF.
PERIODISM – a disorder that involves excess synthesis and secretion of thyroid hormones by thyroid gland. It leads to a hypermetabolic condition of thyrotoxicosis. One important symptom in this condition is TACHYCARDIA. Prolonged tachycardia leads to CARDIOMYOPATHY.

Increasing pressure in the system of the LA-PV-AC with threat of development of pulmonary congestion and edema

DANGER !!!

See continuation in the algorithm of HYPERTENSION AND AF

Note: Similarly, we can build a relationship algorithm of other diseases and conditions, accompanied by an increase in EDP, with the occurrence of AF.

Figure 4: Hyperthyroidism and AF.

FIGURE 4

ATRIAL FIBRILLATION
The mechanical systoles of LA and RA are absent. EDP of LV is equal to diastolic pressure of left ventricle

EDP = DPlv

CARDIOVERSION
AF converts to sinus rhythm

The return of mechanical left and right atrial systoles

EDP increases due to addition of the left atrial systolic pressure (atrial kick)

EDP = DPlv + AKp

Preload increases due to addition of the right atrial systolic pressure

The increasing pressure in a certain critical value in the system of LA-PV-AC creates a threat of transudation of the fluid into the interstitium of the lung

DANGER !!!

Development of pulmonary congestion and edema

Figure 5: The literature describes cases from medical practice of worsening of the patient’s conditions with pulmonary congestion or edema after cardioversion from AF to sinus rhythm or after implantation of the pacemaker (atrial rhythm). The proposed hypothesis can explain this complication and build algorithm of this phenomenon [7,8].

FIGURE 5
Conclusion

The above proposed hypothesis suggested that AF is a physiological protective mechanism for reducing the pressure in the LA-PV-AC system by terminating the atrial mechanical systoles. This hypothesis clearly explains many facts and phenomenon associated with AF and allows the building of algorithms showing relationships between LV dysfunction and AF, different diseases and conditions and AF. Also it can help to understand the pathophysiological mechanism of development of AF.

References