The Importance of Echocardiography for the Evaluation of Cardiac Sources of Embolism

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Abstract

The investigation of cardiac sources of embolism by echocardiography is frequently required in the context of embolic strokes. These findings may also determine the embolic risk of other cardiac diseases even before the embolic event takes place. In this review we present the role of echocardiography regarding the main sources of cardiac embolism. These sources of embolism are divided into high-risk sources (atrial fibrillation, acute myocardial infarction and left ventricular aneurysm, cardiomyopathies, mitral stenosis, endocarditis, valvular mechanical prosthesis, tumors and proximal aortic atheromas) and low-risk sources (mitral valve prolapse, calcified aortic stenosis, giant Lambl's excrescences and paradoxical embolism – patent foramen ovale and atrial septal aneurysm). Due to the great interaction between the wide range of cardiovascular diseases with embolic potential it is hard to obtain data about the isolated embolic risk for each imaging finding. However, the imaging findings that predict a higher embolic risk are better determined for high-risk embolic sources.

Introduction

The embolisms from cardiac source are the cause for 15% to 30% of the cerebrovascular accidents (CVA)[1,2]. Given that CVA is a disease with high mortality and morbidity rates, and health care costs, identifying the patients prone to undergoing this event is capital. The patients who underwent embolism are potential candidates for echocardiography for evaluation of the cardiac sources of embolism (CSE).

The investigation of CSE by echocardiography has two main approaches: the transthoracic echocardiography (TTE) and the transesophageal echocardiography (TEE). Although TTE may be considered the best method for non-invasive viewing of cardiac structures, TEE has already proven to be superior to TTE in most situations of investigation of cardiac sources of embolism, besides being more cost-effective[3,4]. Fundamentally, the superiority of TEE over TTE includes the better capacity for viewing structures, such as the left atrial appendage (LAA), the left atrium (LA), the interatrial septum and the thoracic aorta artery. The great anatomical proximity between the esophagus and the back of the heart, the fact that there is no interposition of the pulmonary or bone tissue and the possibility of using higher ultrasound frequencies also enable TEE to yield cardiac images with higher resolution and, as a consequence, better detection of intracardiac thrombi, patent foramen ovale (PFO), valvar vegetations, atheromatous plaques of the thoracic aorta and spontaneous echo contrast (a marker of blood stasis)[3]. These techniques may be improved, as for their capacity of detection and characterization of cardiac diseases, and for the use of eco-Doppler, three-dimensional echocardiography (3D), injection of contrast solutions etc.

Obviously, the investigation of CSE will be determinant for the subsequent therapeutic approach, but this discussion is out of the scope of this study. This research features a review of the literature published about the importance of echocardiography for evaluating CSE, starting by an introduction about the cardioembolic CVAs, following by a review of the role of echocardiography for the main CSEs, which may be divided into high-risk and low-risk sources (Table 1)[5].

Cardioembolic CVA — cerebral embolism, ischemic CVA and transient ischemic accident (TIA)

CVA is the second major single cause of death in Europe[6]. Echocardiography is fundamental for evaluating CVAs with suspected cardiac source and may also play a role on cryptogenic CVAs. These two categories together stand as circa 50% of the ischemic CVAs[7].

The investigation of CSE should be systematized since the onset of the clinical investigation and imaging when there are suspected CVA and TIA. The clinical aspects that may raise suspicion of CVA from cardioembolic source are the following: abrupt start of symptoms, particularly in patients with AD without previous history of TIA or CVA, and severe manifestations of this first cerebrovascular event; high severity of CVA in elderly (CVA scale from the National Institutes of Health ≥ 10 and age ≥ 70 years). The aspects connected to the image include: wide cerebral infarction areas; multiple locations (on the back or front cerebral circulation or on both sites), particularly if separated in time (different locations at different ages); more than one cerebral infarction within the same distribution area or if there are signs of concomitant systemic thromboembolism; sign of hyperdense middle cerebral artery (provided not accompanied by severe stenosis of the ipsilateral internal carotid artery) and fast rechanneling of a great cerebral artery (to be evaluated by repeated cervical cephalic vascular ultrasounds)[5].

Keywords

Echocardiography/diagnosis; Stroke; Embolism and Thrombosis; Echocardiography, Doppler; Echocardiography, Three-Dimensional.

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Table 1 – Cardiac Sources of Embolism

High risk	Low risk
Atrial fibrillation (AF)	Mitral valve prolapse
Acute myocardial infarction (AMI) and left ventricular (LV) aneurysm	Calcific aortic stenosis
Cardiomyopathies	Giant Lambl's Excrescences
Mitral Stenosis	Paradoxical embolism — patent foramen ovale (FOP) e atrial septal aneurysm (ASA)
Endocarditis	
Valvular mechanical prosthesis	
Tumors	
Proximal aortic atheromas	

Factors connected to the patient should be taken into account. In patients of older age and presenting comorbidities, an atherosclerotic etiology for CVA is more probable, which leads to more predominantly nonspecific findings for echocardiographic evaluation[8]. In younger patients, the rarest causes of cardiac embolism should excluded, such as arterial thrombi in sinus rhythm and cardiac tumors[8].

This way, the use of the echocardiography for investigating a CVA to evaluate CSE will have more successful results if applied to patients younger than 50 years old; patients of any age with total occlusion of a great cerebral vessel; older patients without evidence of cerebrovascular disease or other obvious causes of CVA; patients to whom the choice of therapy will depend on the echocardiographic findings; and patients presenting cerebrovascular disease of questionable significance, but with suspected embolism[9,10].

The echocardiography is not applicable to patients with a cerebrovascular disease of such a nature that is enough for explaining the clinical event, or patients for whom the echocardiography will not impact clinical decisions[8].

Pulmonary thromboembolism (PTE)

Insomuch as the left heart may present CSE, the right heart may be the source for embolism, specifically the pulmonary embolism. However, PTE is a disease that is more frequently associated with deep venous thrombosis (DVT)[11]. Notwithstanding this, it has already been demonstrated that the cardiac disease is a risk factor for PTE without concomitant DVT and that this risk increases nearly 40 time after the three months after an Acute myocardial infarction (AMI)[12]. Currently, there is no recommendation for echocardiographic examinations for diagnosing CSE in patients with PTE, since probably this examination will not have major therapeutic implications and its sample will be problem low.

CSE of high risk

Atrial Fibrillation (AF)

The AF is a CSE of high risk, particularly when associated with advanced age, history of CVA or TIA, systemic hypertension (SH), Diabetes mellitus (DM), left ventricular dysfunction (LVD) and LA dilation[8]. The prevalence of AF in the general population amounts to circa 1% - 2%[13]. There are several factors which, associated with AF, represent a high risk for CVA in patients, such as: thrombi in LAA,, atherosclerotic plaques in the aorta, spontaneous echo contrast, diminished LAA speeds[14-16].

The TTE has great relevance for the evaluation of patients with AF aiming to characterize the following aspects: valvular cardiac disease; ascertainment of the size of heart chambers; dimensions and thickness of LV; systolic and diastolic functions of LV; dimensions and function of right ventricle; tricuspid regurgitation with right systolic ventricular pressure and pericardial disease[5]. The TEE also plays a prominent role in the study of AF. It is fundamental for the evaluation of LAA and investigation of thrombi inside of it, since this structure may not be thoroughly viewed in TTE. This evaluation is mandatory to conduct electrical cardioversion in acute AF with more than 48 hours of evolution without standard oral anticoagulation of three weeks[17,18]. The evaluation of function of LAA may be performed by its flow velocity by TEE with Doppler[19]. Peak velocities in LAA $\leq$ 20 cm/s are associated with embolic events[20]. The ascertainment of peak velocities of LAA by TEE with Doppler is also significant after the cardioversion. This test may be used to detect the phenomenon of left atrial contractile dysfunction after cardioversion, known as atrial stunning, which increases the embolic risk, mainly on the three days after the restoration of sinus rhythm[21]. Some authors have been suggesting that patients with normal LAA function seven days after an electrical cardioversion are deemed to present low embolic risk, and can be safely discharged from the therapy with anticoagulants[22].

Acute myocardial infarction and left ventricular aneurysm

After an AMI, the presence of a thrombus in the LV is a risk factor for an embolic event[23]. Most of these thrombi are formed over the three months subsequent to an embolic event and are associated with ventricular dysfunction that sometimes persists after the infarction[7]. However, its incidence has been decreasing since the development of the revascularization therapy, both in thrombolysis and angioplasty, which diminish the degree of ventricular dysfunction when carried out at an early stage[2]. In the case of AMI, whether recent or old, and CVA, the echocardiography is the supplemental diagnostic modality recommended for investigating a LV thrombus, and should be performed routinely[8]. In the case of investigation of the presence of thrombi in LV, the TTE is superior to TEE mainly due to the difficult viewing of the LV apex by TEE[5]. This diagnostic acuity of TTE may still be increased by resorting to color Doppler and intravascular contrast agents[24]. Over the evaluation of the presence of a LV thrombus, the shape or characteristic of a thrombus (mural or protruding) should be observed, along with its size, mobility (fixed or free-moving) and the presence of concomitant LV aneurysm (identified by the presence of an akinetic or dyskinetic area with LV strain, both during systole and diastole)[5]. According to these characteristics, a high risk of embolism could be correlated with larger, moving and protruding thrombi, especially in older patients[25].

Cardiomyopathies

The LV dysfunction is, by itself, a cause for stasis that may increase the propensity to the formation of thrombi[7]. On account of this, it includes a cardiomyopathy of any nature that brings on LV dysfunction, and which may expose the patient to the risk of embolism[26]. In point of fact, the left ventricular ejection fraction (LVEF) is inversely correlated with the risk of CVA; i.e., for a LVEF < 29%, there is a rate of CVA of 1.7%/year, and for a LVEF of 29% - 35%, there is a rate of 0.8%/year[26]. This way, the echocardiography obtained for the investigation of the cardiomyopathy will bring prognostic information regarding the embolic risk in keeping with a given LVEF.

Mitral Stenosis

The mitral stenosis is associated with an increase in the risk of embolism owing to the stasis caused by the occlusion of blood flowing from LA for LV. Epidemiologically, in Europe or developed countries, the embolism by rheumatic mitral stenosis has been decreasing either as a result of the decrease of the rheumatic mitral stenosis by itself, or due to the implementation of long-term anticoagulation measures for these patients[27]. The mitral stenosis is a characteristically well documented by TTE, and typically there is no need for TEE, except for the cases in which the patient's characteristics do not allow a good viewing of structures by TTE.

Endocarditis

The infective endocarditis is still a disease that brings on high rates of mortality and embolic events, the latter ranging from 20% to 50%[28,29]. When a therapy is instituted, the figures of the new embolic event in this clinical context are lower (around 7.3%)[28]. The echocardiography has an important prognostic value for evaluating these patients, namely with regard to the characteristics of vegetations[28]. Great cardiac vegetations (>10 mm), vegetations presenting a higher mobility, vegetations located in the mitral valve (particularly in the anterior cuspid), in addition to the variance of the size of vegetations after the institution of antibiotic therapy, are characteristics that entail a bad prognosis for new embolic events[28,30].

In this context, the performance of TTE and of one TEE is recommended for the appropriate investigation of this disease, and also for the detection of risk factors for embolic events[31]. Although these findings are conclusive about the risk, there is still need for clarifications on the best conduct to be followed and a more aggressive therapy should be determined for each case, not taking for granted other important prognosis factors not associated with the echocardiography (factors connected to the host and factors connected to the pathogen)[28].

Valvular mechanical prosthesis

The formation of thrombi and subsequent embolization are common in patients with valvular mechanical prostheses, especially in patients with mitral or tricuspid prosthesis and suboptimal values of anticoagulation[32].

The conditions that pose a patient with valvular mechanical prosthesis at risk of thrombosis include an early post-surgery risk, interruption of anticoagulation and pregnancy[33]. Both TTE and TEE should be carried out when there is suspicion of an event of this nature. However, TEE is the method of choice to diagnose the main signs of thrombosis, such as: restriction of leaflets or disc, abnormal central regurgitation, absence of view of physiological jets and straight view of thrombus or pannus[5]. In this context, given that the risk of embolic events is associated with the thrombus size, the discovery of thrombi higher than 0.8 cm^2 by TEE may help choose patients who will need surgery, thrombolysis or conservative treatment.

Typically, it is reasonable to suspect there could be an increase in the transvalvular velocities of the valvular function[34]. The diagnosis of partial thrombosis of a mechanical prosthesis is difficult when there is no occlusion or when it is not very discrete. In this context, the TTE has not a great effect and the TEE is the method of choice[35]. However, even by TEE, there may be some factors of confusion for this diagnosis[35], such as small abnormal echogenic formations next to the prosthesis, which are also observed in the infective endocarditis. Other factor that may render difficult the evaluation of an aortic valve prosthesis is the concomitant presence of a mitral prosthesis, which will lessen the transmission of an ultrasound sign[35].

Tumors

The cardiac myxomas are the most frequent primary tumors, representing circa 50% of the cases[36]. These tumors are more frequent in the left atrium and may cause embolic phenomena in 30% - 40% of the patients[5]. In most cases, these tumors may be identified by TTE as a moving mass with a pedicle, which typically comes from the fossa ovalis. If there is doubt, other methods may help in the diagnosis, such as TEE, 3D echocardiography, cardiac magnetic resonance imaging and computed tomography[5].

The papillary fibroelastoma is a tumor more frequently associated with cardiac valves (circa 85% - 90% thereof)[5]. These tumors are hard to be distinguished from Lambl vegetations and excrescences[5]. The literature has no report of sensitivity and specificity of echocardiography for detection purpose, but mobility is known to be an independent predictor of death and nonfatal embolism[5].

Proximal aortic atheromas

The atheroma plaques in the aorta may cause embolism by thromboembolism or atheroembolism. Although having different pathophysiology, these two mechanisms share many of its risk factors[37]. The use of TEE is a gold standard imaging method for diagnosing this disease[7]. The presence of complex atherosclerotic plaques (protruding, moving or ulcerated) stands as a risk factor for the occurrence of embolic events (and the cutoff point for the size of protrusion of the plaque ranges between 3 and 5 mm according to several publications)[38-40]. The mortality of patients with complex plaques was 43.4% at seven years, against 15.4% in patients with normal aorta[41]. The occurrence of embolism is significantly higher in patients who are subject to catheterization procedures[42].

Low-risk CSE

Mitral valve prolapse

The mitral valve prolapse has an incidence of circa 2% - 3%[43]. It is a risk factor for mitral regurgitation, congestive heart failure, arrhythmias and endocarditis[44]. The method of diagnosis for choosing this disease is echocardiography. The use of TTE or TEE, two-dimensional (2D) or 3D, combined with Doppler, allows a detailed evaluation of the structure and function of this valve and accurate characterization of this disease[44].

Calcific aortic stenosis

It is not clear in the current literature if the increase of embolic risk is associated with calcific aortic stenosis, as well as its magnitude, except for the cases in which patients are subject to catheterizations. This disease may be thoroughly evaluated by 2D TTE with Doppler[7].

Lambl's Excrescences

Lambl's excrescences are filiform formations that arise out in places of closing of cardiac valves. The giant Lambl's excrescences happen when multiple adjacent excrescences form adhesions and coalesce in a higher structure[45]. Most patients are asymptomatic. However, the individuals with giant Lambl's excrescences in the aortic valve may have embolic CVA[45]. This disease may be characterized by TTE and, if there is still any doubt afterwards, a TEE may be carried out[45]. Patients with history of recurring CVA without another identified cause other than these formations may benefit from an excrescence surgical debridement[45].

Paradoxical embolism — patent foramen ovale e atrial septal aneurysm (ASA)

FOP is characterized by the presence of a right-left atrial septal defect, which is physiological during the intrauterine life, and is closed naturally after birth, owing to the higher pressure existing in the left atrium. The presence of this type of shunt was associated with paradoxical embolism, and has already been demonstrated that a risk of cryptogenic CVA is three times higher by each age decade of patients with FOP[46]. Given this problem, several techniques have been developed form closing this defect, although there is recent evidence which pointing out that the closing of FOP brings no benefit against the occurrence of embolic events[33].

The presence of ASA is diagnosed when there is a moving formation in the area of fossa ovalis, which moves toward one of the atria, protruding at least 10 mm from the midline[5]. ASA associated with FOP increases the risk of cryptogenic CVA, mainly in young patients. The mechanism proposed to explain this association is that ASA works as a network which captures small thrombi and displaces them to FOP[33]. The therapeutic strategy to be adopted in these conditions is controversial and will have to weigh anti-aggregation, anticoagulation or even the closing of this event, given that the most aggressive approaches are reserved to higher defects, presence of concomitant ASA and recurring CVA or TIA[47]. The TEE has been traditionally considered as the reference standard for detecting the right-left shunt. However, if a patient is excessively anaesthetized during this procedure, he may not be appropriately subject to a Valsalva maneuver[48] and, thus, TTE may be ideal to overcome this difficulty, mainly if furnished with recent technologies, such as harmonic imaging, which allows a better image quality[49]. The transcranial Doppler with injection of shaken saline solution may also be used to diagnose the presence of FOP[50].

Conclusions

Given the multifactorial nature of cardiovascular diseases and the great interaction between the several comorbidities that concur in their pathogenesis, the ascertainment of predictive values of embolic risk for independent echocardiography findings is extremely difficult. Although the frequent resorting to echocardiography allowed the revelation of several echocardiographic findings with important prognostic value regarding cardioembolic diseases, there is still a long way to go for determining the independent risk of each one of these findings for preventing these events. The identification of the impact of this imaging method for supporting therapeutic decisions that allow setting the guidelines based on scientific evidence is the following step for most diseases or abnormalities which are CSE.

For cases of CSE of high risk, the imaging findings are better defined as predictors of a high embolic risk, whereas the CSE of low risk still have several findings of unknown meaning. In most cases, the echocardiography interest for evaluating the embolism source remains strongly associated with the clinical context of the patient at hand.

Authors' contribution

Investigation conception and design: Puga LAR, Macedo LFVP; Data collection: Puga LAR, Macedo LFVP; Data analysis and interpretation: Puga LAR, Macedo LFVP; Manuscript Drafting: Puga LAR, Macedo LFVP; Critical review of the manuscript regarding the important intellectual content: Puga LAR, Macedo LFVP.

Potential Conflicts of Interest

No relevant potential conflicts of interest.

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