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REVIEW ARTICLE

Clinical Applications of Transthoracic Doppler Echocardiographic Coronary Flow Reserve Measurements in the Left Anterior Descending Coronary Artery

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Transthoracic Doppler echocardiography (TDE) is a noninvasive tool for measuring coronary flow reserve in the epicardial coronary arteries. In the absence of stenosis in the epicardial coronary artery, TDE can detect impaired microvascular vasodilatation associated with diseases, including reperfused myocardial infarct, systemic arterial hypertension, diabetes mellitus, coronary vasospasm, microvascular angina, and hypertrophic cardiomyopathy by demonstrating a decrease in the coronary flow reserve. Because it is noninvasive, TDE allows for serial coronary flow reserve evaluations to explore the effect of various therapies. This noninvasive imaging technique expands the field of diagnostic echocardiography and brings new insight into the pathophysiology of ischemic heart disease. This review outlines rationale of TDE to evaluate coronary flow reserve in the left anterior descending coronary artery and discusses its clinical applications.

Introduction

Coronary flow reserve (CFR) is defined as the ratio of hyperemic (stimulated) to baseline (resting) coronary blood flow for a given perfusion pressure [1]. CFR measurement is used both to assess epicardial coronary stenoses and to examine the integrity of microvascular circulation. In the absence of coronary artery stenoses, the CFR may be decreased when coronary microvascular circulation is

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compromised by arterial hypertension, diabetes mellitus, coronary vasospasm, cardiac syndrome X, and hypertrophic cardiomyopathy [2].

Functional anatomy of the coronary arterial system

The coronary arterial system is composed of three compartments with different functions, although the borders of each compartment cannot be clearly defined anatomically [3]. The first compartment of the coronary arterial system is known as the proximal compartment and is comprised of conductive arteries. It is represented by the large epicardial coronary arteries, which have a capacitance function and offer little resistance to coronary blood flow. The diameter of the epicardial coronary arteries ranges from approximately 500 μm to 2—5 mm. The second compartment of the coronary arterial system is known as the intermediate compartment. It is comprised of prearterioles that are characterized by a measurable pressure drop along their length. These vessels are not under direct vasomotor control by diffusible myocardial metabolites because of their extramyocardial position and wall thickness. Their diameter ranges from approximately 100—500 μm, and their specific function is to maintain pressure at the origin of the arterioles within a narrow range when coronary perfusion pressure or flow changes. The third compartment of the coronary arterial system is known as the distal compartment. It is comprised of intramural arterioles that are characterized by a considerable drop in pressure along their path. The intramural arterioles have diameters of less than 100 μm, and their function is the matching of myocardial blood supply and oxygen consumption.

When blood flow changes, epicardial coronary arteries and proximal arterioles have an intrinsic tendency to maintain a given level of shear stress by endothelial-dependent dilatation [4]. When aortic pressure increases, distal prearterioles undergo myogenic constriction to maintain a constant pressure at the origin of the arterioles. Arterioles have a fundamental role in the metabolic regulation of coronary blood flow [5]. They have a high resting tone and dilate in response to the release of metabolites by the myocardium as a result of an increase in oxygen consumption. Arteriolar dilatation decreases both resistance in the overall network and pressure in the distal prearterioles, which in turn induce the dilatation of myogenically sensitive vessels. Furthermore, the dilatation of distal prearterioles and arterioles results in an increase in shear stress, which triggers flow-dependent dilatation in larger prearterioles and conductance arteries. Coronary microvascular dysfunction is defined as disordered function of small coronary resistance vessels (<100—200 μm) [6].

Assessment of the coronary microcirculation

Presently, there is no technique to visualize coronary microcirculation *in vivo* in humans. Several measurements that rely on the quantification of blood flow through the coronary circulation are commonly used to assess the function of coronary microvasculature. Coronary blood flow is a measurement of the amount of flow through a given coronary vessel per unit of time and is usually expressed in milliters per minute [7]. Techniques for measuring coronary blood flow include intracoronary thermodilution, which uses a thermal dilution curve to measure blood flow, and an intracoronary Doppler wire, which measures blood flow ultrasonographically according to the Doppler principle. Another invasive technique for assessing coronary blood flow is the Thrombolysis in Myocardial Infarction (TIMI) frame count. It does not quantify the flow, but it is useful for comparative purposes [8]. Recently, transthoracic Doppler echocardiography (TDE) has been used as a noninvasive technique to measure coronary blood flow [6,9].

CFR is the magnitude of the increase in coronary flow that is achieved from basal coronary perfusion to maximal coronary vasodilation. Since flow resistance is primarily determined by the microvasculature, CFR is a measurement of the ability of the microvasculature to respond to a stimulus and, therefore, presumably of the function of the small vessels. CFR is determined by measuring the coronary or myocardial blood flow both at rest (basal flow) and with maximal hyperemia, and it is achieved with an intracoronary or intravenous infusion of adenosine or an intravenous infusion of dipyridamole. CFR is then expressed as the ratio of blood flow during hyperemia to blood flow at rest. Echocardiographic CFR is defined as the ratio of hyperemic to basal peak diastolic coronary flow. In patients with coronary artery disease (CAD), the extent of the reduction in CFR is directly related to the severity of stenosis, whereas in persons with angiographically normal arteries it is a marker of microvascular dysfunction [7]. A CFR of less than 2.0 is often considered abnormal (Fig. 1) [10].

Coronary microcirculatory dysfunction affects the left ventricle globally [11] and regionally [12]; therefore, CFR assessment of left anterior descending (LAD) artery, which would be inadequate for CAD detection, is an excellent option for evaluating the global coronary microcirculation [10]. The application of the latest ultrasound technology of the second harmonic has gained a great step in ultrasound coronary evaluation. By applying anatomical knowledge and the newest technical applications, it is now possible to make a complete a coronary evaluation of the LAD artery in clinical practice.

Ultrasound coronary anatomy reference points

The LAD coronary anatomy is the first artery investigated with ultrasound when using a transesophageal or transthoracic approach. The first anatomical structure is the proximal LAD artery. The left atrial appendage and pulmonary artery represent the key reference points in detecting the proximal LAD coronary tract. The second anatomical structure is the intermediate LAD artery. The septal perforans branches represent the key references obtainable by regulating the probe slightly lower and maintaining the focus on the anterior interventricular sulcus. The third anatomical structure is the distal LAD tract, which can be highlighted by investigating the lower part of the interventricular anterior sulcus near the apex under Color Doppler guidance and by adopting growing