Coronary Angiography: Current Clinical Application Status and Future Prospects

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Abstract. Coronary angiography is a key technique in the diagnosis and treatment of coronary heart disease in modern cardiology. This review comprehensively discusses the principle, operation process, clinical application and important position of this technology in the diagnosis and treatment of cardiovascular diseases. As the "gold standard" for the diagnosis of coronary heart disease, coronary angiography can visually display the anatomical structure and lesions of coronary arteries, providing an important basis for treatment decision. However, its limitations such as invasive characteristics, high cost and limited ability to diagnose early lesions should not be ignored. In recent years, the development of emerging technologies such as intra-coronary ultrasound imaging (IVUS) and optical interference tomography (OCT) has provided new ways to overcome these limitations. The indications, contraindications, preoperative preparation and other clinical practice issues of coronary angiography are also discussed in this paper, aiming to provide a comprehensive understanding for medical professionals and look forward to the future development direction of this technology.

Keywords: Coronary angiography; coronary artery disease; cardiac catheterization; intravascular imaging; interventional cardiology.

1. Introduction

Coronary angiography is one of the most important techniques in the diagnosis and treatment of coronary heart disease. As an invasive diagnostic method, it provides doctors with a visual picture of coronary disease by injecting contrast agents directly into the coronary arteries, allowing the blood vessels to be clearly visible under X-rays. The development of this technology can be traced back to 1959, when Sones, a pediatrician at the Cleveland Medical Center in the United States, accidentally discovered the feasibility of injecting contrast agents directly into the coronary artery [1]. This discovery shattered the medical community's understanding of the dangers of such procedures and laid the foundation for the birth of selective coronary angiography.

In the decades that followed, coronary angiography was developed and perfected. In 1964, Sones performed the first coronary arteriography via brachial incision. By 1967, Judkins performed selective coronary angiography by puncturing the femoral artery, further perfecting and popularizing the technique. Nowadays, coronary angiography has become the "gold standard" in the diagnosis of coronary atherosclerotic heart disease (coronary heart disease) and plays an irreplaceable role in clinical practice.

Although coronary angiography has many advantages, such as clearly showing the lesions of coronary arteries and providing an important basis for the formulation of treatment plans, it also has some limitations. For example, this technology has high requirements for equipment and operators, expensive inspections, and invasive operations that may cause some physical damage to patients. In addition, its limited ability to diagnose early lesions has prompted the development of other complementary techniques such as intra-coronary ultrasound imaging (IVUS) and optical interference tomography (OCT).

This review will discuss in detail the principles, procedures, clinical applications, advantages and limitations of coronary angiography, as well as future trends. By taking a comprehensive look at this technology, we aim to provide medical professionals with an in-depth understanding of coronary

angiography and provide ideas for further improvement and optimization of this important diagnostic tool.

2. Coronary Artery Anatomy

Before diving into the discussion of coronary angiography, understanding the anatomy of the coronary arteries is crucial to correctly interpreting the angiography results. The coronary artery system mainly consists of the left coronary artery (LCA) system and the right coronary artery (RCA) system [2].

The LCA originates from the left coronary sinus behind the ascending aorta and is subsequently divided into the anterior descending branch (LAD) and the left circumflex branch (LCX). The LAD mainly supplies part of the blood to the left ventricle, the anterior wall of the right ventricle and the anterior 2/3 of the interventricular septum, and its important branches include the diagonal branch, the right anterior ventricular branch and the interventricular septum branch. The LCX is mainly responsible for the blood supply to the left atrial wall, the left ventricular lateral wall, and a portion of the anterior and posterior walls of the left ventricle, and its main branch is the blunt marginal branch (BM).

The RCA opens in the right anterior coronary sinus of the ascending aorta and supplies most of the myocardium of the right atrium, anterior wall of the right ventricle, and diaphragmatic surface of the heart. Its important branches include the posterior descending branch (PD) and the posterior left ventricular branch (PL).

This complex anatomy makes coronary angiography a key tool for assessing coronary heart disease, as it visually shows the morphology and lesions of these vessels.

3. Principle and Operation of Coronary Angiography

The basic principle of coronary angiography is to inject contrast agent directly into the coronary artery through a special cardiac catheter, and then use X-ray imaging technology to observe the flow of contrast agent in the coronary artery. This method can clearly display the anatomical structure and pathological conditions of coronary arteries, and provide an important basis for diagnosis and treatment decision.

The procedure usually begins with a percutaneous puncture into the femoral artery of the lower limb or the radial artery of the upper limb [3]. The doctor will retrograde a specially shaped cardiac catheter along the blood vessel to the ascending aortic root, then explore the left or right coronary artery opening and insert the catheter. After the injection of contrast agent, real-time X-ray imaging was performed by angiography machine to observe the morphology and blood flow of coronary arteries. This highly specialized device provides high-quality, real-time images to help doctors accurately determine the condition of the coronary artery (Fig. 1).

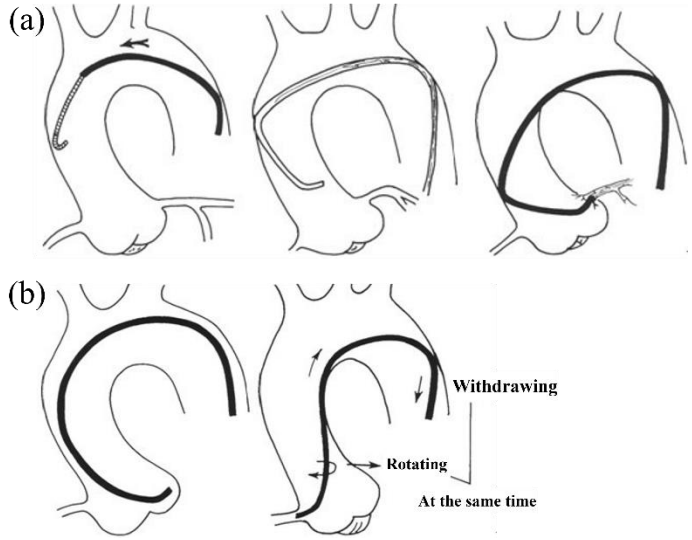

Fig. 1 Procedure of coronary angiography: (a) left coronary artery; (b) Right coronary artery.

4. Clinical Application

Coronary angiography plays a key role in the diagnosis and treatment of cardiovascular disease. In terms of diagnosis, it is not only the "gold standard" for coronary heart disease, but can also help diagnose other heart diseases such as unexplained arrhythmias, left heart dysfunction, and coronary artery abnormalities associated with congenital heart disease and valvular disease. By clearly showing the entire coronary artery system, doctors can accurately determine whether there is a narrow lesion in the blood vessels, as well as the location, extent, and severity of the lesion [4].

In terms of treatment, the results of coronary angiography directly guide the formulation of treatment plan. It can help doctors decide whether coronary interventions (such as balloon dilation, stenting, etc.) are needed, assess whether coronary artery bypass surgery is needed, or guide adjustments to medication. In addition, coronary angiography can be used to evaluate the outcome of interventional therapy or bypass surgery, as well as for long-term follow-up and prognostic assessment.

5. Indications and Contraindications

Indications for coronary angiography can be divided into two categories: diagnostic and therapeutic. Diagnostic indications include unexplained chest pain, arrhythmia or left heart insufficiency, and postoperative recurrence of angina pectoris. Therapeutic indications include stable angina pectoris, unstable angina pectoris that does not respond well to medical treatment, and acute myocardial infarction and other conditions that require urgent interventional treatment.

However, not all patients are candidates for coronary angiography. Major contraindications include allergy to iodine or contrast agents, severe cardiopulmonary insufficiency, uncontrolled severe arrhythmias, electrolyte disturbances, and severe hepatic and renal insufficiency. The presence of these contraindications underscores the importance of thorough evaluation prior to coronary angiography.

6. Preoperative Preparation and Vascular Approach Selection

To ensure the safety and effectiveness of coronary angiography, adequate preoperative preparation is essential. This includes completing relevant tests (e.g., echocardiography, X-rays, biochemistry, blood clotting indicators, etc.), testing for iodine allergy, and obtaining informed consent from

patients and their families. The cath room should have the necessary equipment, drugs and experienced operating doctors and auxiliary personnel.

The choice of vascular approach is another important consideration. At present, percutaneous puncture of the radial artery is the most commonly used method, which is less invasive and has fewer complications. Traditional femoral artery puncture is still used in some cases, especially when larger diameter catheters are required. In special cases, the brachial artery may also be chosen as the approach.

7. Limitations and Related Technical Progress

Although coronary angiography is the "gold standard" for diagnosing coronary heart disease, it has some limitations. As an invasive procedure, it requires high technology and equipment, is expensive to examine, and may cause some physical damage to the patient. In addition, although it is effective in the diagnosis of arterial lesions with significant luminal stenosis, its ability to diagnose early lesions is limited [5, 6].

In order to make up for these deficiencies, a number of complementary technologies have been developed in recent years. IVUS can show the structure of the vessel wall and help to detect intimal thickening or plaque that is present in normal vessel segments shown on conventional angiography. OCT can provide a higher resolution image of the vessel wall, which can help to evaluate coronary artery disease more accurately. The development of these new technologies opens up new perspectives for the diagnosis and treatment of coronary artery disease.

8. Conclusion

As an important diagnostic and therapeutic tool in modern cardiology, coronary angiography has made great contributions to the life and health of countless patients in the past decades. Although it has some limitations, its clinical value continues to increase through the combination of emerging technologies. In the future, as the technology is further developed and optimized, coronary angiography will continue to play a key role in the diagnosis and treatment of cardiovascular diseases, providing patients with more accurate and safer medical services.

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