Development and evolution of coronary arteriography

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In 1955, the first practical fluoroscopic image amplifiers became available to us. This made possible the development of techniques for studying the central circulation with x-ray motion picture photography. By combining the techniques of right and left heart catheterization with contrast visualization, it was possible to develop diagnostic protocols that permitted the simultaneous acquisition of physiologic data pertinent to the study of congenital malformations of the heart with selective opacification of individual heart chambers and great vessels. These techniques made possible a great improvement in the diagnostic accuracy of complex intracardiac malformations at the time when our surgical colleagues were developing intracardiac surgery with extracorporeal circulation facilitated by the first pump oxygenators. The evolution of these techniques required the development of insights, which at that time were far removed from the knowledge traditionally required of the cardiologist or radiologist. It seemed evident to me then that we needed people who understood at least the practical aspects required of both disciplines in order to exploit the potentials of what was really a new technology. At this juncture, I am painfully aware that no human on earth commands a full understanding of all the facts that are pertinent to

our discipline. The purpose of this Symposium has been to bring together many of those who have participated in the evolution of coronary arteriography. We shall share our insights, hopefully for the benefit of those who entrust their lives to our care.

During the period 1955 through 1960, we explored the potentials and attempted to define the limitations of several image amplifier configurations including 5-, 11-, and 8-inch fields, combined with 35 and 16 mm optical recording systems. By 1958, it became evident that the techniques we were using advantageously in the study of congenital malformations of the heart might be usefully applied to the study of the coronary circulation. At that time we could frequently recognize the complications of coronary artery obstruction, but we had no way of defining the presence of, or estimating the severity of, the underlying arterial disease. In 1959, at our behest, the United States Catheter and Instrument Company produced a woven catheter designed to facilitate selective opacification of the coronary arteries using a brachial artery approach to the ascending aorta. Shortly thereafter, the technique of direct current counter shock for the control of lethal ventricular arrhythmias was developed by Kouwenhouven and Jude. By providing effective control of these most feared complications, the evolution of selective coronary arteriography seemed assured. Our experience with the first 1000 coronary arteriograms performed between 1959 and 1962 confirmed our ability to recognize the location and estimate the severity of obstructive lesions in the coronary artery tree, and we began to be able to define the origin and distribution of collateral arterial channels in patients with severe arterial obstructions. By selective opacification of the left ventricle in appropriate projections, we began to recognize the location and extent of scar tissue replacement in the left ventricle as well as the occurrence of mitral regurgitation or septal perforation caused by previous arterial occlusion. Of greatest clinical importance at that time, however, was the ability to rule out the presence of arterial obstructions in large numbers of patients whose lives were needlessly restricted because the diagnosis, based on clinical assessment, was in error.

In January 1962, we were able to demonstrate for the first time that internal mammary artery implantation could provide collateral flow to distal segments of obstructed coronary arteries. During the 5 years that followed, Effler and Favaloro developed techniques of single and double internal mammary artery implantation that were capable of augmenting coronary blood flow in properly selected patients to all major distal segments of the coronary artery tree. In 1967, Favaloro placed the first interposed vein graft into a completely obstructed right coronary artery, reestablishing normal direct flow to the myocardium perfused by its distal branches. During the ensuing 3 years, he and his surgical colleagues pioneered the development of bypass vein graft techniques to all major segments of the coronary artery tree responsible for left ventricular perfusion. The technique of internal mammary artery bypass to the anterior descending coronary artery developed by Green was extended by Favaloro to proximal segments of the left circumflex coronary artery. The effectiveness of this technique was confirmed by hundreds of postoperative studies that demonstrated a patency rate exceeding 97%.

Coincident with the surgical evolu-

tion made possible by the development of selective coronary arteriography, a host of technical developments occurred that significantly extended utilization of coronary arteriography or resulted in improved image quality. Retrospectively, it seems that the most important of these were

1. The development by Judkins of appropriate preformed catheters to permit selective coronary arteriography by the percutaneous transfemoral approach.
2. The development of x-ray generators capable of producing short, square wave pulses that could be synchronized with motion picture camera shutters.
3. The development of closed circuit television imaging and recording systems.
4. The development of the cesium iodide phosphor to improve the efficiency of energy conversion of image amplifier tubes.
5. The development of improved mechanical systems to facilitate greater comfort to patients, more efficient utilization of laboratory facilities, and craniocaudal and caudocranial projections.

The development by Gruntzig, of transluminal dilatation of certain obstructions in proximal segments of the coronary artery tree will certainly provide a new chapter in the evolution of our technology. He has proved beyond question that, in certain circumstances, this technique is feasible. The challenges involved in better defining the patients for whom this technique will be useful and in providing better instrumentation for its implementation will tax our best possible efforts in the foreseeable future.