

## HISTORY OF MEDICINE

# CABG at 50 (or 107?) — The Complex Course of Therapeutic Innovation

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Anniversaries offer opportunities to commemorate crucial discoveries of modern medicine, such as vaccination (May 14, 1796), ether (October 16, 1846), and insulin (January 11, 1922). But zeroing in on specific dates can obscure important dynamics. Innovation in medicine is a complex and continuous process that generally can't be pinned down to a single moment in time.

The history of coronary-artery bypass grafting (CABG) demonstrates the subtleties of medical innovation well. Fifty years ago, on May 9, 1967, Cleveland Clinic surgeon René Favaloro performed his first CABG procedure. By 1970, he and his colleagues — who are often credited with having “revolutionized the treatment of ischemic heart disease”<sup>1</sup> — had performed more than 1000 such operations. Impressed by their results, surgeons throughout the United States adopted the technique. But although Favaloro's work popularized CABG, he was not the first to perform the operation. Moreover, he quickly modified his initial approach, and surgeons have been continually modifying the operation ever since (see diagram). CABG, like all significant medical interventions, is the product of innumerable innovations by many physicians.

The idea behind CABG had actually been around for decades. In 1910, Alexis Carrel published an account of an operation he'd performed on a dog: he used a segment of carotid artery to connect the descending aorta to the

left coronary artery.<sup>1,2</sup> If the initial idea were the key aspect of innovation, Carrel would be considered the inventor of CABG. Yet he reported only a single, unsuccessful attempt: ventricular fibrillation developed, and the dog died. Carrel concluded that the procedure would succeed only if a surgeon could complete the anastomoses in less than 3 minutes, something that was beyond even his prodigious surgical skill.

Discouraged by Carrel's experience, surgeons tried other approaches to tackling coronary disease over the next 50 years.<sup>1,2</sup> Some reduced cardiac workload by means of thyroidectomy or sympathectomy. Others tried to increase blood supply to the myocardium by dusting the heart with asbestos to induce vascular adhesions, suturing omentum onto the heart, ligating or implanting the internal thoracic artery, or ligating the coronary sinus.

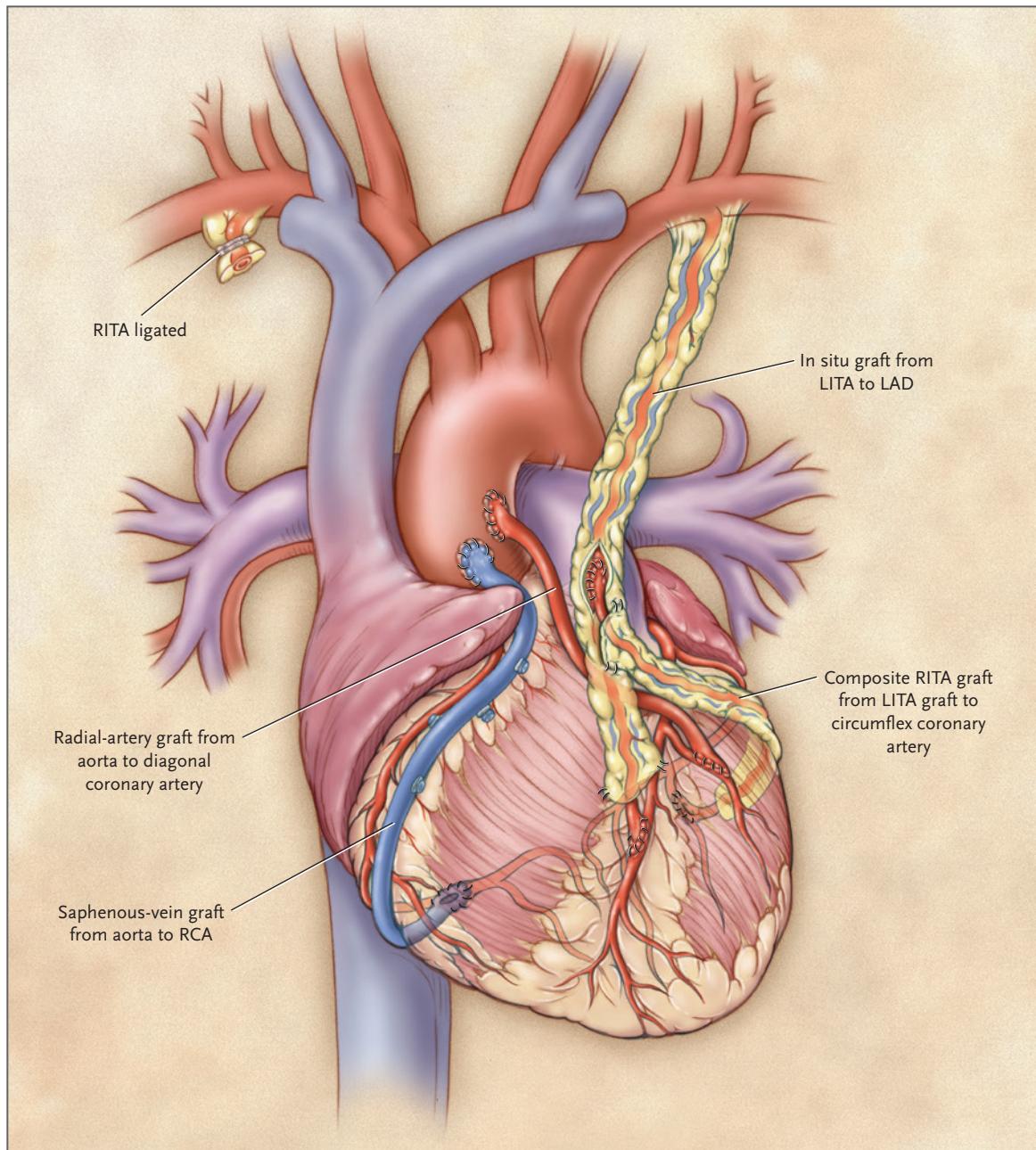
Yet CABG was not forgotten. In the 1940s and 1950s, Toronto surgeon Gordon Murray conducted experiments in animals. He excised coronary segments, inserted interposition grafts, and placed bypass grafts from various arteries. Unfortunately, ventricular fibrillation and graft thrombosis occurred frequently. Moscow surgeon Vladimir Demikhov also experimented with coronary bypass grafts, successfully anastomosing the internal thoracic artery in dogs in July 1953.<sup>3</sup> Michael DeBakey surveyed the field in 1964 and found 12 or 14 laboratories working on coronary-artery bypass.

He didn't think their techniques, whose average success rate was just 50%, were ready for use in humans.<sup>2</sup>

Nevertheless, surgeons had begun trying.<sup>1,2</sup> In May 1960, German emigré Robert Goetz anastomosed the right internal thoracic artery onto the right coronary artery of a patient at Van Etten Hospital in the Bronx.<sup>4</sup> In 1962, David Sabiston used a saphenous vein graft to create a bypass from a patient's ascending aorta to the right coronary artery. Leningrad's Vasilii Kolesov performed a successful internal thoracic artery bypass graft in February 1964; he had completed more than 30 similar operations by 1969.<sup>3</sup> In November 1964, Edward Garrett and DeBakey placed a saphenous graft between a patient's aorta and left coronary artery. Donald Kahn and William Longmire each performed two bypass procedures in 1966.

Most of these surgeons had setbacks. Goetz's colleagues considered the operation “not only highly experimental, but also unwarranted” and prevented him from performing a second bypass.<sup>4</sup> Sabiston became discouraged after his patient died from a postoperative stroke. Garrett and DeBakey's patient had a perioperative infarction. One of Longmire's patients died during the surgery; the other one's graft failed. Only Kolesov pursued a long case series.

If the credit for a procedure belongs to the surgeon who first operated on a human patient, then Goetz wins the prize. He was



#### Completed CABG Procedure.

The surgery depicted involves a saphenous-vein graft from the aorta to the right coronary artery (RCA), an in situ graft from the left internal thoracic artery (LITA) to the left anterior descending coronary artery (LAD), a composite right-internal-thoracic-artery (RITA) graft from the LITA graft to the circumflex coronary artery, and a radial-artery graft from the aorta to the diagonal coronary artery.

also the first to publish on CABG in humans, though he buried his achievement in a two-sentence addendum to a 1961 article about his animal experiments.<sup>3</sup> Kolesov

published his results — in Russian — in 1965.<sup>3</sup> Longmire published in a French journal in 1966.<sup>2</sup> Kolesov reported his results in 12 patients in the *Journal of*

*Thoracic and Cardiovascular Surgery* in October 1967. Kahn, Garrett, and Sabiston did not publish until 1971, 1973, and 1974, respectively. Favaloro's noted efforts came

after these others. A young Argentinian physician driven by politics into self-imposed exile in rural Argentina, Favaloro aspired to become a cardiothoracic surgeon.<sup>2,5</sup> He flew to Cleveland in January 1962 with only a letter of introduction. As he worked his way up from resident to staff surgeon, he gained expertise with many coronary techniques, including internal thoracic artery implants, endarterectomy, and patch grafts. In 1966, his attention turned to CABG.

Favaloro later explained that he learned about saphenous vein grafts from vascular surgeons who used them to repair renal-artery stenosis. He probably knew about Kolesov as well. When Kolesov submitted his manuscript to the *Journal of Thoracic and Cardiovascular Surgery* in November 1966, the journal's editor, Brian Blades, sent it to Donald Effler, Favaloro's mentor, for comment; Effler probably read Kolesov's report before Favaloro's first CABG attempt.

Favaloro performed a saphenous vein interposition graft on May 9, 1967.<sup>1,2,5</sup> He completed another 13 of these procedures before performing his first aorto-coronary-artery graft on October 19. When he published the results from his first 15 patients in April 1968, he mentioned another 40 in an addendum. His results were soon corroborated by two other surgeons, W. Dudley Johnson in Milwaukee and George Green in New York. Their case series buttressed Favaloro's claims about the value of CABG.

American surgeons adopted the operation enthusiastically. They were performing more than 100,000 CABG procedures per year by 1977, and more than 600,000 by 1997. CABG also provided a cru-

cial precedent for coronary angioplasty, which was first described by Andreas Grüntzig in 1977.

Surgeons continued refining CABG. They tested various conduits, including the gastroepiploic-artery and radial-artery autografts. They learned to place multiple grafts to provide more complete revascularization. They expanded the clinical indications for the procedure: Kolesov performed a CABG for acute myocardial infarction in February 1968, and Favaloro did the same that April.<sup>1</sup>

Technical innovations improved clinical outcomes and reduced complication rates. Beating-heart CABG and minimally invasive procedures became popular in the 1990s, though these haven't replaced traditional approaches. New diagnostic techniques (e.g., intravascular ultrasonography and measurement of fractional flow reserve) allow refined selection of patients. Physicians and patients can now choose hybrid procedures with a combination of angioplasty, stents, and bypass grafts. Biomedical engineers are working to develop synthetic vascular grafts. Even as CABG and angioplasty grow increasingly sophisticated, physicians recognize that the ideal approach to coronary disease is prevention — yet people in whom disease develops still need to be treated.

With every innovation came demands that surgeons submit their techniques to the rigorous standards of the emerging field of evidence-based medicine. CABG was one of the first major operations subjected to a randomized, controlled trial. The results of the first such trial, the Veterans Administration Cooperative Study, were published in the *Journal* in

September 1977. Scores of others have followed.

In 1989, the Society of Thoracic Surgeons established a national cardiac surgery registry, which facilitates ongoing quality-improvement efforts. The same year, New York State began public reporting of cardiac surgery outcomes. These efforts have made CABG perhaps the most thoroughly examined operation in the surgical repertoire. Cardiac surgeons and cardiologists now collaborate on heart teams to provide the best data to their patients for shared decision making.

Coronary revascularization, now representing a major sector of the health care economy, has relieved angina in countless patients and extended many lives. The Favaloro anniversary honors one moment in the continuing evolution of the procedure — a multifaceted process of social and scientific innovation that continues today.

Disclosure forms provided by the author are available at [NEJM.org](http://NEJM.org).

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