Supported Angioplasty: A New Contribution for Extra-Corporeal Circulation Technology

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Abstract

To date there have been no fewer than seven palliative treatments for atherosclerotic coronary artery disease. The expanding role of interventional cardiology in the treatment of patients with severe coronary artery disease will result in a mandatory and significant allocation of perfusion services dedicated to the catheterization laboratory.

Historical, and now more recent data, indicate that femoro-femoral bypass can be utilized as a resuscitative tool and as an adjunct to interventional cardiology techniques. The role of the perfusion team in the catheterization lab will evolve and expand along with the growing application of interventional cardiology techniques.

Introduction

A new chapter in the history of perfusion is being written. "Supported Angioplasty" (4,5) involves an extracorporeal circuit that is employed to provide circulatory support during high-risk transluminal coronary angioplasty (PTCA) or valvuloplasty procedures performed in the cardiac catheterization laboratory.

The availability of a specifically designed femoral artery-femoral vein cardiopulmonary bypass with a modified percutaneous cannulation procedure, complete with special cannulae, has made Supported Angioplasty an emerging elective procedure. The arterio-venous bypass circuit allows decompression of the heart (4) and maintenance of systemic perfusion pressure during prolonged coronary artery lumen or valve orifice occlusion.

Supported Angioplasty has allowed the guidelines for PTCA to change in some institutions and has presented new professional challenges and opportunities for perfusion service teams.

History

Surgical Treatment For Coronary Artery Disease

There have been no fewer than seven palliative surgical treatments (Table 1) for atherosclerotic coronary artery disease (CAD).

The Beck procedures (1,2) introduced extreme mechanical means to stimulate collateralization of coronary arteries. Dr. Beck first created epicardial inflammation by chemicals (talc) or abrasion and the Beck II operation partially ligated the coronary sinus to increase the coronary venous pressure in an attempt to open collateral coronary circulation.

Dr. Vineberg made a tunnel in the ventricular muscle and implanted the internal mammary artery which even-
### Table 1
**Palliative Surgical Treatments for CAD**

<table>
<thead>
<tr>
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<th>Procedure</th>
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<tbody>
<tr>
<td>1</td>
<td>Beck I Procedure</td>
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<tr>
<td>2</td>
<td>Beck II Procedure</td>
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<td>3</td>
<td>Vineberg Procedure</td>
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<td>4</td>
<td>Coronary Endarterectomy</td>
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<td>5</td>
<td>Internal Mammary Artery Graft</td>
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<tr>
<td>6</td>
<td>Saphenous Vein Graft</td>
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<td>7</td>
<td>Percutaneous Transluminal Coronary Angioplasty</td>
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Angioplasty

Interventional cardiologists are employing chemical and mechanical coronary artery angioplasty and the use of stents to create and maintain luminal patency. They are choosing from several new devices to tailor the treatment to the patient’s pathology. Some patients are not stable enough to undergo angioplasty or the obstruction of a coronary artery with the angioplasty balloon, either of which may render them critically unstable. For this reason, cardiologists have sought technologies that decrease the risk of PTCA. One “surgical instrument” that is available to invasive cardiologists is extracorporeal circulation by femoral cannulation. Femoro-femoral bypass provides circulatory assistance to allow prolonged PTCA balloon inflation and minimize patient risk.

Supported angioplasty is one more indication for femoral bypass to be added to the historical list of emergency indications that currently include cardiac arrest, cardiogenic shock, congestive heart failure, pulmonary embolus, profound accidental hypothermia, and many others (25). Lititz (19) reviews the genesis of emergency femoral bypass from the early usage by Stuckey (1958) (20), Cooley (1961) (21) and Kennedy (1969) (22) to the extended use of the emergency pump oxygenator by Mattox and Beall in 1975 (23–25). The femoral bypass systems of the 1970s and today’s systems are capable of providing 100% of the patient’s circulatory and respiratory needs with blood flow rates established via femoral cannulation.

**Present**

Suggested standards (guidelines) for PTCA were recently published (7). The task force from the American College of Cardiology and The American Heart Association that authored the standards acknowledges that PTCA complications can occur (7). The complications are reported to include non-fatal myocardial infarction, vascular trauma, re-stenosis, cardiac arrest, and death.

The guideline states:

“... Balloon inflation results in localized trauma to the coronary artery wall; the net result is usually atheroma fracture and arterial expansion that produce an increase in the luminal area available for blood transport (7).”

And recommends:

“An experienced cardiovascular surgical team should be available within the institution for emergency surgery for all angioplasty procedures. The Subcommittee feels strongly that there should be no exception to this requirement. . . . (7)”

**Change in the Cardiac Catheterization Laboratory**

Many cardiac catheterization laboratories have or are building adjoining surgical suites to accommodate open chest coronary surgery secondary to complicated PTCA. Laser angioplasty and other advanced therapies may be accomplished in this setting.

This practice is justified in light of the number of PTCA patients (approx. 3.5%) (7) that require emergency bypass surgery. There are, however, many cardiology teams that do not, or cannot, have immediate access to cardiac surgical teams.

Emergency femoro-femoral bypass initially provided the surgeon and cardiologist access to a mechanism to provide full circulatory support for patients in refractory shock or cardiac arrest (23–25). As the role of interventional cardiology has expanded, so has the role of femoro-femoral bypass in the catheterization laboratory.

Historical, and now more recent data (8,9), indicate that femoro-femoral bypass can be utilized not only as a resuscitative tool, but also as an adjunct to other interventional cardiology techniques. These data demonstrate the feasibility of using femoro-femoral bypass to support patients otherwise too hemodynamically unstable to receive needed therapies. In addition, femoro-femoral bypass has been shown, in many cases, to relieve symptomatic myocardial ischemia (angina, S-T segment depression) secondary to PTCA balloon inflation. These data suggest a reduction in myocardial oxygen consumption by use of the femoral bypass system to decompress the heart. Femoral bypass could be used more broadly for patients presenting with an evolving myocardial...
infarction (10). However, research to corroborate or refute these observations is vital.

Today, the proliferation of PTCA centers that need to have their own open heart team (7) has been hypothesized as one of the causes of the perfusionist shortage in North America (11). This, along with the elective use of cardiopulmonary bypass in the catheterization laboratory, presents the perfusion community with substantial challenges.

Leachman (15) lists electrode tipped catheters to study and alter cardiac electrical conductivity; catheters that cut plaque and employ mechanical, thermal, chemical or electrical energy for angioplasty; and catheter-delivered stents or umbrella-like occluders as devices of the future that are changing the role of the catheterization lab.

As cardiologists advance to interventional procedures (PTCA), percutaneous catheter insertions have become a “surgical” procedure and are no longer a “medical” or diagnostic intermediate step. The era of, and attitudes about, cardiology have changed with the cardiologists’ evolution from “primary” diagnostician to interventionalist.

Future

About 141,000 PTCA procedures were performed in 1987 and as many as 185,000 balloon angioplasty procedures will be performed in the United States in 1988 (exhibiting about a 31% annual growth rate) (12). The PTCA catheter market is predicted to grow from 202 million dollars last year to over one billion dollars in 1993 due to the growth in PTCA (13).

This growth is likely fueled not only by the increasing number of patients qualifying for PTCA under broadening selection criteria, but by the now common reports of successful multiple coronary angioplasty procedures. As well, restenosis after angioplasty and repeat PTCA are frequent (12).

New PTCA Technology

Today, PTCA is assumed to refer to “balloon” angioplasty. It is now clear that a variety of new technologies are being developed to accomplish the recanalization of coronary arteries through means other than the “fracturing” of an atheromatous plaque. Techniques or therapies currently being developed or in limited clinical use include laser, mechanical or chemical arthrectomy and coronary arterial stenting. All of these therapies will expand the number and type of coronary artery disease patients that will be treated by an interventional cardiologist before being referred to a cardiovascular surgeon.

Interventional cardiology is leading the invasive cardiologist out of the conventional role of diagnostician and medical manager into a more active treatment role. The expanding role of interventional cardiology in the treatment of patients with severe coronary artery disease is resulting in a mandatory and significant increase in allocation of perfusion services dedicated to the catheterization laboratory.

Controlled Reperfusion

In 1986, Okamoto, Allen, Buckberg and Cohorts (10) proposed a clinical model for the treatment of patients with acute myocardial infarction. They suggest that control of reperfusion conditions and reperfusion composition to ischemic segments of myocardium can lead to minimizing histochemical damage and maximizing recovery of function.

In the development of PTCA, Gruentzig and others proposed the concept of maintaining coronary perfusion during dilation (16). Angelini, Heibig and Leachman (17) determined the feasibility of maintaining distal hemoperfusion during PTCA balloon inflation of 3 to 5 minutes by presenting a new technique to achieve “...a major step toward the long-sought goal of extracorporeal coronary circulation during PTCA.”

Lazar, et al. (18) demonstrated that revascularization and immediate reperfusion with arterial blood impairs LV function. The authors further concluded that this damage can be avoided by reperfusion with blood cardioplegia in the arrested heart.

Today’s cardioplegia delivery systems are the “controlled reperfusion” ECCs of tomorrow. Perfusionists and others will operate ECCs that provide assisted circulation, cardiac decompression and isolated, distal PTCA balloon catheter coronary perfusion. The coronary reperfusate will be a blood-based, hyperosmotic, hypercalcemic, substrate-enhanced solution.

The new treatment of choice for acute myocardial infarct may well become PTCA with or without chemical or mechanical arthrectomy with controlled reperfusion for several minutes after angioplasty (personal communication, GD Buckberg, MD, UCLA Medical Center, Los Angeles, California, October, 1988.) Post PTCA reperfusion with normal arterial blood may be contraindicated and ECC reperfusate composition and delivery methods will be exhaustively studied as cardioplegia delivery has been.

Synchronized Retrograde Coronary Perfusion

Lazar (28) recently reviewed coronary sinus surgical interventions, specifically new techniques to retroperfuse the sinus. The protective role of synchronized retrograde coronary sinus perfusion (SRCSP) during coronary artery angioplasty has been defined by Weiner et al (27).

Gross (3) experimentally in 1937, Beck (1,2) clinically in 1948, and later, Farcot (26) clinically in 1978 with SRCSP, demonstrated the efficacy of coronary sinus
intervention in reducing myocardial necrosis during coronary artery occlusion. Perfusionists and physicians will continue to employ and study retrograde coronary sinus perfusion and the future application of SRCSP to deliver reperfusate during PTCA.

Some heart lung machine designs are currently outfitted to perform SRCSP with use of ECG-synchronization pulsatile flow control devices attached to a pressure-regulated, low-flow roller pump. In the future, reperfusate may be delivered retrograde via the coronary sinus in the decompressed, beating heart to avoid the problems (16,17,29) (high pressure drop and hemolysis) associated with distal PTCA catheter perfusion during balloon inflation.

Research Needs

At least five manufacturers are providing femoral cannulae for modified Seldinger technique percutaneous introduction. These cannulae must be evaluated for ease of insertion, pressure drop, maximum safe flow rate, and blood handling ability and possible microemboli generation. Additionally, future research must prove the ability to decompress the heart by femoral venous cannulation and femoral introduction of a LV sump catheter.

The femoral bypass operator must aid the physician to assure and document cardiac decompression, reduction of myocardial work and relief of ischemia during angioplasty. The monitoring and preservation of the awake patient’s neurologic status will prove a challenging area for research and evaluation.

In summary, we are in the early days of the expanded use of circulatory support in the catheterization laboratory. The role of the perfusion team in the catheterization lab will evolve and expand along with the growing applications of interventional cardiology surgical techniques.

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