AORTOCORONARY BYPASS SURGERY: A STUDY OF POSTOPERATIVE VEIN GRAFT BLOOD FLOW

by

Judith Ann Kedersha

A Thesis Submitted to the Faculty of the COLLEGE OF NURSING In Partial Fulfillment of the Requirements For the Degree of MASTER OF SCIENCE In the Graduate College THE UNIVERSITY OF ARIZONA

1975
STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: Judith Ann Kedzierska

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Karen Sechrist
KAREN SECHRIST
Assistant Professor of Nursing

Date
October 17, 1975
ACKNOWLEDGMENTS

The successful completion of this project involved a tremendous amount of help from many friends. I would like to acknowledge all their help and kindnesses.

I am deeply grateful to the members of my thesis committee for their constant support, patient understanding, and valuable critiques throughout the many months required to complete this project. Karen Sechrist, R.N., Ph.D., chairperson of the committee, was a source of continuous encouragement and optimism during the course of this and several other projects. I thank her for her many valuable suggestions. Virginia Miller, R.N., M.S., has been a good friend and teacher and generous with her time and support. To Richard G. Sanderson, M.D., a teacher and surgeon par excellence who has been consistently generous with his time and talents, go my deep thanks for sharing his knowledge of cardiac surgery.

A special thank you goes to Mary Frances Hughes, a longtime friend, for the drawing of the Doppler flow probe.

Appreciation is also extended to the people at the Arizona Heart Institute, particularly to Edward B. Diethrich, M.D., Director of the Institute, who permitted my participation in their study, and to Carolyn House, R.N., M.S., Administrative Assistant at the Institute, who was so...
helpful during the planning stages of the project. Special recognition and deep appreciation are expressed to the staffs of the intensive care unit and operating room for their interest and concern in the outcome of this project.

I also wish to thank my family for their constant support and occasional prodding when I needed it. Their faith in me has never faltered.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF ILLUSTRATIONS</td>
<td>viii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>ix</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>2. REVIEW OF THE LITERATURE</td>
<td>20</td>
</tr>
<tr>
<td>3. METHODOLOGY</td>
<td>28</td>
</tr>
<tr>
<td>Coronary Artery Disease</td>
<td>1</td>
</tr>
<tr>
<td>Surgical Approaches to Coronary Artery</td>
<td>2</td>
</tr>
<tr>
<td>Indications for Surgery</td>
<td>8</td>
</tr>
<tr>
<td>Operative Results</td>
<td>12</td>
</tr>
<tr>
<td>Significance of the Problem</td>
<td>13</td>
</tr>
<tr>
<td>Statement of the Problem</td>
<td>15</td>
</tr>
<tr>
<td>Theoretical Framework</td>
<td>16</td>
</tr>
<tr>
<td>Relevance to Nursing</td>
<td>18</td>
</tr>
<tr>
<td>Patency Rates</td>
<td>20</td>
</tr>
<tr>
<td>Factors Affecting Graft Patency</td>
<td>22</td>
</tr>
<tr>
<td>Blood Flow</td>
<td>22</td>
</tr>
<tr>
<td>Histological Changes</td>
<td>25</td>
</tr>
<tr>
<td>Summary</td>
<td>26</td>
</tr>
<tr>
<td>Research Design</td>
<td>28</td>
</tr>
<tr>
<td>Population and Sample</td>
<td>29</td>
</tr>
<tr>
<td>Data Collection</td>
<td>30</td>
</tr>
<tr>
<td>The Tools</td>
<td>32</td>
</tr>
<tr>
<td>Blood Flowmeters</td>
<td>32</td>
</tr>
<tr>
<td>Physiologic Monitoring Equipment</td>
<td>36</td>
</tr>
<tr>
<td>Limitations</td>
<td>39</td>
</tr>
<tr>
<td>Assumption</td>
<td>39</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>39</td>
</tr>
</tbody>
</table>
TABLE OF CONTENTS—Continued

4. PRESENTATION AND ANALYSIS OF DATA ............................ 41
   Description of the Sample ........................................ 41
   Subject One .................................................... 41
   Subject Two .................................................... 42
   Presentation of the Data ........................................ 43
   Patterns of Vein Graft Blood Flow .............................. 44
   Presentation of the Subject Data ............................... 45
   Characteristics of Vein Graft Blood 
   Flow and Arterial Pressures 
   During Premature Ventricular 
   Contractions ............................................. 52

5. DISCUSSION OF FINDINGS, CONCLUSIONS, 
   AND RECOMMENDATIONS .......................................... 58
   Discussion of the Findings .................................... 58
   Patterns of Vein Graft Blood Flow ............................ 59
   Discussion of the Subject Data ............................... 60
   Characteristics of Vein Graft Blood 
   Flow and Arterial Pressure During 
   Premature Ventricular Contractions ......................... 62
   Conclusions ................................................... 64
   Recommendations for Future Study ............................ 65

6. SUMMARY ............................................................ 68

APPENDIX A, DATA COLLECTION FORM ............................... 71

APPENDIX B, VEIN GRAFT BLOOD FLOWS AND 
PHYSIOLOGIC PARAMETERS FOR 
SUBJECT ONE .................................................. 73

APPENDIX C, VEIN GRAFT BLOOD FLOWS AND 
PHYSIOLOGIC PARAMETERS FOR 
SUBJECT TWO .................................................. 75

APPENDIX D, VEIN GRAFT BLOOD FLOWS AND ARTERIAL 
PRESURES BEFORE, DURING, AND AFTER 
PREMATURE VENTRICULAR CONTRACTIONS 
(PVC) ...................................................... 77

SELECTED BIBLIOGRAPHY ........................................... 79
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Means and Standard Deviations of the Physiologic Parameters for Subjects One and Two</td>
<td>47</td>
</tr>
<tr>
<td>2. Correlations (R) and Significance R Between Peak Vein Graft Blood Flow and the Physiologic Parameters for Subject One</td>
<td>48</td>
</tr>
<tr>
<td>3. Correlations (R) and Significance R Between Both Peak and Mean Vein Graft Blood Flows and the Physiologic Parameters for Subject Two</td>
<td>50</td>
</tr>
<tr>
<td>5. Means and Standard Deviations of Vein Graft Blood Flows and Arterial Pressures Before, During, and After Premature Ventricular Contractions (PVCs)</td>
<td>55</td>
</tr>
</tbody>
</table>
# LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Drawing Depicting the Doppler Flow Probe Positioned Around the Vein Graft</td>
<td>35</td>
</tr>
<tr>
<td>2.</td>
<td>Diagram of a Simultaneous Recording of Electrocardiogram, Arterial Pressure, and Vein Graft Blood Flow During Systole and Diastole</td>
<td>46</td>
</tr>
<tr>
<td>4.</td>
<td>Graphic Representation of the Means of Vein Graft Blood Flows and Arterial Pressures Before, During, and After Premature Ventricular Contractions (PVCs)</td>
<td>56</td>
</tr>
</tbody>
</table>
ABSTRACT

Aortocoronary bypass surgery is currently the most effective means of myocardial revascularization. Optimal surgical results are achieved when vein grafts remain patent. Intraoperative vein graft blood flow is a reliable indicator of long-term patency. This study attempted to identify postoperative physiologic parameters which would correlate with changes in vein graft blood flow.

A Doppler flowmeter was positioned around the vein grafts of two subjects during surgery. Postoperative vein graft blood flow measurements were obtained and correlated with the physiologic parameters.

Vein graft blood flow was continuous yet phasic throughout the cardiac cycle with the greater portion occurring during diastole. Vein graft blood flow and systolic blood pressure were greater when ventilatory support was provided by T-piece oxygen apparatus than by ventilator or oxygen face mask. One subject demonstrated a positive correlation between vein graft blood flow and systolic blood pressure at the .05 level of significance. Correlations obtained between vein graft blood flow and the parameters of central venous pressure and temperature were highly variable. No statistical significance was demonstrated between vein graft blood flow and diastolic blood
pressure, cardiac rate, or respiratory rate. The effect of premature ventricular contractions on vein graft blood flow appeared minimal.
Despite continuing medical advancements on all fronts, heart disease remains the nation's number one killer. Each year coronary artery disease claims over 650,000 American lives through its most devastating manifestation—myocardial infarction. About 250,000 of these deaths are sudden and unexpected. Of particular social and economic importance is the significant number of deaths and disabilities occurring in young men who are heads of households and in their prime productive years. The toll that coronary artery disease imposes in terms of disability, grief, hardship, and economic loss is difficult if not impossible to accurately measure or describe.

Coronary Artery Disease

Coronary artery disease is a complicated disease process that is not fully understood. Hurst and Logue (1970:906) note the development of fatty granulomatous lesions in the walls of the coronary arteries which undergo a series of changes that may lead to hardening and/or occlusion of the vessel:

The lesions, known as atheromas (Greek for gruel), are characterized by focal intimal thickening, variable amounts of intimal and subintimal
lipid deposition, deformation and fragmentation of the internal elastic membrane, and, in advanced cases, fibrosis and calcification.

According to Corday and Swan (1973:3):

The overriding problem . . . is that we do not as yet understand the basic mechanisms underlying the development of the lesions, nor how various risk factors influence the progress of these lesions to the point where signs of clinical disease become evident.

The results of these lesions projecting into the lumen of the vessel are better understood than the disease process itself. As the vessel narrows, the blood supply to the myocardium becomes limited. When the blood supply becomes temporarily inadequate to meet the oxygen needs of the heart muscle, the myocardium is said to be ischemic. This ischemia, in turn, stimulates pain fibers and gives rise to coronary artery disease's characteristic symptom of angina pectoris. When the ischemia is prolonged and leads to the death of the cells in the affected area, a myocardial infarction is said to have occurred (Sanderson, 1972).

Surgical Approaches to Coronary Artery Disease

Surgical procedures to augment standard medical therapy in the treatment of coronary artery disease have been proposed since Heberden first described the symptom of angina pectoris in the eighteenth century. In the early 1900's, various cardiac denervation procedures were performed to relieve the pain of ischemic heart disease;
these procedures, however, did nothing for the anatomic-pathophysiologic base of the problem (Favaloro, 1970; Norman, 1972). Surgical thyroidectomies, and later medically-induced thyroidectomies using radioactive iodine ($^{131}$), were advocated with the expectation that low metabolic requirements would counteract coronary insufficiency. These procedures, however, increased serum cholesterol levels and, like the denervation procedures, are no longer recommended (Meier and Senning, 1973).

Indirect myocardial revascularization procedures were first proposed in 1935 when Beck theorized that the formation of pericardial adhesions would result in myocardial revascularization from an extracardiac blood supply. A multiplicity of agents for producing these adhesions were evaluated, including asbestos. In 1941, the Beck I operation was introduced and was an expansion of Beck's original theory. This fourfold procedure involved the abrasion of the epicardium and visceral pericardium, the application of asbestos to the abraded surface, the suturing of the pericardial fat, and the partial ligation of the coronary sinus. This operation was later abandoned since additional blood flow to the myocardium could never be accurately demonstrated (Corday and Swan, 1973; Diethrich, 1974).

The Beck II procedure, proposed seven years later, modified the original Beck I. In the first of two separate stages, a vein graft was placed between the descending
thoracic aorta and the coronary sinus; one month later, the coronary sinus was partially occluded by ligation. The high operative mortality and the need for two separate surgical procedures led to the rejection of the Beck II procedure (Corday and Swan, 1973; Diethrich, 1974).

Internal mammary artery revascularization procedures were first performed in 1939 and involved the ligation of this artery in order to stimulate the expansion of pre-existing collaterals and thus enhance blood supply to the myocardium. In 1946, Vineberg (Favaloro, 1970; Meier and Senning, 1973) proposed a tunnel implantation of the internal mammary artery into the ventricular myocardium with the subsequent development of anastomoses between the coronary circulation and the internal mammary artery. Despite considerable controversy, this procedure and its modifications enjoyed widespread application for many years.

The decade of the 1950's brought several technical advances that were indispensable to present-day coronary artery surgery. The introduction of cardiopulmonary bypass in 1953 by Gibbon (Favaloro, 1970) permitted surgeons to operate in a quiet, bloodless, surgical field and benefitted all areas of cardiac surgery. In 1958, Sones (Favaloro, 1970) introduced the diagnostic technique of selective coronary arteriography which can reveal the exact location and extent of the atherosclerotic lesions. According to Effler (Favaloro, 1970:xi), coronary
arteriography did much more than improve the diagnosis of coronary artery disease.

Figuratively speaking, Sones's catheter pried open the lid of a veritable treasure chest and brought forth the present era of revascularization surgery. His technic did provide for accurate diagnosis in coronary arterial disease but, more important, it defined the needs of the individual patient. For these reasons alone, coronary arteriography was a monumental contribution.

The era of direct myocardial revascularization began in the 1950's. Mechanical endarterectomy was introduced in 1957 and involved the removal of the atheromatous plaque through an arteriotomy. Mortality rates were high due to a "snow plow" effect. "The main artery has been effectively cleared by the aggressive use of the snow plow; unfortunately, clearing the main artery has impacted all areas of lateral communications" (Meier and Senning, 1973:80).

Venous patch grafts, and later pericardial patch grafts, were proposed in association with endarterectomies to enlarge the lumen of the obstructed coronary artery. Mortality rates were also high due to frequent dissections of the distal portion of the coronary circulation or occlusions of important side branches (Favaloro, 1970; Meier and Senning, 1973).

In recent years, practically all previous revascularization procedures have been abandoned in favor of aorto-coronary bypass surgery. In May, 1967, Favaloro first began to use a venous interposition procedure but this was soon
replaced by the well-known vein graft surgery. Today this method dominates the field of coronary artery surgery. Mortality rates are amazingly low in some centers and reported benefits are encouraging.

According to Cooley, Hall, Dawson, Hallman, Wukasch, and Garcia (1973:146),

Aorto-coronary saphenous vein bypass (CAB) has become the preferred technique for myocardial revascularization in patients with ischemic heart disease. CAB is direct and affords a prompt increase in coronary blood flow to areas of myocardium distal to total or high-grade occlusive disease.

Lichtlen and associates (1972:450) note the following:

It is the aim of surgical revascularization to restore myocardial blood flow to a degree that will prevent ischemia at rest and during exercise in previously underperfused areas, and thus relieve angina pectoris.

According to Sanderson (1972), the operative procedure involves the removal of a segment of an appropriate vessel, usually the saphenous vein in the thigh. One end is anastomosed to the ascending aorta and the other end to the coronary artery to a point distal to the diseased or obstructed area. In this way, blood is bypassed or circumvented around the obstructed area to provide the myocardium with a supply of blood that was previously denied to it because of disease. The underlying atherosclerotic disease process is left unaltered. Thus, the operation is aptly named an aortocoronary bypass.
The fact that the procedure relieves angina pectoris in almost all patients is widely accepted. Urschel and associates (1972b:1048) go beyond this and optimistically propose that "direct coronary artery surgery aims to improve the quality of life and postpone or prevent death, myocardial infarction, and its complications." Whether aorto-coronary bypass surgery actually does this remains to be proven. Continuing study is needed to determine how the long-term results of surgery compare with intensive medical management. According to Diethrich and associates (n.d.:17) "We must approach the subject as a scientific experiment with the proper collection of meaningful and comparable data."

Continuing improvement in the coronary endarterectomy procedure, now using carbon dioxide, has led to a combined procedure using aortocoronary bypass surgery and carbon dioxide endarterectomy in selected patients. Carbon dioxide endarterectomy involves the injection under high pressure of a relatively soluble gas which smoothly dissects the plaque from the outer adventitia over a long distance without the snow plow effect of mechanical endarterectomy. According to Urschel and associates (1972a:10),

Distal carbon dioxide coronary gas endarterectomy with a proximal vein bypass graft provides immediate direct revascularization of the myocardium in patients whose blood vessels are diffusely or totally occluded and who are not amenable to standard vein bypass graft procedures.
Cooley (1973:73) notes, "This technique of combined endarterectomy with saphenous vein bypass graft extends the applicability of the principle of direct myocardial revascularization."

Recent efforts to achieve revascularization by direct anastomosis between systemic arteries, usually the internal mammary artery, and the coronary artery have been reported. This procedure has the advantage of using an arterial vessel in a high pressure arterial system and initial reports concerning graft patency are very good. In angiographic studies in patients who were operated upon two weeks to three years previously, Green (1972) notes a patency rate of ninety-seven per cent for myocardial revascularization using the internal mammary artery as compared with sixty per cent using the saphenous vein. The internal mammary artery operation, however, is longer and more technically difficult because of the fragile nature of the artery (Favaloro, 1970). Aortocoronary bypass surgery using the saphenous vein remains the more widely accepted procedure at this time.

**Indications for Surgery**

Although all the indications for aortocoronary bypass surgery are not firmly established, two major areas must be considered: angiographic and clinical criteria. According to Kaltman (1973:420), "Coronary arteriography
with demonstration of significant proximal large vessel occlusion is paramount in the consideration for surgery."

An occlusion is considered significant when the lumen is reduced in size by at least sixty to seventy-five per cent. The importance of a good distal runoff is stressed by Shirey (1971) and echoed by Favaloro (1971). Favaloro also notes (pp. 1039-1040) that "obstruction by lesions distal to the major obstruction should not exceed fifty per cent."

Kaltman (1973:420) observes that although visualization of a good distal runoff is desirable, it is not essential since patent distal vessels may be found at operation when they were not apparent angiographically.

Angiographic evaluation of the left ventricle is essential in the selection of patients for surgery. According to Favaloro (1971:1040), "The ideal patient will show good contraction of the left ventricle on a routine left cineventriculogram with normal end-diastolic pressure, and cardiac output within normal limits." Kaltman (1973) notes that the results of surgery as reflected in mortality and morbidity is closely related to the performance of the left ventricle. The risks of operation increase as evidence of poor left ventricular function appears. Kaltman notes:

An operative mortality rate of less than five per cent in patients with good ventricular function can be thirty to fifty per cent in the presence of severe cardiac enlargement and failure (p. 421).
In another communication, Favaloro (1973:45) describes the best candidate for surgery:

... one who has severe obstruction somewhere in the coronary circulation but who has not yet had a myocardial infarction (M.I.), and whose heart muscle is still good.

Nevertheless, all patients who are being evaluated for surgery are not ideal surgical candidates.

A significant number of patients are being evaluated after several myocardial infarctions and will show, in addition to the widespread disease in the coronary circulation, impaired contraction of the left ventricle with elevated end-diastolic pressures and diminished cardiac output. If careful evaluation of the cineangiograms reveals the feasibility of multiple bypasses, the operation should be performed as the only chance for recuperation (Favaloro, 1971:1040-1041).

The second major area for consideration involves clinical criteria. Clinical criteria must be evaluated and correlated with angiographic criteria. Presently, angina pectoris that is refractory to optimum medical treatment constitutes the principal clinical indication for aorto-coronary bypass surgery (Ehrlich, 1974; Kaltman, 1973). Operative mortality for this group of patients with stable angina and satisfactory ventricular function is relatively low. Gott (1974) and Wilson (1974) note that most centers are reporting mortality rates under six per cent. Shumway and associates (1974) report an elective mortality rate of 0.8 per cent.

Other clinical indications for surgery have not been fully defined or agreed upon. Aortocoronary bypass surgery
has been used with increasing frequency in the treatment of patients with unstable angina. This anginal complex has also been referred to as crescendo, accelerated, and pre-infarction angina and is characterized by a sudden exacerbation of chronic angina and is refractory to intensive medical management (Kaltman, 1973). According to Favaloro (1971:1041), "There is no doubt that admission to the coronary care unit is not enough."

Although emergency surgery for an uncomplicated myocardial infarction (M.I.) is not generally accepted at this time, the acute M.I. patient in cardiogenic shock presents a different problem. The mortality rate for this latter group is exceptionally high when treated by intensive medical management alone (including the use of balloon counterpulsation). Initial surgical revascularization attempts seem moderately effective in selected patients (Ehrlich, 1974; Kaltman, 1973; Wilson, 1974; Mundth and associates, 1972).

Critical high-grade left main coronary artery lesions may be considered another indication for surgery since even with the best medical therapy, the incidence of sudden death is high. Surgery has also been employed in the treatment of refractory life-threatening ventricular arrhythmias with effective results being reported. In the treatment of congestive heart failure, surgery has not proven beneficial; the presence of severe congestive heart
failure with severe ventricular dysfunction is a strong deterrent against surgical intervention in an otherwise acceptable revascularization candidate (Corday and Swan, 1973; Ehrlich, 1974; Kaltman, 1973; Shirey, 1971; Wilson, 1974).

Operative Results

Reports have been impressive concerning the symptomatic improvement of patients with the subjective relief of angina pectoris following aortocoronary bypass surgery. Shumway and associates (1974) report that angina was completely relieved in seventy-nine per cent of 375 patients with sixty-three per cent returning to full employment. Only twelve per cent were symptomatically unchanged or incurred major late complications. DeBakey (1972) reports that approximately ninety per cent of 900 patients undergoing revascularization surgery (bypass surgery with or without endarterectomy) experienced a significant improvement in their symptoms with about eighty per cent restored to virtually normal activities. After studying data from several centers, Gott (1974:431-432) concludes:

Approximately 85 per cent of the patients who survive the procedure experience relief of angina and 60 per cent have no further chest pain. . . . Most of these patients have been able to return to work and from the standpoint of the patient, the operation has been highly successful.

Reported results regarding the effectiveness of aortocoronary bypass surgery on left ventricular (L.V.)
function have been conflicting. In summarizing these reports, Wilson (1974) notes that normal preoperative L.V. function shows no change or a slight reduction in function postoperatively; moderate dysfunction frequently improves; severe L.V. impairment associated with preinfarction angina may dramatically improve; chronically severe dysfunction with minimal angina usually does not improve. Ventricular improvement is thought to be due to the revascularization of the ischemic myocardium. "The effect of saphenous vein by-pass on left ventricular function must then be regarded as a mixed bag" (Wilson, 1974:442).

**Significance of the Problem**

The key to the effectiveness of aortocoronary bypass surgery lies in the long-term patency of the vein graft which restores or improves blood supply to the ischemic myocardium. According to Urschel and associates (1972b:1048) "The success of this surgical endeavor can only be assured by prolonged patency of the reconstructed conduits."

Patency, furthermore, appears to be significantly influenced by the amount of blood flowing through the vein graft. Vein graft blood flow measurements are frequently performed at the time of operation and are considered reliable predictors of long-term patency (Diethrich and associates, n.d.; Edwards, 1971; Grondin and associates, 1971b; Moran, Chen, and Rheinlander, 1971).
Researchers involved in vein graft blood flow measurements using electromagnetic flowmeters have identified factors relating to measurement recordings. Greenfield and associates (1972) found that blood flow was highest during the time on cardiopulmonary bypass and decreased to a stable level thirty minutes after bypass. Moran and associates (1971:539) note, "Following the surgical insult and cardiopulmonary bypass, usually with hypothermia, variable and unpredictable degrees of coronary vasospasm exist which may affect the value of such measurements." Like Grondin and associates (1971a), Moran and associates injected Papaverine Hydrochloride directly into the graft to temporarily relax vasospasm and additional flow measurements were obtained. Grondin and associates (1971a:818) further suggest:

Validity of blood flow measured at surgery has been questioned since general anesthesia, surgical manipulation, and local ischemia do not represent "normal" physiologic conditions. Opening of the chest may cause a decrease in cardiac output of up to 30%.

Edwards (1971:663) echoes this concern and advises that "care must be taken to control variables, particularly blood volume and cardiac output." Diethrich and Prian (1973:103) note that "Ideally, long-term graft flow would be measured," but acknowledge the difficulties in doing this.

Benchimol and Desser (1973) were among the few who have studied blood flow velocity through the vein graft in
the postoperative period. They measured vein graft blood flow velocity with a Doppler flowmeter catheter tip at the origin of the vein graft in twelve subjects who had undergone aortocoronary bypass surgery from one to eighteen months previously. They found that blood flow velocity was greater during diastole than during systole. Velocity decreased in a few subjects who experienced ventricular arrhythmias and the inhalation of Amyl Nitrite resulted in augmented flow velocity in two subjects.

Research involving blood flow measurements through aortocoronary bypass grafts has chiefly taken place at the time of operation or in animal laboratories. Few reported studies have centered on blood flow measurements in the postoperative period under more "normal" and stable physiologic patient conditions.

**Statement of the Problem**

This investigation studied vein graft blood flow in the immediate postoperative period following aortocoronary bypass surgery. The problem considered was: Do changes in postoperative blood flow through aortocoronary bypass grafts correlate with changes in the physiologic parameters of arterial pressure, cardiac rate and rhythm, central venous pressure, temperature, respiratory rate, or type of ventilatory support? In particular, what is the relationship between cardiac arrhythmias and vein graft blood flow?
Theoretical Framework

The theoretical framework focuses on the factors affecting patency of the aortocoronary bypass grafts. The importance of maintaining patency is not to be underestimated for, according to Bourassa, Goulet, and Lesperance (1973:127), "Whenever aortocoronary vein grafts became occluded after surgery, the benefit expected from the bypass procedure is cancelled." The surgery is then for naught.

Urschel and associates (1972b) have summarized the factors influencing vein graft blood flow and graft patency. These factors have been divided into three main areas: physiological, pathological, and technical considerations. Physiological factors include: Poiseuille's law (pressure-resistance-flow relationship), the cardiac cycle, the equation of continuity (velocity-cross-sectional area effect), Hooke's law (tension-length effect), and Laplace's law (tension-radius effect). Pathologic factors affecting vein graft blood flow include competitive flow, postcardiotomy syndrome, and infection. According to these investigators, the most important pathophysiologic factor is "competitive flow between the coronary artery and vein graft, as well as between vein grafts into systems with good intercoronary collateral circulation" (Urschel and associates, 1972b:1048). Post-cardiotomy syndrome and mediastinal and sternal infections are associated with high graft occlusion rates. The technical factors involve the selection and preparation
of the vein graft and the management and placement of both anastomoses.

Diethrich and Prian (1973) suggest a similar group of factors affecting patency in aortocoronary bypass grafts. These include technical, physiologic, and metabolic factors. Technical factors are the primary determinants of early patency and include aspects such as the selection and preparation of the saphenous vein, the aortic and coronary anastomoses, and the pericardial closure. Physiologic factors affect both graft patency and left ventricular performance. These factors include the pressure gradient across the stenotic lesion, the distal arterial runoff, the presence or absence of collateral circulation, and the blood flow through the graft. Metabolic factors are composed of abnormalities such as diabetes and lipoprotein derangements.

Based on these three major factors, Diethrich and Prian then propose a patient classification system to analyze the results of the operative procedure. The patient in Class I has the greatest chance for long-term graft patency (over ninety per cent). He has a high-grade, proximal stenotic lesion, high initial graft flow, a "perfect" saphenous vein, stable atherosclerosis, and a perfect operative technique. The patient in Class II has moderately diffuse coronary disease with associated metabolic disease; he has a usable saphenous vein and the potential for technical error is present. The Class II patient has a higher
initial graft failure, with a projected three year patency rate of sixty to seventy per cent which decreases an additional ten to fifteen per cent at the five year point. The patient in Class III has the poorest prognosis. He has diffuse coronary disease, a marginal saphenous vein with a marginal distal arterial runoff, low initial graft flow, and accelerated atherosclerosis with associated metabolic disorders; technical errors are present and the operation is "inappropriate." The Class III patient's five year projected patency is nil.

Relevance to Nursing

This study is relevant to nursing in that nurses as well as physicians who participate in the postoperative care of aortocoronary bypass patients should be concerned with the future patency of the grafts. They should understand the relationships between graft patency, blood flow through the vein graft, and the various physiologic parameters they are monitoring. According to Sanderson (1972:v),

The cardiac nurse is expected to play a new and expanded role in comprehensive patient care. The cardiac nurse should have an in-depth knowledge about the underlying disease processes, the diagnostic and therapeutic maneuvers used to treat cardiac disease, and the techniques of meticulous care of these critically ill patients.

The importance of research has been stressed in nursing literature in recent years. Research conducted by
House (1973:106) involving arrhythmias following revascularization surgery

... points out that it is possible to carry out nursing research in a fairly technical area of study and that the results have meaningful implications for the design and delivery of nursing care.
CHAPTER 2

REVIEW OF THE LITERATURE

Aortocoronary bypass surgery is designed to improve and re-establish coronary blood flow to the ischemic myocardium. In order to achieve this goal, the vein graft must remain patent. Review of the literature will focus on vein graft patency rates and the factors affecting patency.

Patency Rates

Vein graft patency following aortocoronary bypass surgery is determined by postoperative coronary angiography and reported results vary. An early patency rate of 90.3 per cent is reported by Grondin and associates (1971a) based on studies performed within one month of operation on seventy patients with a total of 103 grafts. This same group reports a one-year postoperative late patency rate of 77.5 per cent in ninety-six patients whose 133 grafts were patent shortly after surgery (Grondin and associates, 1972).

Aronow and Stemmer (1974) note that eighteen of twenty-seven grafts in twenty patients remained patent after one year (67 per cent). Cooley, Hall, Dawson, Hallman, Wukasch, Garcia, and Sandiford (1973) report a patency rate of seventy-three per cent based on one hundred patients studied an average of 7.2 months postoperatively.
Angiographic studies performed six months to three years on four hundred postoperative patients at The Cleveland Clinic demonstrated a patency rate of eighty-five per cent (Effler and associates, 1971). After reviewing reports involving over eight hundred grafts studied from one week to over one year after operation, Wilson (1973) noted patency rates ranging from sixty-four to ninety-six per cent with an average of eighty-five per cent.

Some investigators, furthermore, note that late graft occlusion is uncommon after a specific time interval. Flemma and associates (1972) reviewed reports from three large groups of patients who were angiographically studied from zero to thirty-two months after operation. They note an early vein graft closure rate of nine per cent and a late closure rate of thirteen per cent. No vein grafts, however, occluded after an eighteen month period from the time of operation.

Gott (1974:431) notes, "Although vein patency is reduced to between 65 and 75 per cent 1 year postoperatively, the occlusion rate over the next 2 years appears to be only 5 to 6 per cent." And Favaloro (1973:45) reports:

It is interesting to note that the majority of the graft failures have occurred within three months of the operation. In patients who have been restudied two years or more after the operation 92 per cent of the grafts are open. In patients with multiple bypass, we know that at least one graft is open in 93 per cent of them."
One of the longest follow-ups of a successful aorto-coronary bypass procedure with a patent vein graft is reported by DeBakey, Edward, and Dennis (1973). Seven years after the operation, the left anterior descending graft was patent and functioning well at the time of angiography, although the atherosclerotic process had progressed in the right and left main coronary arteries. Left ventricular hemodynamics were normal at this time. According to these investigators, "It is likely that continued patency of the graft accounts for satisfactory left ventricular function and prolongation of life in this particular patient" (p. 794).

Factors Affecting Graft Patency

Patency of the vein graft is of utmost importance if aortocoronary bypass surgery is to succeed in bringing a new blood supply to the myocardium. Vein graft blood flows and histologic changes within the graft have been identified as factors affecting patency and will be discussed in this section.

Blood Flow

The most reliable factor correlating with graft patency appears to be the intraoperative measurement of blood flow through the vein graft (Diethrich and associates, n.d.; Edwards, 1971; Grondin and associates, 1972; Urschel and associates, 1972b). A high percentage of vein grafts with mean blood flows less than 40 to 50 cubic centimeters
per minute (cc/min) will eventually occlude while vein grafts with higher flows (greater than 40 to 50 cc/min) will more likely remain patent (Diethrich and associates, n.d.; Grondin and associates, 1971b; Wilson, 1974).

Various factors have been reported which correlate with vein graft blood flow and thus with patency. Grondin and associates (1972) report the results of angiographic studies performed one year after aortocoronary bypass surgery. Factors in this study which influenced late patency were: favorable blood flow measurements at the time of operation, the caliber of the recipient coronary arteries, and the distal arterial runoff. Patent grafts were characterized by a mean intraoperative blood flow of 74.8 cc/min as compared with blood flows of 44.4 cc/min in occluded grafts. Late occlusions occurred more frequently in grafts to coronary arteries with diameters of 1.5 millimeters (mm) or less than grafts to arteries 2 mm or greater in diameter. The size, length of the graft, and vein graft-to-coronary artery ratio did not affect late patency.

Diethrich and associates (n.d.) report on correlation studies from one hundred consecutive intraoperative angiographic and hemodynamic studies. They conclude that intraoperatively measured blood flow has shown to be an important predeterminant of vein graft patency and function. They predict that a high percentage of low flow grafts (below 40 cc/min) will eventually occlude. Their studies
suggest that angiographic runoff is the most important predictor of vein graft blood flow. No evident correlation, however, was found between blood flow and pressure gradients across the atherosclerotic narrowing in the coronary artery.

The findings of Moran and associates (1971) and Najmi and associates (1974) coincide with the previous studies. Moran and associates note that graft patency depends largely upon vein graft blood flow, which in turn is related to several factors, including oxygen demand. Blood flow, however, "depends primarily on the capacity of the distal coronary bed to accept blood flow" (p. 539). This property is referred to as coronary vascular resistance. Moran and associates also refer to the importance of technical adequacy in performing the operation.

Najmi and associates (1974:42) also note that good clinical results correlate with higher intraoperative vein graft blood flow and that "flows through the saphenous bypass was directly related to the state of the distal coronary arterial system." These investigators also observe that most of the patients who died in their study had poor distal runoffs and that the best results from the operation were obtained in patients who had a good distal runoff and adequate ventricular function.

The usefulness of velocity of vein graft blood flow as an additional prognostic indicator of graft survival was suggested by Furuse (1972:282). Based on a study of fifteen
dogs, he observed that "in clinical coronary artery bypass, there may be considerable advantage in using a small-diameter bypass vessel . . . to ensure a higher velocity flow through the graft."

Edwards (1971:663) suggests that turbulence is as significant a factor as blood flow in maintaining graft patency. A very precise, smooth anastomosis with minimum turbulence is required." Edwards also suggests the use of small-diameter vein grafts which are close to the caliber of the distal artery to reduce turbulence. He notes that "there is some cause for concern" when a large vein is used (p. 664).

In a study involving vein graft blood flow measurements in fifty-seven patients, Greenfield and associates (1972) found no correlation between blood flow and the following: left versus right coronary artery vein grafts, the presence or absence of collateral circulation, total versus partial occlusion, and the presence or absence of ventricular dyskinesis.

Histological Changes

Other investigations concern histologic changes within the vein graft. In reviewing reports of several studies, Wilson (1974:438) concludes that "early occlusion results from thrombosis, often promoted by stasis; late
occlusion largely is the result of subintimal hyperplasia within the vein graft."

In experimental studies in dogs, Brody and associates (1972) note short-term and long-term histologic changes in the vein grafts. Short-term changes consist of "myocyte necrosis and fibrocytic metaplasia of medial myocytes leading to medial fibrosis"; and long-term changes involve "intimal thickening with myointimal cell proliferation and intimal fibrosis" (p. 852). Medial necrosis leading to fibrosis was induced when the grafts were made ischemic by interruption of the blood supply to the vein. Intimal proliferation and fibrosis occurred by subjecting the grafts to arterial pressure. The investigators note that "these findings demonstrate that pressure and ischemia are important factors which act independently to produce changes in vein grafts following aorto-coronary bypass" (p. 852).

According to Flemma and associates (1972:232),

Histological evaluation has revealed subintimal fibrous hyperplasia to be the predominant factor involved in late closure of the vein bypass. Its manifestations are variable, and the multifactorial etiology is as yet unclear.

**Summary**

A review of the literature reveals that vein graft blood flow is a prime prognostic indicator of graft patency following aortocoronary bypass surgery. Histologic changes
within the graft also affect graft patency. Graft patency will determine the success of the operation in augmenting blood supply to the ischemic myocardium, thus relieving the symptoms of coronary artery disease.
CHAPTER 3

METHODOLOGY

The research procedures that were utilized are presented in this chapter.

Research Design

This descriptive study was designed to identify the physiologic parameters that affect vein graft blood flow in the immediate postoperative period following aortocoronary bypass surgery. The research was conducted at the Arizona Heart Institute as part of a larger study being conducted by the Institute. Patient consent to be included in the larger project, therefore, was prerequisite to participation in this study. Permission for the study was obtained from the Director of the Arizona Heart Institute.

During the surgical procedure, a specially-designed Doppler ultrasound flow probe was placed around either the left anterior descending or the left circumflex vein graft. This was done by the surgeon or his assistant after the completion of cardiopulmonary bypass and prior to chest closure. An electromagnetic flow probe was also applied to the vein graft at this time and the ultrasound signal was calibrated to the electromagnetic value, enabling the ultrasound measurements to be recorded in cubic centimeters per
minute (cc/min). The initial readings were taken with the assistance of the biomedical electronics engineer. The electromagnetic flow probe was removed prior to the completion of the operation while the Doppler probe remained in place for further postoperative readings. The Doppler cable tubing exited the skin at the lower sternal border.

At the completion of surgery, the patients were taken directly to the intensive care unit (ICU). Further Doppler flow readings as well as patient physiologic parameters were obtained in the ICU at one-half hour intervals in the immediate postoperative period. After all the data had been obtained, the Doppler was removed by a physician at the patient's bedside by activating the probe's release mechanism.

Population and Sample

The population consisted of patients who were scheduled for aortocoronary bypass surgery at the Arizona Heart Institute during August of 1974. This time period was later extended seven months through March of 1975. Although the research design originally called for ten subjects, only two were available for inclusion in the study during this seven month period. Sample criteria consisted of the following:

1. All patients had a high-grade bypassable stenotic lesion in a main branch of the left coronary artery
(either the left anterior descending or circumflex artery) with a relatively good distal arterial runoff as demonstrated by preoperative angiography. The location of the left coronary artery (LCA) vein grafts on the anterior surface of the heart more aptly suited the positioning of the Doppler flow probe than the posterior right coronary artery (RCA) grafts.

2. All patients had normal left ventricular function as determined by preoperative angiographic data.

3. Patients undergoing combined operative procedures were excluded from the study. Thus, patients undergoing simultaneous aortocoronary bypass surgery and valve replacement or aneurysectomy did not participate. Patients who received multiple vein grafts, however, were included although only flows in the left anterior descending (LAD) or circumflex (CIRC) grafts were studied.

Data Collection

Data were collected on the participating patients in the postoperative intensive care unit. The first nine postoperative hours were arbitrarily chosen as the data collection period since this period was theorized as the most likely interval when the patient would progress from an unstable anesthetized condition to a more normal and stable
postoperative state. Thus changes could be readily demonstrated. All data were collected at one-half hour intervals with additional readings being obtained whenever the patient's condition changed (i.e., the development of an arrhythmia) or when further readings seemed beneficial. The patient was in a supine position when all measurements were obtained. The Arizona Heart Institute ICU nurses and this investigator worked together during the data collection period and all measurements were obtained and recorded by them.

A Data Collection Form (Appendix A) was developed to facilitate the recording of data. The patient's study number, hospital number, age, sex, and a brief preoperative history were recorded to provide baseline identifying data. The preoperative diagnosis, operative procedure and findings, as well as intraoperative vein graft flood flow were also recorded for this purpose. One-half hour measurements of vein graft blood flow, arterial pressure, cardiac rate and rhythm, central venous pressure, temperature, and respiratory rate were recorded on this collection form as well as mention of the type of ventilatory support the patient was receiving. Whenever additional measurements seemed warranted, this full set of readings was obtained again. A section labeled "Comments" was included on the Data Collection Form for the recording of all other pertinent information.
The Tools

Blood flowmeters and physiologic monitoring equipment were the tools used in this study.

Blood Flowmeters

Blood flow through the vein graft was measured by using a Doppler ultrasound flow probe which had been calibrated to an electromagnetic flow probe. Despite some differences, ultrasound and electromagnetic flowmeters are similar in their basic concept.

They both operate by coupling a field through a vessel wall and measure, external to the vessel, a parameter which is dependent upon the velocity of flow. The advantage of this concept is that the vessel remains unopened (Cappelen, 1968:23).

Thus, with the transducer head of the probes fitted snugly around the vein graft, the amount of blood flow through the graft was measured. The electromagnetic probe contains electrodes on either side of the probe and directly opposite each other. According to Guyton, Jones, and Coleman (1973:123), blood "is a conductor of electricity, and electrodes placed... on the surface of the vessel will record the electromotive force developed by the flowing blood."

Instead of electrodes, Doppler ultrasound probes contain minute piezoelectric transmit-receive crystals at diagonally opposite ends of the probe. Ultrasound signals
are transmitted through the blood from one crystal to another.

An electronic apparatus alternates the direction of sound transmission several hundred times per second, transmitting first downstream, then upstream. Sound waves travel downstream with greater velocity than upstream. An appropriate electronic apparatus measures the difference between these two velocities, which is a measure of blood flow (Guyton, 1971:207).

**Electromagnetic Flowmeter.** Electromagnetic flowmeters were first widely used in peripheral vascular surgery to aid in the assessment of immediate and long-term results of reconstructive surgery. More recently, this type of flowmeter has been used during aortocoronary bypass surgery. The realization of the importance of blood flow in maintaining graft patency has prompted the extensive use of these flow probes to evaluate operative results. According to Guyton and associates (1973:124) "The electromagnetic flowmeter is today one of the most valuable of all flowmeters." Roberts (1972:79) notes that "the electromagnetic flowmeter is regarded as a standard against which other systems for blood flow measurement are often compared." This flowmeter "is without a doubt the most widely used, accepted method of measuring flow in an intact vessel" (p. 6). At the Arizona Heart Institute, a Statham electromagnetic flow probe was used.
Doppler Ultrasound Flowmeter. Doppler ultrasound is one of the newer flowmeters now available. According to Roberts (1972:5):

Ultrasound has a wide and increasing place in the study of arterial and venous flow. . . . Its greatest appeal lies in the fact that it is possible to transmit sound waves safely into the body and retrieve information which is both interpretable and meaningful.

The specially-designed probe used in this study employed a commercially available 10mHz Doppler transmitter-receiver. The cast epoxy transducer head contained minute piezoelectric transmit-receive sound wave crystals mounted at forty-five and fifteen degree angles to the flow of blood. The wires connecting the crystals were protected by silicone rubber tubing, which permitted transducer flexibility within the pericardial area and allowed the transducer to follow the movements of the myocardium. The wires were then extended for an additional two inches and connected to a low-noise coaxial cable within a polyvinyl chloride tubing. The polyvinyl chloride tubing, which is similar to chest drainage tubing, was led through the anterior thorax and exited the skin at the lower sternal border (Figure 1). Appropriate connections were then made to external Doppler electronic apparatus containing a write-out display system which simultaneously recorded arterial pressures and cardiac rhythms as well as vein graft blood flows. The transducer head of the probe was equipped with
Figure 1. Drawing Depicting the Doppler Flow Probe Positioned Around the Vein Graft
a special release mechanism which permits its removal without surgical intervention (Sansbury, Diethrich, and Goldfarb, 1974).

Studies at the Arizona Heart Institute indicate the following:

Doppler ultrasound is a suitable technique for postoperative measurement of blood flow in coronary artery bypass grafts. The information thus obtained is of sufficient quality and correlates with cardiac output and arterial pressure to accept its validity (Sansbury and associates, 1974:3).

They caution, however, that "movement of the patient from the operating room to the ICU can result in transducer dislocations affecting calibration and integrity" (p. 3).

Physiologic Monitoring Equipment

Patient physiologic parameters were measured using a variety of monitoring equipment. Most of this equipment can be found in a standard intensive care unit that accepts cardiac surgical patients.

Arterial Pressure. Arterial pressures were monitored by radial artery cannulation. The cannula with its connecting tubing was attached to a flushing manifold and then to a strain gauge pressure transducer. The transducer contains a "sensitive diaphragm which, when displaced by pressure changes, transmits a wave form through the electrical circuitry to a display system" (Sanderson, 1972: 350). The oscillographic display system was a SpaceLab
design. A separate write-out display system also recorded arterial pressures, electrocardiograms, and vein graft blood flows.

**Cardiac Rhythm.** Electrocardiograms were displayed on SpaceLab monitoring equipment as well as the above mentioned write-out display system.

**Cardiac Rate.** Cardiac rates were determined by using a stethoscope to auscultate the apical heart rate for one full minute.

**Central Venous Pressure (CVP).** A standard water manometer with a three-way stopcock was used to measure central venous pressures. A catheter was inserted into the subclavian vein and advanced to a position near the right atrium. The catheter was connected to an intravenous fluid system with the manometer and stopcock interposed. With the manometer zeroed at the level of the right atrium, a CVP reading was taken by first turning the stopcock to fill the manometer and then allow the fluid to fall and stabilize at the venous pressure measurement.

**Temperature.** Rectal temperatures were taken using an electronic thermometer.
Respiratory Rate. Respiratory rates were obtained by counting the number of breaths taken by the patient during one full minute.

Ventilatory Support. Immediately after the operation, a Monaghan 225 volume-cycled ventilator provided ventilatory support to the patient through a cuffed endotracheal tube. Ventilator settings were determined on an individual basis by the physician. When the patient appeared sufficiently alert to initiate breathing without support from the ventilator, a trial period off the ventilator was begun. During this period, the patient received humidified oxygen through the endotracheal tube via T-piece ventilatory apparatus. If the patient showed no overt signs of respiratory distress or fatigue and if tidal blood volume and arterial blood gas studies remained satisfactory, the endotracheal tube was removed at the end of this trial period. The patient then received humidified oxygen through a non-rebreathing face mask. An aggressive post-extubation program of pulmonary care was then begun involving coughing, deep breathing, turning, and intermittent positive pressure breathing (IPPB) treatments. If the patient demonstrated a need for prolonged ventilatory support, he was kept intubated and placed back on the ventilator and the weaning process was reinstituted at a later time.
Limitations

The limitations inherent in this study include the following:

1. The sample size was limited in number, as only two patients participated.
2. The data collection period lasted for only a maximum of nine hours; thus the study was limited in time.
3. Because this study was part of a larger one being conducted at the Arizona Heart Institute, protocols that affected the Institute's project also affected this study.

Assumption

The assumption affecting this study was: the monitoring equipment used to measure blood flows and patient physiologic parameters accurately reflected the patient's true physiologic status.

Data Analysis

The data collected in this study were submitted to computer analysis and analyzed using correlation statistical procedures. Correlation techniques, according to Ipsen and Feigl (1970:88),

... provide statistical measures of the association of two (or more) quantitative variables. ... For two quantitatively measured variables the statistic known as the correlation coefficient indicates the degree of (linear) association between the two variables in addition to establishing the statistical significance or nonsignificance of the association.
In this study, the vein graft blood flow measurements and physiologic parameters of arterial pressure, cardiac rate and rhythm, central venous pressure, temperature, respiratory rate, and type of ventilatory support were designated as the variables.
CHAPTER 4

PRESENTATION AND ANALYSIS OF DATA

The purpose of this chapter is to present and discuss the data collected during the study period. The sample is described and the findings are discussed and analyzed.

Description of the Sample

The sample consisted of two Caucasian men who underwent aortocoronary bypass surgery during February and March of 1975 at the Arizona Heart Institute and who met the criteria for admission to the study.

Subject One

Subject One was a fifty-eight year old male whose preoperative coronary angiogram revealed significant triple vessel coronary artery disease. Aortocoronary vein grafts were placed distal to the obstructed areas on the right coronary, left anterior descending, and circumflex arteries; carbon dioxide endarterectomy was also performed on the right coronary artery. The circumflex graft, which had a mean intraoperative blood flow of 85 cc/min, was used for the postoperative Doppler study. The probe was positioned and calibrated on the graft. The patient tolerated the
operative procedure well and no major problems were encountered.

Appropriate connections were made to the Doppler recording equipment in the intensive care unit and recordings were begun after the second postoperative hour. The subject's first nine hours in the intensive care unit were free of any major complication although some minor problems did occur. Approximately two hours after surgery, Subject One developed an increasing number of unifocal premature ventricular contractions (PVCs). Hypokalemia was thought to be the cause of this arrhythmia since the PVCs disappeared after the patient received additional potassium chloride. Later, signs of hypovolemia began to appear although the situation was soon reversed with the administration of Plasmanate. Subject One's vital signs remained stable throughout this period and the cardiac monitor remained in a mild sinus tachycardia. He was extubated without difficulty and continued to do quite well. Technical problems with the recorder, however, forced the cancellation of Doppler readings after six study readings. Only peak vein graft blood flows were obtained on Subject One in the postoperative period; mean flows were not available.

Subject Two

Subject Two was a forty-five year old male whose preoperative coronary angiogram revealed an isolated
ninety-nine per cent obstructing lesion in the left anterior descending branch of the left coronary artery. An aorto-coronary vein graft was placed distal to the obstructed area and the Doppler flow probe was positioned around the graft and calibrated. Mean intraoperative blood flow through the graft was 105 cc/min.

Data collection began in the ICU after the second postoperative hour and continued at half-hourly intervals for seventeen readings. Both peak and mean vein graft blood flows were obtained. The subject's postoperative course during this period was stable. He remained in a normal sinus rhythm without ectopic beats. His vital signs remained stable. Arterial blood gas analysis revealed a metabolic acidosis which was reversed with the administration of sodium bicarbonate. Like Subject One, Subject Two began to show signs of hypovolemia and was also treated with Plasmanate. He was extubated without incident and continued to have a satisfactory postoperative course.

Presentation of the Data

The data collected in this study will be presented in three main sections: a descriptive review of the patterns of vein graft blood flow, a presentation of the subject data, and the characteristics of vein graft blood flow and arterial pressures during premature ventricular contractions.
Patterns of Vein Graft Blood Flow

A review of the raw data from the Doppler write-out display system revealed two major patterns involving vein graft blood flow. First, blood flow through the vein graft was continuous throughout the cardiac cycle. Rarely did blood flow reach baseline zero levels. Second, vein graft blood flow was noted to be phasic, with the peak flows occurring in the diastolic portion of the cardiac cycle and lesser flows in the systolic component. Flow during diastole was noted to be longer in duration and greater in volume than systolic flow which was relatively short in time span and lower in volume. This corresponded with ventricular diastole which was longer than ventricular systole. Diastolic flow appeared continuous and lasted throughout the diastolic period, whereas the systolic flow seemed to rise to a peak and then decline.

Peak diastolic flows usually occurred early in diastole, frequently just after the T wave on a simultaneously recorded electrocardiogram. Diastolic flow ended immediately prior to the QRS complex. This corresponded with diastole on the arterial waveform after allowing for a slight delay in transmission to the radial artery. Peak diastolic flow occurred on the downslope of the waveform immediately prior to or within the dicrotic notch. Peak systolic flows occurred immediately after the QRS complex.
but prior to the T wave. This also corresponded with the arterial waveform in systole (Figure 2).

Presentation of the Subject Data

The raw data pertaining to the vein graft blood flows and physiologic parameters for Subjects One and Two are presented in Appendices B and C, respectively. The means and standard deviations of the physiologic parameters are presented in Table 1.

The mean intraoperative vein graft blood flow for Subject Two was 105 cc/min and the initial postoperative mean flow was 78 cc/min. The flow gradually rose to a high of 260 cc/min before beginning a decline to a low of 50 cc/min at the end of the study. The peak vein graft blood flows followed suit. The first postoperative reading (170 cc/min) rose to 400 cc/min and then declined to a low of 130 cc/min. The vein graft blood flow pattern was similar for Subject One. An initial postoperative peak flow of 180 cc/min increased to 200 cc/min before declining to 130 cc/min near the end of the study.

Correlations and the levels of significance between peak vein graft blood flows and physiologic parameters for Subject One are presented in Table 2. Correlations between peak vein graft blood flows and systolic blood pressure, diastolic blood pressure, heart and respiratory rates were not statistically significant. A negative correlation
Figure 2. Diagram of a Simultaneous Recording of Electrocardiogram, Arterial Pressure, and Vein Graft Blood Flow During Systole and Diastole
Table 1. Means and Standard Deviations of the Physiologic Parameters for Subjects One and Two

<table>
<thead>
<tr>
<th>Physiologic Parameter</th>
<th>Subject One</th>
<th>Subject Two</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraoperative Vein Graft Blood Flow</td>
<td>(Mean) 85 cc/min</td>
<td>105 cc/min</td>
</tr>
<tr>
<td>Postoperative Mean Vein Graft Blood Flow (Mean)</td>
<td>N.A.(^a)</td>
<td>119 cc/min ± 56</td>
</tr>
<tr>
<td>Postoperative Peak Vein Graft Blood Flow</td>
<td>169 cc/min ± 27</td>
<td>225 cc/min ± 65</td>
</tr>
<tr>
<td>Systolic Blood Pressure</td>
<td>142 mm Hg ± 25</td>
<td>113 mm Hg ± 9</td>
</tr>
<tr>
<td>Diastolic Blood Pressure</td>
<td>86 mm Hg ± 8</td>
<td>61 mm Hg ± 6</td>
</tr>
<tr>
<td>Cardiac Rate</td>
<td>106 beats/min ± 9</td>
<td>73 beats/min ± 6</td>
</tr>
<tr>
<td>Central Venous Pressure</td>
<td>6 cm H(_2)O ± 1</td>
<td>4 cm H(_2)O ± 1</td>
</tr>
<tr>
<td>Temperature</td>
<td>100.2°F ± .9</td>
<td>101.2°F ± .2</td>
</tr>
<tr>
<td>Respiratory Rate</td>
<td>17 breaths/min ± 2</td>
<td>18 breaths/min ± 5</td>
</tr>
</tbody>
</table>

\(^a\)N.A.—Not Available.

\(^b\)S.D.—Standard Deviation.
Table 2. Correlations (R) and Significance R Between Peak Vein Graft Blood Flow and the Physiologic Parameters for Subject One

<table>
<thead>
<tr>
<th>Variable One</th>
<th>Variable Two</th>
<th>Correlation (R)</th>
<th>Significance R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Flow</td>
<td>Systolic Pressure</td>
<td>.55757</td>
<td>.12516</td>
</tr>
<tr>
<td>Peak Flow</td>
<td>Diastolic Pressure</td>
<td>.54972</td>
<td>.12924</td>
</tr>
<tr>
<td>Peak Flow</td>
<td>Cardiac Rate</td>
<td>.40516</td>
<td>.21276</td>
</tr>
<tr>
<td>Peak Flow</td>
<td>CVP</td>
<td>.99191</td>
<td>.00005***</td>
</tr>
<tr>
<td>Peak Flow</td>
<td>Temperature</td>
<td>-.74266</td>
<td>.04541*</td>
</tr>
<tr>
<td>Peak Flow</td>
<td>Respiratory Rate</td>
<td>.66582</td>
<td>.07443</td>
</tr>
</tbody>
</table>

*Significant at the .05 level.

***Significant at the .001 level.
between peak vein graft blood flow and temperature was significant at the .05 level. A positive correlation between peak vein graft blood flow and central venous pressure was strongly significant at the .001 level.

Correlations and the degree of significance between both peak and mean vein graft blood flows and physiologic parameters for Subject Two are presented in Table 3. A positive correlation between peak and mean vein graft blood flow was strongly significant at the .00001 level. No statistical significance was demonstrated between either peak or mean vein graft blood flows and diastolic blood pressure, heart or respiratory rates. Although the correlation between mean vein graft blood flow and systolic blood pressure was similar to the peak flow:systolic blood pressure correlation, the former was not statistically significant whereas the latter was significant at the .05 level. Positive correlations between both peak and mean vein graft blood flow and temperature were significant at the .01 level. Negative correlations between peak and mean vein graft blood flow and central venous pressures were also significant at the .01 level.

Figure 3 illustrates the means of the peak vein graft blood flows and systolic blood pressures according to the type of ventilatory support for both subjects. Mean peak flows or systolic pressures for Subject One were not available for the period on the ventilator since the subject
Table 3. Correlations (R) and Significance R Between Both Peak and Mean Vein Graft Blood Flows and the Physiologic Parameters for Subject Two

<table>
<thead>
<tr>
<th>Variable One</th>
<th>Variable Two</th>
<th>Correlation (R)</th>
<th>Significance R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Flow</td>
<td>Mean Flow</td>
<td>.97028</td>
<td>.00001***</td>
</tr>
<tr>
<td>Peak Flow</td>
<td>Systolic Pressure</td>
<td>.40620</td>
<td>.04720*</td>
</tr>
<tr>
<td>Mean Flow</td>
<td>Systolic Pressure</td>
<td>.39657</td>
<td>.05162</td>
</tr>
<tr>
<td>Peak Flow</td>
<td>Diastolic Pressure</td>
<td>-.20199</td>
<td>.21075</td>
</tr>
<tr>
<td>Mean Flow</td>
<td>Diastolic Pressure</td>
<td>-.17011</td>
<td>.24989</td>
</tr>
<tr>
<td>Peak Flow</td>
<td>Cardiac Rate</td>
<td>.18209</td>
<td>.23479</td>
</tr>
<tr>
<td>Mean Flow</td>
<td>Cardiac Rate</td>
<td>.22028</td>
<td>.18988</td>
</tr>
<tr>
<td>Peak Flow</td>
<td>CVP</td>
<td>-.56491</td>
<td>.00729**</td>
</tr>
<tr>
<td>Mean Flow</td>
<td>CVP</td>
<td>-.62077</td>
<td>.00299**</td>
</tr>
<tr>
<td>Peak Flow</td>
<td>Temperature</td>
<td>.54644</td>
<td>.00948**</td>
</tr>
<tr>
<td>Mean Flow</td>
<td>Temperature</td>
<td>.55921</td>
<td>.00792**</td>
</tr>
<tr>
<td>Peak Flow</td>
<td>Respiratory Rate</td>
<td>.05939</td>
<td>.40746</td>
</tr>
<tr>
<td>Mean Flow</td>
<td>Respiratory Rate</td>
<td>-.00730</td>
<td>.48853</td>
</tr>
</tbody>
</table>

*Significant at the .05 level.
**Significant at the .01 level.
***Significant at the .00001 level.
Figure 3. Graphic Representation of the Means of the Peak Vein Graft Blood Flows and Systolic Blood Pressures According to Ventilatory Support
did not tolerate this type of support and was immediately placed on the T-piece postoperatively. The data indicate that vein graft blood flows and systolic blood pressures were higher when the subjects were receiving ventilatory support via the T-piece. Mean peak flow for Subject One on the T-piece was 190 cc/min and 149 cc/min when using an oxygen face mask after extubation. Mean systolic blood pressures were 144 mm Hg and 127 mm Hg for these same periods. The mean of the peak vein graft blood flows for Subject Two were 192 cc/min when on the ventilator, 303 cc/min when on the T-piece, and 209 cc/min when using the oxygen face mask. Mean systolic blood pressures were 111 mm Hg, 127 mm Hg, and 109 mm Hg, respectively (Table 4).

Characteristics of Vein Graft Blood Flow and Arterial Pressures During Premature Ventricular Contractions

Shortly after surgery, Subject One developed an increasing number of hypokalemia-induced unifocal premature ventricular contractions (PVCs). The PVCs occurred late in the cardiac cycle. They usually obscured the P waves and were followed by a short compensatory pause. The normal R-R intervals were rarely disturbed by the presence of the PVCs. Thirteen of these PVCs were captured on the write-out display and their relationships to arterial pressures and vein graft blood flows were demonstrated. The raw data are presented in Appendix D. The means and standard deviations
Table 4. Means and Ranges of Vein Graft Blood Flows and Systolic Blood Pressures According to Type of Ventilatory Support for Subjects One and Two

<table>
<thead>
<tr>
<th>Type of Ventilatory Support</th>
<th>Subject One</th>
<th></th>
<th></th>
<th>Subject Two</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peak Mean</td>
<td>cc/min</td>
<td>mm Hg</td>
<td>Mean Range</td>
<td>cc/min</td>
<td>mm Hg</td>
</tr>
<tr>
<td>Ventilator Mean Range</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>192</td>
<td>95</td>
<td>111</td>
</tr>
<tr>
<td>T-Piece Mean Range</td>
<td>190</td>
<td>N.A.</td>
<td>144</td>
<td>303</td>
<td>184</td>
<td>127</td>
</tr>
<tr>
<td>Oxygen Face Mask Mean Range</td>
<td>149</td>
<td>N.A.</td>
<td>127</td>
<td>209</td>
<td>103</td>
<td>109</td>
</tr>
</tbody>
</table>

aN.A. -- Not Available.
of arterial pressures and vein graft blood flows before, during, and after the PVCs are presented in Table 5 and a graphic representation of their relationships is presented in Figure 4.

The arterial blood pressures responded in a uniform fashion to the PVCs. All systolic and diastolic blood pressures initially decreased during the PVC. Following the ectopic beat, all of the systolic blood pressures "overshot" the pre-PVC level, then "undershot" it slightly before stabilizing. The diastolic component tended to follow the systolic blood pressure but the amount of change was not as great.

The PVCs did not affect the vein graft blood flows in the same manner that they affected arterial blood pressures. At the time the PVC occurred, the vein graft blood flows decreased five separate times and increased eight times. The result was a mean vein graft blood flow that remained at 160 cc/min during the pre-PVC to the PVC period.

On the beats following the PVCs, the vein graft blood flow tended either to remain the same or to increase. The overall result was a mean increase in vein graft blood flows over pre-PVC and PVC levels. Mean flows during the first three beats post-PVC were 169 cc/min, 167 cc/min, and 175 cc/min as compared to 160 cc/min on the beat before the PVC.
Table 5. Means and Standard Deviations of Vein Graft Blood Flows and Arterial Pressures Before, During, and After Premature Ventricular Contractions (PVCs)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pre-PVC</th>
<th>PVC</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vein Graft Blood Flow (cc/min)</td>
<td>160&lt;sup&gt;a&lt;/sup&gt; ± 16&lt;sup&gt;b&lt;/sup&gt;</td>
<td>160 ± 16</td>
<td>169 ± 12</td>
<td>167 ± 18</td>
<td>175 ± 12</td>
</tr>
<tr>
<td>Systolic Blood Pressure (mm Hg)</td>
<td>146 ± 5</td>
<td>108 ± 11</td>
<td>156 ± 5</td>
<td>139 ± 6</td>
<td>149 ± 6</td>
</tr>
<tr>
<td>Diastolic Blood Pressure (mm Hg)</td>
<td>95 ± 3</td>
<td>81 ± 4</td>
<td>97 ± 3</td>
<td>93 ± 4</td>
<td>95 ± 3</td>
</tr>
</tbody>
</table>

<sup>a</sup>Mean.<br><sup>b</sup>Standard Deviation.
Figure 4. Graphic Representation of the Means of Vein Graft Blood Flows and Arterial Pressures Before, During, and After Premature Ventricular Contractions (PVCs)
The PVCs seemed to significantly affect vein graft blood flow in only one of thirteen cases. During the tenth PVC, the flow decreased from 200 cc/min to 120 cc/min. Immediately following the PVC, the amount of flow increased to 198 cc/min and then remained at pre-PVC levels. The arterial pressure, at this time, dropped only minimally. This tenth PVC did not appear any differently electrocardiographically than the other twelve PVCs.
CHAPTER 5

DISCUSSION OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

A discussion of the findings, conclusions, and recommendations for future studies are presented in this chapter.

Discussion of the Findings

The purpose of the study was to determine if post-operative changes in aortocoronary vein graft blood flows would correlate with changes in the physiologic parameters of arterial pressure, cardiac rate and rhythm, central venous pressure, temperature, respiratory rate, and the type of ventilatory support. Vein graft blood flows were measured in two subjects by means of a Doppler ultrasound flow probe which had been positioned around the vein grafts at the time of operation. The findings of the study will be discussed according to three main areas of consideration: the patterns of vein graft blood flow, the subject data, and the characteristics of vein graft blood flow and arterial pressures during premature ventricular contractions.
Patterns of Vein Graft Blood Flow

Blood flow through the aortocoronary vein grafts revealed two major characteristics. First, the blood flow was noted to be continuous throughout the cardiac cycle. Rarely did it reach baseline zero levels. Second, the blood flow was phasic, with the peak flows occurring during diastole and lesser flows in the systolic portion of the cardiac cycle.

These findings are in accord with those reported by Benchimol and Desser (1973) in their postoperative Doppler study of aortocoronary bypass graft blood flow velocity. They note that "The predominant diastolic blood flow velocity wave probably results from a decrease in coronary arterial resistance during the left ventricular filling period" (p. 898).

In describing normal coronary artery blood flow, Hurst and Logue (1970:106) note the phasic nature of the flow and relate it to two factors: "first because it is dependent on phasic aortic pressure, and secondly because the myocardium offers a variable degree of resistance to flow during systole." Sanderson (1972) notes that at least two-thirds of coronary artery blood flow occurs in diastole while approximately one-third occurs during systole.

Thus the findings of this study are in accord with those reported by Benchimol and Desser (1973) and are
similar to the normal functioning of the coronary arteries during systole and diastole.

Discussion of the Subject Data

Statistical procedures revealed some correlations between vein graft blood flow and physiologic parameters. A highly positive correlation was demonstrated between peak and mean vein graft blood flows. This result was an expected one since high peak flows would naturally result in high mean flows.

Statistical significance with a positive correlation was demonstrated between peak vein graft blood flow and systolic blood pressure in Subject Two but not in Subject One. No statistical significance was established between vein graft blood flow and diastolic blood pressure in either subject although the write-out display revealed a high diastolic flow. The relationships between vein graft blood flow and heart and respiratory rates were also not statistically significant.

An interesting correlation was demonstrated between vein graft blood flows and the parameters of temperatures and central venous pressures for both subjects. Subject One demonstrated a negative correlation between vein graft blood flow and temperature, while the same parameters were positively correlated for Subject Two. Likewise, the correlation between vein graft blood flow and central venous
pressure was strongly positive for Subject One and negative for Subject Two. The reasons for this conflicting data were unclear. One possible explanation is that other physiologic mechanisms may have been occurring which were not apparent and not measured in this study. Also, perhaps erroneous data were obtained through malfunctioning equipment.

Mean systolic blood pressure and peak vein graft blood flow were noted to be higher when the subjects were intubated and using the T-piece oxygen apparatus than when they were either intubated and on the ventilator or extubated and using an oxygen face mask. Blood flows and systolic pressures during the latter two periods were similar (Figure 3). One possible explanation for the rise in vein graft blood flow and systolic blood pressure following the period of intubation on the ventilator centers on the ventilator's effects of increasing intrathoracic pressure and decreasing venous return to the heart, thereby decreasing the cardiac output. The lowered cardiac output may then be reflected in a lower arterial pressure and vein graft blood flow. Removal of the positive pressure effects of the ventilator would cause a rise in both values.

Although the change in intrathoracic pressure may offer an explanation for the rise in both vein graft blood flow and systolic blood pressure with the change in ventilatory support from the ventilator to T-piece, it does not explain
the reasons for the mean decrease in these recordings following extubation with the use of the oxygen face mask.

The trend for the vein graft blood flows to decrease near the end of the study period when the subjects are using an oxygen face mask (Appendices B and C), raises the question of whether this downward trend will continue. The adequacy of myocardial perfusion and continued patency of the vein graft must be questioned with such vast changes in vein graft blood flow.

Characteristics of Vein Graft Blood Flow and Arterial Pressure During Premature Ventricular Contractions

The effects of premature ventricular contractions (PVCs) on aortocoronary vein graft blood flow appear minimal in this study. Blood flow did not respond in any set pattern during or after a PVC. The mean peak flow through the vein graft remained the same when a PVC occurred and then increased only slightly (Figure 4). In only one of thirteen cases did the vein graft blood flow decrease sharply with a PVC and then rise again to pre-PVC flows.

Likewise, changes in arterial pressure during and after PVCs did not seem to affect vein graft blood flows. Arterial pressures decreased sharply when a PVC occurred. On the beat following the PVC, arterial pressures (particularly the systolic pressure) increased and "overshot" the pre-PVC level before returning to stable levels.
The results of this study are not in accord with those reported by Benchimol and Desser (1973) in their Doppler study of aortocoronary bypass graft blood flow velocity. In four cases of catheter-induced PVCs, a twenty to sixty per cent reduction of vein graft blood flow velocity measurements were obtained. They note that greater reductions of flow velocity appeared to be related to shorter extrasystolic coupling intervals. They also note the presence of a blood flow velocity "overshoot" associated with the beat following the PVC. When PVCs occurred in succession, the patients experienced an average seventy per cent reduction in vein graft blood flow velocity. They conclude:

Abrupt shortening of diastole, diminished ventricular filling, and reduced stroke output in the aorta are probably main factors influencing the reduction of graft blood flow velocity during ventricular premature depolarizations. Our data suggest that arrhythmias may have untoward effects on myocardial perfusion in patients with bypass grafts (p. 899).

In an earlier and similar study on preoperative patients, Benchimol, Stegall, and Gartlan (1971) reported that extrasystoles had a variable influence on flow velocity through coronary arteries and depended on the timing of the extrasystoles during the cardiac cycle. They found that shorter intervals between the extrasystolic beat and the preceding beat produced smaller peak velocities. Premature ventricular contractions occurring very early in the cardiac
cycle, therefore resulted in greater flow velocity reductions. They also note the presence of a blood flow velocity "overshoot" following the PVC.

Conclusions

The study has revealed some interesting findings concerning aortocoronary bypass surgery. The pattern of blood flow through the vein graft was similar to that reported in normal coronary arteries. Flow was both continuous and phasic, with larger flows occurring in diastole.

Correlations were determined between vein graft blood flow and physiologic parameters. Vein graft blood flow was greater during the period of intubation on the T-piece oxygen apparatus than when ventilatory support was provided by either a ventilator during intubation or an oxygen face mask following extubation. A significant positive correlation (at the .05 level) between vein graft blood flow and systolic pressure was demonstrated in one subject but not in the other. Changes in vein graft blood flow were not correlated with changes in diastolic blood pressure, heart or respiratory rates. The highly conflicting data regarding vein graft blood flow and the parameters of central venous pressure and temperature render these data of little practical value at the present.
Although PVCs do affect arterial pressures in a predictable manner, their effect on vein graft blood flow is variable. The data in this study suggest that PVCs do not adversely affect blood flow through aortocoronary bypass grafts by decreasing blood flow.

The results of this study have implications for nurses and physicians who participate in the postoperative care of aortocoronary bypass patients. One of the objectives of their care is to promote graft patency. Identification of parameters that do and do not correlate with changes in vein graft blood flow and thus with graft patency is one step in determining measures to promote graft patency. Nurses who exemplify Sanderson's (1972:v) expanded role of the cardiac nurse could incorporate the results of this type of study in the delivery of nursing care to aortocoronary bypass patients to provide more comprehensive care and ensure successful long-term results.

**Recommendations for Future Study**

The following recommendations for future study are offered.

1. Replication of this study should be undertaken with a larger population of subjects over a longer period of time.

2. Further refinement of the Doppler flow probe and recording equipment is suggested. The use of an
electromagnetic flowmeter in place of the Doppler might also be beneficial.

3. The relationship between vein graft blood flow and physiologic parameters other than those measured in this study should be investigated. Other parameters might include pulmonary artery pressure, cardiac output, and the effects of intermittent positive pressure breathing (IPPB) treatments. The use of atrial and ventricular pacing to vary the heart rate might also be included.

4. Since arrhythmias are a frequent postoperative problem, special emphasis should be placed on the effects of arrhythmias on vein graft blood flow.

5. The effects of medications such as nitroglycerin, Papaverine hydrochloride, and various vasopressors on vein graft blood flow should be determined.

6. Studies should be undertaken which compare the different vein grafts used to bypass the various coronary arteries; that is, left anterior descending vein grafts as compared with circumflex vein grafts or grafts to the right coronary artery.

7. Studies comparing bypass grafts using the internal mammary artery as compared with the saphenous vein might yield interesting results.

8. After the parameters which affect vein graft blood flows have been identified, specific measures should
be investigated which will maintain high blood flows through the vein graft and thereby promote graft patency.
Aortocoronary bypass surgery is currently the most effective means of myocardial revascularization in patients with coronary artery disease. The success of the procedure is largely determined by the continued patency of the vein grafts. Intraoperative vein graft blood flow has proven to be a prime prognostic indicator of long-term graft patency. Few clinical studies have focused on postoperative vein graft blood flow and the factors that affect flow after surgery. This study attempted to determine if changes in the physiologic parameters of arterial pressure, cardiac rate and rhythm, central venous pressure, temperature, respiratory rate, and type of ventilatory support would correlate with changes in vein graft blood flow in the immediate postoperative period.

A specially designed Doppler ultrasound flow probe was positioned and calibrated on the vein graft at the time of surgery. Vein graft blood flow measurements and the physiologic parameters were recorded on two patients in the immediate postoperative period. The data were described and analyzed using correlation statistical procedures.
The study revealed the following information. Vein graft blood flow was both continuous and phasic. Blood flow was greater during diastole than during systole. Peak and mean vein graft blood flow had a highly significant positive correlation. The positive correlation between systolic blood pressure and peak vein graft blood flow was significant at the .05 level in one of the two subjects. Highly conflicting correlations between vein graft blood flow and the parameters of central venous pressure and temperature render these data of little practical value at the present. Blood flow through the vein graft tended to be higher when the subjects were intubated and received ventilatory support by means of T-piece apparatus. Statistical or practical significance was not apparent between vein graft blood flows and diastolic blood pressure, cardiac rate, or respiratory rate. In addition, PVCs seemed to have little effect on blood flow through the vein graft although PVCs did produce a decrease in arterial pressures.

The results of this study have implications for nurses who participate in the care of aortocoronary bypass patients. This study is one of many steps in efforts to promote vein graft patency by determining the parameters that affect vein graft blood flow, and promoting graft patency is one of the objectives of postoperative nursing care.
Recommendations for future study include the investigation of all parameters that might affect vein graft blood flow, including the effects of medications, arrhythmias, intermittent positive pressure breathing, and the choice of vessel used in surgery. A replication of this study using a larger sample would be beneficial as would the refinement of the measuring tools. After the parameters which affect vein graft blood flow have been identified, measures should be investigated which increase blood flow and promote graft patency.
APPENDIX A

DATA COLLECTION FORM
Patient Study No.:  
Hospital No.:  

Age:  Sex:  
Preoperative History:  

Operative Procedure:  
Operative Findings:  

Intraoperative 
Vein Graft Blood Flow:

<table>
<thead>
<tr>
<th>Vein Graft Blood Flow</th>
<th>Arterial Pressure</th>
<th>Cardiac Rate</th>
<th>Cardiac Rhythm</th>
<th>CVP</th>
<th>Temperature °F</th>
<th>Respiratory Rate</th>
<th>Type of Ventilatory Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study Time</td>
<td>Peak/Mean cc/min</td>
<td>SBF/DBP mm Hg</td>
<td>beats/min</td>
<td>Cardiac</td>
<td>CVP cm H₂O</td>
<td>Rectal breaths/min</td>
<td>Comments</td>
</tr>
</tbody>
</table>


APPENDIX B

VEIN GRAFT BLOOD FLOWS AND PHYSIOLOGIC PARAMETERS FOR SUBJECT ONE
<table>
<thead>
<tr>
<th>Study Time</th>
<th>Vein Graft Blood Flow Peak/Mean cc/min</th>
<th>Arterial Blood Pressure SBP&lt;sup&gt;a&lt;/sup&gt;/DBP&lt;sup&gt;b&lt;/sup&gt; mm Hg</th>
<th>Cardiac Rate beats/min</th>
<th>Cardiac Rhythm</th>
<th>CVP&lt;sup&gt;c&lt;/sup&gt; cm H&lt;sub&gt;2&lt;/sub&gt;O</th>
<th>Temperature °F</th>
<th>Respiratory Rate breaths/min</th>
<th>Type of Ventilatory Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>170 78</td>
<td>116 70</td>
<td>88</td>
<td>NSR&lt;sup&gt;e&lt;/sup&gt;</td>
<td>5.0</td>
<td>100.6</td>
<td>12</td>
<td>Ventilator</td>
</tr>
<tr>
<td>2</td>
<td>200 90</td>
<td>112 60</td>
<td>76</td>
<td>NSR</td>
<td>3.0</td>
<td>100.8</td>
<td>12</td>
<td>Ventilator</td>
</tr>
<tr>
<td>3</td>
<td>180 90</td>
<td>108 60</td>
<td>72</td>
<td>NSR</td>
<td>3.0</td>
<td>101.2</td>
<td>12</td>
<td>Ventilator</td>
</tr>
<tr>
<td>4</td>
<td>220 98</td>
<td>110 70</td>
<td>76</td>
<td>NSR</td>
<td>3.0</td>
<td>101.2</td>
<td>12</td>
<td>Ventilator</td>
</tr>
<tr>
<td>5</td>
<td>190 120</td>
<td>110 70</td>
<td>76</td>
<td>NSR</td>
<td>3.0</td>
<td>101.2</td>
<td>12</td>
<td>Ventilator</td>
</tr>
<tr>
<td>6</td>
<td>240 130</td>
<td>134 70</td>
<td>80</td>
<td>NSR</td>
<td>4.0</td>
<td>101.3</td>
<td>12</td>
<td>T-Piece</td>
</tr>
<tr>
<td>7</td>
<td>260 144</td>
<td>132 64</td>
<td>80</td>
<td>NSR</td>
<td>3.6</td>
<td>101.3</td>
<td>20</td>
<td>T-Piece</td>
</tr>
<tr>
<td>8</td>
<td>400 260</td>
<td>124 60</td>
<td>76</td>
<td>NSR</td>
<td>3.2</td>
<td>101.4</td>
<td>20</td>
<td>T-Piece</td>
</tr>
<tr>
<td>9</td>
<td>310 200</td>
<td>116 56</td>
<td>76</td>
<td>NSR</td>
<td>3.2</td>
<td>101.4</td>
<td>20</td>
<td>T-Piece</td>
</tr>
<tr>
<td>10</td>
<td>300 200</td>
<td>112 58</td>
<td>68</td>
<td>NSR</td>
<td>3.2</td>
<td>101.4</td>
<td>16</td>
<td>T-Piece</td>
</tr>
<tr>
<td>11</td>
<td>220 120</td>
<td>104 52</td>
<td>72</td>
<td>NSR</td>
<td>3.2</td>
<td>101.4</td>
<td>24</td>
<td>Face Mask</td>
</tr>
<tr>
<td>12</td>
<td>240 130</td>
<td>110 52</td>
<td>68</td>
<td>NSR</td>
<td>3.0</td>
<td>101.4</td>
<td>16</td>
<td>Face Mask</td>
</tr>
<tr>
<td>13</td>
<td>250 126</td>
<td>110 54</td>
<td>68</td>
<td>NSR</td>
<td>3.4</td>
<td>101.4</td>
<td>22</td>
<td>Face Mask</td>
</tr>
<tr>
<td>14</td>
<td>220 112</td>
<td>106 54</td>
<td>68</td>
<td>NSR</td>
<td>4.0</td>
<td>101.3</td>
<td>24</td>
<td>Face Mask</td>
</tr>
<tr>
<td>15</td>
<td>130 50</td>
<td>110 60</td>
<td>68</td>
<td>NSR</td>
<td>6.0</td>
<td>101.2</td>
<td>20</td>
<td>Face Mask</td>
</tr>
<tr>
<td>16</td>
<td>160 60</td>
<td>106 60</td>
<td>68</td>
<td>NSR</td>
<td>6.0</td>
<td>101.2</td>
<td>20</td>
<td>Face Mask</td>
</tr>
<tr>
<td>17</td>
<td>160 56</td>
<td>118 60</td>
<td>62</td>
<td>NSR</td>
<td>6.0</td>
<td>101.1</td>
<td>28</td>
<td>Face Mask</td>
</tr>
</tbody>
</table>

<sup>a</sup>SBP—Systolic blood pressure.<br/>
<sup>b</sup>DBP—Diastolic blood pressure.<br/>
<sup>c</sup>CVP—Central venous pressure.<br/>
<sup>d</sup>°F—Degrees Fahrenheit.<br/>
<sup>e</sup>NSR—Normal sinus rhythm.
APPENDIX C

VEIN GRAFT BLOOD FLOWS AND PHYSIOLOGIC PARAMETERS
FOR SUBJECT TWO
<table>
<thead>
<tr>
<th>Study Time</th>
<th>Vein Graft Blood Flow Peak cc/min</th>
<th>Arterial Pressure SBP^a/DBP^b mm Hg</th>
<th>Cardiac Rate beats/min</th>
<th>Cardiac Rhythm</th>
<th>CVP^c cm H_2O</th>
<th>Temperature Rectal °F^d</th>
<th>Respiratory Rate breaths/min</th>
<th>Type of Ventilatory Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>180</td>
<td>146 90</td>
<td>112</td>
<td>ST^e</td>
<td>6.6</td>
<td>98.8</td>
<td>18</td>
<td>T-Piece</td>
</tr>
<tr>
<td>2</td>
<td>200</td>
<td>136 86</td>
<td>104</td>
<td>ST</td>
<td>7.6</td>
<td>100.0</td>
<td>20</td>
<td>T-Piece</td>
</tr>
<tr>
<td>3</td>
<td>190</td>
<td>150 100</td>
<td>104</td>
<td>ST</td>
<td>7.2</td>
<td>100.0</td>
<td>16</td>
<td>T-Piece</td>
</tr>
<tr>
<td>4</td>
<td>170</td>
<td>140 92</td>
<td>122</td>
<td>ST</td>
<td>6.2</td>
<td>100.0</td>
<td>18</td>
<td>Face Mask</td>
</tr>
<tr>
<td>5</td>
<td>146</td>
<td>120 80</td>
<td>100</td>
<td>ST</td>
<td>5.6</td>
<td>101.2</td>
<td>16</td>
<td>Face Mask</td>
</tr>
<tr>
<td>6</td>
<td>130</td>
<td>120 80</td>
<td>96</td>
<td>NSR^f</td>
<td>4.8</td>
<td>101.3</td>
<td>16</td>
<td>Face Mask</td>
</tr>
</tbody>
</table>

^aSBP—Systolic blood pressure.

^bDBP—Diastolic blood pressure.

^cCVP—Central venous pressure.

^d°F—Degrees Fahrenheit.

^eST—Sinus tachycardia.

^fNSR—Normal sinus rhythm.
APPENDIX D

VEIN GRAFT BLOOD FLOWS AND ARTERIAL PRESSURES BEFORE, DURING, AND AFTER PREMATURE VENTRICULAR CONTRACTIONS (PVC)

<table>
<thead>
<tr>
<th>PVC Number</th>
<th>Parameter</th>
<th>Pre-PVC Level</th>
<th>PVC Level</th>
<th>Post-PVC Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flow\textsuperscript{a}</td>
<td>150</td>
<td>145</td>
<td>164</td>
</tr>
<tr>
<td>1</td>
<td>SBP\textsuperscript{b}</td>
<td>145</td>
<td>105</td>
<td>158</td>
</tr>
<tr>
<td></td>
<td>DBP\textsuperscript{c}</td>
<td>95</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>Flow</td>
<td>160</td>
<td>172</td>
<td>164</td>
</tr>
<tr>
<td></td>
<td>SBP</td>
<td>150</td>
<td>110</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>DBP</td>
<td>95</td>
<td>82</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>Flow</td>
<td>180</td>
<td>162</td>
<td>162</td>
</tr>
<tr>
<td></td>
<td>SBP</td>
<td>148</td>
<td>105</td>
<td>158</td>
</tr>
<tr>
<td></td>
<td>DBP</td>
<td>95</td>
<td>80</td>
<td>98</td>
</tr>
<tr>
<td>4</td>
<td>Flow</td>
<td>164</td>
<td>150</td>
<td>164</td>
</tr>
<tr>
<td></td>
<td>SBP</td>
<td>148</td>
<td>98</td>
<td>155</td>
</tr>
<tr>
<td></td>
<td>DBP</td>
<td>95</td>
<td>78</td>
<td>96</td>
</tr>
<tr>
<td>5</td>
<td>Flow</td>
<td>148</td>
<td>156</td>
<td>170</td>
</tr>
<tr>
<td></td>
<td>SBP</td>
<td>145</td>
<td>92</td>
<td>155</td>
</tr>
<tr>
<td></td>
<td>DBP</td>
<td>95</td>
<td>78</td>
<td>96</td>
</tr>
<tr>
<td>6</td>
<td>Flow</td>
<td>160</td>
<td>162</td>
<td>176</td>
</tr>
<tr>
<td></td>
<td>SBP</td>
<td>144</td>
<td>98</td>
<td>154</td>
</tr>
<tr>
<td></td>
<td>DBP</td>
<td>95</td>
<td>78</td>
<td>95</td>
</tr>
<tr>
<td>7</td>
<td>Flow</td>
<td>160</td>
<td>164</td>
<td>164</td>
</tr>
<tr>
<td></td>
<td>SBP</td>
<td>138</td>
<td>110</td>
<td>154</td>
</tr>
<tr>
<td></td>
<td>DBP</td>
<td>90</td>
<td>80</td>
<td>95</td>
</tr>
<tr>
<td>8</td>
<td>Flow</td>
<td>160</td>
<td>178</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>SBP</td>
<td>145</td>
<td>114</td>
<td>155</td>
</tr>
<tr>
<td></td>
<td>DBP</td>
<td>95</td>
<td>82</td>
<td>98</td>
</tr>
<tr>
<td>9</td>
<td>Flow</td>
<td>160</td>
<td>172</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>SBP</td>
<td>144</td>
<td>90</td>
<td>154</td>
</tr>
<tr>
<td></td>
<td>DBP</td>
<td>94</td>
<td>78</td>
<td>95</td>
</tr>
<tr>
<td>PVC Number</td>
<td>Parameter</td>
<td>Pre-PVC Level</td>
<td>PVC Level</td>
<td>Post-PVC Levels</td>
</tr>
<tr>
<td>------------</td>
<td>-----------</td>
<td>---------------</td>
<td>-----------</td>
<td>----------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>Flow</td>
<td>200</td>
<td>120</td>
<td>198</td>
</tr>
<tr>
<td></td>
<td>SBP</td>
<td>140</td>
<td>115</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>DBP</td>
<td>95</td>
<td>85</td>
<td>90</td>
</tr>
<tr>
<td>11</td>
<td>Flow</td>
<td>160</td>
<td>156</td>
<td>182</td>
</tr>
<tr>
<td></td>
<td>SBP</td>
<td>142</td>
<td>114</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>DBP</td>
<td>95</td>
<td>80</td>
<td>92</td>
</tr>
<tr>
<td>12</td>
<td>Flow</td>
<td>130</td>
<td>168</td>
<td>168</td>
</tr>
<tr>
<td></td>
<td>SBP</td>
<td>154</td>
<td>124</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>DBP</td>
<td>100</td>
<td>84</td>
<td>100</td>
</tr>
<tr>
<td>13</td>
<td>Flow</td>
<td>150</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>SBP</td>
<td>152</td>
<td>128</td>
<td>168</td>
</tr>
<tr>
<td></td>
<td>DBP</td>
<td>102</td>
<td>90</td>
<td>100</td>
</tr>
</tbody>
</table>

\( ^a \) Flow—Vein graft blood flow, measured in cc/min.

\( ^b \) SBP—Systolic blood pressure, measured in mm Hg.

\( ^c \) DBP—Diastolic blood pressure, measured in mm Hg.
SELECTED BIBLIOGRAPHY


