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The Subclavian and Axillary Arteries as Inflow Vessels for Coronary Artery Bypass Grafts – Combined Experience from Three Cardiac Surgery Centers

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ABSTRACT

Background: The subclavian and axillary arteries represent reliable inflow vessels in peripheral vascular surgery. During recent years they have also been used for special situations in coronary artery bypass grafting. We report on a preliminary, triple center experience with subclavian/axillary artery to coronary artery bypass grafting.

Methods: Twenty-one patients (11 male, 10 female, median age 70 years) received subclavian artery/axillary artery to coronary artery bypass grafts. Indications for application of this bypass variation were internal mammary artery problems during minimally invasive coronary artery bypass grafting (n = 10), untouchable ascending aorta (n = 6), high risk reoperations (n = 3), severe chronic obstructive pulmonary disease (COPD) (n = 1) and right ventricular ischemia after ascending aortic replacement for acute aortic dissection type A (n = 1).

Fourteen procedures were carried out via minithoracotomy, and seven via sternotomy. Inflow vessels were the left subclavian/axillary artery in 12 cases, the right subclavian/axillary artery in eight cases and bilateral subclavian/axillary artery in one case. Bypass conduits were the saphenous vein (n = 20 for revascularization of the left anterior descending artery, the right coronary artery and obtuse marginal branches) and the radial artery (n = 2 for revascularization of diagonal branches).

Results: The procedure was without major technical problems in all patients. Hospital mortality was 1/21. Neither brachial plexus injury nor arm ischemia occurred. Mean pre- and postoperative angina classification was 3.0 +/- 0.8 and 1.2 +/- 0.4 respectively ($p < 0.001$). After a mean follow-up period of seven months, one out of 14 axillo-coronary vein grafts studied by ultrasonic duplex scan or angiography was found occluded. Graft patency could be demonstrated for an observation period of up to two years.

Conclusion: Subclavian/axillary artery to coronary artery bypass is feasible and can be applied for complications in minimally invasive coronary artery bypass grafting, for redo operations and for management of the severely atherosclerotic ascending aorta. To reach the left anterior descending artery-system, the saphenous vein as well as the radial artery can be used. Complications concerning the infraclavicular incision seem to be no problem. Short-term patency rates are acceptable.

INTRODUCTION

The subclavian and axillary arteries are gaining increasing interest in the cardiac surgery community as they have been successfully used as cannulation sites for cardiopulmonary bypass in thoracic aortic procedures and redo operations. They have also been taken for insertion of intraaortic balloon pumps, and most recently they are under discussion for use as an inflow vessel in coronary artery surgery. Anatomical studies in cadavers have shown the technical feasibility of the subclavian/axillary artery to coronary artery bypass [Bonatti 1998a], and animal experiments have demonstrated acceptable flow rates of the graft [Bonatti 1999a].

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Table 1. Demographic data

Male	11
Female	10
Age (years)	70 (52–93)
Preoperative Angina Classification:	
CCSC I	1
CCSC II	6
CCSC III	7
CCSC IV	7
Cardiovascular Risk Factors:	
Hypertension	15
DM	3
Hypercholesterolemia	9
Smoking	9
Comorbidity:	
COPD	9
Chronic renal failure	3
PVD	5
CVD	5
Preoperative Patient Condition:	
Single vessel disease	8
Double vessel disease	5
Triple vessel disease	8
Elective procedure	10
Urgent procedure	9
Emergent procedure	2
Redo procedures	7
LVEF (%)	48 (20–83)

CCSC = Canadian Cardiovascular Society Classification, DM = Diabetes Mellitus, COPD = Chronic Obstructive Pulmonary Disease, PVD = Peripheral Vascular Disease, CVD = Cerebrovascular Disease, LVEF = Left Ventricular Ejection Fraction

Single case reports [Coulson 1997, Knight 1997, Yaryura 1997, Bhimji 1998, Machiraju 1998, Tovar 1998a, Shabb 1999, Wolf 1999] and small patient series [Coulson 1998, Bonatti 1999b] are published in the current literature suggesting that extraanatomical bypass grafts arising from the subclavian/axillary arteries might also be useful for increased clinical application.

The first indication for using the axillary artery may occur when the ascending aorta is found to be too severely diseased to permit proximal anastomoses to the ascending aorta. In these situations the axillary artery can be approached as it is generally free of disease and can be used as an alternative inflow source. The term AXCOR (AXilloCORonary bypass) has been suggested for this type of procedure.

The second indication for resorting to the subclavian or axillary artery is the occurrence of an inflow source during MIDCAB (Minimally Invasive Direct Coronary Artery Bypass) surgery, when for a variety of reasons the internal mammary artery is inadequate. For this type of operation, the term SAXCAB (Subclavian/Axillary to Coronary Artery Bypass) is proposed as an acronym. As indications are still rare at single institutions, the aim of the present study was to present a retrospective evaluation of intra- and postoperative results in subclavian/axillary artery to coronary artery bypass grafting at three cardiac surgery centers, with special regard to short-term graft patency rates.

MATERIALS AND METHODS

During the period from Feb 2, 1996 to April 20, 1998, 21 patients underwent subclavian/axillary artery to coronary artery bypass grafting at the University Hospital of Innsbruck, Austria and Dameron Hospital/St. Joseph's Hospital in Stockton, California. Demographic data for the patients operated on are listed in Table 1 (◎). Single subclavian/axillary artery to coronary artery bypasses were performed in some cases. In others, the subclavian/axillary artery to coronary artery bypass was combined with other grafts. Table 2 (◎) lists the procedures in detail. Indications for performance of the procedure were internal mammary artery problems during minimally invasive direct coronary artery bypass operations in 10 cases, extraanatomical bypass to detour a severely atherosclerotic ascending aorta in six cases, high risk coronary reoperations in three cases, severe chronic obstructive pulmonary disease (COPD) and avoidance of chest wall trauma in one case, and acute myocardial ischemia during a Bentall procedure for acute aortic dissection in another case. In the majority of cases, the indication for the procedure was established intraoperatively.

Operative technique

The operative technique has been published previously [Coulson 1997, Bonatti 1998a, b]. Fourteen operations were carried out via minithoracotomy, making it a typical SAXCAB procedure, seven were performed as AXCOR procedures via sternotomy. The inflow vessels were the left subclavian/axillary artery (n = 12) as well as the right subclavian/axillary artery (n = 8); in one case the subclavian/axillary arteries were used bilaterally. Artery exposure was done in the infraclavicular region using a transverse or oblique incision. The Stockton groups preferred to use the junctional zone between the third part of the subclavian artery and the axillary artery for anastomosis to the inflow artery. The grafts performed by these groups were introduced into the chest through a window made in the second rib. The coronary artery anastomosis was done first in order to calculate the length of the graft with maximum inflation of the lungs. The Innsbruck group, on the other hand, chose the second or third part of the axillary artery as the arterial inflow site. The graft was sutured to the axillary artery first and then brought to the coronary artery through a generous window in the adjacent intercostal space.

In the majority of the operations (20 grafts), the saphenous vein was taken as the bypass vessel; in two instances, however, a radial artery graft was inserted from the left subclavian artery to a diagonal branch. The radial artery was excised in its whole length, and a 40 cm length of saphenous vein was harvested prior to bypass grafting in order to guar-

Table 2. Revascularization Procedures Performed (CABG x single bypass = 10, CABG x double bypass = 7, CABG x triple bypass = 3, CABG x quadruple bypass = 1)

Target Vessel	Graft Type	Inflow	Combination with Other Grafts	Number of Procedures
LAD	SV	Left axillary artery		6
RCA	SV	Right axillary artery		2
LAD	RA	Left axillary artery		1
LAD	SV/RA	Left axillary artery		1
RCA	SV	Right axillary artery	LIMA–LAD	4
LAD	SV	Left axillary artery	bilateral procedure +	
RCA	SV	Right axillary artery		1
Dg	RA	Left axillary artery	LIMA-LAD	2
OM1	SV	Left axillary artery	LIMA-LAD, RIMA-RCA	1
OM1+Dg (Y-Graft)	SV	Left axillary artery	LIMA-LAD	1
OM1+PDA (Y-Graft)	SV	Right axillary artery	LIMA-LAD	1
PDA+OM1+DG (Y-Graft)	SV	Right axillary artery	LIMA-LAD	1

CABG = Coronary Artery Bypass Grafting, LAD = Left Anterior Descending Artery, SV = Saphenous Vein, RCA = Right Coronary Artery, RA = Radial Artery, LIMA = Left Internal Mammary Artery, Dg = Diagonal Branch, OM = Oblique Marginal Branch, RIMA = Right Internal Mammary Artery, PDA = Posterior Descending Artery

antee adequate graft length. Twenty procedures were performed on the beating heart, and one was done on a fibrillating heart. Six operations required supportive cardiopulmonary bypass. Performance of a SAXCAB procedure is shown in the video (◎), and a scheme of a SAXCAB graft to the left anterior descending artery is depicted in Figure 1 (◎).

RESULTS

Major technical problems were not encountered intraoperatively. Postoperative results are depicted in Table 3 (◎). The median postoperative stay in the intensive care unit was 48 hours (range of 8-720 hours), and median hospital stay was nine days (range of 2-40 days). No cases of arm ischemia or brachial plexus injury occurred. All patients improved their angina classification postoperatively (mean angina classification preoperatively was 3.0 ± 0.8, postoperatively 1.2 ± 0.4 ($p < 0.001$)). The actuarial patient survival was 85% at one year and 80% at two years. Fourteen subclavian/axillary artery to coronary vein grafts were regularly monitored by ultrasonic duplex scan or angiography. One graft occlusion was found at five months, and all other grafts were patent at a mean follow-up of seven months. The observation period for three vein grafts reached 24, 24 and 20 months. All of these axillo-coronary bypass grafts are widely patent. A typical angiographic appearance of a saphenous vein graft from the right subclavian artery to the right coronary artery is shown in Figure 2 (◎).

DISCUSSION

Our report on 21 patients receiving the subclavian/axillary artery to coronary artery bypass graft as an extraanatomical coronary artery bypass variation demonstrated that this recently introduced technique can be safely and successfully applied in high risk CABG patients. The study, in addition, revealed a patency rate of the bypass

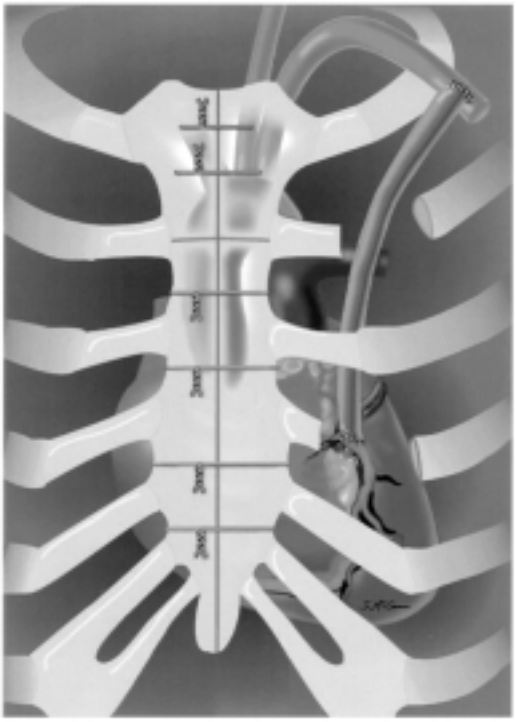

Figure 1. Scheme of a SAXCAB graft to the left anterior descending artery. A saphenous vein graft is sutured to the transition between the left subclavian and axillary artery and enters the chest through a window in the second rib. (SAXCAB = Subclavian/Axillary to Coronary Artery Bypass).

Table 3: Postoperative Outcome

Reexploration for Bleeding	0
Blood loss 12 h (ml)	298 (60–1315)
Inotropic Support/Vasopressors	19
IABP	0
Ventricular Arrhythmia	2
Supraventricular Arrhythmia	6
Myocardial Ischemia	3
Myocardial Infarction (new Q-waves)	0
Neurologic Deficit	1
Wound Infection	2
Hospital Mortality	1

IABP Intraaortic Balloon Pump

that reaches the standards of aortocoronary vein grafts. The patient population described can be classified as high risk, a fact which is underlined by the significant number of urgent operations, redo procedures, and comorbidities. In addition, median age was higher and left ventricular ejection fractions were lower than in average CABG cohorts. Several authors who reported on the method before have suggested the subclavian/axillary artery to coronary artery bypass as an option in high-risk CABG situations [Bhimji 1998, Shabb 1999, Wolf 1999].

In the majority of cases, a SAXCAB graft was performed for problems with the internal mammary artery during a MIDCAB procedure. If an internal mammary artery is damaged by electrocautery, direct suture or elongation of the IMA using a segment of saphenous vein, radial artery, or inferior epigastric artery [Calafiore 1996] is an option but difficult to carry out near the origin of the IMA. Previous operations may have rendered the internal mammary artery unusable [Coulson 1997] or, less often, atherosclerotic lesions or post-irradiation changes [Wolf 1999] may be a reason for not using the internal mammary artery. In the aforementioned situations, the SAXCAB bypass can be regarded as a true rescue procedure because conversion to sternotomy would be the only alternative.

Using the AXCOR bypass for management of a severely atherosclerotic ascending aorta has been reported by the Innsbruck group previously [Bonatti 1998b]. One argument against using axillary artery inflow in such situations might be that the innominate artery and internal mammary artery represent alternatives that do not require additional incisions or a transpleural course. Nevertheless, we regard the AXCOR bypass as a useful option because the internal mammary artery may be of small caliber and because the innominate artery is often involved in the atherosclerotic process, which may preclude tangential clamping [Tobler 1988]. It is a major attraction of the subclavian/axillary artery source that these arteries are rarely involved with atherosclerosis and, if any embolism does occur, the brain and the kidneys are spared. The carotid artery and descending thoracic artery may also be considered as inflow vessels when the ascending aorta is severely diseased, but these vessels usually are also significantly affected by the atherosclerotic process.

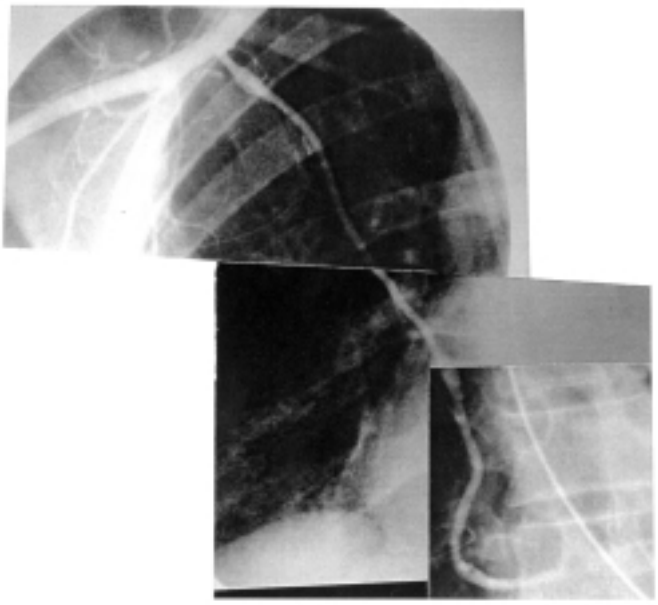

Figure 2. An axillocoronary bypass to the right coronary artery seen on angiography. The composite picture is made from three different angiographic exposures.

Coronary redo procedures carried out via resternotomy exhibit a considerable risk in unstable, multimorbid patients with impaired left ventricular function. A previously used internal mammary artery can be regarded as an additional significant risk factor [Blanche 1995, Shabb 1999]. In these situations, a subclavian/axillary artery to coronary bypass performed through minithoracotomy may be the only surgical option and the only option for coronary reintervention if the target vessel is inaccessible to a catheter based procedure. In this regard, we think that the technique described in this study is a very useful tool in the cardiac surgeons armamentarium.

In some patients with advanced COPD, rib retraction to harvest the IMA for a routine MIDCAB would negatively impact their postoperative respiratory status [Matsumoto 1997]. Thus, in one such case a primary SAXCAB approach was chosen instead of a procedure using the internal mammary artery. Another argument for proceeding in this way is that the classical MIDCAB procedure may be technically challenging in patients with extremely developed COPD.

Extraanatomical coronary artery bypass grafting in the presence of aortic dissection has been described years ago [Bilgutay 1976]. We performed one subclavian/axillary artery to coronary artery bypass for right ventricular ischemia after a Bentall procedure for acute aortic dissection type A. Placement of a partial occluding clamp on the conduit would have compromised the distal aortic and right coronary anastomosis. Therefore right coronary artery revascularization was carried out using a subclavian/axillary artery to coronary vein graft. This case shows the possibility of a detour of ascending aortic pathology by a graft originating from the axillary artery.

How should a bypass graft arising from the subclavian/axillary artery be routed into the thorax? Both rib resection and creation of intercostal openings have been chosen in the present series. So far no clear answer has been found as to which of these routes is preferable [Tovar 1998b], and no graft occlusion occurred at the thoracic entry side in our combined experience.

Data on the graft length required have been published by us previously [Bonatti 1998a, Bonatti 1999b]. This is one of the first reports on the use of the radial artery to revascularize the left anterior descending artery system from the left subclavian/axillary artery. Use of a vein graft has so far been one major criticism of subclavian/axillary artery to coronary artery bypass grafting, and with the radial artery an accepted arterial bypass graft can be offered in certain cases. To date there has been no incidence of arm ischemia or brachial plexus injury in subclavian/axillary artery to coronary artery bypass grafting. The lack of complications in this area is in accordance with experience in vascular surgery during the performance of axillofemoral bypasses.

The clinical efficacy of treatment is shown by significant improvement of angina symptoms in our patients. As might be expected, late survival in this high risk group is less than in average cohorts undergoing CABG, but no late death was due to acute graft occlusion. Patency rates of subclavian/axillary artery to coronary artery bypass grafts have so far been reported for single cases [Yaryura 1997, Coulson 1998, Bonatti 1999b]. The vein graft patency rate in the present series, which was 13/14 at a mean follow up of seven months, seems to be comparable to the patency rate for routine aortocoronary vein grafts [Loop 1986].

From this study we conclude that subclavian/axillary artery to coronary artery bypass grafting is technically feasible and useful for special complications in coronary artery surgery, such as internal mammary artery problems during the MIDCAB procedure, redo procedures, especially those involving a previously used internal mammary artery, and for management of the severely atherosclerotic ascending aorta. Due to the length of graft required in most of the cases, the saphenous vein will have to be used as the bypass vessel. For revascularization of the LAD system, however, a radial artery graft can as well be taken. Short-term patency rates of the subclavian/axillary artery to coronary vein graft seem to be acceptable.

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REVIEW AND COMMENTARY

1. Editorial Board Member MB134 writes:

This is an excellent discussion of the options facing a surgeon with these different techniques, the rationale and the indications.

There is probably no need to create new names for these procedures, and I do not see any significant difference in the described technique of SAXCAB and AXCOR, so I think these names are artificial and do not clarify the discussion. It does not matter if done through a thoracotomy or sternotomy; they all seem to be AXCOR anatomy and physiology.

Authors' Response by Johannes Bonatti, MD:

The reason why we used both expressions SAXCAB and AXCOR was that at the three institutions reporting in this paper different terms were used for the procedures. We are aware of the fact that they have the same meaning. Creating "artificial" names for new procedures may reflect a creative surgeon's natural instinct to emphasize that his operation is unique, but abbreviations like the ones suggested in this paper also may serve a practical purpose in promoting communication among surgeons.

2. Editorial Board Member AR11 Writes:

Why is length of stay so prolonged with this modification? Were there 1–2 long outliers that adversely affected the average, or are most of the patients kept longer for other reasons?

Authors' Response by Johannes Bonatti, MD:

We have reported length of stay as median and range and outliers alone have not affected the result. In the cases where a minithoracotomy was used, median hospital stay was five days, whereas in cases performed via full sternotomy median hospital stay was 10 days. Our patient population can be classified as high risk and this may be one reason why hospital stay was relatively long. Careful observation of patients undergoing a new procedure is another reason why hospital stay was extended in comparison to routine CABG procedures. In addition, several procedures were done in a European country where pressure to discharge patients early after CABG is less than in the United States.

3. Editorial Board Member SG14 writes:

I personally disagree with the indication for this technique in case of damage of the IMA in MIDCAB. As IMA to the LAD is a must in CABG, RIMA bypass to the LAD should be performed. In the section Operative Technique, it is mentioned that coronary anastomosis is first performed for better estimation of the length of the graft. The other way can be performed also.

Authors' Response by Johannes Bonatti, MD:

This reviewer's suggestion to use RIMA to LAD if the LIMA is damaged during MIDCAB implies that he would in any case convert to median sternotomy. In our own experience, patients converted to median sternotomy during MIDCAB problems can experience higher perioperative morbidity than with conventional CABG. Therefore a rescue procedure that can be performed via minithoracotomy is an attractive option at least in high risk patients. The fact that the coronary or axillary anastomosis can be performed first is mentioned in the paper, and both methods were definitely performed in our series.