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Distal Leg Protection for Peripheral Cannulation in Minimally Invasive and Totally Endoscopic Cardiac Surgery

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ABSTRACT

Background: The introduction of minimally invasive and totally endoscopic cardiac surgery is associated with increased use of femoral artery perfusion. Selective antegrade perfusion of the cannulated artery may be a helpful strategy to avoid ischemia of the lower extremities. The aim of the study was to evaluate the efficacy of selective distal vessel perfusion under continuous monitoring of oxygen saturation using near-infrared spectroscopy (NIRS).

Methods: All patients (n = 236) who underwent peripheral cannulation for remote access perfusion and endoaortic balloon occlusion for minimally invasive or totally endoscopic cardiac surgery were prospectively analyzed. Perioperative complications, creatine kinase levels, and major complications at the long-term follow-up were recorded.

Results: Minor or major complications of leg perfusion occurred in only 4 patients (1.7%); the complications in 2 of the patients were associated with an additional arterial cannula placed at the contralateral side. NIRS monitoring revealed diminished perfusion in 5 cases. Even patients with complications associated with remote-access perfusion had a rapid recovery, and no residual peripheral vascular complication was detected during follow-up.

Conclusions: The use of antegrade selective perfusion of the lower extremity at the side of peripheral cannulation for port-access perfusion and endoaortic occlusion is of utmost importance in patients undergoing minimally invasive or endoscopic cardiac surgery. NIRS monitoring has proved to be very helpful for the diagnosis of impaired leg perfusion.

INTRODUCTION

During recent years, the introduction of minimally invasive cardiac surgery has been associated with an increased use of peripheral vessel cannulation for cardiopulmonary bypass (CPB). Recently developed thinner peripheral cannulae with an increased inner diameter and superior flow characteristics have enabled cannulation with the Seldinger technique [Mohr 2001; Casselman 2003]. The use of remote-access CPB with balloon-carrying catheters for aortic endo-occlusion and cardioplegia administration is a prerequisite for performing totally endoscopic cardiac procedures on the arrested heart [Bonatti 2004; Bonaros 2006]. This technique requires peripheral vessel cross-clamping, which may lead to transient perfusion deficits of the lower extremities [Bonatti 2006]. Strategies to prevent muscle necrosis or development of compartment syndrome include invasive or noninvasive monitoring of tissue oxygen saturation of the involved extremity and prophylactic use of selective perfusion distally to the cannulation site [Dogan 2002; Jeanmart 2007].

The aim of this study was to evaluate the efficacy of selective distal leg perfusion through the arterial perfusion cannula under continuous monitoring using near-infrared spectroscopy (NIRS) in patients undergoing totally endoscopic, robotically assisted cardiac surgery.

PATIENTS AND METHODS

We prospectively evaluated the use of remote-access perfusion with balloon-carrying catheters in surgical candidates for totally endoscopic cardiac surgery using the da Vinci telemanipulator (Intuitive Surgical, Sunnyvale, CA, USA) or minimally invasive techniques that were performed through

Table 1. Procedures Performed with Remote Access Perfusion with Balloon-Carrying Devices for Endoaortic Occlusion

Totally endoscopic coronary artery bypass grafting, n	184
Single-bypass grafting	
Double-bypass grafting	
Single-bypass grafting + percutaneous intervention	
Totally endoscopic closure of an interatrial communication, n	35
Totally endoscopic removal of a displaced atrial septal occluder, n	5
Robotically assisted mitral valve repair, n	2
Closure of an interatrial communication through a minithoracotomy, n	10

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Table 2. Patient Demographic and Perioperative Data*

Age, y	56 (16-76)
Male/female sex, n	158/78
Height, cm	172 (148-188)
Weight, kg	77 (43-129)
BMI, kg/m^2	25.7 (18.4-39.8)
Primary diagnosis, n	
Coronary artery disease	184
Interatrial communication	45
Displaced septal atrial occluder	5
Mitral valve insufficiency	2
EuroSCORE	1 (0-8)

*Data are presented as the median (range) where indicated. BMI indicates body mass index.

a minithoracotomy. Of the 311 patients who underwent their operations with robotic technology, 235 patients underwent procedures involving totally endoscopic, robotically assisted cardiac surgery, including totally endoscopic coronary artery bypass grafting on the arrested heart (AH-TECAB), totally endoscopic closure of interatrial communications, totally endoscopic removal of displaced atrial septal closure devices, and robotically assisted mitral valve repair. Ten additional patients underwent minimally invasive closure of interatrial communications (Table 1). The ESTECH System (ESTECH, San Ramon, CA, USA) or the Edwards Lifesciences/CardioVations ENDOCPB System (Redwood City, CA, USA) were used for remote-access perfusion, aortic balloon endo-occlusion, cardioplegia administration, and venting. Femoro-femoral CPB or femoro-femoral and jugular CPB was established as previously described [Bonatti 2004; Bonaros 2006]. In brief, a 3- to 5-cm oblique incision was performed parallel to the inguinal crease at the left groin (for TECAB procedures) or right groin (for all other procedures) for exposure of the femoral vessels. The bifurcation of the common femoral artery was exposed and encircled; only the anterior wall of the femoral vein was additionally exposed. Distal femoral perfusion was established either by installing a 5.5F to 8.5F arterial-access sheath (Teleflex Medical/Arrow, Reading, PA, USA) in the superficial femoral artery or by sewing an 8-mm Gore-Tex graft on the superficial femoral artery.

The proximal and distal parts of the femoral artery were clamped with 120° vascular clamps. After performing a 1-cm longitudinal incision, we advanced the ESTECH cannula into the common femoral artery. We then advanced the guide wire under transesophageal echocardiography (TEE) guidance into the ascending aorta and placed the tip of the cannula approximately 1 cm distal to the aortic valve. After CPB initiation, the aortic-occlusion balloon was inflated, and cardiac arrest was induced by injecting 3 mg of adenosine. The proper position of the catheter balloon at 1 cm distal to the aortic valve was continuously monitored by TEE and by bilateral evaluation of radial artery pressure curves. Special attention was paid to the monitoring line for the right radial artery, which showed a decrease in the pulse wave (compared with the left side) if the balloon occluded the innominate artery. If this situation occurred, the balloon was deflated and relocated to avoid cerebral ischemia. When the catheter balloon reached a proper position, cardioplegia was started.

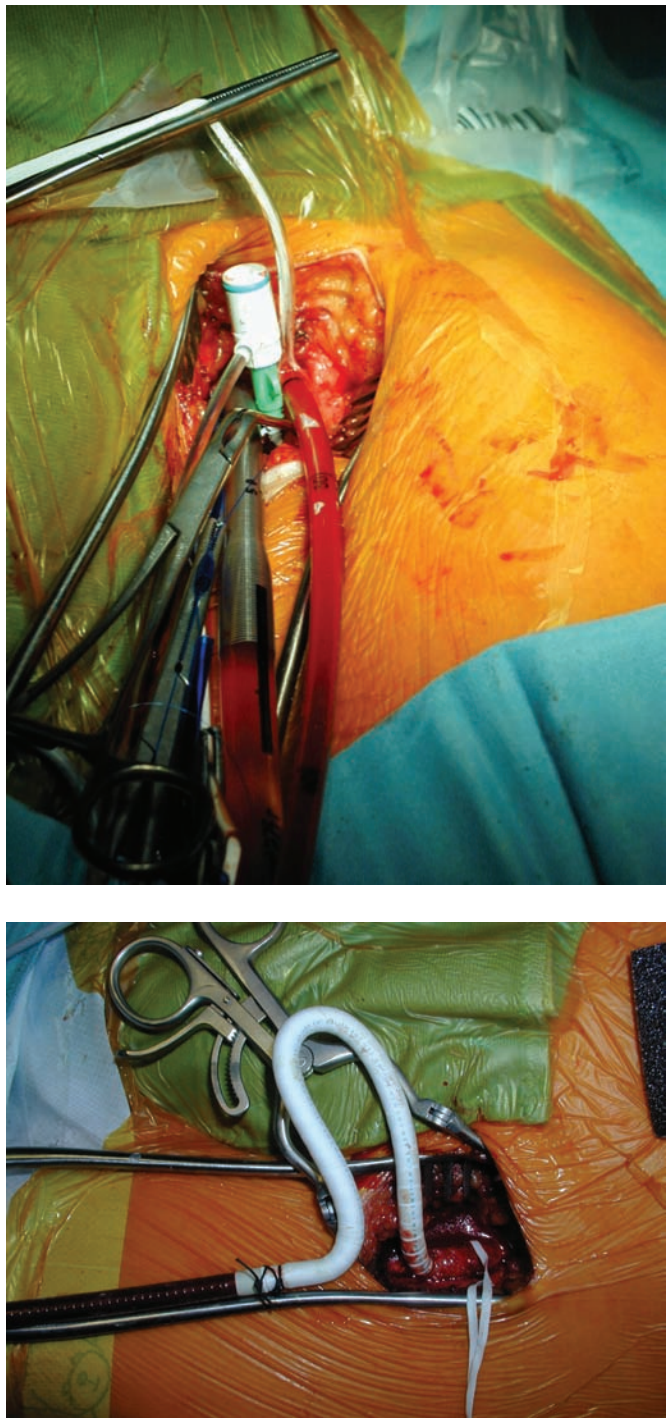

Figure 1. Selective perfusion of the distal femoral artery with a common arterial perfusion sheath (A) and an 8-mm Gore-Tex side graft (B).

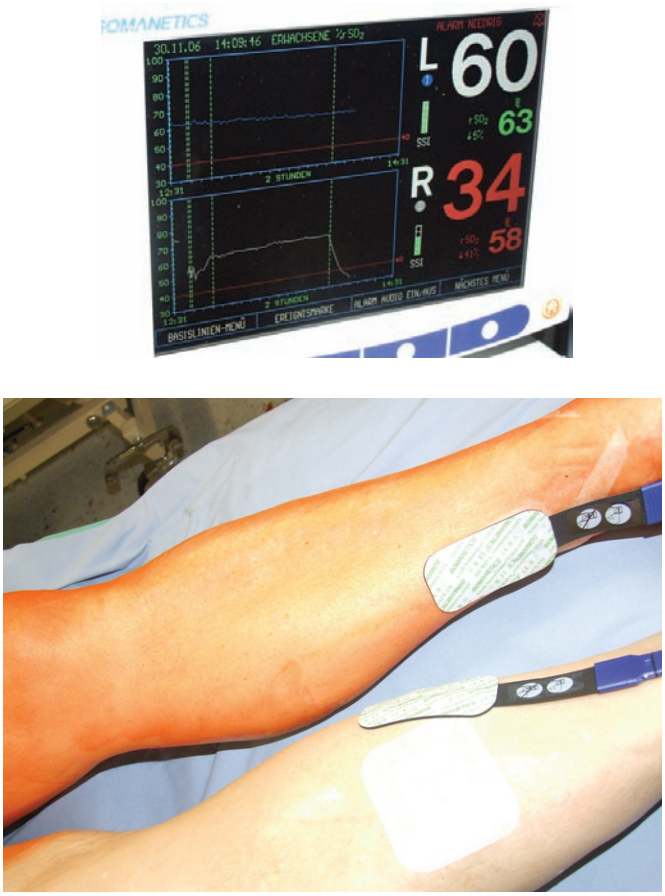

Figure 2. Near-infrared spectroscopy for monitoring tissue oxygen saturation and efficacy of distal leg perfusion in patients undergoing minimally invasive or totally endoscopic cardiac surgery with remote-access perfusion.

When we used the CardioVations system, we performed a 5-mm transverse incision in the common femoral artery and directly introduced the arterial-perfusion cannula, which we fixed with umbilical tape and a tourniquet. The endo-occlusion balloon catheter was introduced through the side arm and positioned under TEE guidance approximately 1 cm distal to the aortic valve. In case of any difficulties in identifying the guide wire or the balloon catheter in the ascending aorta, we used a mobile C-arm (OEC 9800; GE Healthcare, Chalfont St. Giles, UK) for fluoroscopic control during further guide wire advancement. After weaning the patient from CPB, we reconstructed the femoral artery with a Gore-Tex patch or, preferentially, with a pericardial patch.

RESULTS

We prospectively analyzed 236 patients (patient demographic and perioperative data are presented in Tables 2 and 3); all but 17 patients underwent selective distal leg perfusion during CPB. No perioperative mortality was observed in this patient series. Distal leg perfusion was performed by using a common arterial sheath in all but one case (Figure 1A). In this patient, an 8-mm Gore-Tex graft was sutured to provide optimal flow to the distal part of the superficial femoral artery (Figure 1B). We used NIRS monitoring in 47 patients (20%) to control the efficacy of selective distal perfusion (Figure 2), and NIRS monitoring detected kinking or occlusion of the femoral artery perfusion catheter in 5 patients (2%). In all of these cases, we corrected the catheter position or exchanged the catheter for a nonflexible catheter to ensure adequate distal perfusion. Four patients had perioperative leg ischemia. Ischemia at the contralateral side was noted in 2 of these cases: A patient with preexisting peripheral vascular disease and multiple stenoses of the popliteal artery developed a compartment syndrome on the first postoperative day and was treated with fasciotomy. This patient had a rapid recovery early in the postoperative period and was able to walk without significant impairment at the 3-month follow-up. In the second patient, a local dissection of the ipsilateral iliac artery was noted after removal of the cannulae. The intima flap was treated intraoperatively by direct stenting at the dissection site. The perioperative and postoperative courses were uneventful. An additional patient who required a second arterial cannula at the contralateral site for flow reasons developed a symptomatic ischemia-reperfusion injury combined with increased creatine kinase levels. Postoperative sonography and computed tomography angiography revealed normal perfusion of the lower extremity without stenosis or evidence of thromboembolism. This patient also experienced a markedly rapid recovery and remained asymptomatic at the 3-month follow-up. A similar complication was observed in an overweight patient who required an additional arterial perfusion cannula at the contralateral side for CPB-flow reasons. The patient experienced a rupture of the iliac artery, which was treated surgically after extension of the initial incision.

The vast majority of the patients (232/236, 98.3%) treated with this method had an uneventful postoperative course. Moreover, there were no patients with new onset of peripheral artery vascular disease after minimally invasive or totally endoscopic cardiac surgery and remote-access perfusion. Creatine kinase levels reached a maximum of 60,699 U/L. Only 13 (5.5%) of the patients had maximal creatine kinase levels >4000 U/L.

DISCUSSION

The expansion of minimally invasive cardiac surgery and the improvement of the existing materials for CPB have

Table 3. Perioperative Results*

Operating room time, min	303 (175-724)
CPB time, min	120 (20-428)
Aortic-occlusion time, min	66 (25-230)
CK, mg/dL	736 (59-60699)
CK-MB, mg/dL	26 (7-883)
Troponin T, ng/dL	0.113 (0.001-22.3)

*Data are presented as the median (range). CPB indicates cardiopulmonary bypass; CK, creatine kinase; CK-MB, creatine kinase isoenzyme MB.

resulted in an increased use of peripheral cannulation for arterial perfusion and/or venous drainage. Although this technique has been performed routinely in selected cases, such as aortic dissections or extracorporeal membrane oxygenation support, the advent of modern minimally invasive surgical techniques and mainly the implementation of totally endoscopic procedures require the use of aggressive catheters that not only are able to maintain arterial perfusion but also can be used for endoluminal occlusion of the ascending aorta and administration of cardioplegia [Schachner 2005]. Because the use of cannulae for remote-access perfusion with endoaortic balloon occlusion requires cross-clamping of the femoral artery and introduction of the cannula via open arteriotomy, selective distal leg perfusion is of major importance for avoiding ischemia of the ipsilateral lower extremity [Hendrickson 1998].

We experienced a very low incidence of peripheral vessel complications in our series because the vast majority of the patients received selective distal leg perfusion before placement of the arterial cannula. Glower et al [1999] experienced minor or major complications after femoral cannulation in up to 10% of their patients who underwent port-access minimally invasive cardiac surgery. Other authors have reported rapid improvement of clinical symptoms, even in patients who experienced major complications after peripheral cannulation, such as major leg ischemia or local dissection [Sagbas 2007]. In our hands, 2 of the 4 complications noted were not observed at the side of introduction of the balloon endo-occlusion catheter but at the contralateral side, which was cannulated with an additional arterial-perfusion cannula that was required for adequate CPB flow. The routine use of distal leg perfusion may explain the low incidence of complications in this patient series.

Strict selection criteria play a major role in minimally invasive port-access cardiac surgery, and previous authors have underlined its significance [Wimmer-Greinecker 1999]. We routinely perform preoperative computed tomography scans to exclude severe atherosclerosis of the balloon-occlusion site in the ascending aorta, as well as major calcification of the descending abdominal aorta and of the iliac or femoral vessels. Special care is taken in the clinical evaluation of a patient's peripheral circulation (temperature differences at the level of the lower extremities, palpability of peripheral pulses, use of the brachial/ankle index, and sonographic evaluation in case of inconclusive results). Because of the higher risk of ischemic complications, thromboembolism, and retrograde aortic dissection, previous investigators have also excluded patients with severe peripheral vascular disease or with evidence of severe generalized arterial calcification [Reichenspurner 1998]. Other studies have shown that the prolonged period of limb ischemia in patients undergoing complex minimally invasive operations has the potential to cause ischemic complications in the cannulated extremity [Allen 1993].

To minimize the risk of peripheral cannulation, we routinely use a continuous perfusion monitoring by means of NIRS [Schachner 2008]. This technique provides information regarding the efficacy of distal perfusion during the procedure. Displacement of the selective-perfusion cannula, temporary obstruction through kinking, embolic arterial disease, or even inadequate perfusion of the lower extremity due to severe peripheral calcification or arterial spasm can be detected at any moment during the procedure and can be treated immediately [Muhs 2005]. After introduction of NIRS, the clinical evidence regarding the validity of NIRS monitoring in evaluating arterial perfusion in peripheral vessels or in cases of aortic dissection has increased [LeMaire 2006; Redlin 2006; Ubbink 2006].

We conclude that the use of antegrade selective perfusion of the lower extremity at the side of peripheral cannulation for port-access perfusion and endoaortic occlusion is of utmost importance in patients undergoing minimally invasive or endoscopic cardiac surgery. The complication rates were very low in this selected patients series, and the long-term results have been excellent. NIRS monitoring has proved to be very helpful for the diagnosis of impaired leg perfusion.

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