

# Extracorporeal Circulation without External Clamping and Cannulation of the Aorta: Transventricular Placement of a New Multifunctional Aortic Cannula

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## ABSTRACT

**Background:** Stroke is a devastating outcome of coronary artery bypass grafting (CABG). An atherosclerotic ascending aorta is a major risk factor for plaque detachment during cannulation and external clamping in patients undergoing CABG while on extracorporeal circulation (ECC). To avoid external cannulation and clamping we developed and tested a new multifunctional cannula in a pig model.

**Methods:** The cannula has a double-balloon endoclamping function and is placed via the apex of the left ventricle through the aortic valve in the ascending aorta. It has 2 integrated lines for cardioplegic solution and for venting the left ventricle. In this animal model, a single balloon cannula was used because of the short ascending aorta in pigs.

**Results:** The cannula was placed smoothly and reproducibly with a guide-wire technique. The cardioplegic solution was administered via aortic root perfusion. Weaning from ECC was uneventful, and macroscopic examination did not reveal any damage to the aortic valve.

**Conclusions:** This cannula could be used in patients with a severe atherosclerotic ascending aorta. The risk of plaque detachment and stroke during ECC might be reduced.

## INTRODUCTION

Stroke is a significant and often disastrous complication in cardiac surgery. Embolization of atheroma resulting from manipulation of the severely atherosclerotic ascending aorta is one of principal causes of stroke in patients undergoing cardiac surgery with extracorporeal circulation (ECC). Cannulation of the ascending aorta for inception of bypass may lead to a release of atheromatous debris; however, external clamping of the aorta and the release of the clamps is the primary cause of plaque detachment [Barbut 1994]. Intraoperative ultrasonographic evaluation of the ascending aorta in 100 consecutive patients undergoing cardiac surgery resulted

in detection of mild atherosclerosis in 33%, moderate atherosclerosis in 19%, and severe atherosclerosis in 10% of the patients. Older age and diabetes were independent predictors of the presence of severe atherosclerosis in the ascending aorta [Davila-Roman 1991]. Even in the absence of postoperative stroke, organ dysfunction and length of hospital stay correlate with the amount of embolization during on-pump coronary artery bypass grafting (CABG) [Barbut 1997a]. In selected patients, off-pump CABG (OPCAB), without ECC, is certainly an alternative that reduces manipulation of the atherosclerotic ascending aorta. However, Khan et al demonstrated recently that the graft patency rate was lower in patients undergoing off-pump surgery than in patients undergoing on-pump CABG [Khan 2004].

In this study, our aim was to establish extracorporeal circulation without external or transmural (cannulation) manipulation of the ascending aorta. We developed and tested a new multifunctional cannula with an endoclamping function placed via the apex of the left ventricle through the aortic valve in the ascending aorta.

## METHODS

### Cannula

The cannula is custom made and was developed in cooperation with Jostra AG, Hirrlingen, Germany. It is placed via the apex of the left ventricle through the aortic valve in the ascending aorta. This cannula has 2 integrated lines for cardioplegic solution and for venting the left ventricle. Cardioplegic solution can be administered via aortic root perfusion, and alternatively, retrograde cardioplegic perfusion is feasible. The cannula is an extended arterial cannula with 2 soft balloons attached to its distal end that gently provide aortic occlusion. With the balloons inflated a space can be excluded for sewing the proximal anastomosis in patients undergoing CABG on pump (Video online).

Because of the short ascending aorta in pigs the cannula is designed as a single-balloon device in the animal model.

### Operative Procedure

The procedures and animal care conformed to the *Guide for the Care and Use of Laboratory Animals* [ILAR 1985] and the German law on the protection of animals.

We used German Landrace pigs (42, 46 kg) and started with an intramuscular (IM) preanesthetic medication with 0.05 mg/kg body weight of atropine and 4.0 mg/kg of

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azaperone. Under IM sedation with 1.0 mg/kg diazepam and 7.0 mg/kg ketamine, the animals were transported to the operating room. After placement of an auricular venous line and pre-oxygenation, general anesthesia was induced with 0.006 mg/kg fentanyl, 2 mg/kg propofol, and 0.2 mg/kg vecuronium. Animals were intubated endotracheally and ventilated volume controlled (FiO<sub>2</sub> 0.4; tidal volume 15 mL/kg, respiration rate 12/min). Anesthesia was maintained with flunitrazepam (32 µg/kg per hour) and propofol (2.5 mg/kg per hour). Continuous analgesia was achieved with fentanyl (8 µg/kg per hour). An arterial line was placed in the right carotid artery and a central venous line via the internal jugular vein.

First we tested the transventricular placement of an aortic cannula and weaning from ECC. The thorax was opened through a midline sternotomy. A sufficient-sized purse string suture was placed at the apex of the left ventricle. A needle was inserted and a guide wire was placed in the ascending aorta. The cannula was inserted and placed inside the ascending aorta. The position was controlled by touch. Purse string sutures were then tied to secure the cannula. The guide wire and dilator were removed. After placement of a venous cannula ECC was established. Weaning from ECC did not present any problems, and macroscopic examination did not reveal any damage to the aortic valve.

The second experiment was carried out to test the extended cannula. The transventricular placement and starting ECC were identical. The soft balloon was then inflated using 10 to 15 mL sterile saline. We administered cardioplegic solution via aortic root perfusion and sewed the proximal anastomosis in a conventional fashion (Video online).

### Measurements

Arterial, central venous, and cardiac output were monitored and registered online by a data acquisition program (PO-NE-MAH digital acquisition analysis and archive systems; PO-NE-MAH, Simsbury, CT, USA). Cardiac output was measured by an ultrasound flowprobe (Transsonic Systems, Ithaca, NY, USA).

## DISCUSSION

There has been increased awareness recently concerning atheromatous disease within the aorta as a cause of emboli during cardiac surgery. The relationship between the rising age of patients and the increase of central nervous system complications has become evident. Not only major neurological complications such as stroke but also the length of hospital stay are related to the number of emboli produced during CABG on pump [Barbut 1994, 1997a]. It has been demonstrated that embolization starts at the onset of ECC and is dramatically increased when the aortic cross and side clamps are removed [Barbut 1994, 1997a, 1997b, Ascione 1999]. This finding might be one reason for the recent increase in off-pump coronary bypass operations. Mack and coworkers [2004] pointed out that older and sicker patients benefit from off-pump CABG, which is associated with less morbidity, including decreases in blood loss, stroke, renal failure, and pulmonary and gastrointestinal complications. These findings were essen-

tially confirmed by Puskas et al [1998] based on comparing off-pump with on-pump CABG. Patients who underwent off-pump CABG achieved similar completeness of revascularization, similar in-hospital and 30-day outcome, shorter length of stay, and reduction in transfusion requirement, but no difference in stroke rate. These results suggest that emboli are released in conjunction with partial aortic clamping, which is applied in most off-pump patients. However, Kahn and coworkers [2004] have demonstrated that graft patency rate was lower at 3 months in patients undergoing off-pump CABG compared to on-pump CABG. They concluded that this finding might have implications regarding long-term outcomes.

There are two lines of thought with respect to reducing side effects caused by particulate emboli during on-pump CABG. One is to capture particulating emboli with an intraaortic filter and the other is to endoclamp the aorta with a balloon to avoid or minimize the release of particles. Both devices necessitate cannulation of the diseased aorta. With the proposed cannula in this study, ECC can be established completely without cannulation or external manipulation of the ascending aorta. Release of plaque and its formation can be reduced by virtue of transventricular placement, the double-balloon function, and the integrated line for venting and administration of the cardioplegic solution. This reduction in plaque formation and release might, in turn, lower the rate of neurological complications as well as the length of hospital stay after CABG on pump.

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