A simplified cardiopulmonary bypass technique for animal experiments on implantable ventricular assist devices

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ABSTRACT: We have developed and report on a simplified cardiopulmonary bypass technique for experiments on implantable ventricular assist devices in calves. We used an electromechanical implantable ventricular assist device with a double cylindrical cam in three calves. Cannulas for the ventricular assist system were designed to be inserted between the left atrium and the descending aorta. We used the outflow cannula of the ventricular assist device, anastomosed to the descending aorta, as a temporary arterial return route for the cardiopulmonary bypass. A cannula for venous drainage was inserted into the right ventricle through the pulmonary artery. There were no problems related to the procedure and the cardiopulmonary bypass was successful. In conclusion, this simplified cardiopulmonary bypass technique without neck incision in calves, as used in developmental work involving implantable ventricular assist devices, can be reliably performed. (Int J Artif Organs 2002; 25: 147-50)

KEY WORDS: Ventricular assist device, Cardiopulmonary bypass, Cannulas

INTRODUCTION

When applying a ventricular assist device, either the left atrium or the left ventricular apex has been used as a site for inflow cannulation (1). Although left atrial or left ventricular cannulation can provide equally adequate support for an extracorporeal ventricular assist (VAD) (2), a shorter and straighter inflow cannula is usually inserted into the left ventricular apex with the aid of a cardiopulmonary bypass for an implantable VAD (3-5). To do a cardiopulmonary bypass in animal experiments using sheep or calves, the carotid artery and the jugular vein in the neck are usually isolated and cannulated as an arterial return site and venous drainage site respectively due to their particular cardiovascular anatomy (6,7). However, this technique has two potential pitfalls: problems associated with the creation of a secondary operative field in addition to a main operative site and problems associated with the difficulty of preserving the neck vessels after cardiopulmonary bypass. Therefore we developed a simplified technique for cardiopulmonary bypass without neck incision in calves during developmental work on an implantable ventricular assist device.

MATERIALS AND METHODS

We used an electromechanical implantable VAD with a stroke volume at 70 cc (Fig. 1). A pulsatile blood flow is generated by a cylindrical cam which has double tracks carved on its side surfaces. The tracks go up and down along the circumference of the cam making it possible to convert the unidirectional rotational motion of a motor to the reciprocal linear motion of a pusher plate. The blood sac was made of smooth, seam-free segmented polyurethane (Pellethane 2363-80A, Dow Chemical Co, Midland, MI, USA), contained within a rigid polyurethane housing (Isoplast 301, Dow Chemical Co, Midland, MI, USA). Medtronic-Hall mechanical heart valves (Medtronic Hall 21 AHK, Medtronic Inc., Minneapolis, MN, USA) were used in the inlet and outlet ports.

Three Holstein calves were used for the device
implantation. The weights of the animals ranged from 75 to 85 kg. Anesthesia was done using ketamine and the animals were intubated with a 12 mm intratracheal tube. The lungs were ventilated artificially with 100% oxygen. Ringer’s lactate solution was used as maintenance fluid and was infused through the cephalic or recurrent tarsal vein. Anesthesia was maintained with 1-2% enflurane.

For the experiment with our implantable left ventricular assist device (LVAD), PVC cannulas of 1/2 inch internal diameter were designed to be inserted between the left ventricular apex and the descending aorta (Fig. 2). The descending aorta was exposed by left lateral thoracotomy, and 100 IU/kg of heparin was administered. After applying a partial clamp, a 14 mm woven Dacron graft, attached to a left outflow cannula, was anastomosed end-to-side to the descending aorta using a polypropylene monofilament suture (Prolene 4-0; Ethicon Sutures Ltd., Peterborough, Ontario, Canada). After checking hemostasis at anastomosis, 200 IU/kg of herapin was additionally administered. A subcostal incision was made to create a preperitoneal pocket for the pump-actuator assembly. The opposite end of the cannula, anastomosed to the descending aorta, was drawn into the perperitoneal pocket just beneath the diaphragm from the chest cavity. The cannula was then connected to the outflow tubing system of the cardiopulmonary bypass circuit for arterial return of the cardiopulmonary bypass was inserted into the right ventricle through the pulmonary artery; thus a cardiopulmonary circuit between the pulmonary artery as a venous drainage site and the descending aorta as an arterial return site was established (Fig. 3/A).

Cardiopulmonary bypass was done using a 5-head roller pump (American Optical Corporation, Greenwich, CT, USA) and a membrane oxygenator (Univox-IC, Bentley Inc., Baxter Healthcare Corp., USA). During cardiopulmonary bypass, apical cannulation was performed upon the beating heart. Four U-stitches of 3-0 prolene reinforced with teflon pledgets were passed in the ventricular apex at the cardinal points. Another eight stitches were then used to complete the circumference in a similar way. All 12 stitches were passed through an apical polyurethane ring and left untied. The myocardium inside the ring was then excised using a specially made corer. The left ventricular cavity was manually examined with an index finger inserted into the apical hole and then the inflow cannula was inserted. The apical ring purse-string was then tied. The opposite end of the apical cannula was also drawn into the preperitoneal pocket just beneath the diaphragm from the chest cavity. Cardiopulmonary bypass was discontinued. The cannula,
anastomosed to the descending aorta, was separated from the cardiopulmonary bypass circuit, and connected to the VAD. The apical cannula was then connected to the device for the left ventricular drainage (Fig. 3B). Finally, the VAD between the left ventricular apex and the descending aorta was activated. The surgical wounds were then closed and the endotracheal tube was extubated.

RESULTS

Cannulation was successfully performed in all cases. Cardiopulmonary bypass was administered smoothly with average bypass time of 45 minutes. Mean systemic pressure was maintained at 65-90 mmHg and flow rates ranged from 50-70 ml/kg/min with normothermia. No difficulties were met in the transition from the arterial return cannula of the cardiopulmonary bypass to the outflow cannula of the VAD in the descending aorta.

All animals survived the experimental procedure. They stood up and ate food vigorously. Of these, one survived 8 days and the experiment was terminated due to a line separation by accidental traction of the line connected to the external console. The other animals were sacrificed earlier, also due to causes unrelated to the operative procedure (accidental heparin overdose and thromboembolism, respectively).

DISCUSSION

Proper animal experimentation technique is a prerequisite for evaluating the in vivo feasibility of a circulatory assist device. To minimize the inherent risks accompanying an animal experiment, minimal operative involvement is desirable. We studied the possibility of an approach to the left thoracotomy alone, without neck incision, in cardiopulmonary bypass for the experiment of an implantable LVAD. We used the outflow cannula of the ventricular assist device, attached to the descending aorta temporarily as an arterial return route. A cannula for venous drainage of the cardiopulmonary bypass was inserted into the right ventricle through the pulmonary artery. This made the operative procedure and much easier to perform. We did not experience any complications related to the procedure simpler and cardiopulmonary bypass was well administered. In conclusion, we offer a simplified reliable technique for administering cardiopulmonary bypass, without neck incision, in calves, as used for a developmental experiment involving implantable ventricular assist devices.

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