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A Single Bicaval Venous Cannula Used for Optimization of Endoscopic Robotically Assisted Procedures of the Heart

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ABSTRACT

Robotically assisted heart operation is one of the minimally invasive approaches that have revolutionized many surgical procedures. Robotic procedures on the heart, however, are by no means routine, and their optimization requires development of new instruments and techniques. Described here is the robotically assisted use in a sheep model of a new peripherally inserted bicaval venous cannula in the totally endoscopic closure of atrial septal defect. The exposure of the surgical target area was successful with no obstructions in the surgical view. The cannula shows sufficient flow characteristics for cardiopulmonary bypass. Subsequent suturing of the atrial septum defect was achieved without complications in the 4 experimental animals.

INTRODUCTION

In the past few decades, minimally invasive techniques have revolutionized a wide spectrum of surgical procedures; however, robotically assisted operation of the heart is by no means a routine procedure. In particular, the access paths with their small incisions have limited the possibilities in minimally invasive cardiac heart surgery because of the necessity of special accessory tools such as retractors, stabilizers, and vascular cannulas. A constant search for improvement with different materials that can optimize minimally invasive techniques in cardiac surgery is required for such procedures to become clinically routine.

In contrast to open heart procedures, minimally invasive cardiac surgery necessitates a different kind of vascular cannulation technique. This study reports our initial experience with a new peripherally inserted single bicaval venous cannula used in the totally endoscopic closure of atrial septal defects.

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TECHNIQUE

A single 32F bicaval venous cannulation system (Aotec, Baar, Switzerland) was used with a computer-enhanced surgical telemanipulation system (da Vinci; Intuitive Surgical, Sunnyvale, CA, USA) for the totally endoscopic closure of atrial septal defects in a sheep model. This robotic system comprises two different units: the control console (Figure 1) and the surgical arm components (Figure 2). The control component includes the operating device with a spatial optical 3-dimensional screen display in true color. For the surgical arm unit, 3 ports in the anterolateral part of the chest are used. One port enables the access of the endoscopic camera, and the other 2 ports allow access for the endoscopic surgical instruments [Carpentier 1998, Argenziano 2002].

The bicaval cannula is a wire-reinforced polyvinyl chloride cannula. The cannulas exist in 28F and 32F sizes (Figure 3). The usable length is 50 cm. Additionally, the distance between the drainage holes for the two sizes is 11 cm and 14 cm, respectively.

The new venous cannula was inserted into the jugular vein with the Seldinger technique and located in the inferior and superior vena cava [Jegger 1999]. Blood loss was avoided during the insertion by inflating the balloon inlaid between the drainage holes and deflating it for removal (Figure 3). Positioning of the cannula should take place with echographic assistance [Tevaearai 1999, Tevaearai 2001]. Afterward, both veins were snared to establish total cardiopulmonary bypass (CPB). The carotid artery was used for arterial cannulation.

The animals were fully anticoagulated with 3 mg/kg BM heparin (Liquemin; Hoffmann-LaRoche, Basel, Switzerland). CPB was performed with a vacuum-assisted venous drainage system connected to the heart-lung machine. Controllable backflow was obtained by creating negative pressure according to the central venous pressure with the usual roller pump as an adjunct on the venous reservoir. After cannulation, CPB was established, and the heart was fibrillated. The atrial septum was exposed by opening the right atrium. After the intentional opening of the atrial septum, the atrial septal defect was closed with 7-cm long monofilament 5-0 suture. The right atrium was closed, and the heart was defibrillated externally. After the procedure, all animals were in sinus rhythm.

The experimental setup for the 4 animals (weight range, 60-92 kg) is illustrated in Figure 4. Insertion of the cannula was easy and successful in all 4 cases. The mean CPB flow

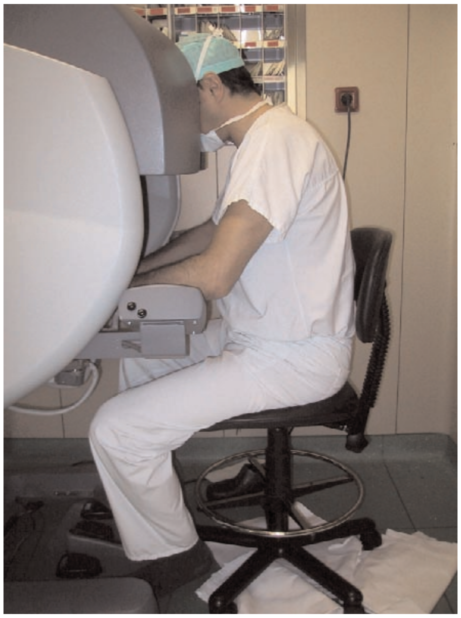

Figure 1. Surgeon console of the da Vinci surgical telemanipulator.

was 3.87 ± 0.39 L/min or 97.7% ± 4.5% of the theoretical flow (3.97 ± 0.42 L/min) with snared venae cavae and a vacuum-assisted venous drainage of 0 to 20 mm Hg and a mean central venous pressure of 9.5 ± 5.7 mm Hg.

The exposure of the area of interest was very successful, and the subsequent suturing of the atrial septal defect was achieved in all of the animals.

COMMENT

Minimally invasive robotically assisted heart surgery requires an easy venous cannulation technique. We have demonstrated in this study the easy use and implementation of a new bicaval venous cannula in an in vivo setting. This multiluminal cannula warranted the target venous flow. Additionally, the extracaval snaring around the cannula facilitated optimal drainage of the superior and inferior vena cava. It is very important to place the distal holes in the superior vena cava and position the proximal holes in the inferior vena cava. Therefore, echocardiographic control is needed to ensure the correct positioning of the cannula to avoid a sucking-in phenomenon and to enable sufficient venous flow.

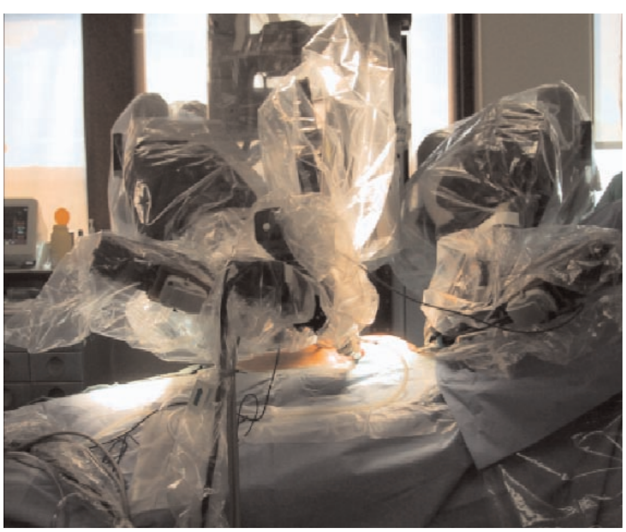

Figure 2. Patient-side surgical-arm component of the da Vinci telemanipulator.

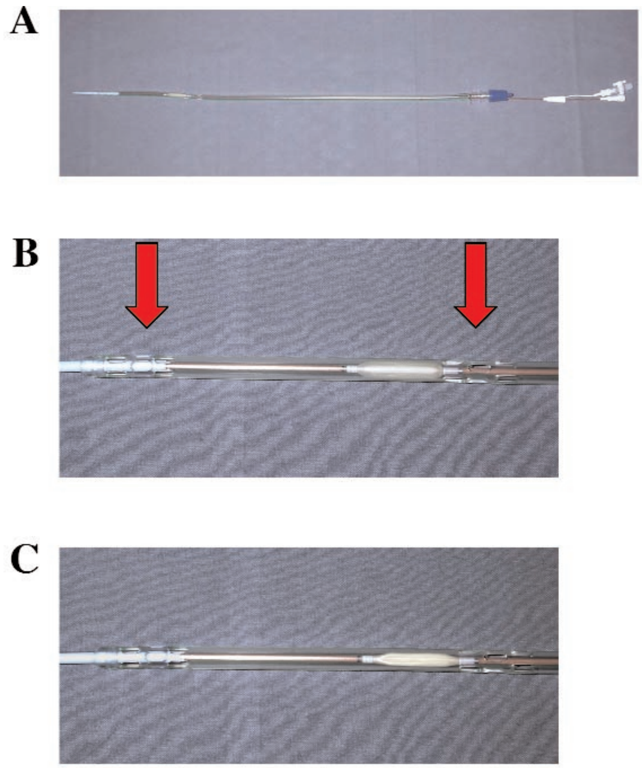

Figure 3. Single bicaval venous cannula. A, Overview. B, Proximal end with inflated balloon; arrows indicate proximal and distal drainage holes. C, Proximal end with deflated balloon.

Venous drainage can be adjusted with vacuum assistance, depending on the central venous pressure. Running an optimal CPB without sucking the vessel wall into the holes of the cannula requires maintaining the vacuum level in accord with the central venous pressure, which should be at least 5 mm Hg. In our experience, vacuum-assisted venous drainage was possible with a maximum negative pressure of –26 mm Hg dependent on the backflow. The level varied in the same animal from +2 mm Hg down to –26 mm Hg. A lower vacuum pressure has been described to lead to a sucking in of the vessel wall, which then can cause severe tissue damage [Gregoretti 1996].

Paracannular leakage is the disadvantage of conventional cannulas. This gap causes an unwanted persistent blood flow into the region of interest that can severely aggravate and therefore jeopardize minimally invasive surgical procedures. In the cannula described here, the venous backflow can be supported with the use of a negative pressure.

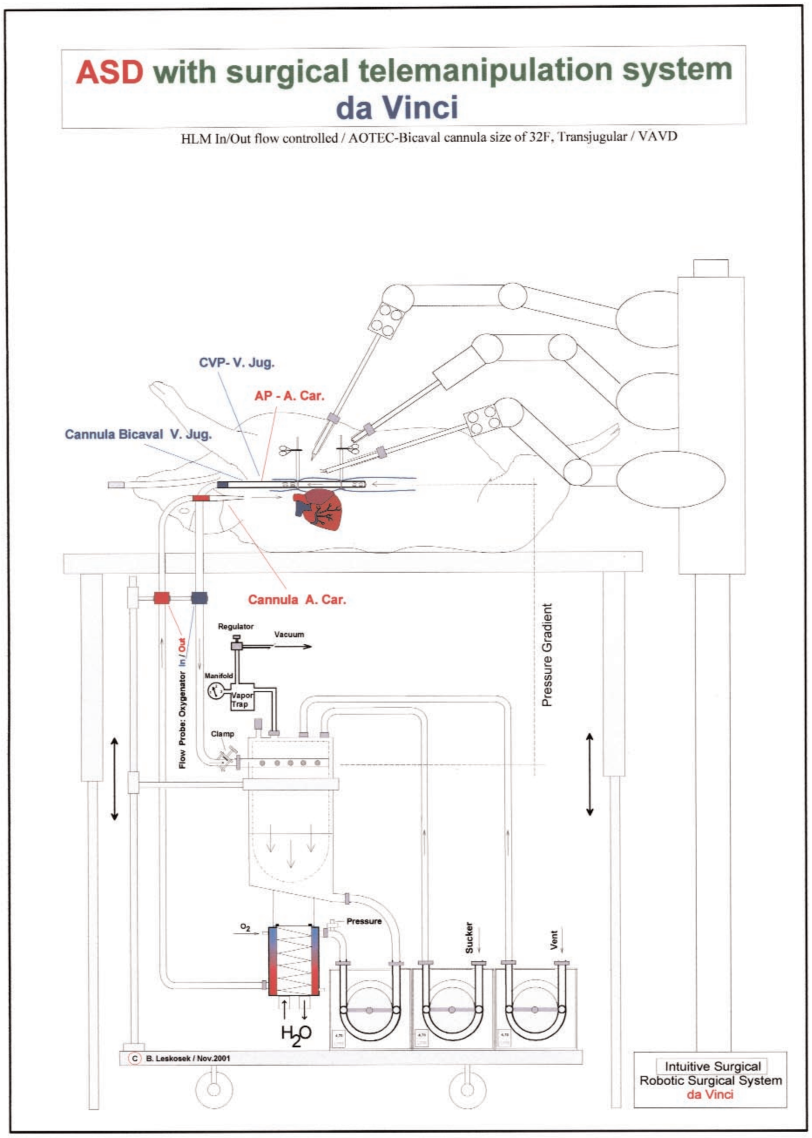

Figure 4. Surgical setup with animal in supine position with cannulas inserted into the right jugular vein (V. Jug.) and the right carotid artery (A. Car.). ASD indicates atrial septal defect; HLM, heart-lung machine; VAVD, vacuum-assisted venous drainage; CVP, central venous pressure; AP, arterial pressure.

The properties of this cannula enable an undisturbed view of all possible atrial structures. The intermediate portion of the cannula lying in the atrium leads to no obstruction of the surgical view. All atrial structures are perfectly visualized, and we have experienced no restrictions of the surgical exposure.

Our experience with this peripherally inserted bicaval venous cannula effected good results so that its clinical application in robotically assisted cardiac surgery procedures is warranted.

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