A simple bypass technique for superior vena cava reconstruction

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Abstract

Superior vena cava (SVC) clamping can be required during thoracic surgery for SVC replacement or repair. In such cases, bypass techniques can be necessary to avoid hemodynamic instability, cerebral venous hypertension and hypoperfusion. Here, we report a novel and simple SVC bypass technique which does not require full systemic heparinization, specialized cannulation techniques or pumping devices and which can be applied percutaneously in the preoperative phase or intraoperatively. The preoperative shunt consisted in two Swan–Ganz catheters inserted in the jugular and femoral veins and connected by perfusion tubing with a three way stopcock. The intraoperative shunt consisted of a Pruitt-catheter inserted in the left innominate vein and connected to a femoral Swan–Ganz catheter by perfusion tubing. We validated our system in seven patients undergoing SVC reconstruction. We monitored the systemic arterial blood pressures, the heart rate and volume which can lead to hemodynamic deteriorations, arterial pressure alone, cardiopulmonary bypasses, and temporary innominate-to-atrium prosthetic bypasses [1, 3–6]. Each of these techniques was proven efficient but was shown to have limitations, such as specific material requirement and careful patient selection. For example, SVC repair using pharmacological support alone must be limited in time (max 60 min), planned prior to surgery and involve patient selection with no cardiopulmonary limitations [5, 6]. Also, cardiopulmonary bypass was shown to induce major complications, such as low cardiac output (35%), stroke (7%), pulmonary edema (7%) and bleeding (21%) [3]. Finally, intraoperative temporary jugulo-atrial prosthetic bypass was shown to be applicable in situations where the innominate system was uninvolved but takes physical space in the surgery field, requires specific equipment, cardiac surgery experience and increases the overall procedure time [1]. Here, we report a simple bypass technique for the clamping of the SVC which does not require specific material except two Swan–Ganz catheters for the preoperative jugulo-femoral bypass or a Swan–Ganz and a Pruitt-catheter for the intraoperative innominate-femoral bypass. Because SVC clamping induces a jugulo-femoral pressure gradient, this system does not require a pumping device or additional heparinization beyond that required for SVC reconstruction.

2. Patients and methods

2.1. Preoperative workup and peri/postoperative management

The SVC bypass technique was evaluated on seven patients undergoing SVC clamping and reconstruction between 2003...
and 2009 in our institution. All patients underwent standard preoperative pulmonary and cardiac evaluation according to the algorithms of Bolliger and Miller, respectively [7]. Patients with predicted forced expired volume in one second (FEV1) and diffusion capacity of the lung for carbon monoxide (DLCO) of <80% underwent spirometry and patients with a maximum oxygen uptake utilised in one minute during maximum exercise (VO2) max of <20 ml/kg/min had split function testing by ventilation/perfusion scan; surgery was performed if a postoperative predicted VO2 max of >10 ml/kg/min was obtained. All patients >50 years and those with a history of heart disease underwent echocardiography.

2.2. Perioperative and postoperative monitoring

An arterial catheter was inserted in one radial artery to monitor blood pressure. Arterial systolic and diastolic pressures, heart rate and blood oxygen saturation were measured every 2–5 min before, during and after SVC clamping, respectively. For each patient, we monitored the vasocative peptide needs and fluid balance before, during and after the SVC clamping in the presence of the SVC bypass. A postoperative neurological examination was performed by a qualified neurologist in all patients after extubation.

2.3. Preoperative percutaneous jugulo-femoral SVC bypass (n=5 patients)

After intubation and administration of 10,000 IU heparin/24 h by perfusion, the patient was kept in prone position and two standard Swan–Ganz sheath catheters (Arrow-Flex 8.5 Fr ×4) were introduced in the internal jugular and the right-sided femoral vein, respectively, using a standard percutaneous sheath introducing set (Ref WH-09899-T). Both sheaths were connected by a standard perfusion tubing system (1.4×1.16×100 cm 5/8 Medtronic®) to which a side-arm was connected for monitoring and drug administration purposes (Figs. 1 and 2). The side-arm allowed bypass tubing flow control by infusion or extraction of fluids. Using the three-way cock, the bypass was opened prior to SVC clamping and closed when clamps were removed. At the end of the surgery, the bypass device was removed. Pressure and mathematical evaluations suggested the bypass could perform a 3.5-l/min laminar flow, while avoiding excessive upper body venous hypertension (≤20 mmHg, data not shown).

2.4. Intraoperative innominate-femoral SVC bypass (n=2 patients)

The SVC was encircled proximally and distally, and the innominate vein distal to the diseased SVC segment. A purse-string suture of 5-0 Prolene® was applied on the innominate vein proximal to the diseased SVC segment and a Pruitt-irrigation catheter (LeMaitre Vascular, Sulzbach, Germany) was inserted at that level in the innominate vein through the operation field and connected to a standard Swan–Ganz sheath catheter (Arrow-Flex® 8.5 Fr ×4) which was percutaneously introduced in the right femoral vein using a standard percutaneous sheath introducing set (Ref WH-09899-T), (Fig. 3). Intraoperative innominate-femoral SVC bypass was performed either in the supine position via sternotomy or hemiclamshell approach, or in the lateral decubitus position via posterolateral thoracotomy.

Fig. 1. Percutaneous jugulo-femoral SVC bypass technique: scheme of the jugulo-femoral bypass technique including the two Swan–Ganz sheath catheters inserted in the jugular and femoral veins, the tubing system and the three-way cock to which the sidearm is connected. The shunt is activated by simple rotation of the three-way cock and flow follows the pressure gradient from the upper to the lower part of the body. SVC, superior vena cava.

Fig. 2. Documentation of the material consisting of a standard perfusion tubing system and two Swan–Ganz sheath catheters with the percutaneous introducing sets.
3. Results

The preoperative percutaneous jugulo-femoral SVC bypass was evaluated in five patients and the intraoperative innominate-femoral SVC bypass in two. Mean patient age was of 53.1±3.5 years and the male to female ratio was 2:5. Surgery was performed for thymic tumors (n=4), NSCLC (n=3) and teratoma (n=1) and consisted of thymectomy alone (n=1) or combined with bilobectomy (n=1) or pleuropneumonectomy (n=2), bilobectomy (n=1) and lobectomy (n=2). The resections were performed through a hemiclammshell approach (n=3), a posterolateral thoracotomy (n=2) or a sternotomy (n=2). Complete en bloc SVC resection with reconstruction by end-to-end interposition of a reinforced polytetrafluoroethylene graft was performed in six patients, whereas one patient underwent partial SVC resection and primary repair. The mean duration of surgery was of 281±25 min and mean SVC clamping time was of 24±3 min. The mean number of peroperative blood transfusions was 1.3±0.5. Complete tumor resection was achieved in all patients.

We found that SVC clamping in the presence of SVC bypass initially caused a moderate decrease in systolic blood pressure without affecting the diastolic blood pressure (Fig. 4). In parallel, SVC clamping was associated to a mean four-fold increase in vasoactive peptide perfusion which allowed the systolic pressure to reach its initial preclamping values during the SVC clamping procedure. At declamping, there was no effect on systolic or diastolic blood pressures but the vasoactive peptide needs remained higher than before clamping. We found no significant differences in oxygen saturation and heart rate before, during or after SVC clamping (Fig. 5). Clinically, one of seven patients developed a discrete face edema and cyanosis during the SVC clamping phase. Perioperative bispectral encephalo-gram indexes were measured in two patients before, during and after SVC clamping and showed no variation throughout the procedure.

A clinical postoperative neurological examination after extubation revealed no neurological deficit in any patient but one patient presented severe agitation during awakening and required additional sedation and delayed extuba-
tion for an extra 24 h. Other postoperative complications included acute renal failure in four patients, atrial fibrill-
ation in two and pneumonia in two. There was no 90 days postoperative mortality. The mean duration of intensive care unit stay was of 16±11 days and the mean hospital stay was of 30±9 days.

4. Discussion

Replacement of the SVC is a challenging procedure but may be justified in selected patients with lung and mediastinal tumors. Complete en bloc resections for NSCLC or thymic tumors with SVC involvement have shown five-year survival rates of 31% and 42%, respectively [5, 6, 8–10]. After tangential SVC resections, a primary repair may be attempted but often a circumferential SVC resection is required with SVC reconstruction by end-to-end interposi-
tion of a prosthetic graft or by autologous pericardium fashioned into a tube [5, 6, 11, 12]. These methods have shown excellent long-term primary patency rates in up to 92% of patients [5, 6]. However, the clamping of a patent SVC can have dramatic hemodynamic consequences. It may cause a sudden drop in systemic blood pressure and venous...
stasis which can induce cardiac arrhythmias and/or arrest [1]. Most of all, SVC clamping may cause cerebral venous hypertension and decrease cerebral perfusion which may ultimately lead to brain damage [1]. For all these reasons, various studies have reported different methods to prevent these complications.

For example, it was shown that SVC cross-clamping and reconstruction can be performed with pharmacological support alone, provided a mean systemic blood pressure of 80 mmHg can be maintained [5, 6]. However, patients undergoing anti-hypertensive treatments or in which the clamping of SVC compromises the azygos return are likely to develop severe hypotension and may not be suited for this procedure [2]. Other methods for SVC repair and replacement include the use of a cardiopulmonary bypass and the surgical confection of a temporary jugulo-atrial bypass [3, 4, 13]. The cardiopulmonary bypass was validated in this context but requires full heparinization which may induce diffuse bleeding during extensive mediastinal resections. Temporary prosthetic jugulo-atrial bypass is a safe procedure but takes space in the operation field and requires time [4]. Here, we describe a new temporary SVC bypass technique which is safe and simple. The material is available in any surgical facility and the method does not require specialized personnel. It consists of a standard perfusion tubing system with Swan–Ganz sheath catheters/percutaneous introducing sets (jugulo-femoral shunt) and/or a Pruitt® irrigation catheter (innominate-femoral shunt). It does not require full dose systemic heparinization and does not take physical space in the surgical field.

Our results demonstrated that this simple SVC bypass technique prevented hemodynamic instability during and after SVC clamping in all patients. As opposed to SVC cross-clamping with pharmacological support alone where vasoactive peptide needs can be dramatically increased, our system allowed hemodynamic stability (no overall change in blood pressure, heart rate and oxygen saturation values) with minimal vasoactive drug increase throughout and after the SVC clamping procedure. Tubing thrombosis was avoided by keeping the shunt as short as possible and delivering prophylactic heparin to patients. Of interest, two of seven patients were on long-term anti-hypertension therapy and developed no major hemodynamic event during SVC clamping. Clinically, face edema and cyanosis were only observed in one patient during SVC clamping which rapidly disappeared following SVC reconstruction. Also, this patient remained hemodynamically stable throughout the procedure. We observed no neurological impairments following extubation in all patients. The SVC bypass technique allowed a careful and calm operation technique with complete tumor resections and patent SVC reconstructions in all patients. Finally, we observed no mortality in our study. In surgeries involving SVC clamping, it seems that mortality is more related to the resection extent than to the SVC clamping and reconstruction. However, our system permitted hemodynamic stability which may have participated in good patient outcome.

As our system can be implanted percutaneously prior to surgery, one of its additional advantages is to be activated prior to induction of anesthesia. It was shown that patients with SVC obstruction syndrome are at risk for unexpected life-threatening conditions or deaths with the induction of anesthesia [1] and previous work had emphasized the importance of a jugulo-femoral shunt implantation prior to induction [14].

Finally, the need for SVC clamping, resection and reconstruction can be discovered intraoperatively. While most SVC clamping situations require preoperative planning, our SVC bypass technique can rapidly be implanted intraoperatively using a Pruitt® irrigation catheter which is placed through the operation field in the innominate vein and connected to a percutaneously introduced femoral catheter. This intraoperative SVC bypass technique can be applied in the patient’s supine as well in the lateral decubitus position. Therefore, in complex situations, our system can be particularly useful. However, in rare situations, the innominate or jugular veins may not be accessible for cannulation and SVC cross-clamping with strict medical support remains the only option.

In conclusion, we have developed a simple SVC bypass technique for surgeries where clamping is likely to be used that can be implanted prior or during surgery. It prevents the occurrence of hemodynamic instability and of upper body venous hypertension. It is simple enough to be implanted during surgery in supine or lateral position if required. Other methods and techniques have been described to problems induced by SVC clamping. However, our system is applicable to any surgery facility as it does not require specialized material or personnel.

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References


