Single Catheter Gravity Drainage of the 
Right Atrium or Right Ventricle During 
Total Cardiac Bypass

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The currently employed cannulations preparatory to establishing cardiac bypass with the aid of a pump-oxygenator, include isolation of the superior and inferior vena cavae over tapes and the insertion of catheters into each of these vessels.1-3 At the onset of bypass the caval tapes are tightened around the indwelling catheters and venous drainage is effected by suction applied to the venous line by one of a variety of pumps. During procedures in which the right atrium or right ventricle is opened the venous return to these cavities through the coronary sinus or Thebesian veins is commonly aspirated by low pressure suction and injected into the venous line by pump action.

Some workers4,5 have advocated gravity drainage of the venous return after insertion of individual caval catheters as described. They have described a smoother operation with absence of venous flutter as advantages of this method.

Paneth5 has obtained direct measurements of total venous return through gravity siphon drainage of individual catheters placed in each cava, and in the right atrium and has found that these measurements reflected accurately the arterial pump output over a wide range of perfusion rates. Blood loss during perfusion was accurately reflected in a corresponding reduction in venous return and could be replaced quantitatively from an appropriate reservoir.

Our laboratory and clinical experience with the direct approach to the aortic and mitral valves suggested a simplification of this gravity drainage system. It consists of siphonage of total venous return through a single catheter inserted in the right atrium or in the right ventricle. Such drainage is applicable only to bypass employed during operative procedures on the left heart chambers or ascending aorta.

**Experimental Methods**

**Series I**: Adult mongrel dogs were anesthetized, intubated and attached to mechanical respirators. The right femoral artery was cannulated with a no. 14 or no. 15Fr plastic catheter. Right thoracotomies through the fifth intercostal space or midline sternum-splitting incisions were employed. Upon entering the chest the right auricular appendage was encircled with a purse string suture and total venous drainage obtained by inserting a no. 28Fr multiple-hole plastic catheter into the right atrium

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and draining this catheter by gravity siphonage into a reservoir placed between 40 and 50 cm below the operating table level. Extracorporeal circuits varied as follows:

1. In nine animals a double Sigmamotor pump and a bubble oxygenator were employed (Fig. 1).

2. In six animals the autogenous lungs were used in their normal oxygenating capacity necessitating cannulation of the pulmonary artery and left atrium (Fig. 2). Details of this procedure will be described elsewhere.6

At the onset of bypass the pulmonary artery was clamped at its base. Direct exposure of the aortic valve was obtained after inducing cardiac

FIGURE 1: Venous blood is drained by a single catheter in the right atrium into a reservoir about 40 cm below table level. From here it is pumped through an oxygenator and then by a second pump head into the femoral artery. Clamps are placed at the base of the pulmonary artery and in the ascending aorta if the latter is to be entered.
arrest by the Melrose technique. Arterial pressures were monitored throughout the experiments. Caval pressures were measured with water manometers before and during bypass.

Series II: Fourteen dogs were prepared in similar fashion except that left thoracotomies were performed through the fifth intercostal space. The left femoral artery was cannulated preparatory to perfusion. "Venous" drainage was obtained by inserting a no. 24Fr catheter through the right ventricular outflow tract and directing it proximally into the right ventricular cavity (Fig. 3). This catheter was secured with a purse string suture in the wall of the right ventricle and drained as previously described into a dependent reservoir. At the onset of bypass the pulmonary artery was clamped at its base to insure complete emptying of venous return. A pump-oxygenator circuit was employed and direct exposure of the mitral valve was obtained through an incision at the base of the left atrium. In five experiments cardiac arrest was induced by injection of potassium-citrate-blood mixture into the beating left ventricle after cross-clamping of the aorta. Arterial and venous pressures were obtained.

**Figure 2:** Venous blood is drained by gravity by a single catheter in the right atrium into a low reservoir. From here it is pumped into the main pulmonary artery. "Arterialized" blood is collected from the left atrium via single catheter and gravity drainage and pumped into the femoral artery. Clamps are placed at A and B if aortotomy is performed.—**Figure 3:** Venous blood is obtained through gravity drainage of a single catheter in the right ventricular outflow tract and pumped through an oxygenator from which it is pumped by a second pump head into the femoral artery. Clamps are placed at A before aortotomy or left atriotomy is performed and also at B if elective arrest is to be used.
Results

Gravity drainage of the right atrium or ventricle proved eminently satisfactory in all instances. Venous return under the circumstances described paralleled closely arterial pumping rates and reflected accurately the status of the total circulating volume. Blood losses were rapidly reflected in the blood level in the venous reservoir. By the same token, over-transfusion would cause an increase in reservoir blood. Venous pressures were typically 5 to 10 cm lower than those recorded before bypass. Arterial pressures were kept at mean values between 60 and 110 mm Hg during perfusion by employment of flow rates between 50 and 70 cc/Kg/min.

Clinical Cases

Since October 8, 1957, 16 patients have been operated upon using cardiopulmonary bypass with a pump-oxygenator and single catheter gravity drainage.
drainage. In 13, direct correction of aortic stenosis or insufficiency was carried out. One patient underwent open, transaortic coronary endarterectomy. These procedures were carried out employing elective potassium arrest and, in all, the “venous” catheter was inserted into the right atrium.

Two patients were operated upon for correction of severe mitral regurgitation. Polar cross fusion of the mitral annulus was performed as described by Nichols. Because of the advanced status of the valvular lesion, and the presence of large, tense, left atria which would make the usual techniques difficult, it was felt that cardiopulmonary bypass would provide a wider margin of safety and facilitate the operative maneuvers. Accordingly, a large catheter (no. 38 or no. 40Fr) was inserted into the outflow tract of the right ventricle and secured with a purse string suture. “Venous” blood was thereby drained by gravity into a reservoir from where it was pumped through an oxygenator and into the right femoral artery. A left posterolateral thoracotomy through the fifth interspace was used. The closed manipulations and placement of sutures across the incompetent mitral valves were tremendously facilitated by the bypass. Cardiac contractions persisted throughout, and were restored to normal strength as soon as bypass was terminated.

Again, our clinical experience with this method of “venous” drainage was most gratifying. The only difficulty encountered arose during the open coronary endarterectomy. The atrial purse string became loose with consequent dislodgement of the catheter and exposure of the holes at its tip. Air was thus sucked into the drainage tubing breaking the siphon. With loss of siphonage the venous blood entering the right atrium proceeded through the right ventricle and pulmonary circulation to enter the left side of the heart and escape through the aortic incision. Profuse hemorrhage resulted and the operation had to be terminated by rapid closure of the aortotomy accompanied by massive blood replacement. Fortunately, the patient survived but this experience has driven home the importance of accurate placement and secure anchoring of the draining catheter.

Discussion

The results described have convinced us of the simplicity and effectiveness of these techniques in cardiac bypass for operations on the left heart. They lend themselves well to emergency situations arising during preliminary manipulations in contemplated open-heart procedures. Rapid cannulation of the right atrium or ventricle with a single catheter is much more expeditious than individual isolation of the cavae with positioning of catheters in each vein. In mitral valve surgery single catheter drainage of the right ventricle will allow the surgeon to use a left thoracotomy in place of the more traumatic bilateral incision.

Care must be exercised in the selection of the caliber of the drainage catheter and tubing inasmuch as this factor determines the capacity of the siphon system and therefore the maximum flow possible. We have found that a no. 40Fr plastic catheter connected to 7/16” I.D. Tygon tubing has a siphon capacity of well over 4,000 cc. per minute and is satisfactory for the highest flows we have employed to date. It is easy to establish the capacity of smaller catheters and tubing which might be used with lower flow rates.

SUMMARY

Conventional methods of cannulation preparatory to cardiac bypass with a pump-oxygenator involve individual catheterization of the vena cavae. Drainage is then instituted by pump action or gravity.

A method is presented whereby operations on left heart structures, such as the mitral valve or the aortic valve area, may be simplified through the use of single catheter drainage of the right atrium or right ventricle. Gravity siphonage is employed
and the "venous" blood is collected in a dependent reservoir from where it may be pumped into an artificial or a biological oxygenator. Laboratory experiences with this setup showed it to be a satisfactory device in circuits employing an artificial oxygenator and in others in which the animal's own lungs were the oxygenating element. Encouraged by these results, we have used the single catheter method of drainage in patients suffering from mitral or aortic valve lesions. Three precautions should be observed during its use:

1. This method is applicable only to surgery on left heart structures in the presence of an intact septum.
2. The catheter employed and the drainage tubing should have a siphoning capacity compatible with the perfusion flows contemplated.
3. Care should be exercised in the correct placing and anchoring of the drainage catheter to prevent interruption of siphonage during operation. A simple safety device designed to re-establish siphonage by suction is illustrated.

Addendum: Since submitting the original article, twenty-five "open" aortic procedures employing the autogenous lung and forty-one plications of the mitral annulus by the Nichols' technique, with by-pass support, have been performed. Also, in more than 50 operations on the aortic valve, the artificial pump oxygenator was employed. In all, single catheter drainage was used and proved to be singularly efficient and trouble free.

RESUMEN

Los métodos habituales de canalización previa a la derivación del paso del corazón con un oxygenador de bomba incluye la cateterización individual de las cava. La canalización es entonces instituida la acción de la bomba o por gravedad.

Se presenta aquí un método por el cual en operaciones de corazón izquierdo tales como las mitrales o de válvulas aórticas, se puede simplificar la técnica por el uso de un sólo catéter que canaliza el atrio o el ventrículo derecho.

El sifón de gravedad se emplea y la sangre "venosa" se reúne en una depósito abajo de donde puede ser bombeado hacia un oxygenador artificial o biológico.

Las experiencias de laboratorio con este arreglo se mostraron satisfactorias en los circuitos que emplean un oxygenador y en otros en que los propios pulmones del animal actúan como oxygenadores. Alentados por estos resultados hemos usado este método en enfermos de lesiones mitrales o aórticas. Se deben observar tres precauciones:

1. Este método es aplicable sólo a la cirugía del lado izquierdo y en presencia de un septum intacto.
2. El catéter empleado y el tubo de drenaje deben tener una capacidad de sifón compatible con la corriente de perfusión que se espera usar.
3. Debe tenerse cuidado en la correcta colocación y el anclaje del catéter de drenaje para evitar la interrupción del mecanismo de sifón durante la operación. Un artificio sencillo usado para restablecer el sifonado por succión se presenta ilustrado.

RESUME

Les méthodes habituelles de mise en place de canules préparatoires à la traversée cardiaque avec oxygenateur à pompe comprennent le cathétérisme de la veine cave. Un drainage est alors institué par l'action de la pompe ou de la pesenteur.

Les auteurs présentent une méthode par laquelle les opérations sur les éléments du cœur gauche, telles que valve mitrale ou zone des valvules aortiques, peuvent être simplifiées grâce à l'emploi d'un drainage par simple cathétérisme de l'oreillette droite ou du ventricule droit. Le siphonage par pesanteur est utilisé et le sang "veneux" est recueilli dans un réservoir attenant d'où il peut être pompé dans un oxygenateur artificiel ou biologique. Les expériences de laboratoire faires avec ce procédé ont montré qu'il s'agit d'un moyen satisfaisant pour les circuits utilisant un oxygenateur artificiel et pour ceux qui utilisent des poumons d'animaux comme élément oxygenateur. Encouragés par ces résultats, les auteurs ont utilisé la méthode de drainage par simple cathétérisme chez les malades souffrant de lésions des valvules mitrales ou aortiques. Trois précautions doivent être observées pendant son emploi:

1. Cette méthode n'est applicable que pour la chirurgie des éléments du cœur gauche avec paroi intacte.
2. Le cathéter utilisé et le tube de drainage doivent avoir une capacité de siphonage compatible avec les perfusions envisagées.
3. On doit faire attention à la mise en place et à l'amarrage correct du cathéter de drainage pour éviter l'interruption du siphonage pendant l'opération. Un simple appareil de sécurité destiné à rétablir le siphonage par succion est proposé, tâné à rétablir le siphonage par succion est proposé.
ZUSAMMENFASSUNG

Die konventionellen Methoden der Kanüleneinführung zur Vorbereitung eines kardialen Kollateralkreislaufs mit einem Pumpen-Oxygenator machen im einzelnen eine Katheterisierung der Vena cavae erforderlich. Die Drainage wird dann ins Werk gesetzt durch Pumpentätigkeit oder durch Schwerkraft.

Es wird über eine Methode berichtet, mit deren Hilfe Operationen an den Organen des linken Herzens, wie z.B. der Mitralklappe oder dem Gebiet der Aortenklappen, vereinfacht werden können durch die Verwendung einer einzigen Katheterdrainage des rechten Vorhofes oder des rechten Ventrikels. Es wird dann die Absaugung durch Schwerkraft benutzt, und das "venöse" Blut wird gesammelt in einem herabhängenden Reservoir, von wo es in einen künstlichen oder biologischen Oxygenator gepumpt werden kann. Laboratoriumsuntersuchungen mit dieser Anordnung ergaben, dass sie eine befriedigende Einrichtung ist für künstliche Kreislaufsysteme sowohl bei Gebrauch eines Oxygenators als auch bei solchen, bei denen die eigene Lunge des Tieres das sauerstoffversorgende Element darstellt. Durch solche Resultate ermutigt, haben wir die Ein-Katheter-Methode der Drainage angewandt bei Kranken mit Läsionen der Mitralk- oder Aortenklappen. Drei Vorsichtsmassregeln müssen jedoch bei ihrer Anwendung beobachtet werden:

1. Diese Methode lässt sich nur verwenden bei Operationen an Organen des linken Herzens, wenn das Septum intakt ist.
2. Der Katheter und das Drainageröhrensystem müssen ein Saugvermögen haben, das der beabsichtigten Durchströmungsgeschwindigkeit angemessen ist.
3. Es muss Sorge getragen werden für eine korrekte Platzierung und Befestigung des Drainagekatheters, um eine Unterbrechung der Absaugung während der Operation zu vermeiden. Es wird eine einfache Sicherheitvorrichtung erläutert, die dazu be stimmt ist, die Aushebung durch Ansaugung wieder in Gang zu setzen.

REFERENCES


