

Heparin-Free Cardiopulmonary Support, Utilizing a Carmeda Coated Circuit, for a Patient with Pulmonary Hemorrhage and Multiple Trauma

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Abstract

The emergent use of closed-chest cardiopulmonary support to resuscitate and support moribund patients in cardiac and/or pulmonary failure has been well documented. However, when massive trauma is associated with this pathology, contraindicating systemic anticoagulation, this patient population becomes unapproachable utilizing "standard" bypass support equipment.

Studies of heparinized surface coatings have shown a reduction in complement and platelet activation and an increase in thromboresistance when compared to standard cardiopulmonary bypass circuits. To date, heparin-free cardiopulmonary bypass utilizing heparinized surfaces had only been attempted on animal models.

We present the first reported human application of heparin-free cardiopulmonary support utilizing a heparin-coated circuit on a 26-year-old male who developed severe pulmonary hemorrhage after sustaining massive lung contusion and other multiple injuries in an industrial accident.

Introduction

Emergent cardiopulmonary support has been utilized to salvage moribund patients with a variety of etiologies.(1-5) It is well-known that extracorporeal circulation requires the administration of heparin to prevent thromboembolic complications. For this reason, patients requiring extracorporeal circulatory support but are overtly bleeding, are at an increased risk of death due to massive hemorrhage. The survival rate of trauma patients resuscitated utilizing cardiopulmonary support, with standard heparinization protocols, is dismal.(5,6)

Larm et al.(7) have developed a thromboresistant coating in which heparin is covalently bonded and end-point attached to the surface of the equipment. With the advent of heparin-coated extracorporeal circuits, laboratory studies with animal models have demonstrated the potential for substantially decreasing or even eliminating administration of an anticoagulant prior to extracorporeal circulation.(8-17)

This report presents a patient, who after sustaining massive trauma, developed severe pulmonary insufficiency

as a result of intrabronchial hemorrhage. The patient was placed on closed-chest cardiopulmonary support, the oxygenator and tubing coated with CARMEDA BioActive Surface (CBAS).^a No anticoagulant was administered to the patient prior to, or during, the bypass period.

Case Report

A 26-year-old white male was admitted for severe multisystem trauma sustained when a steel girder, to which he was strapped, fell a distance of 30 feet. Initial examination revealed oropharyngeal blood, abdominal distension, left flank hematoma, unstable pelvis, with multiple upper and lower orthopedic injuries. The patient was transferred to the operating room for an exploratory laparotomy.

The patient was noted to have a ruptured spleen, a retroperitoneal hematoma extending from the pelvis to the caudate lobe of the liver and was hemorrhaging intrabronchially, due to a severely contused left lung. The coagulation profile was suggestive of a consumptive coagulopathy (Table 1&2). A splenectomy was performed as was a bronchoscopy. During the course of surgery, the patient's gas exchange status deteriorated and the decision was made to place the patient on cardiopulmonary support.

The cardiopulmonary support circuit consisted of a CBAS coated Medtronic Maxima oxygenator and tubing. Blood contact surfaces not heparin-coated were the Biomedicus^b BP-80 blood pump and percutaneous femoral cannulae. The circuit was primed with 1400cc Plasmalyte-A solution. The decision was made not to anticoagulate the patient.

The purpose of extracorporeal bypass was to provide pulmonary support, supplying the time necessary to perform additional diagnostic studies, to perform more definitive operative procedures, and providing the opportunity to slow the progress of the coagulopathy by means of blood product administration, thereby decreasing the intrabronchial hemorrhage.

Once bypass was initiated there was an immediate improvement noted in the peripheral saturation and arterial blood gases. Upon stabilization the patient was transported, on bypass, to the angiography laboratory and to the

a Medtronic Cardiopulmonary, Inc., Anaheim, CA 92807

b Bio-Medicus, Inc., Minneapolis, MN 55441

Computerized Axial Tomography scanner. The patient was returned to the operating room after 2'15" of transport/diagnostic study. The patient then underwent a right renal explant, retroperitoneal clot removal as well as achieving hemostasis.

Bypass flowrates ranged from 1.8-4.6 liters per minute (LPM). The fluctuation of flowrate was due to hypovolemia, which was treated with fluid administration. Throughout the resuscitation period the patient received crystalloids (23 liters) and blood products (packed red blood cells-50μ, fresh frozen plasma-8μ, platelets-75μ, cryoprecipitate-160μ) to maintain hematocrit/oxygen carrying capacity and to correct the consumptive coagulopathy. Only crystalloids and red blood cells were administered through the bypass circuit. During the bypass period, the activated clotting time (ACT) ranged from 176 seconds to 68 seconds (normal range 90-120 seconds). The activated Partial Thromboplastin Time (aPTT) remained elevated throughout the resuscitation period. The fibrinogen and platelet counts fluctuated in conjunction with blood product administration, active bleeding and surgically induced trauma.

When the coagulopathy was controlled, weaning from bypass commenced, with termination occurring 5'22" after initiation. The patient, hemodynamically stable and coagulopathy controlled, was decannulated and femoral vessels were repaired.

The patient was transferred to the intensive care unit where he remained for 24 days. After a hospital stay of 85 days, the patient was released to a rehabilitation program.

Discussion

Anticoagulation, in the face of a consumptive coagulopathy and multi-system trauma, may result in fatal, massive hemorrhage. Through the utilization of a heparin-bonded circuit, maintenance of high blood flow, and a circuit configuration minimizing the areas of low or stagnant flow, it was assessed the risk of a catastrophic thromboembolic event was low. To verify this, the circuit was gently rinsed with 0.9% normal saline post-bypass. Upon examination of the oxygenator, it was noted to have some areas of thrombin formation in the oxygenator ring, an area of low blood flow (Figure 1). The tubing and connectors coated with CBAS showed no evidence of fibrin formation. The cannulae, uncoated, demonstrated fibrin formation at multiple sites (Figure 2). The fact that the patient's coagulopathy had been abated prior to bypass termination, with no fibrin formation on the CBAS-coated tubing surfaces, was impressive.

The ability to successfully perform emergent bypass, heparin-free, with a thromboresistant, heparin-coated circuit on a human model has been demonstrated. The potential benefits of this technology to selected neurologically compromised and multiply injured patients is clear. The application of heparin-coated surfaces to cardiopulmonary support may therefore result in the successful salvage of

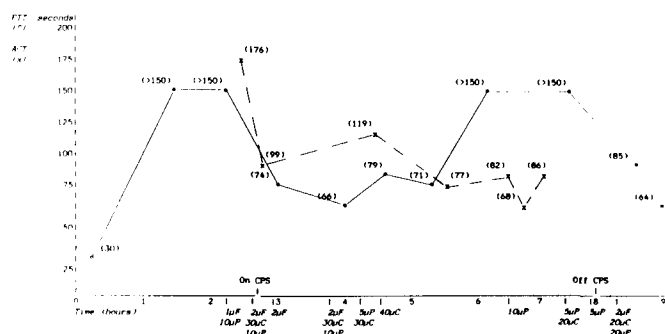
moribund patients previously categorized as unapproachable.

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ACT=Activated clotting time PTT=partial thromboplastin time
F=Fresh frozen plasma P=platelets C=cryoprecipitate

Table 1. Coagulation profile and blood product administration during patient resuscitation.

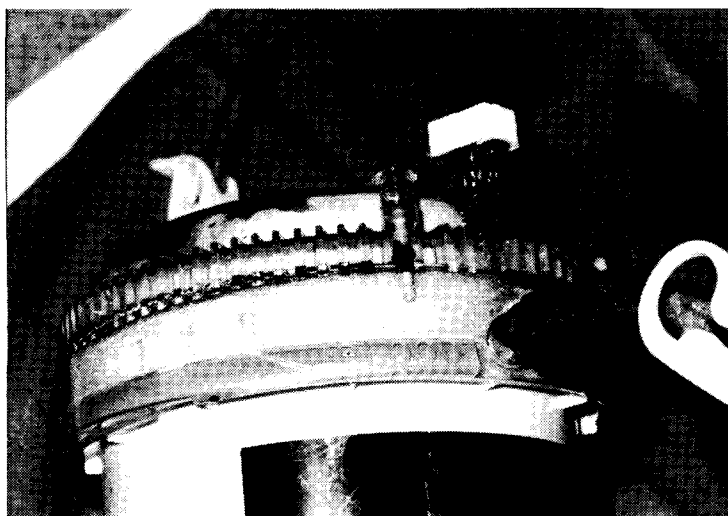
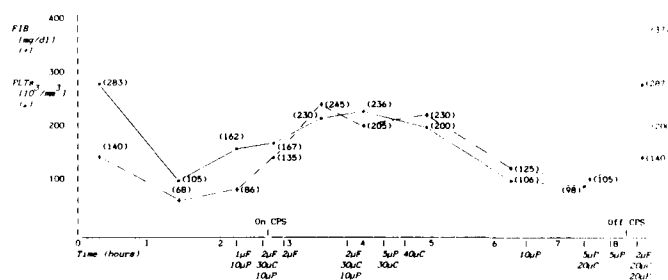


Figure 1.
Photograph of Medtronic Maxima oxygenator after 5' 22" heparin-free bypass.

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FIB=fibrinogen PLTs=platelets F=fresh frozen plasma P=platelets
C=cryoprecipitate

Table 2. Coagulation profile and blood product administration during patient resuscitation.

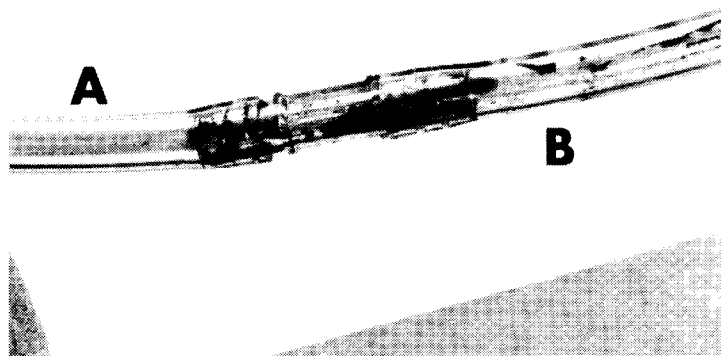


Figure 2
A=Carmeda-coated tubing; B=uncoated cannula after 5' 22" heparin-free bypass.

Questions and Comments

Q. With the fibrin that you noted in your cannula, do you now have your circuit coated tip to tip?

A. We are waiting for the cannulas to arrive.

Ian Shearer, Durham, N.C.

Q. John, what criteria was utilized to determine that this patient was suitable for weaning and what sort of ventilatory support did he require?

A. We knew we were well within the FDA recommendations of six hours on this patient. The patient's coagulopathy seemed to have reversed itself. There had been talk of potentially taking out one of the lung lobes because of the oozing and the hemorrhaging. However, after our bypass run the lungs were bronched one more time; there was no more bleeding. No one knows why it stopped. Whether it was because of the coagulation factors given or not, that was just unknown. After we came off bypass, the patient was on 100 percent O₂, probably about 15-20 PEEP. He remained intubated and in the unit for 24 days. He is a long term survivor. He was in the hospital for 85 days total. He came back to us for two weeks rehab and is alive and essentially well at home now.

Robin Sutton

Q. I was wondering, the fact that this patient was in DIC, did you think that it was an advantage to maintain this patient on a heparinized circuit?

A. I think it was a definite advantage. It was between that and the fact that he had the pelvic fracture which were essentially the only reasons why he did not receive any heparin at all.

Q. In retrospect, do you think there are parameters you might have, I mean it sounds like a horrendous case, and that it is really great you did that type of procedure. But in retrospect, are there any parameters you might measure to determine if you should give this patient platelets and fibrinogen and those sort of things or whether this is keeping the patient anticoagulated well enough? Are there any parameters for d-timer, fibrin split products you might have thought of measuring?

A. In retrospect, yes, we probably should have been measuring that. It was just not really having utilized the circuit before and being tossed into the situation and trying to obtain especially pre-bypass blood work like that...it was difficult. We have standard protocols for our registry. We draw d-timers and fibrin split products and all the other coagulation factors pre-bypass. Again, we are in the Carmeda study and that goes along with some of the parameters they look at.

Gary Sterns, Providence, R.I.

Q. Have you used this system in non-traumatic cases such as supported angioplasty and what do you see as its use for that?

A. We have not used it in angioplasty. However, I have used it two other times. We had an emergency case, a patient with a basilar aneurysm they had to go in for emergency neurosurgery, she was given 2,500 units of heparin pre-bypass and her highest ACT was 262 seconds. She received a total heparinization of 4,500 units during the case. We took her to profound hypothermia, 18 degrees, circulatory arrest for 20 minutes, rewarmed her. The circuit was clean. She is doing well considering the extensive amount of neurologic decompensation she had prior to surgery. We also went to Walla Walla, Wash. by airplane, picked up a patient with pulmonary embolus who was on 1,000 unit heparin per hour by IV infusion, and returned him to Emanuel Hospital for pulmonary embolectomy. There is a tremendous avenue for usage of heparin bonded tubing.