Technical Considerations for Transporting Patients, by Air Ambulance, with Intra-Aortic Balloon Pumps

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Abstract

An increasing demand for the conveyance of patients with acute cardiac decompensation to tertiary cardiovascular centers in our service area prompted investigation of a method for utilizing the intra-aortic balloon pump on helicopters and fixed wing aircraft of the Metro Life Flight system.

Mounting a Datascope[R] System 84 transport balloon console onto an aluminum helicopter litter allowed convenient loading and cabin configuration. Carbon dioxide CO_2 was the driving gas, and no recognizable altitude effects occurred. Reliance on on-board electrical power minimized CO_2 usage and maintained adequate reserves for complementary ground transportation. Compressor start-up can create a power drain which trips inverter circuit breakers. This can be avoided by connecting the tubing from the compressor to the console after it is running. Lengthening of the pressure tubing to the slave chamber facilitated patient movement. Special attention to CO_2 tank position and ground support preparation (personnel and equipment) have assured safe, expeditious transportation for eight patients with cardiogenic shock (seven) or refractory angina pectoris (one).

Introduction

Community hospitals initiate the care and treatment of the vast majority of patients experiencing ischemic heart disease. Most patients can be treated with conventional methods of medical or surgical management. However, cardiogenic shock, malignant ventricular arrhythmias, or unstable angina refractory to medical management develop in approximately five percent of patients. Many studies have provided evidence that patients in such high mortality risk groups benefit significantly from intra-aortic balloon counterpulsation (IABC).[1,2,3,4,5] Treatment modalities for patients supported by IABC are quickly expanded to include cardiac catheterization, coronary angioplasty, coronary revascularization, cardiac transplantation, and artificial heart implantation. The primary difficulty is safely transporting these critically ill patients to facilities which can provide the advanced modalities not available in the community hospital.

Cardiologists are incorporating the use of IABC in their practice at community hospitals where counterpulsation was previously unavailable. They are also offering percutaneous coronary angioplasty in outlying catheterization laboratories. These community hospital based teams have written several reports on the need, capability and difficulty of transporting patients on IABC to institutions of more advanced care by ambulance.[6,7,8] Studies such as these and numerous requests from community hospitals in our own area stimulated us to modify a balloon pump for convenient transfer of these critically ill patients by air ambulance.

Materials and Methods

We have previously reported our method of modifying a Datascope System 84 for convenient use on our Aerospatiale AStar 350B helicopter.[9] This system can be modified easily for use on any rotorcraft which can carry two patients on stretchers. We have also been able to use the pump on a Cessna Citation II twin engine jet for transport of patients from areas beyond our helicopter range.

To meet weight and space limitations the balloon pump was remounted on an aluminum helicopter litter and the "Q" cylinder was replaced originally with "B" cylinders. The system is now adapted to accept "E" cylinders for portable operation. Two tanks are taken for transport. The portable air compressor drives

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Table 1
Requests for Transport with IABC

	Flight	Time from Bed to Craft	Air Time	Time from Craft to Bed	Disposition
1.	2321	0	29	25	Transplant
2.	2375	8	14	20	Expired on arrival
3.	F-108	54	95	45	Transplant
4.	F-126	Expired prior to transport			
5.	F-137	45	60	40	Expired Pre Transplant
6.	3058	0	12	15	Surgery
7.	3063	0	33	0	Surgery
8.	F-141	No IABC			Surgery
9.	F-145	45+	35	35	Transplant
10.	3174	0	14	20	Surgery

All times are in minutes.

The letter F in the Flight column signifies jet transport.

Time of 0 indicates the hospital's balloon pump transported the patient between bed and aircraft.

the balloon in flight, eliminating the need to carry extra CO_2 tanks. Use of CO_2 on the aircraft is minimized.

Results

Table 1 lists the ten requests we received to transport patients using the balloon pump between March and December 1985. Five of the requests involved use of the helicopter, five used the jet. Seven patients were successfully transported using the balloon pump. One patient did not need the pump, one patient expired upon our arrival, and one patient died as we arrived at the receiving hospital. Four of the patients were transferred for the purpose of cardiac transplantation. Four were transferred for surgical revascularization. Seven were treated successfully, and one died two days later while awaiting a donor heart. Table 2 lists the difficulties which occurred during transport.

Discussion

Requirements of Extended Portable Operation

Portable operation of a System 84 lasts approximately 150 minutes with a "Q" cylinder. Battery life of the Datascope 870 and the 3520 are longer. Table 3 lists the times when we drove the balloon by the inverter or by compressed gas during transport. Table 4 presents the mean times for helicopter or jet transfer. The average time on portable operation for the jet includes the ambulance rides each patient requires to and from the airport. These tables demonstrate the need for portable power. We have had no difficulty in meeting these extended time periods with this transport system.

Variations of Atmospheric Pressure

There have been no untoward effects during transport caused by variations in altitude. The helicopters routinely fly at an altitude of 1,000 to 2,000 feet, although they occasionally will fly higher if needed. Cabin pressure in the jet is maintained around 270 torr, the pressure at 8,000 feet. The gas in the balloon is in a closed system, and is unaffected by the external pressures. The compressor is open to atmosphere and should drive the balloon satisfactorily as long as a person can breath comfortably without assistance. CO_2 is discharged into the atmosphere and should be able to drive the console regardless of atmospheric pressure. The one effect related to altitude that we have noted occasionally is a rise in arterial pressure displayed on our 870 monitor, which is not supported by cuff pressures. As this anomaly occurs with other electronic monitors also, the error may be inherent in the transducer systems.

Table 2
Incidents with Equipment during Transport

Flight	Equipment with Incident
1.	Monitor Battery; Compressor; "B" Cylinders
2.	none
3.	none
4.	no transfer
5.	CO_2 Tank Empty
6.	Inverter
7.	none
8.	No IABC
9.	Two CO_2 Tank Problems
10.	none

Table 3
Transport Times on Electrical Power or Compressed Gas

Flight	Time on Portable (CO_2)	Time on Inverter	Total transfer on IABC
1.	54	0	54
2.	28	14	42
3.	99	95	194
4.	No Transport		
5.	85	60	145
6.	27	0	27
7.	0	33	33
8.	No IABC		
9.	80	35	115
10.	20	14	34

All times are minutes.

Table 4
Mean Times on Electrical Power and Compressed Gas

	No. Flights	Mean Time on Portable	Mean Time on inverter	Mean Total Time Transfer
Helicopter	5	25.8	12.2	38
Jet	3	88	63.3	151.3

All times are in minutes.

Incidents of Failures of the System

A counterpulsation device has three components: the pump console, the monitor, and the source of drive gas for the pump. Following is a description of the difficulties we encountered with each component, along with a proposed solution or prophylaxis.

Failure of the Console Pump

Our console is the Datascope 3520. To date we have not noted any failure of this device.

Failure of the Monitor

The Datascope 870 monitor developed a low battery ten minutes into one helicopter flight. This progressed to the point of losing the monitor screen. The mean pressure and heart rate numbers continued to be displayed, and the balloon continued to be triggered.

Our solution was to go to a 1:2 trigger sequence, to limit difficulties that could occur with timing variations which may arise with changes in heart rate. The patient's heart rate remained stable, and transport was completed without difficulty or distress to the patient.

We could not have changed the battery pack in flight even if one had been available. We realized subsequently that we could have plugged the monitor into the aircraft (and ambulance) without difficulty. The monitor only draws 0.2 amps. The combined monitor and console draws less than 3 amps, easily tolerated by the invertors on either vehicle.

Failure of Sources of Drive Gas

A. The Portable Compressor

(1) On one flight to a referring hospital we connected the compressor to the inverter, and it functioned normally. After initiating portable counterpulsation and having started the helicopter engine, we turned on the compressor to discover it would not drive the system. We used CO_2 on the entire flight to drive the balloon. After the flight, the compressor worked normally again.

The compressor should be turned on before the connections are made to the pump console. The compressor will draw about an 8 amp surge and then operate on 4 to 6 amps of current. If the balloon console is in portable operation with CO_2 gas, and the connections are fastened, a 15 amp surge is required by the compressor to pump against the balloon itself, and that is beyond the capacity of most inverters.

(2) The second failure of the compressor to operate occurred when the inverter of the aircraft malfunctioned. Transport was completed on CO_2 without incident. The next day our mechanic reported the inverter was broken. We now carry on all aircraft a ground testing plug for checking the outlets before we lift off.

B. Failures Associated with CO_2

(1) Substituting CO_2 "B" cylinders for the "Q"cylinders proved inadequate. In a test situation, two "B" cylinders of CO_2 were drained while driving the balloon pump in portable operation at a rate of 90 bpm. One tank lasted 18 minutes, the other tank ran 21. In flight the tanks lasted only 10 to 15 minutes.

Two "B"cylinders are approximately equal to one "E" cylinder in weight. One "E" cylinder lasts between 20 to 30 minutes. We switched to the larger tanks because they carry more gas. We take two, and rarely use them. We also are able to call the referring hospitals and request an extra CO_2 tank to be available if needed. This has always been available, and ambulances can bring extra tanks from the receiving hospital to meet us when necessary.

(2) Occasionally we do change tanks. On one occasion we removed the seal from our last CO_2 tank, connected it to the pump, and found it was empty. We had no gas in any tank. We now weigh the tanks before taking them on flights because slow leaks result in partially or completely empty tanks. Our immediate solution on that flight was to fill the balloon with room air. Normal function was obtained until we landed where the waiting ambulance had CO_2 available. We then filled the balloon appropriately.

(3) During the transportation of patient #9 from the airport to the receiving hospital, one unwary attendant was *too* helpful. Condensed, very cold gas started spewing from a valve on the console. The balloon functioned for about three minutes, then stopped while escaping gas frosted the console mechanism. Bothered by the CO_2 tank in an upright position, the attendant had stored it horizontally.

The line was filled with liquid CO_2 which had escaped from the horizontal tank and had frozen. We turned off the tank and slowly released the pressure in the line. The patient arrived safely at the hospital without incident, but the line did not thaw out until after flight completion.

It is important to verify the operation of the console after such an incident. Damage can occur from freezing; release valves need to reseat; and powder or dirt from the gas can coat all the surfaces which it contacts. A major overhaul or repair job could be needed.

(4) On one mission the patient was transferred on the referring hospital's System 84 to the airport by ambulance. About 15 minutes before we were ready to transfer the patient from the ambulance to the jet and our balloon pump, the Q cylinder ran dry. We had to convert to our E cylinders by the adapter we had created.

We now make it a point to travel to the referring hospital from the nearby airport to arrange the necessary transfer of pressure lines, ECG cables, and inotropic drips as well as to place the patient on the flight litter before exiting the hospital. It is easier on the patient, and safer than trying to effect these changes in the back of an ambulance.

Factors Especially Helpful in the System

Slave Chamber

The slave chamber is positioned where it can be readily viewed. This enables quick visual confirmation that the balloon catheter is attached to the machine, and that the balloon is inflating and deflating. For times when the catheter needs to be attached or detached, the chamber is easily accessible. Also, the gas hose between the console and slave chamber can easily be lengthened to give greater mobility in manuvering the patient and machine in tight quarters. We use tubing designed for a pulsatile assist device, approximately 12 feet long.

Pressure and Vacuum Gauges

These guages are on the front of our pump. They have since been discontinued on newer models. The gauges give positive indication that the console is functioning whether by gas or compressor. It is difficult to hear the portable compressor or CO_2 gas escaping in the helicopter, and it may not be possible to hear the alarms. These gauges aid in troubleshooting the system and give early warning on the CO_2 tank levels.

Separate Batteries for Console and Monitor

When the 870 monitor failed, the oscilloscope was the only thing lost. Newer balloon pumps integrate all functions off one battery. The first component to be lost would be the one drawing the greatest amperage, probably the compressor, followed by the pump

Figure 1: Components for the balloon pump mounted on the folded helicopter litter. Thumb screws hold the components to the slide mounts. The litter is fastened to the neonatal cart by one thumb screw at each end. CO_2 tanks are mounted in holders on the opposite side of the cart.

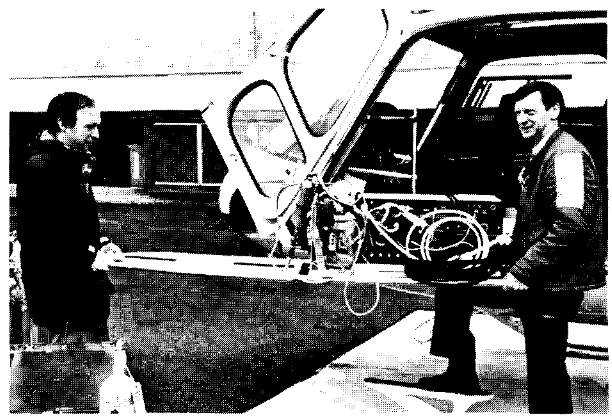

Figure 2: Helicopter litter is in the open position prior to placement in the helicopter.

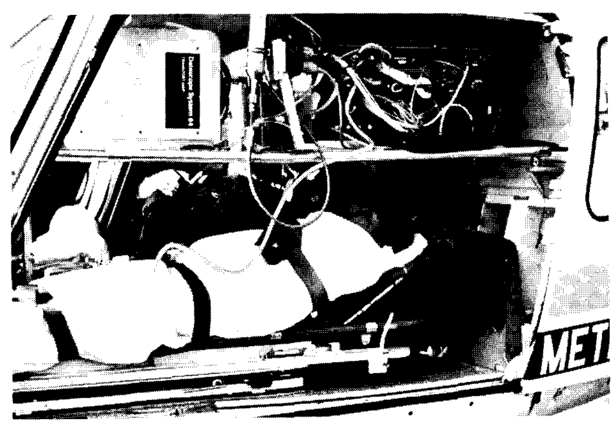

Figure 3: The balloon pump is in position with the compressor over the patient; CO_2 tank will be positioned in the corner by the door.

console or the monitor. Or the system may fail in toto. The new pumps may not offer convenient alternative back-up modes (e.g., conversion to gas delivery) if electric power fails.

Adapting from Q Cylinder to E Cylinder

This modification was effected to save weight. It has been helpful because the E cylinders are convenient to transport and have been readily available at all destinations. That our adaptor allowed us to bypass an empty "Q" cylinder was especially fortuitous.

Support by the Air Team

Choosing the personnel to transport a patient in this situation is critical. People need to have their special responsibilities, be able to work well together in a very close and strenuous environment, and not be too concerned over who does what. Perfusionists are not routine team members, but are necessary to troubleshoot the mechanical failures which may occur. It is also quite important that a physician be available to manage the rapidly changing clinical picture that critically ill patients often manifest. It is unfair to the patient and the routine ambulance crew to transport, with unfamiliar equipment, these highly unstable patients.

Conclusion

We have successfully transported eight patients while maintaining IABC in rotorcraft and fixed-wing air ambulances by using a modified System 84 transport balloon pump. Difficulties encountered with electrical systems and compressed CO_2 were described. Procedures for correcting and preventing problems were presented. Adequate back-up systems are maintained. The importance of having individuals knowledgeable in the care of these critically ill patients and the operation of this equipment is stressed.

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Questions from the Audience

Question: Did you make these modifications on your own or were they made with Datascope?

Answer: We made these modifications on our own. Datascope was not called or consulted. The reason we made the modification was that the Director of Life Flight at our hospital was one of my cardiac surgeons and we were getting many requests from outlying hospitals to come put balloon pumps into patients who needed them. We were trying to figure out the convenient way of doing that.

Question—David Mills: Did I hear you say that you as perfusionists, or part of your staff, attend on the helicopter when you transport a patient?

Answer: That's correct.

Question: What do you have then? You have yourself, a physician in attendance in addition to the patient, and a pilot.

Answer: That's correct. Our usually flight team that goes out to receive a patient on the helicopter consists of the pilot, a nurse, part of the regular team, myself, and a physician. For the most part that has been a thoracic surgeon. When we are bringing the patient back on the helicopter, the nurse remains at the referring institution, and we pick up the nurse at a later time. The nurse is able to set up the inotropic drips on the helicopter pumps as necessary. I've managed the monitoring and the functioning of the balloon in flight, and the physician then is able to manage the changing nature of the patient as we fly. There have been a few times when the physician's attendance in this system has been extremely beneficial. When we use the jet, we are all able to transfer the patient together.