
Power Failure and the Pump: How Effective is Manual Operation?

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Abstract

(*J. Extra-Corpor. Technol.* 19[3] p. 365–368 Fall 1987, 2 ref.) It is the primary concern of perfusionists to maintain flow to the patient under any circumstances. We performed the following study to determine how effectively both the roller and centrifugal force pumps produced flow when operated manually. The Travenol^a roller, Bio-Medicus^b centrifugal and the Centrimed^c centrifugal pumps were hand-cranked to generate a 3 liter/minute flow as measured during 30 second intervals with an arterial line Doppler flowmeter. The work (crank revolutions/minute) required to generate 3 liter/minute flow in both clockwise and counterclockwise directions was:

Pump	Counter-	
	Clockwise	clockwise
Travenol [®] Roller	—	116
Centrimed [®] Centrifugal	56	88
Bio-Medicus [™] Centrifugal	74	90

The Travenol roller produces forward flow only when turned counterclockwise. Clockwise turning produces reverse flow. Both the Centrimed centrifugal and the Bio-Medicus^b centrifugal produce forward flow with either clockwise or counterclockwise turning but the latter is more efficient. The Travenol roller was less efficient during manual operation than either the Bio-Medicus centrifugal and Centrimed centrifugal. Because pumps vary in their ability to produce flow when manually operated, the perfusionist must be prepared to provide the work needed to maintain flow in an emergency.

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Introduction

It is the ambition of every perfusionist to make the system he uses as fail-safe as possible. To do this, we must be prepared to deal with the catastrophic event of arterial pump failure. The majority of hospitals today have their own back-up generator systems in the event of a power failure. A battery pack could be used to maintain power to an arterial pump if necessary. Neither of these emergency systems, however, will work if a motor failure should occur. The objective of this study is to determine the capability of centrifugal force pumps to maintain forward flow in the event of either an electrical or mechanical failure. Since the use of centrifugal force pumps is still somewhat limited, we included a roller pump for comparison.

Materials and Methods

The arterial-venous circuit was kept as simple as possible. Each circuit was composed of the following disposables in sequence:

Bio-Medicus Bio-Pump^a
or
Centrimed System 1 Extracorporeal
Blood Pump^b
or
Travenol 3500 Modular Pump^c
 $\frac{3}{8}$ -inch \times $\frac{3}{32}$ -inch \times 6-inch polyvinyl
chloride arterial line
Shiley Arterial filter with a 20
micron screen^d

a Sarns Inc./3M, Ann Arbor, MI 48103

b Bio-Medicus, Eden Prairie, MN 55344

c Centrimed Corporation, Hopkins, MN 55343

d Shiley, Inc., Irvine, CA 92714-5751

½-inch × ⅜-inch × 6-inch polyvinyl chloride venous line

Cobe CML Disposable Blood Oxygenator^c

A Doppler flowmeter was attached to the arterial line 3 inches distal to the filter to measure flows.

The equipment was tested after the system, including the centrifugal force pump heads, had been used for a cardiopulmonary bypass. All or most of the blood was removed from the system either by direct reinfusion to the patient or by a cell retrieval system. The circuits were then reprimed with crystalloid solution. The arterial and venous cannulae were removed from their respective lines and the ⅜-inch arterial line was directly inserted into the ½-inch venous line to create a simple loop. We first determined the correct direction to crank each centrifugal force pump. We found that cranking the Centrimed equipment clockwise and turning the Bio-Medicus equipment as marked was the correct method of use.

All of the pumps were hand cranked in the correct direction to achieve a 3 liter flow rate. The number of strokes required to produce this flow was counted for 30 seconds. The revolutions per minute registered by the equipment were noted where possible. The entire process was then repeated for the 2 centrifugal force pumps cranking them in the opposite direction. We did not hand crank the roller pump in the opposite direction since we knew in advance that this creates reverse rather than forward flow.

Results

The results of the tests are indicated in Tables 1 and 2. As seen on Table 1, when cranked in the correct direction the Centrimed pump is more efficient than either the Bio-Pump or the Travenol roller pump. Both 3 liter and 5 liter flows were achieved more efficiently as measured by both numbers of strokes and revolutions per minutes. Since revolutions per minute did not register on all the equipment, the number of strokes required to establish flow is the only good point of comparison. The Travenol roller pump is the least efficient in providing a 3 liter flow. It requires 1½ times the number of strokes of the Bio-Pump and twice as many strokes as the Centrimed pump to achieve a 3 liter flow.

Table 2 shows that only the 2 centrifugal force pumps were cranked backwards. Again, the Centrimed centrifugal force pump is more efficient, but only barely so, than the Bio-pump.

^c Cobe Laboratories, Inc., Lakewood, CO 80215

Table 1

Results of Handcranking in the Correct Directions

Pump	Strokes	RPMs	Flow
Bio-Medicus	74	1500	3L
	108	2250	5L
Centrimed	56	1000	3L
	76	1500	5L
Travenol	116	—	3L

Table 2

Results of Handcranking in the Incorrect Direction

Pump	Strokes	RPMs	Flow
Bio-Medicus	54	—	1.5L
	90	—	3L
Centrimed	64	1000	1.5L
	88	1500	3L
Travenol	—	—	—

During the testing, each of these pumps generated their flows against only the minimal resistance of the circuit. While patient resistance does not influence the forward flow of a roller pump, this is not true of the two centrifugal force pumps. Centrifugal force pumps are not occlusive like roller pumps. Flows are somewhat pressure dependent and can vary as much as 200 cc/minute at the same revolutions per minute depending on patient resistance. Thus, the figures on Tables 1 and 2 do not represent flows under actual clinical conditions.

Discussion

A survey of pump accidents by Stoney, et al.¹ revealed 394 accidents caused by electrical or mechanical failure. The report was based on the responses of 965 perfusionists working in 349 cardiac surgical teams. In a five year period, approximately 41% of the perfusionists had to deal with an emergency caused by a pump failure.

A recent issue of Health Devices reported the failure of a centrifugal force pump in the form of a runaway pump head.² Three recommendations were made, one of which was that a roller pump be available as a back-up arterial pump. Although a spare pump sounds like an optimal solution, it does not address the problem of a total power interruption.

When we reviewed the manual operation of the pumps, some significant differences became apparent. Roller pump heads are all mounted directly over their motors. This makes it easy to turn off the console,

install the hand crank and begin pumping. The process of switching to the manual system of the centrifugal pumps is quite different. These pump heads are separate pieces mounted onto the motors. To crank the machine, one must first set up the manual drive equipment and then move the head.

There are also differences in the hand operated equipment for the 2 centrifugal pumps. The Bio-Medicus manual drive equipment is clearly marked to show the user which direction to turn the crank and the revolutions per minute show up only with forward drive. It is, however, somewhat cumbersome to position, and the pump head must be moved from its mounted position in order to install the hand crank apparatus. The Centrimed manual drive equipment is not marked with directional instructions and the revolutions per minute indicators light up with motion in either direction. The equipment, though, is small and can be mounted on the pump mast prior to moving the head itself.

Two conclusions can be drawn when comparing Tables 1 and 2. First, the two centrifugal force pumps are more efficient than the roller pump even when they are operated incorrectly. Second, and perhaps more significant, is that the tables indicate that the 2 centrifugal force pumps will generate forward flow regardless of the direction of cranking. They are, however, considerably more efficient when cranked in the correct direction. The graph in Figure 1 indicates the efficiency of the centrifugal force pumps in delivering a 3 liter flow. Unlike occlusive roller pumps, cranking a centrifugal force pump backwards still provides forward flow to the patient.

The 2 centrifugal force pumps examined in the study have 4 features in common.

1. Both manual drive systems can be cranked clockwise or counterclockwise;
2. Each pump head will provide forward flow regardless of the direction it is cranked;
3. Only revolutions per minute will be indicated by the equipment, *not* flow. As with an exercise bike, revolutions per minute do not mean forward motion.

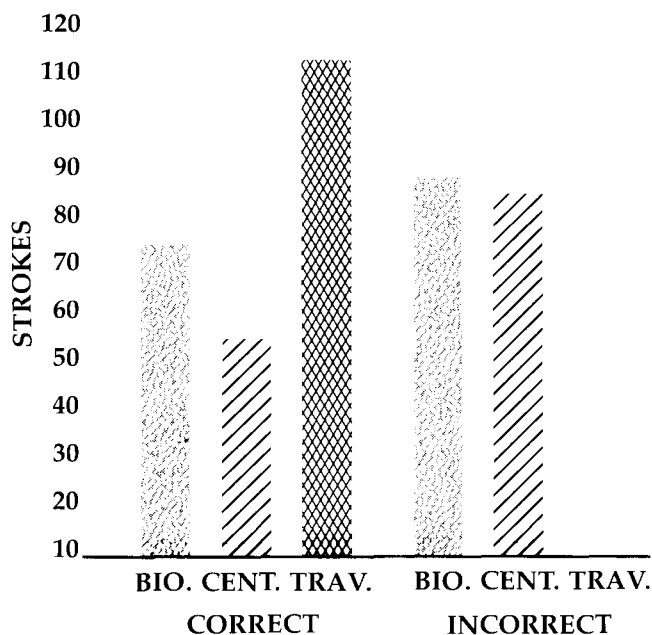


Figure 1: Comparison of the Number of Strokes to Accomplish a 3 Liter Flow

4. Another method, such as a Doppler flowmeter, is necessary to measure flow.

Each of us has a serious responsibility to our patients. It is not enough to be careful, we must also be prepared. We must all be conscious of the emergency equipment available to us, know how it works and how it will perform in a clinical emergency. The Bio-Medicus Bio-Pump and the Centrimed System 1 Extracorporeal Blood Pump demonstrate themselves to be both patient safe and user friendly.

References

1. Stoney, W.S., Alford, Jr., W.C., Burrus, G.R., et. al.: Air Embolism and Other Accidents Using Pump Oxygenators. *Ann. Thorac. Surg.* 29:4, 1980.
2. Anonymous: Failure of a Centrifugal Heart-Lung Bypass Pump. *Health Devices* 15:7, 213-214, 1986.

Questions from the Audience

Question: Joel Davis, South Bend, IN: I'd like to add that if you're using a ½-inch pump header you'd double the efficiency of your handcranking, and that would bring it down to the range of a Centrimed. Though I would also mention the frictional component would be higher—handcranking on a roller pump as opposed to handcranking on a Centrimed pump.

Response: Yes, sir, thank you.

Comment—(Unidentified): One disadvantage of the vortex type pump is that if the pump stops, you're getting an immediate back flow of blood through the unit back into the oxygenator. So you have to act very quickly to prevent draining your patient. Another point is that during the use of the Bio-Pump with the constant RPM as the pressure goes up, you see your flow dropping off. And as the pressure goes down the flow goes up. So the point that you made that what you see, I guess, is essentially no resistance, as far as the amount of RPMs required to produce a certain amount of flow. This may not be the same with the pump, Centrimed or Bio-Pump. But with the roller pump you are getting a constant flow per revolution.

Comment: Maureen Gray, Pittsburgh, PA: I'd just like to make a point with the Bio-Pump. In addition to removing it from the original position and putting it in a handcrank, if you do not have enough tubing from your reservoir to the Bio-Head, you're going to be in a very difficult position, because the Bio-Head is going to have to be in a higher position than it was originally. If your tubing is not long enough you might just have to take the console off the base before you can get into the handcrank.

Response: We did make that observation when we started testing the Bio-Pump. With our initial testing, we had to raise the level of our oxygenator about 3 inches. And later we came to the conclusion that probably it would be safer if we just extended the tubing from the pumphead itself.