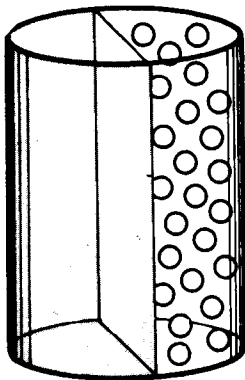


**Aspects:**

# Blood Pump Occlusion

## Its Complex Nature



An *in-vitro* study of four degrees of a hemodialysis blood pump occlusion has been made for: 1) under occluded; 2) just non-occluded; 3) just occluded, and 4) over occluded vinyl, silicone rubber, and polyurethane tubings. Occlusions were defined in a manner that allowed control for repeated comparison of the various degrees of occlusion. Flow rate at constant pump speed was determined for each occlusion while varying line pressure as a parameter. Each material was evaluated for occlusion repeatability between segments.

The results indicate that pump rotation rate is the prime determinant of flow rate only when the tubing segment is over occluded. Flow variations of up to 50% for a given pump rotation rate can occur in common clinical situations.

Where precise measure of flow rate is deemed important for the clinician or researcher, it is essential that each new tubing segment receive an occlusion adjustment. Whenever occlusion is a parameter of a program it must be carefully defined for consistent control.

The definitions given for occlusions in this paper are reproducible and objective, and consequently, may be used to obtain this consistent control.

### INTRODUCTION

Various studies<sup>1-11</sup> have been done in which roller pump occlusion was a controlled parameter. However, the literature contains little agreement for the definition of occlusion<sup>6, 12</sup>, and sometimes there is no definition at all<sup>1, 5</sup>.

Stofer<sup>12</sup> emphasizes the need for careful occlusion of roller pumps, defines an occlusion and points out the wall variation of tubing within the same shipment.

This study was undertaken to evaluate the nature of precise degrees of occlusion and their effect on pump output while varying inlet and outlet pressures independently. Tubing material was also evaluated for occlusion repeatability when one piece is exchanged for another of the same type.

### PART I — OCCLUSION VS. FLOW OUTPUT

#### METHOD

1. The dialysis roller pump\* used was manufactured to the standard concentricity specification. (As the roller head revolves through one-half revolution, the distance between roller and housing will not vary more than .002".) Actual total indicator reading\*\* was found to be .0014" while the pump was operating with 1/4" I.D. x 3/8" O.D. Tygon adjusted "under occlusive" (see #3 below).

\*Cobe Roller pump, serial #1177.

\*\*Alina gauge model M35, .0001" scale.

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**TABLE 1**  
General Characteristics of Pump Segment Material

OBSERVATION:	MAYON VINYL	TYGON VINYL	SILICONE RUBBER	EXPERIMENTAL POLYURETHANE
Shore 'A' Durometer	68	66	44	67
Resilience	Medium	Medium	High	High
Springiness:				
Yield	Medium	Medium	High	Low
Return	Medium	Medium	High	High
Ease of Function with Pump Rollers	Even	Even	Even	Jerky
Manufacturer's Tolerances	±.005" ID ±.005" Wall	±.005" ID ±.0025" Wall	±.002" Wall	—

Circle No: 34



# Blood Pump Occlusion

2. Three types of tubing material were evaluated in size 1/4" I.D.: Mayon polyvinyl chloride, Dow Corning silicone rubber, and Upjohn 2103-65AX polyurethane (experimental). Physical characteristics of each material are described in Table I.
3. Occlusions were controlled as follows:
  - a. Under occlusive: 60 cm column\* of water falls 5 cm in 5 seconds.
  - b. Just non-occlusive: 60 cm column of water falls 2 cm in 5 seconds.
  - c. Just occlusive: 60 cm column of water maintained.
  - d. Over occlusive: 90° turn of the adjustment screw past the just-occlusive setting (calculated 0.010") advance.

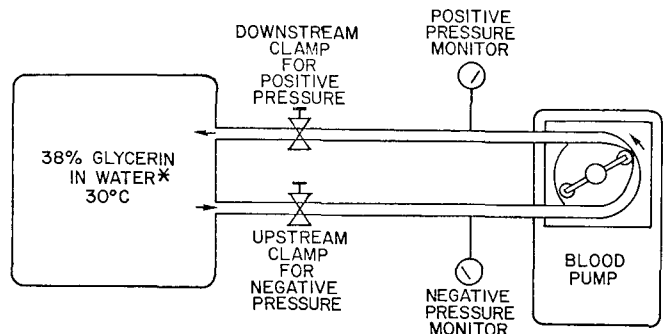
Total advance of the roller to adjust from under-occlusive to over-occlusive was 0.015", or a measured 130° turn at the adjustment screw. This means there was only .005" motion from under-occlusive to just-occlusive settings, or about 1/8 of a turn of the adjustment screw.

4. The *in-vitro* circuit is shown in figure 1. To determine the effect of line pressure, an adjustable clamp was applied to the tubing to induce a variable degree of pressure.

The clamp upstream of the pump gave negative line pressure which will partially collapse the tubing so flow delivery per pump revolution will decrease relative to the degree of negative pressure.

Downstream of the pump, the clamp produced positive line pressure for the pump. High positive pressures in a non-occluded tubing segment will cause regurgitation and low flow delivery.

At each occlusion setting, the flow rate was set for 200 cc/min. at zero inlet and outlet pressures, and then line pressure was varied for either a negative or a positive pressure. Flow output and pressure were monitored for each condition.



\*RELATIVE VISCOSITY OF 2.5  
SIMILAR TO THAT OF BLOOD  
WITH HEMATOCRIT OF 35%

FIGURE 1  
DIAGRAM OF CIRCUIT

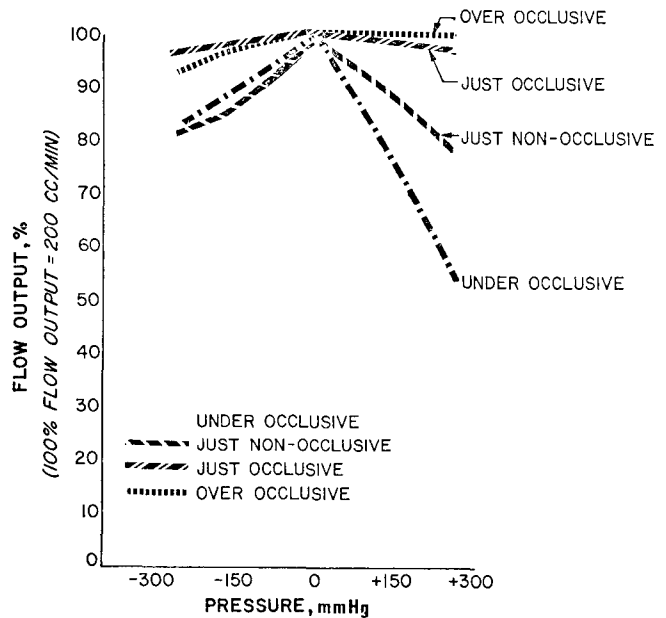


FIGURE 2  
VINYL TUBING  
1/4" I.D. X 3/8" O.D.

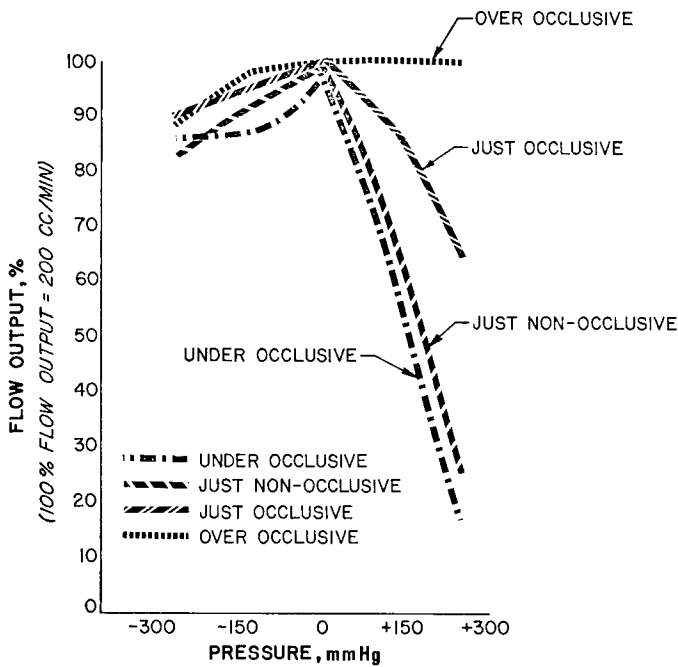
\*Measured from the height of the pump head

TABLE 2  
Occlusion Repeatability:  
shown as time in seconds for 5 cm drop of 60 cm  
column of water

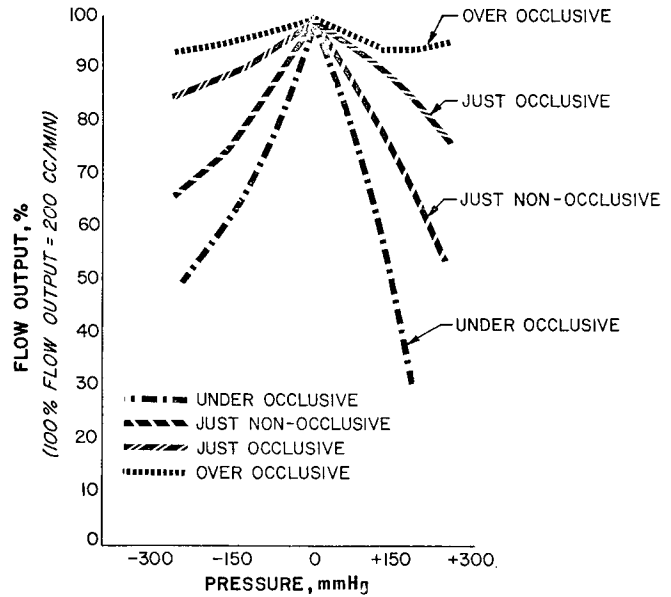
		SPOT A		SPOT B		SPOT C	
		Time	% of Base	Time	% of Base	Time	% of Base
Tubing: 1/4" I.D. x 3/8" O.D. Mayon Vinyl	Lot 1a	5.2 ± .2	86	6.0 ± .2*	100	1.5 ± .1	25
	1b	2.6 ± .1	46	4.4 ± .1	73	2.2 ± .2	36
	1c	17.7 ± 2.5	295	15.8 ± 1.2	263	10.5 ± .6	175
	Lot 2	0.9 ± 0	15	0.9 ± .1	15	0.6 ± 0	10
	Lot 3	150+	2500+	150+	2500+	17.5 ± 2.2	291
Tygon Vinyl	Lot 1a	6.5 ± .4	120	5.4 ± .2*	100	1.7 ± .1	31
	1b	21.8 ± 3.3	403	14.4 ± 4.2	266	2.4 ± .1	44
	1c	6.2 ± .8	114	8.4 ± 1.1	155	2.0 ± 0	37
	Lot 2	4.4 ± .4	81	3.1 ± .1	57	0.9 ± 0	16
	Lot 3	4.2 ± .2	77	2.6 ± .2	48	1.2 ± 0	22
Silicone Rubber Close Tolerance	Lot 1a	1.2 ± .1	24	5.0 ± .3*	100	1.9 ± .1	38
	1b	4.0 ± .3	80	4.5 ± .2	90	1.2 ± 0	24
	1c	16.4 ± 3.3	328	4.8 ± .3	96	2.5 ± .1	50
	Lot 2	1.9 ± .1	31	0.9 ± 0	18	0.5 ± 0	10
	Lot 3	3.3 ± .1	66	0.9 ± 0	18	0.5 ± 0	10

\*base value for tubing type

# Blood Pump Occlusion:



**FIGURE 3**  
SILICONE RUBBER TUBING  
1/4" I.D. X 3/8" O.D.



**FIGURE 4**  
POLYURETHANE TUBING  
1/4" I.D. X 3/8" O.D.

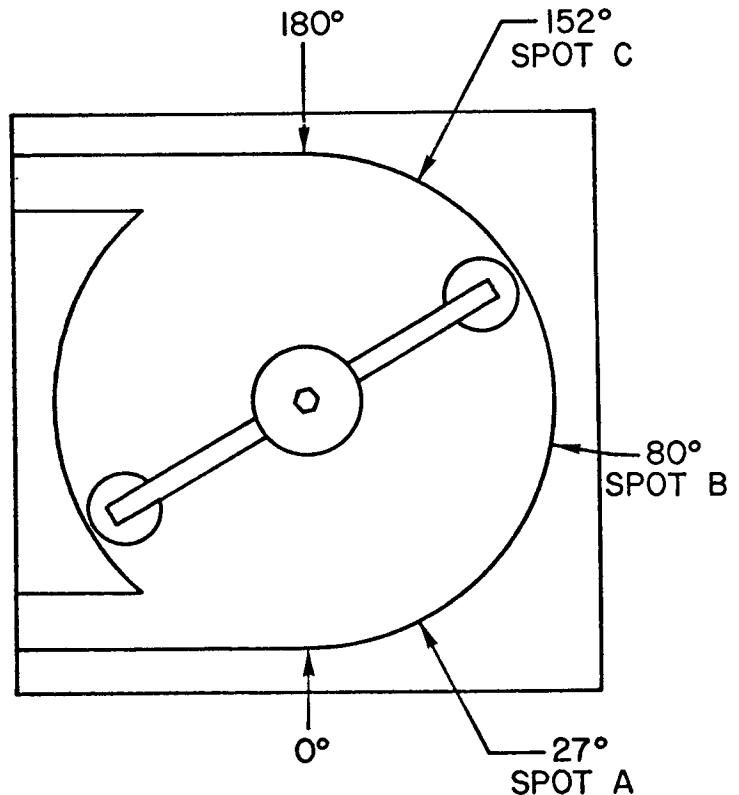
## RESULTS:

Figures 2, 3 and 4 show the results of these tests for vinyl, silicone rubber and polyurethane, respectively. Each set of data points is an average of trails with six different pieces of tubing.

## PART II — OCCLUSION REPEATABILITY

### METHOD:

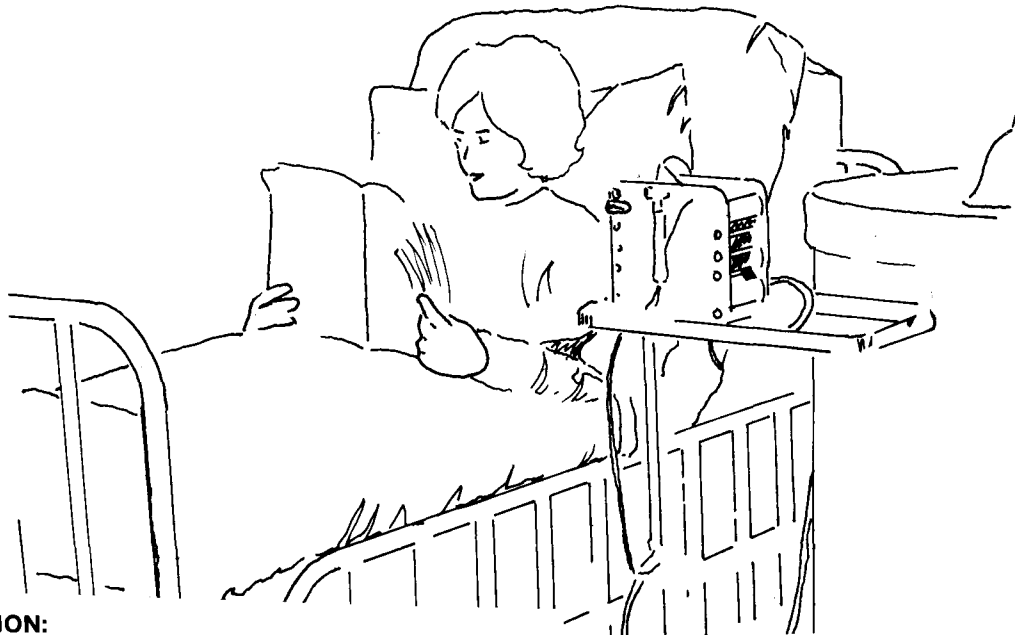
1. 1/4" I.D. x 3/8" O.D. Mayon Vinyl, Tygon vinyl, and Dow Corning silicone rubber (close tolerance) were evaluated for occlusion repeatability a) on the same tubing segment, b) within the same roll of tubing, c) from various manufacturing lots.
2. The same roller pump from Part I was used. Occlusion was tested repeatedly at three locations on the segment (see figure 5), as defined by the time it took for a 60 cm column of water to drop 5 cm, subject to the following conditions:
  - a. Occlusion was set for a 60 cm column of water to fall 5 cm in approximately 5 seconds (see Part I, method #3).
  - b. For each type of tubing, occlusion was set once at spot B: all values, therefore, relate to the first B value ("base") in each group.
  - c. No adjustment of the occlusion was made during the series for one type of tubing.
  - d. The same roller of the pump was always used to set and test occlusion.
  - e. Spot B (see figure 5) was set by alignment of the adjustment tool through the access hole in the case and into the adjustment screw. Spots A and C were simply approximated for repeated trials.
  - f. The pump head was given several (1-4) revolutions between each trial.



**FIGURE 5**  
ROLLER PUMP HEAD

## RESULTS:

1. Data is shown in Table 2. Each figure is an average of 6-8 trials.
2. Data for spot B is more reliable than that for spots A and C due to the repeatable method of roller placement.



#### DISCUSSION:

1. Under-occluded tubing does not provide the same fluid output as occluded tubing in the roller pump. Increased line pressure accents this condition. Consequently:
  - a. Flow rate derived from pump revolutions can be erroneous, resulting in false dialysis and dialyzer performance data.
  - b. With a fistula patient and/or a high resistance dialyzer, where the pump sees high differential pressures, proper occlusion is needed for good flow.
2. To maintain 80% or better flow output for pressures to  $\pm 300$  mmHg:
  - a. Vinyl tubing needs a just-occlusive roller adjustment.
  - b. Silicone rubber requires more than a just-occlusive adjustment.
  - c. The experimental polyurethane needs a just-occlusive roller adjustment.
3. Occlusion repeatability tests reveal the futility of expecting the same occlusion with subsequent tubing segments, even if they are the same type.
  - a. Mayon and Tygon vinyls both vary considerably along one short piece as well as between lots.
  - b. Close tolerance silicone rubber is consistent within a manufacturing lot, but will vary between lots.
  - c. This roller pump manufactured under precise machining tolerances with only .0014" variance through 180° still affects occlusion to a slight degree, as evidenced in Table 2 by spot C vs. spots A and B.
4. Vinyl tubing specs allow the wall to vary as much as .020" (.010" x 2), but only .005" roller adjustment is needed to change a just occluded setting to occluded one. Only .010" roller advance is necessary to alter just-occluded tubing to over-occluded.

#### SUMMARY AND CONCLUSIONS

Since these studies point out the importance of precise tubing occlusion as well as the futility of expecting repeatable occlusion between tubing segments, the clinician and researcher would have to strive to optimize roller pump occlusion with the use of any new tubing segment to assure meaningful results. Otherwise, flow rate must be measured to know what's happening.

This entire study should be repeated within the parameters of open-heart surgery, where some of these findings should be either negated or accentuated by the high flows.

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