Gravity Drainage Capabilities of Venous Tubing and Catheters

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Abstract

The purpose of this paper is for the examination and discussion of the gravity return capabilities of three tubing sizes using three different elevational drops of twenty (20), twenty-five (25), and thirty (30) inches. In addition, the gravity flow limitations of twelve different sized venous catheters combined with these venous lines are evaluated under the same conditions.

It is our conclusion the gravity drainage capability of the one quarter inch venous line ranges from 1.5 to 2.1 liters per minute. The three-eighths line ranges from 2.7 to 3.5 liters per minute, and the one-half inch line ranges from 7.5 to 9.6 liters per minute.

Introduction

As an infant/pediatric perfusionist, it can be quite a challenge tailoring the cardiopulmonary bypass circuit to the smaller patient. In the interest of minimizing the priming volume, the smallest possible tubing should be used. Patients blood flow requirements dictate tubing size, and knowing the flow range limitations enables one to make the proper tubing size choice.

Materials and Methods

The arterial pump head of an Advanced Med-Science Heart-Lung Pump Console[a] was flow calibrated for one-quarter, three-eighths, and one-half inch arterial boot sizes. A large graduated cylinder and stop watch were used during the volume/time measurements to arrive at the liter per minute flow rate for the corresponding RPM on the arterial tachometer (Table 1). The occlusion for all three boot sizes was carefully set to be just occlusive so no water drop occurred thirty inches above the arterial pump head. This was done to avoid any retrograde flow through the arterial boot during high RPMs and relatively elevated arterial line pressures.

Once this data was collected, it was then possible to determine the gravity drainage capability of the three tubing sizes at the three elevational drops. This was accomplished by creating a reservoir with a shallow pan filled with enough water to just cover the opening of the venous tubing. This water level was maintained throughout the measurements to avoid any change in hydrostatic water pressure near the tip of the venous lines. The elevational drop was determined by carefully measuring the distance from the bottom of the shallow pan to the middle of the oxygenating column on the Shiley S070 and S100 A[b] bubble oxygenators. Note that when the one-quarter and three-eighths inch venous lines were evaluated, they drained into the S070 infant/pediatric oxygenator and the half inch venous line drained into the S100 A adult oxygenator. The water was siphoned straight down into the oxygenator through the venous line. Volume in the oxygenator was pumped directly back into the shallow pan by the servo-controlled arterial pump head. The flow rate through the venous line was easily determined by a cross reference of the tachometer RPMs and the liter per minute flow rate in Table 1.

Next the gravity flow limitations for some or all of twelve different venous catheters with each size venous line were determined. The catheter sizes were evaluated in pairs and attached to the legs of a "Y" connector on the end of the venous line. The gravity return capability of the similar pair was determined first. By clamping one of the pair, the return capability of the single catheter was determined next. These values were determined at the three elevational drops of twenty (20), twenty-five (25), and thirty (30) inches. This sequence of steps was followed throughout the study (Table 2).

Conclusion

The information we gathered has taught us exactly what gravity flows our venous extracorporeal circuit is capable of handling. We have learned through experience, however, that due to various reasons, the venous return in the clinical setting is generally closer to the values recorded for the twenty (20) inch elevational drop for all three venous line sizes.

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Table 1
Arterial Pump Flow Calibrations

Arterial Boot Size	¼″	⅜″	½″
RPM	(L/min)	(L/min)	(L/min)
5	.048		
10	.114	.276	.431
15	.158	.393	.647
20	.228	.527	.920
25	.290	.672	1.140
30	.370	.840	1.400
35	.428	.987	1.670
40	.490	1.140	1.920
45	.573	1.320	2.210
50	.650	1.460	2.240
55	.710	1.620	2.800
60	.780	1.760	2.980
65	.840	1.910	3.220
70	.900	2.080	3.640
75	.970	2.280	3.870
80	1.060	2.420	4.080
85	1.120	2.520	4.260
90	1.200	2.680	4.470
95	1.260	2.880	4.800
100	1.325	3.080	5.100
105	1.420	3.180	5.370
110	1.480	3.360	5.610
115	1.570	3.460	6.000
120	1.620	3.640	6.200
125	1.680	3.720	6.600
130	1.760	3.880	6.720
135	1.820	4.020	6.960
140	1.880	4.320	7.320
145	1.98	4.410	7.500
150	2.05	4.530	7.680
155			7.860
160			8.280
165			8.580
170			8.760
175			9.000
180			9.120
185			9.300
190			9.600
195			9.960
200			10.140

Table 2
Venous Return Data

Elevational Drop	**20″**	**25″**	**30″**
	(L/min)	(L/min)	(L/min)
One-Quarter Inch Tubing	1.5	1.76	2.08
Three-Eighths Inch Tubing	2.68	3.18	3.46
One-Half Inch Tubing	7.50	8.76	9.60
One-Quarter Inch Tubing			
Catheter Size (F)			
16	.45	.53	.60
16 × 2	.84	.90	1.00
18	.84	.99	1.14
18 × 2	1.14	1.32	1.46
20	.84	.99	1.14
20 × 2	1.14	1.46	1.50
22	.99	1.20	1.40
22 × 2	1.32	1.46	1.76
24	1.14	1.40	1.50
24 × 2	1.32	1.62	1.76
28	1.35	1.62	1.80
28 × 2	1.46	1.76	1.91
Three-Eighths Tubing			
Catheter Size (F)			
16	.45	.60	.67
16 × 2	.84	1.00	1.20
18	.90	1.14	1.32
18 × 2	1.50	1.68	1.91
20	.99	1.14	1.32
20 × 2	1.46	1.76	2.08
22	1.32	1.46	1.62
22 × 2	1.91	2.10	2.42
24	1.62	1.80	1.95
24 × 2	2.08	2.48	2.60
28	2.08	2.42	2.60
28 × 2	2.52	2.88	3.18
32	2.42	2.70	3.08
32 × 2	2.68	3.08	3.36
36	2.50	2.88	3.18
36 × 2	2.68	3.08	3.40
38	2.50	2.90	3.36
38 × 2	2.68	3.08	3.40
One-Half Inch Tubing			
Catheter Size (F)			
16	.48	.65	.65
16 × 2	.95	1.14	1.25
18	.95	1.14	1.20
18 × 2	1.92	2.21	2.24
20	.95	1.20	1.40
20 × 2	1.92	2.22	2.40
22	1.40	1.67	1.67
22 × 2	2.24	2.90	3.00
24	1.92	2.21	2.24
24 × 2	3.30	4.08	4.47
28	2.98	3.64	3.90
28 × 2	4.96	5.61	6.30
32	4.08	4.80	5.37
32 × 2	6.00	6.72	7.50
*36	4.5	5.37	6.00
36 × 2	6.00	6.96	7.80
**38	5.10	6.00	6.60
38 × 2	6.20	7.50	8.40
*40	4.80	5.61	6.20
40 × 2	6.00	6.96	7.86
46	6.60	7.60	8.76
46–34 (Two Stage)	6.20	7.50	8.76

* –two side eyelets
** –four side eyelets

Questions from the Audience

Question-Thomas M. Frazier: What flow rate limit do you put on your one-quarter inch venous line at your institution when you're doing infant pediatric perfusion?

In response to the presenter's question, one person volunteered 800 cc's.

Question-Phil Wagoner: When you were doing your studies I assumed that you held gas flow through your oxygenators constant. Is that true?

Answer: Yes.

Question—Phil Wagoner: Was that also the same gas flow through the SF70 and S100A?

Answer: Yes.