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Title: LARGE-VOLUME FLUID RESUSCITATION: PREDICTION OF FLOW CAPABILITY

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Introduction. Surgical and traumatized patients often require rapid, large-volume intravenous infusions. Optimum clinical management requires the ability to predict rates of infusion. The flow capabilities of intravenous tubing systems, with and without added devices, have been evaluated in the range clinically used for fluid resuscitation.

Methods. Our test bench for fluid flow measurement is used.[1] A 1L Sorensen pressure bag, controlled by a Zimmer 2000 pressure regulator, compresses 1L Lactated Ringer's Solution. The fluid driving pressure, up to 300 mm Hg, is measured in the solution bag through a fluid-filled cannula connected to a Hewlett-Packard electronic transducer system. The time required for 100 ml aliquots to fill a graduated cylinder is measured with 0.01 second precision. Pressures, volumes, and times obtained in experiments are used to derive flow and resistance. Devices evaluated include tubing sets, check valves, and a 5 micron particulate filter.

Results. The non-linear relationship between pressure and flow in an experimental intravenous tubing set is shown in Fig. 1. The linear relationship between resistance and flow is shown for two tubing sets, alone and with a valve (Fig. 2) or filter (Fig. 3) added. Straight lines drawn are least-squares regression lines.

Discussion. The relationship between pressure (P) and flow (F) for intravenous tubing systems has been shown not to be linear (Fig. 1).[1] Inspection of the Reynold's numbers suggests that both laminar and turbulent components of flow should exist. Therefore, the P - F relationship can be expressed as $P = R_L F + R_T F^2$, where R_L and R_T are the coefficients of the flow and square of flow components, respectively. The relationship bewtween resistance (R) and flow (F) is linear (Figs. 2 and 3). In that relationship, $R = R_L + R_T F$, R_L represents the y intercept and R_T the slope of the line. R_L appears to be the laminar component of total resistance R, and R_T the turbulent component of R.

This mathematical model has been applied to several clinical infusion devices, with excellent correlation. Representative of the devices tested are a check valve and a 5 micron filter. When added to a tubing set, the check valve shows a minimal 11% ± 8% increase in R_L but a large 95% ± 9% increase in R_T. The effect of the valve, then, is primarily on the turbulent component of flow. A device with an increased R_T component demonstrates little effect on flow at low infusion rates (gravity pressure). At rapid infusion rates generated by high driving pressures, this device demonstrates an increasing resistance to flow, and maximum achievable flow is restricted. When the filter is added to the tubing set, there is a large increase in R_L 197% ±5% but a minimal increase 26% ±14% in R_T. The effect of the added filter, then, is primarily to increase the laminar component of flow. A device with an increased R_T component demonstrates an increased resistance to flow which is similar at both low and high infusion rates.

Conclusion. A measurement technique and mathematical model have been developed to analyze the flow capabilities of clinical devices for fluid infusion. This analysis can be used to predict performance and evaluate suitability for use during large-volume fluid resuscitation.

Reference. 1. Philip BK, Raemer DB, Philip JH: Intravenous tubing flow characteristics and fluid infusion monitoring. Proceedings 3rd Space Age Monitoring Conference, 1982

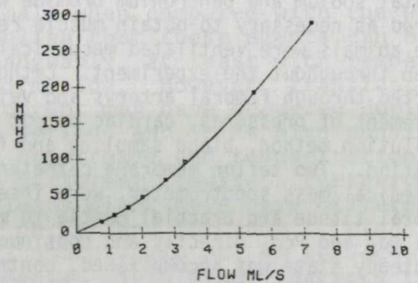

Fig.1 Pressure-flow relationship, Travenol 2C0001 tubing

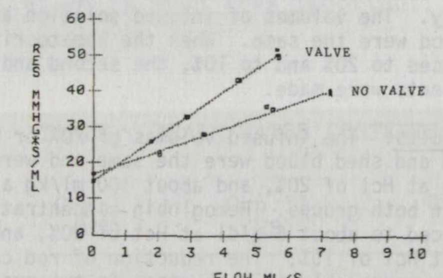

Fig.2 Resistance-flow relationship, Travenol 2C0001.
No valve: r=.992 R_T=3.28±.17 R_L=16.72±.85
Valve : r=.997 R_T=6.34±.22 R_L=14.87±.96

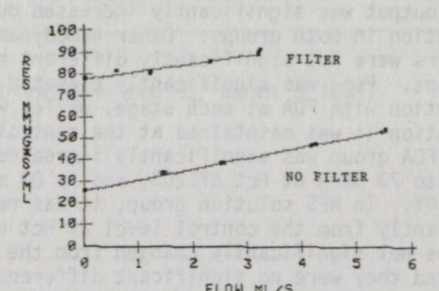

Fig.3 Resistance-flow relationship, Travenol 2C0123s.
No filter: r=.999 R_T=4.98±.11 R_L=26.41±.42
Filter : r=.920 R_T=3.68±.70 R_L=78.00±1.32