

Title: Resistance to Fluid Flow Can Detect Venous Catheter Infiltration

Author: James H. Philip, M.D.

Affiliation: Bioengineering Laboratory, Department of Anesthesia, Brigham and Women's Hospital, Harvard Medical School, Boston, MA 02115

Intravenous access is crucial to the safety of every patient undergoing anesthesia. Intravenous fluid infiltration (tissuing) renders the IV ineffective and poses potential harm to the patient from extravascular drug infusion as well as deprivation of drug and fluid therapy.

Dynamic hydraulic resistance (resistance to fluid flow or more simply, resistance) is a new variable, created to allow IV site monitoring. Resistance (R), equals the ratio of pressure change ( $\Delta P$ ) to flow change ( $\Delta F$ ) when flow is changed from one rate to another.  $R = \Delta P / \Delta F$ .

#### Methods

The protocol was approved by the Committee for the Protection of Human Subjects from Research Risks. Written informed consent was obtained when required.

Flowrate was controlled by a commercially available intravenous infusion pump (IVAC Model 560) which contains an accurate (1) medical-grade pressure transducer separated from the fluid path by a sterile vinyl interface. Flow is controlled and pressure is monitored by the pump with great accuracy.

Resistance was measured in several ways. In each case, resistance was calculated as the ratio of pressure change to flow change. With the multi-flow technique, multiple flowrates were employed, typically 0, 50, 100, 200, 300 ml/hr. Resistance was calculated as the slope of the line which best fit (least squares) the pressure-flow relationship. In the run/stop technique, pressure was measured during constant flow ( $P_{run}$ ) and shortly after abrupt cessation of flow ( $P_{stop}$ ). Resistance was computed as  $R = (P_{run} - P_{stop}) / \text{Flow}$ . In the flow-perturbation technique, flow was varied slightly ( $\pm 10\%$ ) and the resulting pressure change was monitored and used to compute resistance ( $R = \Delta P / \Delta F$ ). With each technique, measurement units for pressure were mmHg, and for resistance were mmHg/ml/hr =  $4.8 \times 10^{-1}$  pascal sec/m<sup>3</sup>.

Two tissue types were studied in a total of 55 subjects, 6 of whom were volunteers. Peripheral veins were studied in 46 subjects, before, during, or after a variety of surgical procedures and anesthetic techniques. All patients were supine with the IV site less than 10 cm above the patient's heart. Infiltration was studied in 12 subjects after it occurred spontaneously (2) or was inadvertently (5 attempted IV starts) or purposefully (5 catheter manipulations in consenting volunteers) created under a variety of situations. Student's t test for unpaired data was used to test whether the resistance of veins and perivascular tissue were significantly different ( $p < .05$ ).

#### Results

For normal peripheral veins, mean resistance was  $R_V = 0.022 \pm 0.020$  SD (range 0-.091). For

infiltrated tissues, mean resistance was  $R_t = 1.125 \pm 1.376$  (range 0.103 to 4.51). The resistance of veins and tissues were different ( $p < .001$ ). See figure.

For each tissue, pressure (mmHg) at 0 flow was also measured. For normal veins, mean  $P = 15 \pm 8$ . For infiltrated tissues, mean  $P_0 = 44 \pm 61$  SD ( $p < .002$ ).

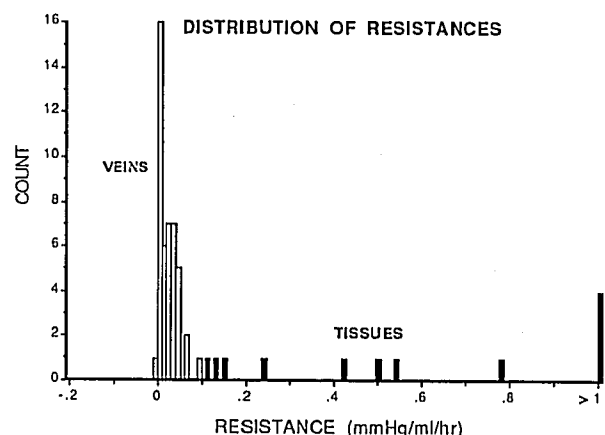
#### Discussion

The resistance of infiltrated tissues is greater than that of normal veins. The difference is statistically significant with no population crossover between groups, at least in the limited sample population studied.

The value for  $P_0$  is different between normal veins and infiltrated tissues. This difference is believed due to fluid buildup during infiltration and would not occur if infiltration were detected immediately and infusion terminated. The small pressure rise would then be obscured by pressure artifacts due to variation in hand elevation or other physical factors. The commonly observed difficulty in detecting infiltration by monitoring pressure alone supports this contention.

#### Conclusion

Resistance to fluid flow has the capability of differentiating between infiltrated tissues and normal veins. Manual measurements of pressure at two or more flowrates allows resistance to be calculated. Automatic control algorithms for pumps capable of monitoring pressure have the potential to provide effective automatic infiltration detection.



#### Reference

- Philip JH. Hydrostatic central venous pressure measurement by the IVAC 560 infusion pump. Med Instr. 1985; 232-35.