DETECTION OF INTRAVENOUS FLUID EXTRAVASATION USING RESISTANCE MEASUREMENTS

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ABSTRACT. Resistance to fluid infusion can be derived from measurements of pressure at two or more flow rates. We measured resistance in 31 patients using a pressure-monitoring infusion pump (Model 560, IVAC) by recording pressure at five flow rates (0, 50, 100, 200, and 300 mL/hr), and computing resistance as the slope of the pressure versus flow curve. Resistance was measured subcutaneously (R_tissue) and intravenously (R_vein) immediately after unsuccessful or successful IV catheter placement. In all patients, R_tissue was always greater than R_vein. The difference ranged from 23 resistance units (RU) to 4166 RU, with a mean difference of 1147 RU (p < 0.0001, Student’s t-test). Unpaired analysis of the data was performed to assess the ability of resistance to indicate extravasation in the absence of prior R_vein measurement. The median value for R_vein was 62 RU (range -13.6 to 420 RU), and for R_tissue, 544 RU (range 65.7 to 4170 RU). Receiver operating characteristic (ROC) analysis revealed that a 200-RU threshold detected infiltration with 0.90 sensitivity and 0.91 specificity. We conclude that elevated resistance during fluid infusion is an important early and easily measurable finding in fluid extravasation.

KEY WORDS. Veins, Veins: catheterization, Fluid therapy, Intravenous infusions, Indwelling catheters. Infiltration, Extravasation of intravenous fluids.

INTRODUCTION

The insertion of intravenous (IV) catheters and infusion of fluid are common and essential procedures in the care of patients. Complications of IV therapy include phlebitis, infusion-related septicemia, and extravasation of fluid and drugs [1-3]. Extravasation of antineoplastic agents, phenytoin sodium (Dilantin), and potassium can result in extensive soft tissue injury [4, 5]. Currently, monitoring of peripheral IV infusions to avoid these complications is usually limited to intermittent physical examination of the venous access site [2, 3, 5].

Fluid infusion into peripheral veins can be studied with a commercially available infusion pump (Model 560, IVAC). This device measures pressure in the fluid delivery system at flow rates of 0 to 999 mL/hr. Prior work has shown that pressure-flow relationships (PFR) in normal veins follow a linear model (up to flows of 300 mL/hr), with the slope of the PFR defined as resistance [6-8]. Preliminary work suggested that resistance to flow is different when a catheter is in tissue (R_tissue) compared with in a vein (R_vein) [9]. We now report paired resistance measurements in 31 patients with witnessed catheter infiltration on initial catheter place-
ment and compare these with the resistance of a subsequent successful venous cannulation. The resistance to flow was always significantly greater in tissue compared with veins, and the results suggest that monitoring resistance can aid in the early detection of IV catheter infiltration and fluid extravasation.

METHODS

Thirty-one adult patients awaiting elective surgery and requiring IV cannulation were studied between September and December 1987 with approval by our hospital's human subjects committee. The age, height, weight, and American Society of Anesthesiology Status of each patient were recorded, as well as cannulation site and catheter size.

IV site monitoring

IV infusions were initiated in the preoperative holding area by anesthesia personnel. The cannulation site and the catheter size chosen were not determined by the study. If on initial insertion, a catheter was suspected of being extravenous, it was studied using the pressure-monitoring pump as outlined below. If swelling developed distal to the catheter tip, the site was classified as infiltrated. If no swelling was observed, the IV infusion set was connected, and IV cannulation was confirmed in a threefold manner described previously [10]. Patients were included in this study if the original IV insertion attempt resulted in extravasation of fluid and a subsequent IV insertion was successful. Resistance measurements at both sites were obtained in an identical manner.

Determination of resistance measurements

A variable pressure volumetric infusion pump (Model 560, IVAC Corp, San Diego, CA) was used to generate flow and perform pressure measurements. This device contains a pressure transducer that measures pressure in the line distal to the pump mechanism. To alter flow rates and record pressures, a portable microcomputer (Epson HX-20) was interfaced to the pump via a serial computer interface module. The pressure was recorded in mmHg at flows of 0, 50, 100, 200, and 300 mL/hr. The height of the catheter insertion site above the reference level of the pump's transducer was measured and subtracted from the pressure readings to reference the pressures to the site of catheter insertion. Fifteen seconds were allowed to elapse after each change in flow to ensure that stable pressures had been reached. Although the pump was regulated by the computer, all alarm and safety mechanisms were still active and able to interrupt the infusion if an alarm or error state occurred.

The tubing for the pump was primed with 0.9% saline and connected to the patient's IV system at a port close to or directly on the catheter. The roller clamp was then closed on the patient's set above the connection point. During the 2-minute test cycle, less than 3 mL of fluid was infused. All clinical assessments were completed and recorded prior to inspection of the computer output.

Statistics

Least-squares linear regression analysis was performed by the computer during data collection in order to characterize the PFR for each site [6]. The slope of this line is the total resistance ($R_{\text{total}}$), which equals the resistance of the tubing and catheter system ($R_{\text{sys}}$), plus the $R_{\text{vein}}$ or $R_{\text{tissue}}$. We previously determined $R_{\text{sys}}$ for all tubing and catheter combinations used in this study [8] and subtracted the appropriate $R_{\text{sys}}$ from $R_{\text{total}}$ to determine the value of $R_{\text{vein}}$ or $R_{\text{tissue}}$. A resistance of 1 mmHg/L/hr was defined as 1 resistance unit (RU). If the occlusion alarm on the pump terminated the infusion due to the pressure exceeding 500 mmHg (2.5 psi), the $R_{\text{tissue}}$ was derived from regression of the pressure and flow (PF) data points gathered before the termination of flow.

The data were analyzed with Student's $t$-test for paired and unpaired data. The paired data were also analyzed as unpaired to examine the ability of a resistance monitoring pump to detect infiltration in the absence of a $R_{\text{vein}}$ measurement.

To determine the best threshold to determine infiltration we constructed a receiver operating characteristic (ROC) curve to evaluate the effect of choice of resistance threshold on the sensitivity and specificity of infiltration detection [11]. This method allowed us to find the best threshold to discriminate between veins and tissues.

RESULTS

Of the 31 subjects, 5 were male and 26 were female. Demographic data are summarized in Table 1. Most patients were ambulatory surgical patients who were admitted for minor elective surgical procedures, and the ratio of males to females in our study population was similar to that seen in our ambulatory surgical operating suite.

The distributions of $R_{\text{vein}}$ and $R_{\text{tissue}}$ are plotted in Figure 1. The median value for $R_{\text{vein}}$ was 62 RU (range