

Dynamic Venous Access Pressure Surveillance in Arterio-Venous (AV) Fistula

Stanley Frinak, M.S.E.E.¹, Gerard Zasuwa B.S.¹, Anatole Besarab, M.D.¹ and Jerry Yee, M.D.¹

From: ¹Division of Nephrology and Hypertension, Department of Medicine, Henry Ford Hospital, Detroit, Michigan (USA)

ABSTRACT

Background:

Early recognition of arterio-venous fistula (AVF) dysfunction in hemodialysis (HD) patients followed by prompt corrective procedures reduces the AVF thrombosis rates and lengthens access survival. We employed a dynamic access pressure surveillance system (Vasc-Alert) previously validated for arterio-venous grafts to calculate the venous access pressure (VAP) during HD from the venous drip chamber pressure (VDP).

Methods:

For a period of one month, 79 HD patients with AVF underwent surveillance while access outcomes were monitored for 6 months. VAP, in patients, was calculated as $VAP = VDP - VDP_0$, where VDP_0 is determined from an empirically derived mathematical model of VDP at varying hematocrit (Hct) (1). The venous access pressure ratio (VAPR) was defined as VAP/MAP . VAPR was calculated only if $MAP > 75$ mmHg, $Q_b > 200$ ml/min and $VDP > 20$ mmHg. A positive venous access pressure ratio test (VAPRT) was defined as three consecutive treatments with VAPR exceeding 0.55 during a given month.

Sensitivity and specificity of VAPRT to predict a graft event, defined by AVG occlusion or requirement for angioplasty, were calculated.

Results: After 3 months, sensitivity and specificity for the detection of a fistula event were respectively 93% and 83% increased to 94% and 86% at 6 months.

Conclusion: The VAPRT is a valuable tool to prospectively monitor for adverse AVF events.

INTRODUCTION

Previously we demonstrated that the venous access pressure ratio test (VAPRT) was an effective method for prospectively monitoring arteriovenous grafts (AVG) for the development of stenotic lesions. The current study was conducted to validate the ratio test (VAPRT) arteriovenous native fistulas (AVF). A native fistula is created when a vein, usually in the patient's arm, is dissected from the connective tissue and directly anastomosed to an artery. This is different from an arteriovenous graft which is constructed using a section of artificial tubing to connect the vein and artery. The intra access pressure in an AVF is in general lower than in an AVG when a significant stenosis is not present. AVF survival is longer, which indicates that development of a significant stenosis is prolonged in AVF.

Early detection of access stenosis, followed by timely corrective procedures, reduces the thrombosis rate and prolongs access survival. The VAPRT computer-based algorithm (Vasc-Alert) analyzes blood pressure, HD venous pressure, and blood pump flow data to identify graft and fistula patients at-risk for thrombosis. The Vasc-Alert system is designed to alert the dialysis staff so the patient can be scheduled for percutaneous transluminal angioplasty (PTA) or surgery to maintain AVF patency without thrombosis occurring in the access site.

During HD, blood is drawn from the AVG at the arterial needle side by the dialysis machine's blood pump. After traversing the dialyzer, the blood passes through the venous drip chamber and returns to the access through the venous needle. The pressure required to infuse blood back into the AVG through the venous tubing and needle and to overcome the pressure within the AVG is recorded as the venous drip chamber pressure

(VDP). One component of VDP is the access pressure at the venous needle site or venous access pressure (VAP). Another component of VDP is the combined pressure required to overcome the low resistance to flow through the tubing distal to the drip chamber and the relatively high resistance through the venous return needle. VDP is also a function of needle size, tubing length and blood viscosity, represented by hematocrit (Hct). If the venous pressure in an AVG at its needle insertion site is 0 mmHg, VDP can be defined as VDP_0 , i.e., the venous drip chamber pressure when the access pressure is zero. Consequently, VDP_0 can be calculated for a given dialysis machine, tubing set and needle size during measurements of Q_b and Hct. After VDP_0 is determined, VAP can be calculated from the measured VDP.

$$\text{Equation (1) } VAP = VDP - VDP_0$$

An elevation of VAP indicates stenosis in the venous outflow limb of the access and is correlated with an increased probability of access failure (6, 8, 11, 14). To normalize variations in VAP attributed to changes in mean arterial pressure (MAP), the venous access pressure ratio (VAPR) is calculated by dividing VAP by MAP.

$$\text{Equation (2) } VAPR = VAP / MAP$$

The VAPRT algorithm utilizes an empirically derived formula to calculate VAP from dynamically obtained measurements of VDP during HD treatment sessions. The VAPRT algorithm analyzes monthly VAPR values and identifies individuals with consistently elevated intra-access pressures at risk for access failure. To eliminate treatment errors such as needle reversal or suboptimal needle insertion, which elevate VDP, we operationally defined an abnormal VAPRT as $VAPR > 0.55$ at three consecutive HD treatments.

MATERIALS AND METHODS

Description of the algorithm for the Venous Access Pressure Ratio Test

This algorithm identifies persistent VAPR elevations that may signify that an AVG or an AVF requires additional evaluation. This algorithm calculates VAPR from VDP and blood pump flow data that is routinely collected at HD and determines persistent increases of VAPR. To limit variability related to differences in needle gauge, patients with less than 48 HD treatments with a new access were eliminated from analysis because smaller gauge needles are frequently used to cannulate new or poorly developed access sites. The program extracts the most recent Hct and individual treatment data from a database and VAPR is calculated when the blood pressure is measured during HD at $Q_b \geq 200$ ml/min, $VDP \geq 20$ mmHg and $MAP \geq 75$ mmHg. Data from the last 60 min of HD is excluded to eliminate the effect of ultrafiltration on Hct, blood pressure and changes in systemic and vascular access resistances. The algorithm is then used to calculate mean VAPR for each HD session. In the majority of cases, three or four measurements are available. The VAPRT is considered abnormal only when VAPR exceeds 0.55 during three consecutive treatments.

The value of VDP_0 used for the current study was obtained from the following equation.

$$VDP_0 = .0005264953Q_b^2 + (.2445071Hct^2 + .2590979Hct + .06133434)Q_b - 12.840906$$

The equation differs slightly from the original published¹ due to change in the dialysis equipment used for treatment.

Clinical Application of Venous Access Pressure Ratio Test

VAPRT were obtained from our HD population (n = 79) during September of 2003. Medical records were examined to identify individuals who required intervention for an access event, defined as an obviously low access flow (<250 ml/min), the inability to provide adequate dialysis within the predetermined treatment time, or the necessity for surgical or angioplasty intervention to maintain AVG patency. Patients tested in September were followed for 6 months and outcomes were evaluated at 3 and 6 months following the September test period.

RESULTS

Table 1 shows study results of VAPRT in 79 fistula patients. In September 2003, 24 of 79 patients (30.4%) had a positive VAPRT. During the next 3 months, 14 individuals (58.3%) experienced access failure, which by month 6 increased to 16 (70.8%) in the positive test group. Two patients that tested negative ultimately experienced access failure (false negative FN, 2.5% of tested population). The statistical analysis of the VAPRT is shown in Table 2. For the 3-month follow-up period, the mean test sensitivity of VAPRT was 93% and specificity 83%, which increased slightly to a mean sensitivity of 94% and specificity of 86% during the 6-month follow-up period. The VAPRT's positive predictive value was 56.7% and the negative predictive value 65% during the 6 month interval.

Table 1 VAPRT Test Results for Three and Six Months

	3 Months	3 Months
True Positive	14	16
True Negative	53	53
False Negative	2	2
False Positive	10	8

Table 2: Statistical Analysis of Venous Access Pressure Ratio Test for Grafts Showing Mean Values for Three and Six Months of Testing

	Test Period	
	0 – 3 mo	0 – 6 mo
Sensitivity (%)	93	94
Specificity (%)	83	86
Positive Predictive Value (%)	56.7	65
Negative Predictive Value (%)	98	98
False Positive rate (%)	17	14
False Negative rate (%)	7	6

REFERENCES

1. Frinak S. Zasuwa G. Dunfee T. Besarab A. Yee J. Dynamic venous access pressure ratio test for hemodialysis access monitoring. American Journal of Kidney Diseases. 40(4):760-8, 2002 Oct