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# Prevention of hemodialysis fistula thrombosis. Early detection of venous stenoses

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**Prevention of hemodialysis fistula thrombosis. Early detection of venous stenoses.** Venous dialysis pressures were measured consecutively in 168 chronic hemodialysis patients for 265 patient-years of monitored dialysis. Venous dialysis pressure > 150 mm Hg measured by the protocol were considered elevated. Seventy-three patients had elevated venous dialysis pressures and 58 agreed to undergo elective venography (fistulogram). Fifty of 58 patients studied (86%) had significant venous stenoses. A combination of percutaneous transluminal angioplasty (PTA) and surgical revision were used to electively treat these stenoses. Early detection and treatment of these stenoses decreased fistula thrombosis and fistula replacement threefold compared with our earlier experiences. Patients with elevated venous dialysis pressure who were venogramed and treated had an occurrence of fistula thrombosis similar to patients with normal dialysis pressure (0.15 and 0.13 episodes per patient year of dialysis respectively, $P$ = NS). In contrast patients with elevated venous dialysis pressure who refused elective fistulogram and treatment averaged 1.4 episodes of thrombosis per patient year of dialysis ($P < 0.001$ compared to both other groups). We conclude that elevated venous dialysis pressure is a reliable method of detecting fistula stenoses and that the elective treatment of these stenoses significantly decreases fistula thrombosis and fistula loss.

Vascular access for hemodialysis patients is provided by the use of endogenous (native) or synthetic arteriovenous fistulas. Maintaining patent vascular access is a major problem especially in an ageing hemodialysis population with limited vascular access sites [1–4]. The most common cause of fistula failure is thrombosis, usually caused by venous stasis associated with venous stenotic lesions [1]. These venous stenoses have typically been detected following fistula thrombosis and have been treated by surgical revision [1–4]. To our knowledge, a systematic approach that involves the early detection and treatment of venous stenoses before thrombosis has not been previously described. We noted previously that high venous dialysis pressure occurred in a high proportion of patients with subsequently detected venous stenoses [5, 6]. We therefore designed this study to focus on elevated venous dialysis pressure as a means of detecting venous stenoses prior to fistula thrombosis. We arrived at our current criteria for elevated pressure by retrospective analysis of the data in our first study [5]. This report summarizes our experience with a method for the elective identification and early treatment of venous stenoses associated with hemodialysis fistulas.

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## Methods

### *Patients*

Chronic hemodialysis patients treated at the Duke University dialysis units were monitored for venous dialysis pressure at each hemodialysis treatment from April, 1986 through November, 1988 (32 months). This reflects 265 patient years of monitored hemodialysis therapy. No hemodialysis patients were excluded from the monitoring procedures in this study. Venous dialysis pressures were measured with a mechanical electrical strain gauge and read from the venous pressure monitor of a Gambro AK-10 or similar hemodialysis machine (Gambro, Inc., Lincolnshire, Illinois, USA). Venous dialysis pressures were measured at extracorporeal blood flows of 200 to 225 ml/min through 16 gauge needles for the first 30 minutes of each treatment before increasing to maximum blood flow. Under these conditions venous dialysis pressure greater than 150 mm Hg consistently present during three consecutive hemodialysis treatments was considered abnormal. Patients with elevated venous dialysis pressure underwent outpatient venography of the fistula (fistulogram) extended to include the entire subclavian vein. If discreet venous stenoses were detected (>50% reduction of the lumen) percutaneous transluminal angioplasty (PTA) was usually performed as the initial therapeutic approach. Lesions longer than six centimeters were referred for elective surgical revision as previously described [5, 6]. PTA was usually performed as an outpatient procedure (96% of the cases) immediately after fistulogram. Patients were dialyzed in the hospital dialysis unit after angioplasty before being dismissed.

The method for angioplasty of hemodialysis fistulas and proximal veins has been previously described [5, 6]. Angioplasty catheters were inserted either into the fistula or the vein proximal to the fistula 62%, the femoral vein 32%, or some combination of the above 6% and were fluoroscopically guided to the stenotic lesion. Contrast studies were obtained post-PTA to document flow across dilated stenoses. Treatment was considered technically successful if the stenosis was reduced >50%. Hemostasis was obtained at the end of the procedure by 15 to 20 minutes of manual compression.

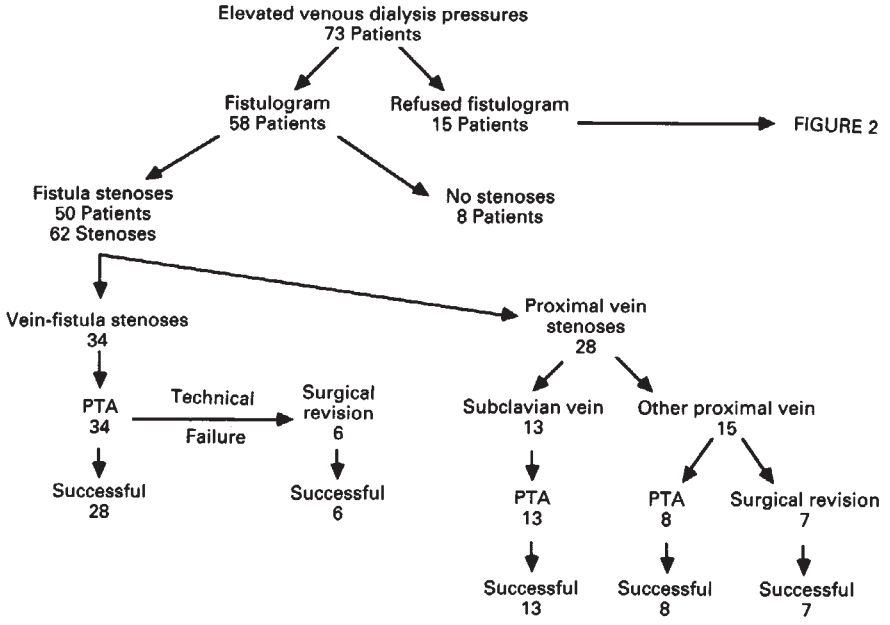


**Fig. 1.** *Treatment selection process for patients with elevated venous hemodialysis pressure.*

Surgical revision and thrombectomy of fistulas were performed by one of three vascular surgeons. All surgical revisions were performed as an inpatient procedure. Thrombectomy was routinely performed as an outpatient procedure.

The protocol for measurement of venous dialysis pressure was developed by analysis of venous pressure in our earlier study [5]. Variability in venous pressure caused by needle placement led to the requirement for elevated pressure on three consecutive treatments. Faster blood flows showed erratic fluctuations in venous pressures, forcing us to standardize pressure measurements at 200 to 225 ml/minute. The entire hemodialysis population was monitored for the occurrence of venous thrombosis, results of thrombectomy, surgical revisions, and replacement of vascular access grafts. Data for the pre-study control period (1985 to 1986) were obtained retrospectively by chart review and from hemodialysis quality assurance reports and operating room files. Data were analyzed with analysis of variance for continuous data and with chi square for categorical data. Data are reported as means ± standard errors.

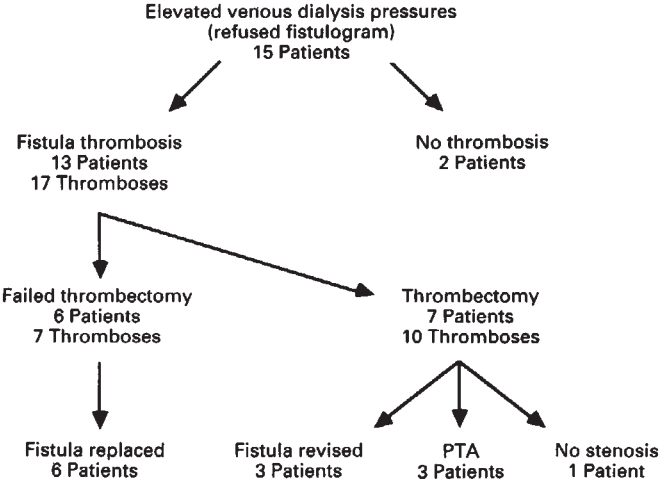


**Fig. 2.** *Clinical outcomes in patients with elevated venous dialysis pressure who refused fistulogram.*

## Results

Elevated venous dialysis pressures were detected in 73 patients (mean age 52 ± 11 years; 36 males, 37 females). Vascular access in these 73 patients included synthetic fistulas (65) in the forearm (27), upper arm (37), or axilla (1) in both loop (40), and straight (25), configuration. Native fistulas (8) were all in the forearm position. Fifty-eight of 73 patients underwent diagnostic fistulograms; fifteen patients refused (Fig. 1).

Of those patients studied, 50 of 58 (86%) had 62 discrete stenoses (Fig. 1). Thirty-four (54%) of these lesions occurred at the vein-fistula anastomosis and 28 (46%) occurred in the proximal vein. All 34 vein-fistula stenotic lesions underwent PTA (Fig. 1). Twenty-eight vein-fistula lesions (82%) underwent successful transluminal angioplasty (Fig. 1). Six of these 34 (18%) were not technically successful (determined by contrast study) and were electively referred for surgical revision. Twenty-eight stenoses were proximal venous lesions. Thirteen of these occurred in the subclavian vein and all underwent transluminal angioplasty. There were no technical failures in those patients with subclavian lesions. Fifteen stenoses were in the proximal venous system other than the subclavian vein. Seven of these 15 (46%) had poor venous maturation with diffuse lesions and were referred for elective surgical revision (Fig. 1).

Five of eight patients with elevated venous pressure who were venogramed and did not have a detectable stenosis ultimately normalized their venous dialysis pressures without intervention. Three of eight patients maintained elevated venous dialysis pressure and one subsequently developed a thrombosis.

Fifteen patients (mean age 46 ± 8 years, 8 males, 7 females) with elevated dialysis pressure refused fistulograms (Figs. 1, 2). Thirteen of these 15 (86%; Fig. 2) developed an episode of

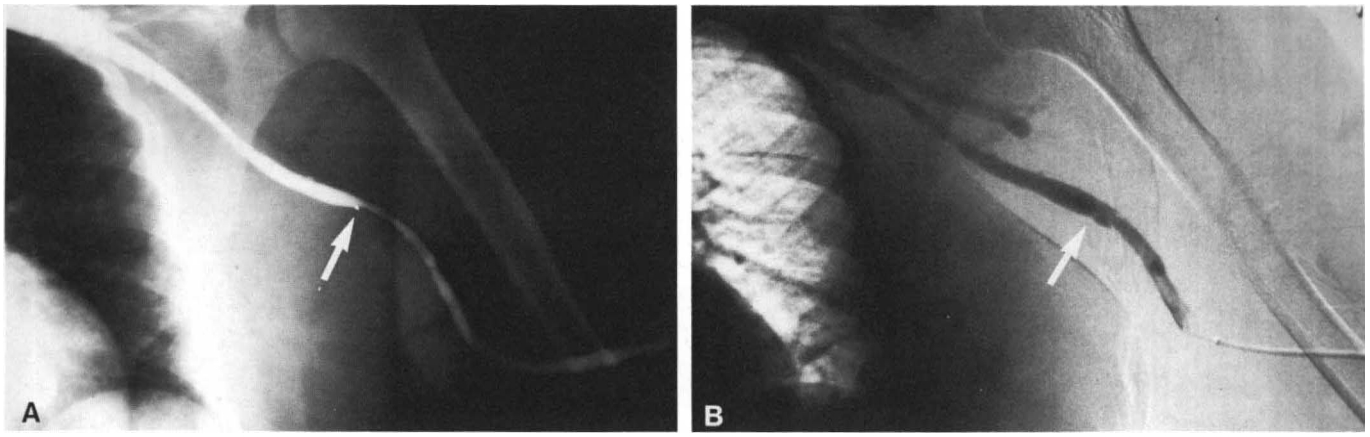


**Fig. 3.** *Diagnostic fistulogram showing a stenosis in a proximal vein.* The white arrow indicates the location of the stenosis before (**A**) and after (**B**) PTA.

thrombosis during the study. Twelve of these 15 patients (80%) had a significant venous stenoses. In six patients the thrombus could not be surgically removed, resulting in placement of a new vascular access graft. The clinical course of these 15 patients is described in Figure 2.

One hundred and forty-three patients maintained normal venous dialysis pressure for all or a part of this study. Fourteen randomly-selected patients (mean age 54 ± 6 years; 7 males, 7 females) with normal dialysis pressure underwent fistulogram. Only one of these patients (7%) had a venous stenosis. These 14 patients are comparable to the entire hemodialysis population with normal dialysis pressure. They are similar in age, time on dialysis, incidence of diabetes, and occurrence of peripheral vascular disease. Based on the assumption that these 14 patients are similar to the dialysis population with normal dialysis pressure a calculated specificity of elevated venous dialysis pressure for detection of venous stenosis is 93% with a sensitivity of 86%. Additional normal patients were not venogramed because of the cost involved with little likelihood of detecting a treatable lesion.

Of those 34 vein fistula stenoses that underwent successful PTA (Fig. 1), four (12%) recurred after a mean follow-up time of 13 months post-procedure. Of the eight proximal venous stenoses that underwent PTA (Fig. 1), there have been two recurrences (25%; mean follow-up time 15 months). Four of 13 (30%) of the subclavian stenoses have recurred after a mean 12 months of follow-up. There have been no recurrences in the 13 lesions treated with surgical revision after a mean of 12 months. In all episodes, the recurrence of the vascular lesion was heralded by elevated venous dialysis pressure. Repeat angioplasty was performed on 9 of 10 patients with technical success. Figure 3 shows the results of PTA in an example of proximal venous stenoses. PTA of a vein fistula stenosis [5] and of a central vein stenosis [6] has been previously shown.

Table 1 examines the occurrence of thrombosis in the treatment group and both control groups: 1.) elevated venous pressure, no fistulogram; 2.) normal dialysis pressure. These groups of patients were similar in age, sex, race, and occurrence of diabetes and peripheral vascular disease. The frequency of thrombosis per patient year of dialysis was lowest in the group of patients with normal venous dialysis pressure (0.13) and was not statistically different from those patients with elevated dialysis pressure who underwent fistulogram and elective treatment (0.15; $P$ = NS; Table 1). In contrast, those patients with elevated dialysis pressure who refused fistulogram had a higher occurrence of thrombosis per patient year of dialysis than the other patient groups (1.4; $P < .001$; Table 1).

**Table 1.** Fistula thrombosis rates

| | Elevated dialysis pressures | | |
|---|---|---|---|
| | Fistulogram | No fistulogram | Normal dialysis pressures |
| Thrombosis episodes | 12 | 17 | 23 |
| Patient years of dialysis | 81 | 12 | 172 |
| Thromboses per patient year | 0.15 | 1.4 | 0.13 |

Figure 4 depicts venous dialysis pressure by patient group. Mean venous dialysis pressure in the total patient population (mean of 5 separate measurements in the hemodialysis population) was 108 ± 12 mm Hg. Mean dialysis pressure in the 14 patients with normal pressure who underwent fistulogram was 109 ± 7 mm Hg. In the 15 patients with elevated dialysis pressure who refused elective fistulogram (Fig. 2) mean pressure was 203 ± 19 mm Hg (Fig. 4). Of the 58 patients who underwent elective fistulogram (Fig. 1) mean pressure was 199 ± 19 mm Hg (Fig. 4). In these 58 patients there were no differences in mean dialysis pressure regardless of whether a stenosis was (201 ± 20 mm Hg; $N$ = 50) or was not (174 ± 17 mm Hg; $N$ = 8) found. Following treatment (PTA or surgery) dialysis pressure fell significantly to 110 ± 9 mm Hg ($P < .001$; Fig. 4).

Before the start of this study (1985 to 1986) there were 52 episodes of vascular access thrombosis with 22 vascular access replacements in our patient population (Table 2). During the study (April, 1986 through November, 1988) only 52 episodes of fistula thrombosis and 19 fistula replacements occurred (Table 2). Thus, the incidence of fistula thrombosis per patient year on

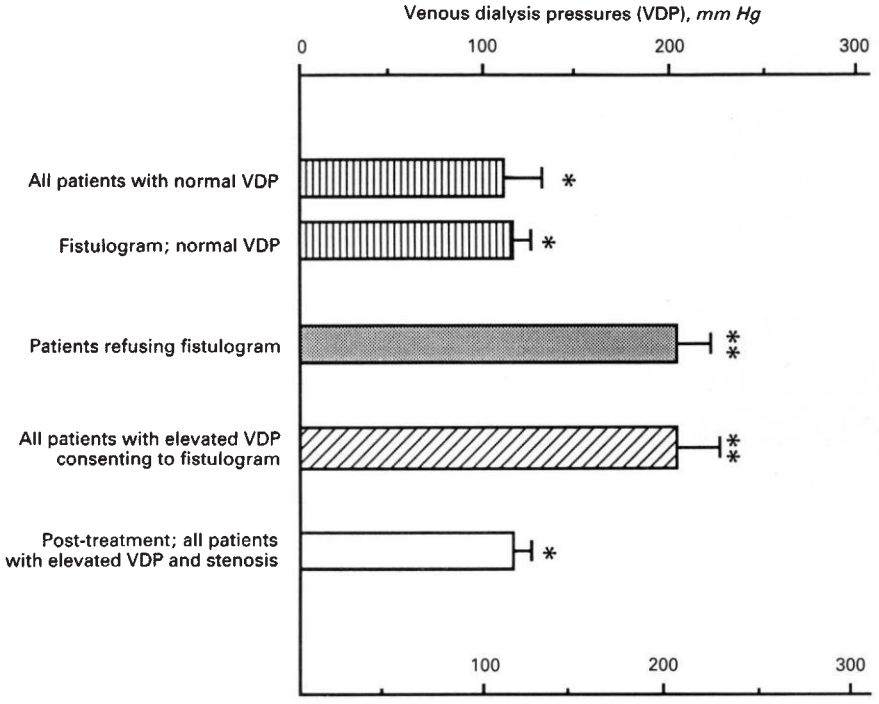


**Fig. 4.** *Venous dialysis pressures in various subgroups of hemodialysis patients.* $*P$ = NS, $**P$ = NS, $***P < .001$

**Table 2.** Thrombosis and fistula replacement

| | Patient years of dialysis | Episodes of thrombosis | Thromboses per patient year | Fistulas replaced | Replacement per patient year |
|---|---|---|---|---|---|
| 1985–1986[a] 12 months | 85.3 | 52 | 0.61 | 22 | 0.26 |
| 1987—1988[b] 32 months | 265 | 52 | 0.20 | 19 | 0.07 |

[a] Pre-study retrospective data
[b] Study data

dialysis was 0.61 (61%) in 1985 to 1986, before the development of the technique described here, and fell to 0.20 (20%) during the study (Table 2). In addition the fistula replacement rate has decreased from 0.26 (26%) to 0.07 (7%) as a result of these techniques (Table 2). There were no changes in surgical technique, surgeons performing these procedures, or synthetic fistula material during the control or study period.

Three complications occurred during this study that required hospitalization. One patient developed an episode of prolonged angina and one patient developed a large femoral hematoma. Contrast extravasation occurred in one instance. There were no other complications associated with the procedure. Specifically there were no episodes of fistula rupture, contrast allergy, or loss of the vascular access patency associated with these procedures.

## Discussion

Providing satisfactory vascular access for hemodialysis remains one of the most challenging problems confronting nephrologists. Synthetic fistulas are now the most common type of vascular access as it becomes more difficult to find satisfactory veins to form a new native fistula as older patients enter dialysis [1–5]. Synthetic fistula survival at one year has varied with two year survival of approximately 50% [1–4]. Stenotic lesions in the venous limb are the most common anatomic cause of thrombosis in both synthetic and native hemodialysis fistulas [1]. The usual method of restoring patency is by surgical thrombectomy of clotted hemodialysis fistulas and surgical revision of stenotic lesions [1–4]. Surgical revision has the major drawback of extending vascular access grafts further up the extremity, thereby, minimizing sites for future placement of vascular access. In addition, surgical therapy of stenotic lesions in the axillary and subclavian veins is technically difficult. We and others have reported preliminary results with percutaneous transluminal angioplasty as a method of treating venous stenoses [5–11].

The early detection of venous stenoses is the essential first step in preventing fistula thrombosis. Elevated venous dialysis pressure serves as an excellent means of electively detecting these stenoses (Fig. 1). Using the venous dialysis pressure protocol as outlined 86% of the patients with elevated dialysis pressure had venous stenosis (Fig. 1). In contrast only 7% of venogramed patients with normal dialysis pressure had a venous stenosis. Thus the calculated specificity of elevated venous dialysis pressures in detecting venous stenoses is 93% and the calculated sensitivity is 86%. Treatment of venous stenoses decreased dialysis pressures to normal (Fig. 4). If stenoses recurred elevated venous dialysis pressures were again detectable. These observations show that venous stenoses can be reliably detected by the use of elevated venous dialysis pressures. Thus, the number of fistulograms can be limited to those patients with a high likelihood of venous stenoses.

Undetected venous stenoses were associated with a higher rate of fistula thrombosis. Patients with elevated venous dialy-

sis pressure who refused elective evaluation and treatment had a high rate of fistula thrombosis and fistula replacement (Fig. 2). This high rate of thrombosis cannot be explained by differences in patient age, sex, race, peripheral vascular disease, or time on maintenance dialysis therapy. It is best explained by the fact that 12 of 15 patients in this group had venous stenoses that went untreated (Fig. 2).

Table 1 depicts the episodes of fistula thrombosis as a function of venous dialysis pressure. Patients with normal venous dialysis pressure had the lowest thrombosis rate (0.13 episodes per patient year of dialysis). Patients with elevated dialysis pressure who refused elective evaluation and treatment had a significantly greater occurrence of thrombosis (1.4 episodes per patient year of dialysis) reflecting untreated venous stenosis. In contrast patients with elevated venous pressure who underwent elective evaluation and treatment of their venous stenoses had an occurrence of thrombosis that was significantly lower than patients with elevated pressure who refused evaluation ($P < .001$) and was not different than patients with normal pressure ($P$ = NS; Table 1).

Thrombosis in a hemodialysis fistula can occur for a variety of reasons. Volume depletion, hypotension and external compression are three commonly cited causes of venous thrombosis that can occur independently of significant venous or arterial stenoses. The occurrence of fistula thrombosis in patients without stenosis is apparent from our data (Figs. 1, 2, Table 1). Nonetheless our results show that the elective identification and treatment of stenoses can significantly decrease the thrombosis rate for hemodialysis fistulas (Table 2). Since the institution of these strategies, the incidence of thrombosis and fistula replacement per patient year on hemodialysis decreased more than threefold compared with data from our center prior to use of these methods (Table 2). Stenoses treated with PTA have a higher recurrence rate than stenoses treated with surgical intervention. However, multiple PTA procedures are possible in a given fistula and upon a single stenosis thereby prolonging the life of the original fistula without extending the fistula further up the arm.

In conclusion, measurement of venous dialysis pressures when used in conjunction with fistulography, angioplasty, and surgical revision provides a strategy for reducing the incidence of thrombosis and fistula replacement.

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