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Primary and Secondary Patency Rates and Complications of Upper Extremity Arteriovenous Fistulae Created for Hemodialysis

Azman Ates, Ahmet Özyazicioğlu, Ibrahim Yekeler, Münacettin Ceviz, Bilgehan Erkut, Sami Karapolat, Cevdet Uğur Koçoğullari and Hikmet Kocak

Department of Cardiovascular Surgery, Atatürk University Medical Faculty, Erzurum, Turkey

Ates, A., Özyazicioğlu, A., Yekeler, I., Ceviz, M., Erkut, B., Karapolat, S., Koçoğullari, C.U. and Kocak, H. *Primary and Secondary Patency Rates and Complications of Upper Extremity Arteriovenous Fistulae Created for Hemodialysis*. Tohoku J. Exp. Med., 2006, **210** (2), 91-97 —— The types of fistulae used and their complication rates are important for the hemodialysis patients. We aimed to compare retrospectively the primary and secondary patency rates and complications of upper extremity arteriovenous fistulae. Between 1984 and 2005, a total of 1,233 upper extremity arteriovenous fistulae were created in 920 patients. The mean age was 42 ± 21 years. The fistulae were divided into the 3 groups; 588 radiocephalic, 205 brachiocephalic, and 127 were created by polytetrafluoroethylene graft. The fistulae types were evaluated with regard to their primary-secondary patency rates and complications. There was a significant difference with regard to development of thrombosis in radiocephalic group compared to other two groups, respectively, $p = 0.0122$, $p = 0.0091$. In brachiocephalic fistulae group, edema and steal phenomenon were statistically significant ($p < 0.0001$). The aneurysm formation was statistically significant in polytetrafluoroethylene fistulae graft group ($p < 0.0001$). During 6 months, 2 and 5 years period, while primary patency rate was higher in three fistulae types, in radiocephalic fistulae both primary and secondary fistulae patency rates were lower ($p < 0.05$). To create successful arteriovenous fistulae with long-term patency, appropriate veins of patients should be carefully preserved; thus initially a distal site should be preferred, and in case of failure the next fistulae should be created proximally. In case of failure of forearm fistulae, primary fistulae with autogenous veins should be tried at the upper arm first, and if this also fails, fistulae formation with synthetic grafts should be considered. ———— arteriovenous fistulae; upper extremity; surgical techniques; patency rate
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Currently, hemodialysis and renal transplantation are the two treatment modalities for chronic renal failure. Among these two, only transplantation can provide near-normal life for the patient. However, a period of hemodialysis inevitably precedes the transplantation in almost all cases. Patients with chronic renal failure are dependent on hemodialysis and need appropriate vascular

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Correspondence: Azman Ates, M.D., Atatürk Universitesi Lojmanlari, 25 / 7, 25240 Erzurum, Turkey.
e-mail: azmanates@yahoo.com

access sites (Rooijens et al. 2004).

Thus, an increasing number of arteriovenous fistulae (AVF) are created in vascular surgery centers. Preservation of upper extremity veins and best possible usage under most appropriate conditions are of great significance. Although access sites in the lower extremities are preferable with respect to better blood flow, technical difficulties and the risk of infection limit their use. AVF in the upper extremities should be created starting from the most distal anatomical location due to the possibility of future use of proximal sites (Rooijens et al. 2004).

Here, we present the primary and secondary patency rates and complications of various types of fistulae in patients with chronic renal disease who do not have the opportunity for renal transplantation and need regular hemodialysis.

Materials and Methods

A total of 1,233 vascular interventions were performed in 920 hemodialysis patients between February 1984 and January 2005 at the Vascular Surgery Unit, Atatürk University Medical School. The study was approved by the Atatürk University ethics committee. The mean age was 42 ± 21 years (range: 9 - 75); 654 patients were male (71.1%) and 266 were female (28.9%). The 48 patients (5.1%) had diabetes mellitus. In most of them, brachiocephalic or polytetrafluoroethylene (PTFE) fistulae graft were preferred.

Diagnostic work up for venous site suitability

The decision regarding the most suitable venous site for the AVF was based on physical examination of both arms, Allen's test, color doppler ultrasonography (after May 2000), and in some cases, venography. During the last decade, we have preferred Brescio-Cimino type AVF over snuffbox AVF due to larger vascular diameters.

In the present clinical study, we used polytetrafluoroethylene graft (PTFE, Gore-Tex PTFE graft II/regular graft, stretch, full ring, standard wall type; WL Gore & Associates, Inc., Flagstaff, AZ, USA) as prosthetic vascular graft material. AVF were created under local anesthesia by the senior staff surgeons of cardiovascular surgery. Type of the anastomosis was usually based on the preference of the surgeon. End-to-side (266; 45.2%) or side-to-side anastomoses (322; 54.7%) were used for radiocephalic fistulae depending on the exploration of the vascular structures and suitability; only end-to-side anastomosis was used for brachiocephalic fistulae. Arterial and venous lumens were exposed for a length of 8-10 mm and 4-7 mm at the wrist end elbow regions, respectively. 6-0 or 7-0 prolene suture material, mostly with continuous suture technique were used for anastomoses. Magnifying loupes and other ocular devices was not used. The non-dominant upper extremity, usually the left, was used preferentially. The lower extremity was avoided because of concerns about infection, technical difficulties, involvement by peripheral vascular disease and for patient's convenience. Generally, a distal location and autogenous veins are preferred.

Postoperative evaluation

Presence of thrill and murmur at the end of the procedure was considered as the evidence for the success. Arm elevation, in addition to the administration of 20.000 IU/day heparin (International normalized ratio [INR] 2-2.5) for 1 to 3 days, was recommended for patients with impaired blood flow and a weak thrill/murmur postoperatively. All patients received prophylactic antibiotics, whereas heparin derivatives were preferred in patients who require them. Dialysis was commenced approximately 3 weeks after AVF was performed, in order to allow for the maturation of the fistulae. But, for patients with synthetic grafting, a 2 weeks period was allowed for the maturation.

The evaluation of adequate of fistulae flow

For evaluation of fistulae flow following anastomosis, postoperatively presence of thrill was examined on venous site. In addition, after the maturation AVF, the quantity of the flow was evaluated during hemodialysis.

Statistical analysis

SPSS 11.0 (Statistical Package for the Social Sciences SPSS Inc, Chicago, IL, USA) was used for the statistical analysis. Data are expressed as means ± S.D. The comparison of the complication rates between fistulae types were made using "Chi square test".

Statistical significant probability level was set at 0.05. The primary and secondary patency rates for fistulae types were analyzed with "Kaplan Meier survival analysis" and "Log rank test".

Results

The analysis included 920 patients: 654 (71.1%) men and 266 (28.9%) women with a

median age of 42 ± 21 (range 9 - 75). A total of 1,233 upper extremity AVF were created in 920 patients.

Surgical procedures

AVF were created starting from the distal forearm. When this approach failed, AVF were then repeated at a more proximal site if appropriate superficial veins were present. Of these fistulae, 588 were radiocephalic at wrist level (260 snuffbox and 328 Brescio-Cimino), and 205 were brachiocephalic at elbow level (187 brachial artery-cephalic vein, 18 basilic vein transposition). AVF were created with PTFE synthetic grafts as a last resort in 127 patients who were deemed to have lost the chance for autogenous AVF. Of these PTFE grafts, 120 were created between the axillary vein and brachial artery, while the rest had a brachioradial fistulization.

Besides, saphenous loop was used in 4 female patients (basilic vein-superior radial artery). But, this group of saphenous loop was excluded from the study, as the data were not suitable for statistical analysis.

Complications

In the brachiocephalic group, the complication rates were found higher compared to radiocephalic and PTFE graft fistulae ($p < 0.0001$ and $p < 0.0001$, respectively) (Table 1). Thrombosis development was more frequent in the radiocephalic group compared to brachiocephalic and PTFE graft fistulae ($p = 0.0122$ and $p = 0.0091$, respectively) (Table 1). In brachiocephalic fistulae group, steal and edema were more frequent compared to radiocephalic and PTFE graft fistulae ($p < 0.0001$ and $p < 0.0001$, respectively) (Table 1).

Aneurysm development was more frequent in PTFE graft fistulae group compared to radiocephalic and brachiocephalic groups ($p < 0.0001$ and $p < 0.0001$, respectively) (Table 1). There was no significant difference between the groups in terms of infection and hematoma development (Table 1).

Functional status of AVFs in early postoperative period (within 30 days)

Of the 588 patients in the radiocephalic fistulae group, 493 AVF could be effectively used, while 95 patients (16.1%) had early occlusion or inadequate flow resulting in dysfunctional fistulae. In these 95 patients, 71 (74.7%) had end-to-side anastomosis fistulae. In the brachiocephalic group 88.2% of the fistulae (181 of 205 patients) were functional at the early postoperative period, while this ratio was 87.4% in patients with PTFE fistulae (111 of 127 patients). In 313 patients secondary surgical interventions were performed due to fistulae failure at varying time points.

Primary-secondary patency

Primary patency was defined as the duration of fistulae patency without revision, and secondary patency was defined as the duration of fistulae patency after successful revision. When primary and secondary patency rates for 6 months, 2 years and 5 years of different fistulae types were examined, they were higher in three fistulae types (Table

TABLE 1. Complication rates by fistulae types

	Radiocephalic		Brachiocephalic		PTFE		*p*
	n	%	*n*	%	*n*	%	
Total complications	246	30.4	201	74.7	103	66.9	0.0000
Thrombosis	75	9.3	12	4.5	8	5.2	0.0174
Edema	31	3.8	50	18.6	24	15.6	0.0000
Aneurysm	32	4.0	61	22.7	25	16.2	0.0000
Steal	25	3.1	52	19.3	28	18.2	0.0000
Infection	27	3.3	10	3.7	10	6.5	0.1709
Hematoma	56	6.9	16	5.9	8	5.2	0.6718

TABLE 2. Patency rates of arteriovenous fistulae after 6 months, 2 years and 5 years.

Fistulae type	Total number of patients (*n*)	Patency at six months (%)		Patency at two years (%)		Patency at five years (%)	
		primary	secondary	Primary	secondary	primary	secondary
Radiocephalic	588	81.0	74.9	71.0	63.9	35.0	9.7
Brachiocephalic	205	97.3	91.0	87.7	71.4	45.3	22.9
PTFE graft	127	94.7	92.3	82.6	77.6	28.5	-

TABLE 3. For primary and secondary patency rates survival analysis with Log rank test.

Fistulae type	Primary Patency Survival time (Median - year)	Secondary Patency Survival time (Median - year)
Radiocephalic	2.75	0.27
Brachiocephalic	3.36	1.49
PTFE graft	4.38	1.62

2). A similar relation was also found for median survivals (Table 3). In the radiocephalic fistulae group, patency rates was significantly lower compared to other two groups (Figs. 1 and 2).

DISCUSSION

Kolff et al. (1994) invented the artificial kidney dialysis machine in 1944. Afterwards, numerous studies have been performed in the area of chronic renal disease and its treatment. However, the practical difficulties associated with hemodialysis could not be overcome until Quinton et al. (1960) developed the shunt technique in 1960. These were followed by the development of internal primary fistulae by Brescia et al. (1966). Subsequently developed snuff-box fistulae technique opened a new era in hemodialysis (Mehigan and McAlexander 1982). Patients with chronic renal disease require hemodialysis via an AVF until they have the chance for transplantation, and this has led to development of more than 20 technical modifications pursuing minimal impairment in patients' quality of life and high patency rates in the long term (Çinar et al. 2005; Fitzgerald et al. 2005).

The National Kidney Foundation guidelines for vascular access suggest that for all kinds of AVF patency rates of 70% at 1 year, 60% at 2 years and 50% at 3 years can be achieved (DOQI 2001). These levels were achieved for three fistulae types in our study.

In our study, patency rates were significantly higher for proximal fistulae types such as brachiocephalic and synthetic graft fistulae compared to distal fistulae like radiocephalic, which is consistent with some studies (Tautenhahn et al. 1994; Culp et al. 1995) and different than others (Polo and Romeo 1989). We presume that a wider vessel lumen, higher flow rate, and easy surgical approach for fistulae creation were the most important advantages of the proximal over the distal forearm AVF.

As reported by Yasuhara and Modarai (Yashuara et al. 1997; Modarai et al. 2005), the secondary patency rates are better than primary patency rates. Our study showed that the primary patency rate was better than secondary patency rate during 6 months, 2 years, and 5 years.

Although the radiocephalic fistulae provides an adequate flow that improves over time with the maturation of the fistulae (Golledge et al. 1999; Rooijens et al. 2004), some authors suggest that this approach is associated with problems such as high incidence of early occlusion and low flow rate (Dixon et al. 2002), particularly more frequently in end-to-side anastomosis compared to

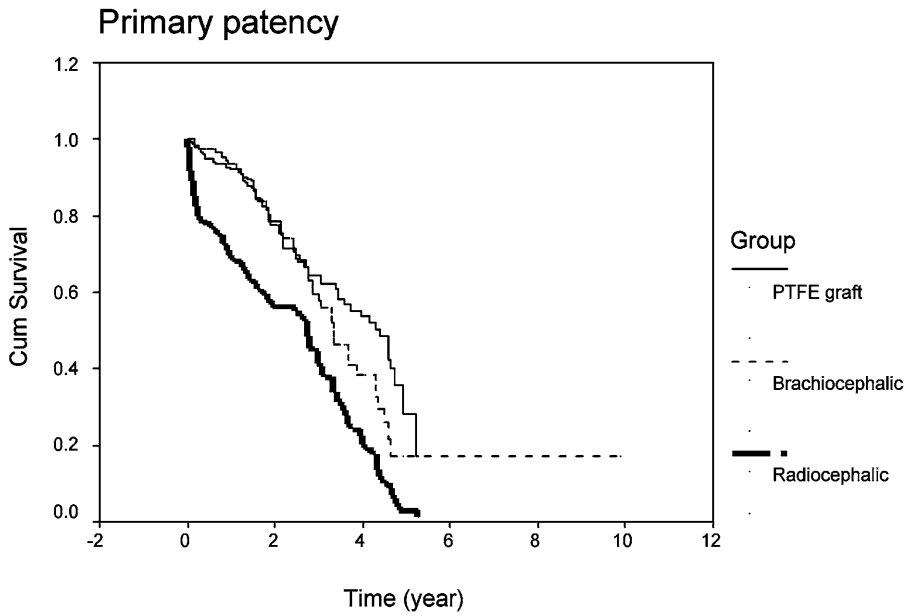


Fig. 1. Kaplan-Meier survival analysis of primary patency for fistulae types (Log Rank 82.90, df: 2, $p < 0.0005$).

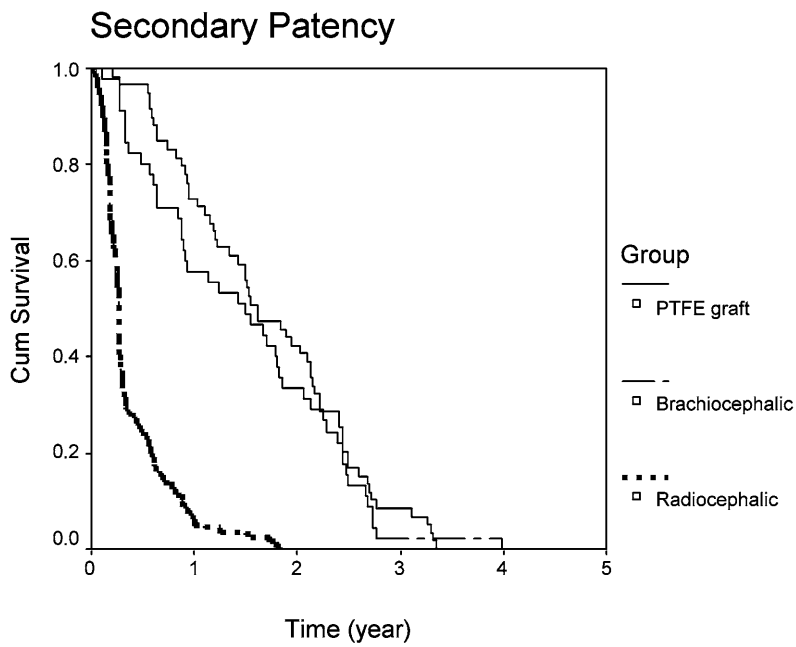


Fig. 2. Graph showing cumulative secondary patency rate (Kaplan-Meier) for fistulae types (Log Rank 168.53, df: 2, $p < 0.0005$).

side-to-side anastomoses. In theory, end-to-side anastomoses are able to convey less blood compared to side-to-side anastomoses (Thomsen et al. 1983). Among other disadvantages associated with end-to-side anastomoses are technical difficulties and the hemodynamic inappropriateness compared to side-to-side anastomoses (Golledge et al. 1999). In our series, early occlusions or inadequate blood flow occurred significantly more frequently in end-to-side anastomoses compared

to side-to-side technique in radiocephalic fistulae type, which is consistent with some reports (Zarin et al. 2004) and opposite to another report (Wedgwood et al. 1984).

Expanded PTFE grafts have become the most commonly used vascular prosthetic grafts for constructing AVF for hemodialysis when autologous fistulae formation is not possible. As reported, in PTFE graft fistulae aneurysm formation is more frequent (Patel et al. 1992; Bhama et al. 2002). Similarly, our results showed that the aneurysm rates were higher in PTFE graft fistulae.

Edema due to venous hypertension is currently encountered following the creation of a proximal forearm AVF (Kojecky et al. 2002; Bachlede et al. 2004). This may cause arterialization of the subcutaneous forearm venous system, manifested by venous hypertension. In our series, the edema due to venous hypertension was higher in brachiocephalic fistulae compared to other two fistulae groups.

Upper extremity ischemia due to steal syndrome occurs in 3.7-5% of dialysis patients and this percentage increases depending on the type of AVF (Lazarides et al. 1998; Morsy et al. 1998; Yeager et al. 2002). In 10-25% of brachiocephalic and basilic AVF, 4.3-6% of forearm prosthetic implants and 1-1.8% of radiocephalic AVF, symptomatic ischemia may develop (Tordoir et al. 2004). Our patients who developed steal syndrome had pale and cold hands without pain and all had diabetes mellitus. Most of our patients with steal syndrome had brachiocephalic fistulae, which is consistent with Tordoir's study.

The reported complication rates in AVF vary between 21% and 64% (Palder et al. 1985), which is similar to that observed in our study. Our results did not show that the complication rate for PTFE grafts was higher than brachiocephalic fistulae, which is consistent with one report (Salahi et al. 2006) but opposite to another report (Modarai et al. 2005). In our study the complication rate for brachiocephalic fistulae (74.7% vs 30.6% and 66.9%) was higher than other two fistulae type. Brachiocephalic fistulae may be preferred on the basis of adequate blood flow and lower risk of thrombosis. Although radiocephalic fistulae (snuff box and Brescio-Simino) have high incidence of thrombosis, they have lower risk for steal syndrome, aneurysm and extremity edema. Another advantage of this technique is that it allows for further proximal interventions since the site of intervention is located distally in the arm. Also, in case complications develop, other techniques can also be used.

Late occlusion mostly occurs in the venous side and usually results from intimal proliferation in the vein or intimal flaps. Therefore, great care must be taken to avoid intimal injury during the creation of the fistulae (Haberal et al. 1999; Murphy et al. 2000). Due to these causes, AVF were created by the senior staff surgeons in our clinic.

Conclusion

To create successful arteriovenous fistulae with long term patency in the future, appropriate veins of chronic renal failure patients should be carefully preserved. If the creation of forearm fistulae fails, then, primary fistulae should be tried, again with autogenous veins in the arm (from distal to proximal direction).

In conclusion, vascular anatomy should be clearly documented prior to fistulae formation. In patients with chronic renal failure, AVF with low incidence of complications and high long-term patency rates should be created. For hemodialysis, great care must be taken to preserve the integrity of the venous anatomy. All complications that develop during dialysis should be immediately communicated to the vascular surgeon, and the appropriate intervention should be performed without delay. Furthermore, as our experience suggests, the technique used for the creation of the fistulae and the skills of the surgeon still play an important role in the early failure of AVF. Although thrombosis rates are high in radiocephalic fistulae, it should be the first choice technique for AVF due to low rate of complications, wide space for puncture and the possibility to use other techniques in case of complications. If fistulae formation in the forearm is not possible, brachiocephalic primary fistulae should be tried before the use of prosthetic grafts.

References

Bachlede, P., Kojecky, Z., Utikal, P., Drac, P., Herman, J. & Zadrazil, J. (2004) Peripheral venous hypertension after creation of arteriovenous fistulae for hemodialysis. *Biomed. Papers.,* **148**, 85-87.

Bhama, J.K., Guinn, G. & Fisher, W.E. (2002) Venous aneurysm following construction of a PTFE arteriovenous dialysis graft. *Ann. Vasc. Surg.,* **16**, 239-241.

Brescia, M.J., Cimino, J.E., Appel, K. & Hurwich, B.J.J. (1966) Chronic hemodialysis using vein puncture and a surgically created arteriovenous fistulae. *N. Engl. J. Med.,* **275**, 1089-1092.

Çinar, B., Göksel, O.S. & Yekeler, I. (2005) Midterm results with the use of polycarbonate urethane heterografts for dialysis access. *Tohoku J. Exp. Med.,* **207**, 233-238.

Culp, K., Flanigan, M., Taylor, L. & Rothstein, M. (1995) Vascular access thrombosis in new hemodialysis patients. *Am. J. Kidney. Dis.,* **26**, 341-346.

Dixon, B.S., Novak, L. & Fangman, J. (2002) Hemodialysis vascular access survival: upper-arm native arteriovenous fistulae. *Am. J. Kidney. Dis.,* **39**, 92-101.

Fitzgerald, J.T., Schanzer, A., McVicar, J.P., Chin, A.I., Perez, R.V. & Troppmann, C. (2005) Upper arm arteriovenous fistulae versus forearm looped arteriovenous graft for hemodialysis access: a comparative analysis. *Ann. Vasc. Surg.,* **19**, 843-850.

Golledge, J., Smith, C.J., Farrington, K. & Thompson, H.H. (1999) Outcome of primary radiocephalic fistulae for haemodialysis. *Br. J. Surg.,* **86**, 211-216.

Haberal, C., Karsli, M. & Kalko, Y. (1999) Complications of arteriovenous fistulae and surgical treatment. *Turkish. J. Vasc. Surg.*, **2**, 80-83.

Kojecky, Z., Utikal, P., Sekanina, Z., Köcher, M. & Briankova, E. (2002) Venous hypertension following average arteriovenous fistulae for hemodialysis. *Biomed. Pap. Med. Fac. Univ. Palacky. Olomouc.,* **146**, 77-79.

Kolff, W.J., Berk, H.T. & Ter-Weil, M. (1994) The artificial kidney: a dialyser with great area. *Acta Med. Scand.,* **115**, 121-134.

Lazarides, M.K., Staramos, D.N., Panagopoulos, G.N., Tzilalis, V.D., Eleftheriou, G.J. & Dayantas, J.N. (1998) Indications for surgical treatment of angioaccess-induced arterial "steal". *J. Am. Coll. Surg.,* **187**, 422-426.

Malovrh, M. (2002) Native arteriovenous fistulae: preoperative evaluation. *Am. J. Kidney Dis.*, **39**, 1218-1225.

Mehigan, J.T. & McAlexander, R.A. (1982) Snuff-box arteriovenous fistulae for hemodialysis. *Am. J. Surg.,* **63**, 252-253.

Modarai, B., Dasgupta, P., Taylor, J., Koffman, G. & Khan, M.S. (2005) Follow-up of PTFE arteriovenous fistulae for hemodialysis. *Int. J. Clin. Pract.,* **59**, 1005-1007.

Morsy, A.H., Kulbaski, M., Chen, C., Isiklar, H. & Lumsden, A.B. (1998) Incidence and characteristics of patients with hand ischemia after a hemodialysis access procedure. *J. Surg. Res.,* **74**, 8-10.

Murphy, G.J., White, S.A. & Nicholson, M.L. (2000) Vascular access for haemodialysis. *Br. J. Surg.,* **87**, 1300-1315.

Palder, S.B., Kirkman, R.I., Whittemore, A.D., Hakim, R.M., Lazarus, M.J. & Tilney N.L. (1985) Vascular access for hemodialysis: patency rates and results of revision. *Ann. Surg.,* **202**, 235-239.

Patel, K.R., Chan, F.A., Batista, R.J. & Clauss, R.H. (1992) True venous aneurysms and arterial steal secondary to arteriovenous fistulae for dialysis. *J. Cardiovasc. Surg.*, **33**, 185-188.

Polo, J.R. & Romero, A. (1989) Brachiocephalic fistulaes for vascular access. *Nephron.,* **52**, 105-106.

Quinton, W., Dillard, D. & Scrihner, B.H. (1960) Cannula ion of blood vessel for prolonged hemodialysis. *Trans. Am. Soc. Artificial. Internal. Organs.,* **6**, 104-113.

Rooijens, P.P., Tordoir, J.H., Stijnen, T., Burgmans, J.P., Smet, de A.A. & Yo, T.I. (2004) Radiocephalic wrist arteriovenous fistulae for hemodialysis: meta-analysis indicates a high primary failure rate. *Eur. J. Vasc. Endovasc. Surg.,* **28**, 583-589.

Salahi, H., Fazalzadeh, A., Mehdizadeh, A., Razmkon, A. & Malek-Hosseini, A. (2006) Complications of arteriovenous fistulae in dialysis patients. *Transplant. Proc.,* **38**, 1261-1264.

Tautenhahn, J., Heinrich, P. & Meyer, F. (1994) Arteriovenous fistulaes for hemodialysis — patency rates and complications — a retrospective study. *Zentralbl. Chir.,* **119**, 506-510.

Third NKF-K/DOQI (2001) Clinical Practice Guidelines for vascular access: update 2000. *Am. J. Kidney. Dis.*, **37**, 1 Suppl. 1, S137-S181.

Thomsen, M.B., Deurell, S.J., Elfström, J. & Alm, A. (1983) What causes the failure in surgically constructed arteriovenous fistulaes? *Acta Chir. Scand.,* **149**, 371-376.

Tordoir, J.H., Dammers, R. & van der Sande, F.M. (2004) Upper extremity ischemia and hemodialysis vascular access. *Eur. J. Vasc. Endovasc., Surg.*, **27**, 1-5.

Wedgwood, K.R., Wiggins, P.A. & Guillou, P.J.A. (1984) Prospective study of end-to-side vs. side-to-side arteriovenous fistulaes for haemodialysis. *Br. J. Surg.,* **71**, 640-642.

Yasuhara, H., Shigematsu, H. & Mutu, T. (1997) Results of arteriovenous fistulae revision n the forearm. *Am. J. Surg.,* **174**, 83-86.

Yeager, R.A., Moneta, G.L., Edwards, J.M., Landry, G.J., Taylor, L.M., Jr., McConnell, D.B. & Porter, J.M. (2002) Relationship of hemodialysis access to finger gangrene in patients with end-stage renal disease. *J. Vasc. Surg.,* **36**, 245-249.

Zarin, M., Ahmad, I., Waheed, D., Zeb, A., Anwar, N., Aslam, V., Ayub, T. & Haider, Z. (2004) Arteriovenous fistulae construction in chronic haemodialysis patients: comparison of end-to-side and side-to-side techniques. *J. Coll. Physicians. Surg. Pak.*, **14**, 619-621.