COMPARATIVE BLOOD FLOW STUDY OF ARTERIOVENOUS GRAFTS WITH HOMOLOGOUS AND AUTOLOGOUS VEIN IN CANINE FEMORAL ARTERIES – INITIAL EXPERIENCE

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Abstract.The objective of this experimental basic study in dogs was the initial inquiry of the blood flow in the arteriovenous grafts, comparing it use in homologous and autologous veins.
Five dogs were used and through in each one of them had been used 2 arteriovenous grafts, being of a side with conserved homologous vein with glutaraldeid 0.25% and of the other with autologous vein, alternating for each animal the side of the employed technique.
After the confection of the grafts, became fulfilled the following gauging: Average flow of the cranial femoral artery, average flow of the distal femoral artery, average flow of the cranial femoral vein and average flow of the body of grafts homologous or autologous. All the measures had been made to the 15 minutes after the confection of the grafts by means of electromagnetic flow meter connected to a program of acquisition of data.
For the analysis of the data the qui-square test was used.
For the two types of arteriovenus grafts, had an increase of the flow through the communications. It reached in up to 10 times in the cranial portion of the femoral artery and the cranial femoral vein to the communication, however in this initial analysis did not obtain statistically to demonstrate differences significant between the 2 groups. In the grafts distal portion, an inversion of the flow in the great majority of the anastomoses in both was gotten the techniques and again it was not obtained to demonstrate significant difference statistically. One concluded that it did not have significant difference of the blood flow between the grafts with veins homologous and autologous in this initial analysis.
Key words: Grafts, homologous vein, autologous vein, blood flow.

1. Introduction

Arteriovenous Fistulae (FAV) , for its characteristic of high flow in its branches, is the first choice for patients that need hemodialysis. However, when these communications are not more possible, the interposition of a conduit between the artery and the vein, is the unique solution for patients that need to continue the hemodialysis treatment.

May et al (1969) reported that arteriovenous graft with homologous saphena vein in patients that did not have available artery or vein was used for the first time in 1969.

Haimov et al (1973) described the techniques of arteriovenous, using the autologous saphena vein and hetero graft venous of bovines, for vascular access for hemodialysis, showing similar rates of primary tatency in both groups. In 1977 the initial experience of homo graft of venous for vascular access for hemodialysis was presented, with veins that previously were removed in varix surgery and conserved in temperature of 4 ºC, and the results were satisfactory.

Piccone (1978) described the use of saphena criopreserved homologous vein for access of hemodialysis. In this case, it was observed high indices of primary patency, absence of infection, low histological destruction for a period of attendance of 3 years.

Mindich et al (1975) comments research experimental studies using heterologous grafts in dogs for access of hemodialysis were carried through in 1975. Jugular vein of animals had been used in research as umbilical vein human at carotid territory, demonstrating that heterologous substitute could be used as graft of vascular access.

Levowitz et al (1976) comments some research in dogs using Dacron arteriovenous phrosteses for fistula in femoral region of dogs, and they studied the index of thrombosis after repeated puncture and also the infection index, demonstrating that these phrosteses could be used as access for hemodialysis.

Gonzalez et al (1977) reported that experimental works in dogs had used veins conserved with glutaraldeid 0.20% comparing the patency of graft in the iliac-femoral segment with vein criopreserved, and obtaining better results with the veins with the glutaraldeid.

It was not found in the literature researched, any work that used the homologous vein conserved with glutaraldeid for making FAV access for hemodialysis accomplishment. The study here presented is an initial experience of comparison of FAV performance using homologous and autologous vein, and this results can be useful as new options of vascular access for hemodialysis.

2. **Material and Method of Research**

2.1. Samples Preparation for *in vivo* Experimental Surgery

It were used five adult dogs (canis familiaris), which were selected with weight greater that 10 kg.

The dogs were directly transferred from the Municipal Kennel of *Santo Andre* and *São Bernardo do Campo*, to the Experimental Surgery Laboratory of *Faculdade de Medicina do ABC*, where they were lodged individual kennel, and having an evaluation from a veterinary medicine as soon as they arrived at the department, receiving in that occasion, antibiotics. They remained for a period of 15 days, considered a period of adaptation.

Ten arteriovenous graft (GAV) were done, five of that manufactured with autologous vein and the other five manufactured with homologous vein, alternating the side of the femoral artery (right and left) (see Fig. (1)).

The homologous veins were collected from anesthetized animals, and later they were be treated and used in the experiments. After the vein was retreat, it was place in a 500 ml physiological solution where 5ml of glutaraldeid to 25% was added together with 10% of a solution of bicarbonate of sodium to maintain the pH of 7,4. The vein stayed during one hour in this solution and after that it was washed with 2 L of physiologic solution and was conditioned in glass with solution of 80mg of gentamicina and 5000 U of anfotericina B and maintained under temperature of 4 °C.

2.2 Experimental Surgery Technique

The animals had received before the anaesthetic procedure, daily pay-anesthetical drugs consisting by acepromazin in the quantity of 0,2 mg/kg and ketalar in the quantity of 10mg/kg. Later, they were maintained with veined anesthesia with sodic Pentobarbital in the quantity of 30mg/kg of weight and with spontaneous breath. In the place of the incisions, lidocaine infiltration was made 1% without vasoconstritor, not exceeding the quantity of 7mg/kg.

The average arterial pressure and the cardiac frequency of the animals were monitored through canulization of artery carotid during all the experiment.

Figure 1a is a schematic representation of a homologous vein showing the graft accomplished among the femoral vessels, with a distal stump of the femoral vein, in this case, the graft was retired the other animal. Figure 1b is a schematic representation of autologous vein showing the graft accomplished among the femoral vessels, with a distal stump of the femoral vein. In the case of the autologous graft the distal segment of the femoral vein was used to constitute the graft.

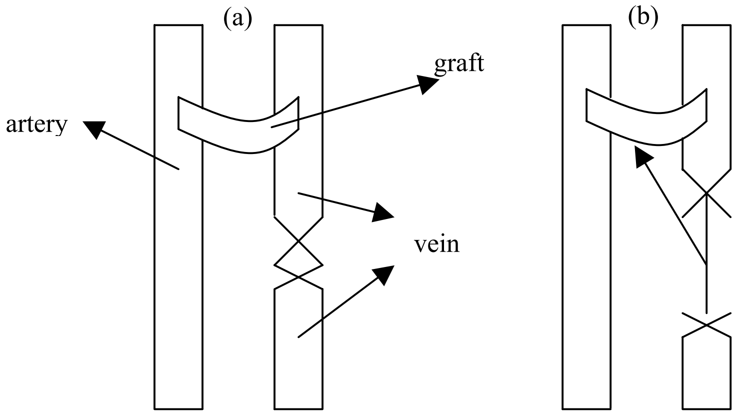

Figure 1: Schematic representation of the arteriovenous grafts: (a) homologous vein; (b) autologous vein

All the volumetric flux measurements were accomplished before and 15 minutes after the arteriovenous grafts were done. It was used an electromagnetic flow meter connected to a microcomputer were a data acquisition program was installed. (Aqdados 5.0) (see Fig. (2)).

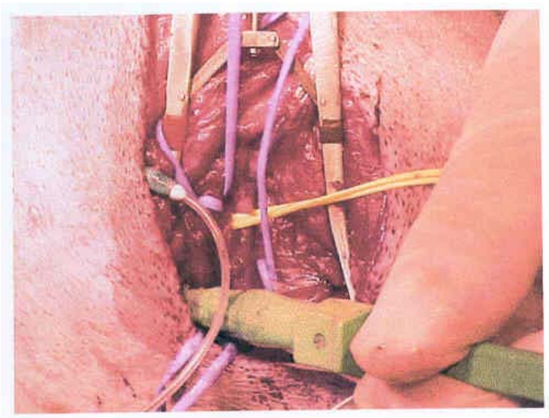

Figure 2: Application of the eletromagnetic flow meter transducer in femoral artery.

The figure below shows the confection of the autologous and the homologous grafts *in vivo.*

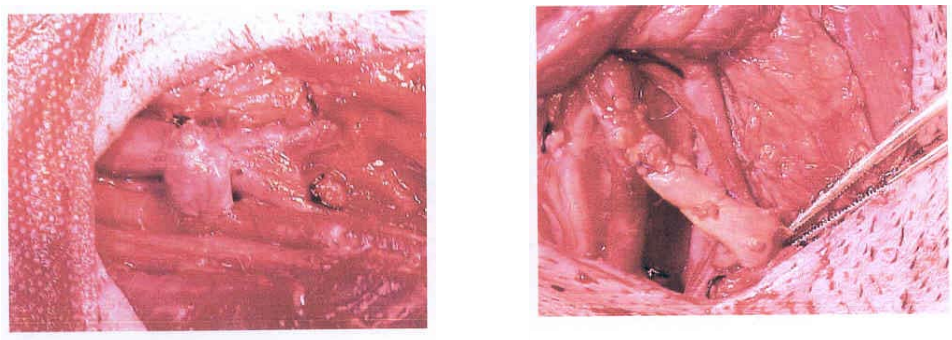

Figure 3: Intraoperatives aspects of grafts AV autologous (left) and homologous(right).

3. Results

The following volumetric flux were measured in the FAV control volume during surgery:

- Q1pré – volumetric flux in the cranial femoral artery before FAV;
- Q1pós – volumetric flux in the cranial femoral artery after FAV;
- Q2 – volumetric flux in the caudal femoral artery after FAV;
- Q3 – volumetric flux in the cranial femoral vein after FAV;
- Q4 – volumetric flux in the graft .

Some numerical simulations were done using Fluent academic code considering the following volumetric flux: Q1 = 300 ml/min, Q2 = -120 ml/min, Q3 = 420 ml/min and Q4 = 420 ml/min. Figure 4 is the representation of this simulation showing regions of flow separation, stagnation points of fluid and recirculation zones. These regions are propitious to the development of stenosis, thrombosis and atherosclerosis.

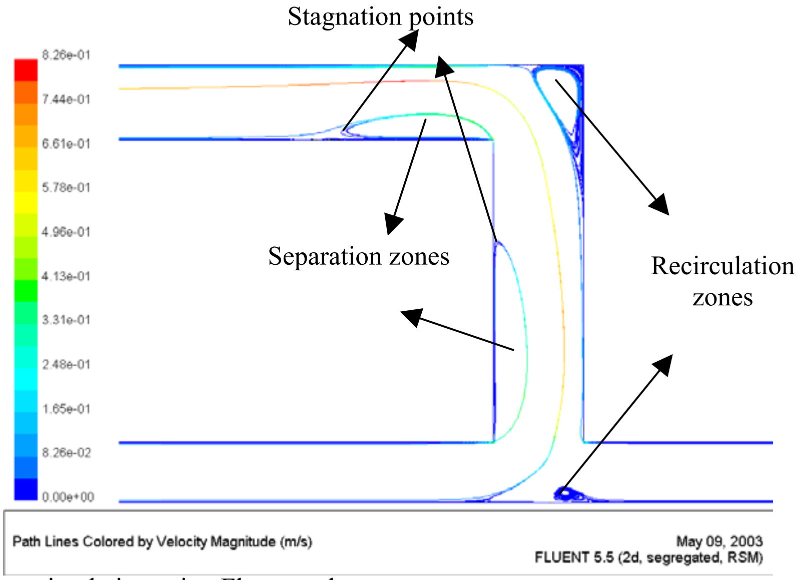

Figure 4. FAV graft flow simulation using Fluent code

The flow separation at the cranial vein region results in a recirculation zone, however, downstream there is a relaminarization of the velocity profile (see Fig. (5)).

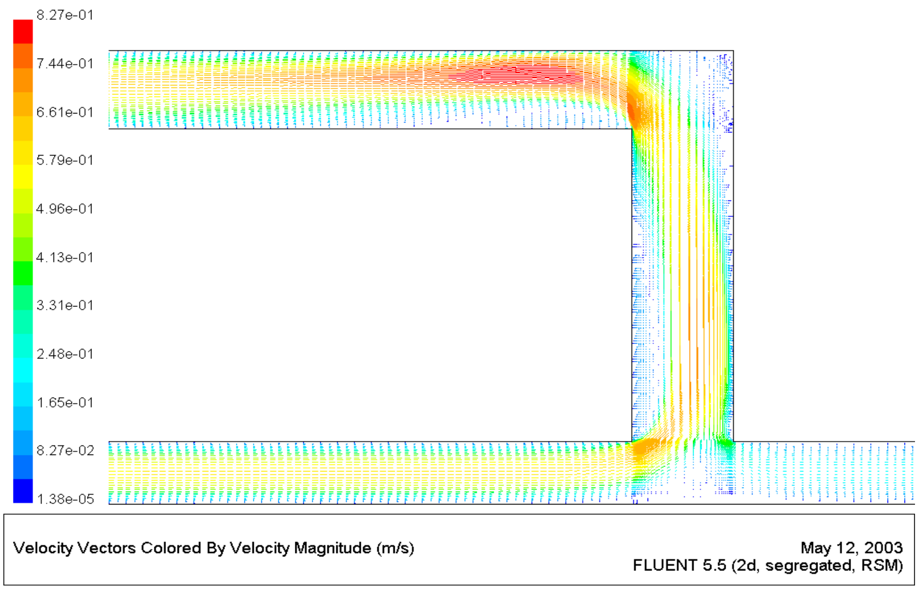

Figure 5. FAV graft flow simulation using Fluent code (flow through cranial vein).

The table below presents some results considering the use of the autologous vein technique.

Table 1. Autologous vein technique (results of weight, diameters, volumetric flux, arterial pressure and cardiac frequency pulse).

Dog	Weight kg	∅art mm	∅vein mm	∅aut mm	Q1 pre ml/min	Q1 pos ml/min	Q2 ml/min	Q3 ml/min	Q4 ml/min	PAM pré mmHg	PAM pós mmHg	FC pré bpm	FC pós bpm
1	17	4	5	6	110	370	-150	290	310	105	95	135	170
2	22	5	9	10	70	900	-100	900	600	105	95	120	145
3	18	4	6	9	80	450	50	400	350	110	110	110	135
4	15	4	5	6	60	400	-30	400	200*	110	110	150	180
5	18	4	5	6	100	320	20	300	350	110	110	130	145

* ∅ - diameter; PAM pré – Average blood pressure before FAV; PAM pós – Average blood pressure after FAV; FC pré – Cardiac Frequency before FAV; FC pós – Cardiac Frequency after FAV; bpm – pulse per minute.

The table below presents some results considering the use of the homologous vein technique.

Table 2. Homologous vein technique (results of weight, diameters, volumetric flux, arterial pressure and cardiac frequency pulse).

Dog	Weight kg	∅art mm	∅vein mm	∅hom mm	Q1 pre ml/min	Q1 pos ml/min	Q2 ml/min	Q3 ml/min	Q4 ml/min	PAM pré mmHg	PAM pós mmHg	FC pré bpm	FC pós bpm
1	17	4	5	6	110	400	-250	480	480	105	95	135	170
2	22	5	9	10	70	300	-150	900	700	105	95	120	145
3	18	4	6	9	80	700	-200	750	500	110	110	110	135
4	15	4	5	6	60	600	-90	850	100*	110	110	150	180
5	18	4	5	6	100	280	-80	450	450	110	110	130	145

* ∅ - diameter; PAM pré – Average blood pressure before FAV; PAM pós – Average blood pressure after FAV; FC pré – Cardiac Frequency before FAV; FC pós – Cardiac Frequency after FAV; bpm – pulse per minute.

The table and figure below shows a comparison of Q1 values measured for the two different graft technique.

Table 3. Comparison of Q1 values (autologous and homologous vein).

Autologous Graft (Q1 – ml/min.)	Homologous Graft (Q1 – ml/min.)
320	280
370	300
400	400
450	600
900	700

Obs.: The statistical validation were done using qui-square test.

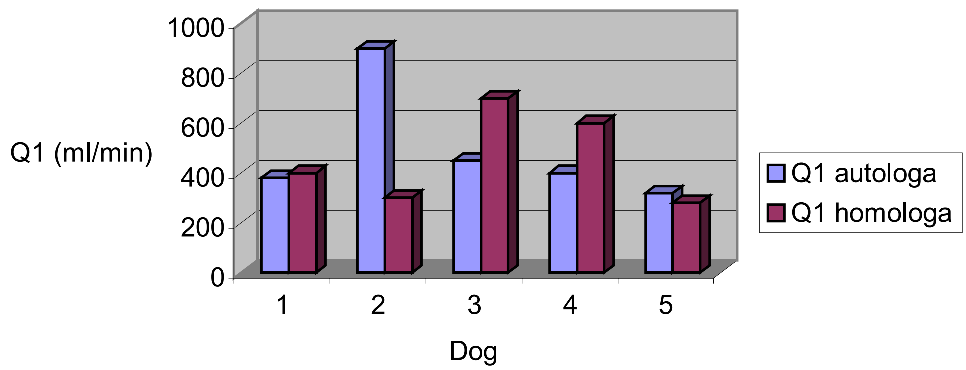

Figure 6. Comparative figure between the techniques for Q1 values measured.

The table and figure below shows a comparison of Q2 values measured for the two different graft technique.

Table 4. Comparison of Q2 values (autologous and homologous vein).

Autologous Graft (Q2 – ml/min.)	Homologous Graft (Q2 – ml/min.)
20	-150
50	-200
-100	-250
-150	-80
-30	-90

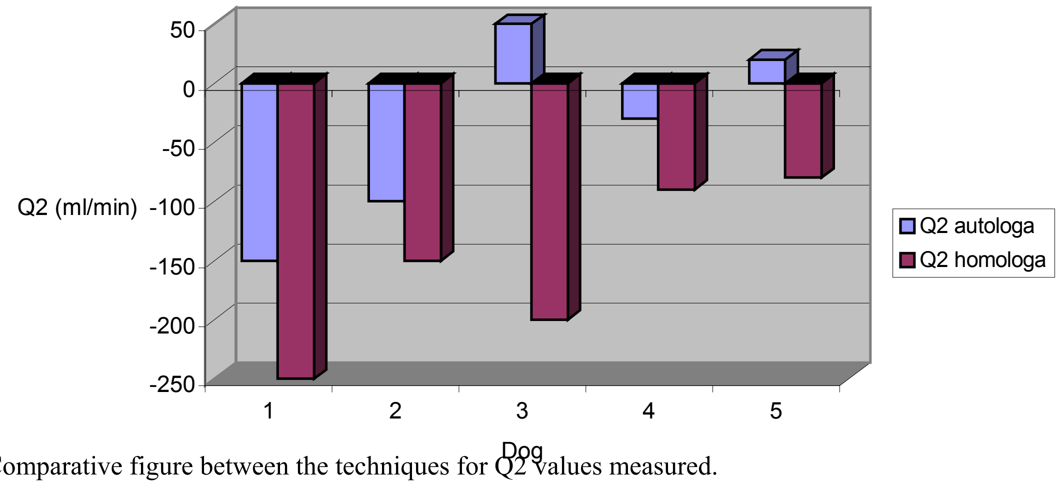

Figure 7. Comparative figure between the techniques for Q2 values measured.

The table and figure below shows a comparison of Q3 values measured for the two different graft technique.

Table 5. Comparison of Q3 values (autologous and homologous vein).

Aulogous Graft (Q3 – ml/min.)	Homologous Graft (Q3 – ml/min.)
300	450
300	480
400	750
400	850
900	900

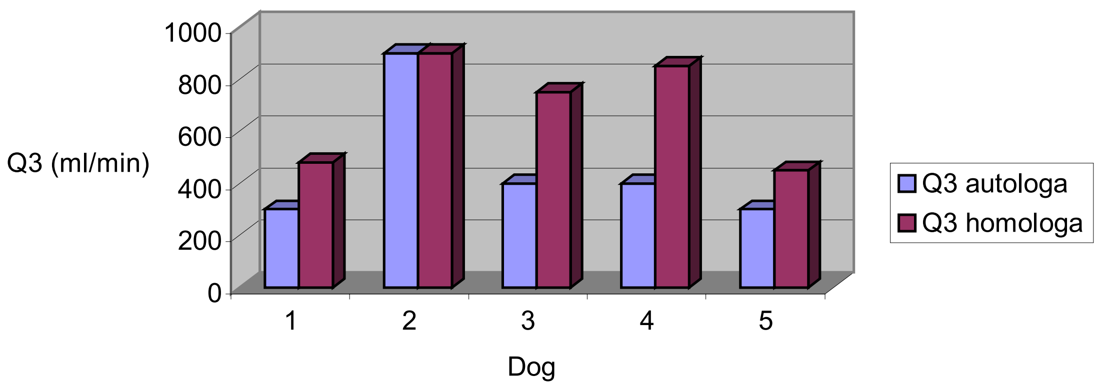

Figure 8. Comparative figure between the techniques for Q3 values measured.

The table and figure below shows a comparison of Q4 values measured for the two different graft technique.

Table 6. Comparison of Q4 values (autologous and homologous vein).

Aulogous Graft (Q4 – ml/min.)	Homologous Graft (Q4 – ml/min.)
200	450
320	480
350	500
350	700
600	700

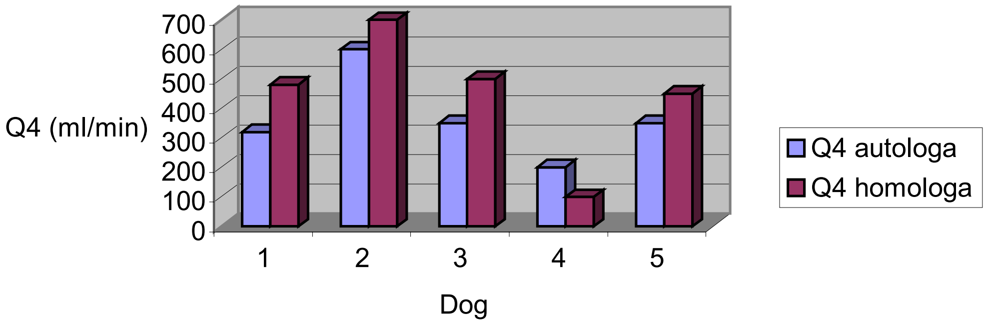

Figure 9. Comparative figure between the techniques for Q4 values measured.

5. Conclusion

Kruhmaar et al (1975), Dawkins et al (1975), Lavigne et al (1977) and Yoshida et al (1988) reported that the dog is an animal very used in several models of FAV for flow study and communications between arteries and veins. Fung (1997) reported that the value of Womersley number $\left(W = L\sqrt{\frac{\omega}{\nu}}\right)^{*}$ for main artery system of the dog is similar of the man which means that scale effect of pulsatile flow in the arterial system is minimized when compared with the blood flow of a man. Otherwise the dog anatomy is familiar and simple to handling. Therefore, the dog was the appropriate animal for the accomplishment of the procedure and of the flow measures in the vessels.

It is possible to conclude in this initial work that the use of homologous vein is more convenient in terms of maintenance of geometric structure of the vessel as we can see in Fig.3. The volumetric flux results however can not give us which is the better solution in terms of flux through the FAV. The continuity of this research is necessary, particularly in terms of shear stress measurements, so that could be possible to correlate volumetric flux with the values of shear stress that could cause stenosis or endothelium damage.

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8. References

May, J., Tiller, D., Johnson, J., Stewart, J. and Sheil, A.G.R.,1969, “Saphenous-vein arteriovenous fistula in regular dialysis treatment”, N Engl J Med, Vol.280, pp.770.

Haimov, M., Burrows, L., Baez, A., Neff, M. and Slifkin, R.,1973, “Alternatives for vascular access for hemodialysis: Experience with autogenous saphenous vein autografts and bovine heterografts”, Surgery, Vol. 75, pp. 447-52.

*W→Womersley number; L→characteristic lenght of the vessel; ω→angular velocity; ν→cinematic viscosity.

Piccone, Jr. V.A., Sika, J., Ahmed, N., Leveen, H.H. and Discala, V.,1978, "Preserved sahenous vein allografts for vascular surgery", Surg Gyn Obs, Vol. 147, pp. 385-90.
Mindich, B.P., Silverman, M.J., Elguezabal, A. and Levowitz, B.S.,1975, 'Umbilical cord vein fistulae for vascular access in hemodyalisis", Trans Am Soc Artif Intern Organs, Vol. 21, pp.273-80.
Levowitz, B.B., Flores, L., Dunn, I. and Frumkin, E.,1976, "Prostehetic arteriovenous fistula for vascular access in hemodyalisis", Am J Surg, Vol. 132, pp. 368-72.
Gonzalez, J., Dufek, J. and Kahn, D.,1977, "Preservation and long term patency of venous grafts", Surg Forum, Vol. 38, pp. 217-8.
Fung, Y.C., 1997, "Biomechanics: Circulation", Springer, New York, New York, 571 p.
Kruhmaar, D., Shmidt, H.D. and Shulz, U.,1975, "Quantitative evaluation of retrograde arterial flow in chronic experimental ateriovenous fistulas", Basic Res Cardiol, Vol. 70, pp. 29-45.
Dawkins, Jr. H.G., Vargish, T. and James, Jr. P.M.,1975, "Comparative hemodynamics of surgical arteriovenous fistulae in dogs", J Surg Res, Vol. 18, pp. 169-75.
Lavigne, J.E., Messina, L.M., Golding, M., Kerr, J.C., Robson, I.I.R.W. and Swan, K.G.,1977, "Fistula size and hemodynamic events within and about canine femoral arteriovenous fistula", J Thorac Cardiovasc Surg, Vol. 74, pp. 551-6.
Yoshida, W.B., Maffei, F.H.A. and Lastoria, S.,1988, "Lumbar sympatectomy and distal arteriovenous fistula as adjuncts to prevent arterial rethrombosis after thrombectomy: experimental study in dogs", J Cardiovasc Surg, Vol. 29, pp. 19-25.