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LONG-TERM PATENCY OF A RAK COLLAGEN VASCULAR PROSTHESIS

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A b s t r a c t

Knitted prostheses are the most frequently used vascular substitutions. The RaK collagen knitted prosthesis is a Czech product designed and manufactured by the Hosiery Research Institute (Výzkumný ústav pletařský) in Brno. They are impregnated with collagen during the manufacturing process. Collagen ensures their impermeability, minimal blood loss during implantation and good healing. The aim of this retrospective study was to evaluate the results of vascular operations based on the RaK prostheses, with particular attention paid to their long-term patency. The study included 80 patients who were operated on at the 2nd Department of Surgery in the period from 1992 to 1996. Vascular surgery was performed in the aortofemoral area and the underlying diagnoses were Leriche's syndrome, asymptomatic aneurysm of the abdominal aorta, stenosis or obliteration of the iliac bed and symptomatic aneurysm of the abdominal aorta. The most frequent risk factors recorded in the patients studied were: smoking, disorders of lipid metabolism, and hypertension. Twenty-five patients (31.2 %) had undergone vascular surgery before they were included in this study. Within 3 years of surgery, nine patients (11.2%) experienced obliteration of the prosthesis. At 12, 24 and 36 months after surgery, the prostheses were patent in 92.5%, 90 % and 88.8 % of the patients, respectively. It is concluded that the RaK collagen prosthesis is a Czech product of high quality, low price and parameters comparable with the other types of vascular prostheses currently used.

K e y w o r d s

Long-term patency, Vascular prosthesis, Aortofemoral bed

INTRODUCTION

Typical characteristics of synthetic arterial substitutions are porosity, durability, dilatation, flexibility, inertia, thrombogenicity and sensitivity to infection. In 1952, Voorhees and his colleagues demonstrated that porous synthetic material can serve as a satisfactory vascular substitution *(10).* It has never been found out why porosity is inevitable for the correct function of a prosthesis. For a long time it was assumed that if the knitted wall of a prosthesis was porous enough, fibroblasts from the surroundings would grow through it and would help to produce a biological surface in the lumen which had the structure of a neointima lined with pseudoendotel. Today it is known that the neointima is formed only in the range of several centimetres from the site of anastomosis and that this applies more to proximal anastomoses than distal anastomoses. In long bypasses, their central part remains covered by more or less organised fibrin that

is anchored in pores of the prosthesis. That is why a new epithelium is more dependent on haemodynamic factors than on in-growth of connective tissue through the prosthesis. This notion is supported by the fact that the use of practically non-porous prostheses made of expanded polytetrafluorethylen (PTFE) has been successful. The necessity of high wall porosity, as strictly required before, was therefore no longer the issue.

Another important quality is the durability of synthetic prostheses. The first prostheses made of Nylon were not satisfactory. Dacron and Teflon fibres were regarded as more convenient. Teflon proved to be least reactive and most resistant. Dacron lost approximately 25% of its elasticity in a year, but Teflon remained as elastic as it was before implantation.

All implanted vascular prostheses dilate after some time, sometimes more than by 25% of their original diameter *(10).* The dilatation itself usually does not cause rupture but it can influence turbulence within the prosthesis and, in this way, induce development of thrombosis.

The flexibility of a vascular prosthesis is related to the fact that the prosthesis can be bent without forming loops. This is especially important in long grafts. In synthetic prostheses, flexibility is primarily achieved by crimping of the prosthesis wall or by use of elastic threads. External spirals or external plastic coils were used to prevent breaking of PTFE prostheses.

Thrombogenicity of the internal prosthesis surface is a limiting factor for application of many kinds of materials. A crucial aspect is also a sufficient blood flow rate; the minimal limit is 150 ml/min for most prostheses. The exceptions are PTFE prostheses because they retain good patency even in the case of a lower flow rate (100 ml/min). Immediately after contact of the blood with the internal surface of a prosthesis, the surface is covered with serum proteins. This is followed by infiltration with leukocytes, fibrin, and erythrocytes that cover the surface. If this process is time-limited, there is a chance that the prosthesis will function correctly. If the deposition of cells and fibrin continues beyond a certain limit, occlusion may occur.

Serious infections of prostheses after implantation appear in 2–6 % of cases, even though antibiotics are prophylactically administered. The general experience is that a prosthesis once infected will not heal and must be removed (*Firt, 1991).* Since the mid-1970s, there have been attempts to create an antibacterial surface of the prosthesis by means of various surface adaptations and impregnation. *Moore* and his colleagues used, for the first time, collagen as a vehicle for linking Amikacin with knitted Dacron. This kind of adaptation has been further developed and used, in modification with Gentamicin, by the Brno producer.

The number of different kinds of vascular prostheses that are produced today is enormous. Three basic groups are distinguished according to the technology of production and, to a certain extent, to the characteristic features of the prostheses.

Knitted prostheses. This is the largest group. The wall of knitted prostheses is made of synthetic fibres, most often polyester. The gradual development has led to a compromise between the porosity necessary for anchoring the internal layer of fibrin, which is gradually being deposited, and the possibility of an efficient preclotting of the prosthesis (this is necessary because large pores would induce excessive bleeding through the prosthesis wall and thus cause an enormous perioperative blood loss). On the other hand, a disadvantage of the prostheses that are too tightly knitted is a worse healing process and more difficult suturing. The knitted prosthesis has a high-quality porous grid, it heals up more quickly than woven prostheses but it requires preclotting.

The last stage in the development of knitted prostheses is characterised by prostheses whose walls have been impregnated with collagen or gelatin during the manufacturing process. This fact ensures wall impermeability and, therefore, a minimal blood loss during implantation. Good healing is made possible by means of the gradual absorption of an artificially applied collagen layer. This type of knitted prosthesis does not require preclotting.

Woven prostheses. The manufacturing technology ensures that this type of prosthesis has only a negligible wall porosity. This prosthesis does not require preclotting before implantation, and bleeding through its wall is minimal. However, in arteries with a low blood flow rate, this quality is a drawback because the layer of fibrin on the internal wall is not sufficiently embedded due to the fact that it has practically no porosity. It may happen that the layer is detached and causes thrombosis. In arteries with a high flow rate (thoracic and abdominal aortas), s strong blood stream does not permit formation of a thick fibrin layer. Thus in arteries, implantation of knitted prostheses has an outcome similar to the use of woven prostheses. The latter, however, may fray at ends when cut, which is a certain disadvantage *(1).*

Polytetrafluorethylen (PTFE, Teflon) prostheses. Although this prosthesis is not porous, a system of multiplex microscopic cavities on both the internal and the external surface of the prosthesis is sufficient to facilitate anchoring of the inner fibrin layer. Because the wall is not solid enough, the surface of this prosthesis is strengthened with a grid, made from synthetic fibres, that is firmly fixed to the external side of the wall. Since 1972, when this Teflon prosthesis was introduced for the first time in vascular surgery, it has increasingly been used, especially for vessels small in diameter. The advantage of these prostheses is a minimal blood loss during their implantation and long-time patency, even when the blood flow rate is low (100 ml/min). Their main disadvantage is their high price.

At the 2nd Department of Surgery at the Faculty of Medicine in Brno, vascular surgery has a long tradition and has included cooperation with the Hosiery

Research Institute in the development of synthetic arterial grafts and research on their utilisation.

At present, knitted prostheses saturated with collagen are preferred in most of the arterial substitution cases. They are applied to the whole length of the abdominal aorta and iliac arteries as far as the inguinal ligament. When effusion is sufficient and when it is not possible to use an autologous venousl graft, they are also used in the femoropopliteal area above the knee joint.

The aim of this retrospective study was to evaluate clinical experience with this type of vascular prosthesis at the 2nd Department of Surgery and to compare some relevant parameters (especially long-term patency) with the results obtained by other researchers. This paper is related to a study on the RaK knitted collagen prosthesis carried out by Staffa, at the Brno Hosiery Research Institute in 1998 *(8)*.

MATERIALS AND METHODS

The methodology of this clinical study complies with the requirements of the European standard EN 540 issued by the Commission for European Normalisation. The record of clinical research was kept in accordance with the European standard EN 12006-2 requiring that the monitored group must consist of at least 75 patients and that clinical research must continue for at least 12 months after the last prosthesis had been implanted in the patient group studied.

The long-term patency of collagen vascular prostheses was evaluated in the group of 80 patients who met the requirements of a retrospective study, i.e., the relevant medical and personal histories were available from either records or interviews and the period of monitoring lasted at least 36 months.

The number of patients undergoing vascular surgery in the 2nd Department of Surgery between 1992 and 1996 was, in fact, much higher but the majority of them could not be included in the group studied because they failed to come to the in-patient vascular care centre for regular check-ups. Therefore, the general state of patency of vascular prostheses cannot be assessed accurately, although it can be assumed that, in most cases, it was sufficient (otherwise the patients would have suffered from obliteration and would probably have come to the vascular care centre).

Patients with ruptured aneurysm of the abdominal aorta who had been admitted to the hospital, had been operated on and had died in the early postoperative period were not included in this study. These patients had a high postoperative mortality that did not permit a long-term monitoring of prosthesis patency; their death was not connected with prosthesis implantation but was the result of an overall serious condition. On the other hand, all the patients at risk whose death occurred due to occlusion or some other complication connected with the implantation of a synthetic vascular prosthesis were included.

In our group, prosthesis patency was evaluated by objective examination (pulse rate, sonography). The patients were examined at regular intervals, i.e., at 1, 3, 6 and 12 months after sugery and then every sixth month. The state of prosthesis patency was described in medical records together with any complications; complications before postoperative day 30 were regarded as early, after day 30, as late.

RESULTS

Patients

Our group consisted of 80 patients who had the same number of vascular operations in the aortofemoral area. *Table 1* shows the percentage of male and

Table 1

Number of patients and operations in the 1992/1996 retrospective study

Year	Total number	Men (%)	Women(%)
1992	8	8 (100)	0 (0)
1993	20	20 (100)	0 (0)
1994	20	19 (95)	1 (5)
1995	29	26 (89,7)	3 (10,3)
1996	18	17 (94,4)	1 (5,6)
Total	95	90 (94,7)	5 (5,3)

Table 2

Average age of the patients

Year	Total number	Total average age	Number of males	Male average age	Number of females	Female average age
1992	8	53,1	8	53,1	0	0,0
1993	20	57,0	20	57,0	0	0,0
1994	20	56,0	19	55,8	1	58,5
1995	29	55,0	26	56,5	3	49,3
1996	18	60,8	17	59,9	1	76,3
Total	95	56,5	90	56,5	5	61,4

Table 3

Number of patients in different age categories

Age category	No. of patients (%)
20–29	1 (1,0)
30–39	0 (0,0)
40–49	24 (25,3)
50–59	32 (33,7)
60–69	30 (31,6)
70–79	8 (8,4)
Total	95 (100)

female patients and the number of operations in the years 1992–1996. The average age of the patients was 57 years. Age differences between the male and female patients are shown in *Table 2* and the frequency of vascular surgery in relation to age is presented in *Table 3.*

Table 4 shows that the most frequent diagnosis in our group was Leriche's syndrome, which was found in 38 patients (47.5%), the second most frequent was asymptomatic aneurysm of the abdominal aorta (13.8 %), and the stenosis or obliteration of the iliac bed (11.3%) and symptomatic aneurysm of the abdominal aorta (11.3 %) each ranked third.

According to the Fontain classification of ischaemic disease of lower extremities, 47 patients (58.8 %) had the preoperative stage IIB, i.e., they complained of limping after walking 200 m or less. The patients who limped after walking more than 200 m were classified as having stage IIA (14 patients, 17.2%). Five patients (6.3 %) who had pain at rest were classified as stage III.

The major risk factors involved in the development of vascular disorders, as recorded in our group of patients, are listed in *Table 5.*

Surgical procedures and their outcome

Before surgery, all the patients had been examined and prepared by an internist; before the implantation of a vascular prosthesis, they were treated with antibiotics (i.v. doses of Zinacef) usually for 2 or 3 days. Reconstruction surgery was carried out under epidural, general, or balanced anaesthesia. Three minutes before the application of vascular clips, total heparinisation was accomplished; depending on the length of the operation, it was again administered after 60 minutes and, at the end of the operation in indicated cases, it was neutralised by protamine sulphate . However, in several patients with very bad effusion, heparin was allowed to subside spontaneously. Of the 80 patients, 25 (31.2 %) had undergone vascular surgery before and 55 (68.8 %) were operated on for the first time. Thirty-three patients (41.3 %) received support medication; anticoagulants (Anopyrin, Curantyl) were given to 23 of them (28.8 %), seven patients took Pelentan (8.8 %) and 3 (3.8 %) were given other supportive substances.

Postoperative complications were either early (within 30 days of surgery) or late (after day 30) *(Table 6)*. Infections of the skin and subcutis (stage I according to Szilagyi) were most frequent and affected 15 patients (18.8 %). They were also associated with several reoperations other than vascular (necrectomy of a wound healing per secundam or_resutured). One patient had to undergo a vascular reoperation, five patients died in the early postoperative period (at 2, 12, 16, 21, and 27 days after surgery, respectively). All of the patients who died showed several risk factors and had ischaemic heart disease before the operation. Only in one patient was the cause of death directly connected to the implanted prosthesis that had become infected (stage III according to Szilagyi).

Table 4

Diagnoses in patients undergoing vascular surgery

Diagnosis	Leriche sy	aAAA	sAAA	rAAA	Other aneur.	Sten. AIC	Sten. AFS
Number	46	11	9	2	2	13	17
%	48,4	11,6	9,5	2,1	2,1	13,7	17,9

aAAA, asymptomatic aneurysm of the abdominal aorta; sAAA, symtomatic aneurysm of the abdominal aorta; rAAA, rupturing aneurysm of the abdominal aorta; other aneur., other aneurysm; sten.AIC, stenosis or obliteration of the iliac bed;

Table 5

Risk factors present in the patients

Risk factor	No.	%
Smoking	51	63,8
Diabetes mellitus	34	42,5
Hypertension	42	52,5
Hyperlipopretinemia	43	53,8
Excess weight	19	23,4

Table 6

Early complications including death

Type of complication	Number of operation	% of operation
Embolism	1	1,3
Bleeding	2	2,5
Skin and subcutis infection	15	18,8
Prosthesis infection	2	2,5
Vascular reoperation	1	1,3
Compartment syndrom	3	3,8
Other reoperation	12	15,0
Exitus	5	6,3

Late complications were less frequent; thrombosis occurred most often (6 patients; 7.5 %) and resulted in the vascular reoperation in four patients. Infections of the skin and subcutis (Szilagyi I) were treated in the out-patient department (2 patients). The patient operated on for Leriche's syndrome died on the 38th postoperative day from peritonitis because of a pancreatic fistula. No late infection of a vascular prosthesis was diagnosed (Szilagyi III) *(Table 7).*

Long-term patency of vascular prostheses

From the total number of 80 vascular operations performed in the aortofemoral area, obliterations were recorded in nine patients (11.2 %) within three years of the operation (at 352 days on average) . The patency of RaK collagen prostheses was 92.5% after one year, 90 % after two and 88.8 % after three years. One case of death was associated with obliteration of the prosthesis due to infection. Successful thrombectomy was carried out in five patients and mid-thigh amputation was performed in three patients. In the group investigated, mortality was 7.5 % and six patients died at a average of 19 days after vascular surgery; their average age was 69 years.

Using Fischer's exact test, we analysed the role of risk factors in the development of obliteration of the vascular substitute. There was no significant difference in the presence of the selected risk factors between the patients who had obliteration and those who had not.

DISCUSSION

This retrospective study included 80 patients who had RaK collagen vascular protheses implanted in the aortofemoral area. Twelve months after vascular surgery, the prostheses were patent in 92.5% of the patients; they were still patent in 90 % and 88.8 % of the patients after 24 and 36 months, respectively. In nine patients who had vascular prosthesis obliteration, no involvement of risk factors such as smoking or obesity was found. This can be explained by a low number of patients studied or by the fact that the factor limiting the function of a vascular prosthesis is the state of the effusion tract and not smoking habits or obesity of a patient.

In the past 10 years, many reports dealing with long-term patency of vascular prostheses implanted in the aortofemoral region have been published. The proportion of patients with potent prostheses at three years after vascular surgery ranged from 89 % to 92 %, as reported by *De Vries and Hunink* (89 %), *Littoy et al*. (91 %), *Mazuch et al*. (90 %), *Nevelsteen and Suy* (92 %), *Staffa et al.* (90,7 %). Our results are comparable with the findings of the authors mentioned above and, therefore, we can conclude that the RaK collagen prosthesis developed and manufactured by the Hosiery Research Institute in Brno is a prosthesis of high quality that fully meets the requirements of long-term patency *(7).*

Table 7
Late complications including death

Type of complication	Number of operations	% of operations
Thrombosis	6	7,5
Atherosclerosis	2	2,5
Skin and subcutis infection	2	2,5
Other reoperations	1	1,3
Vascular reoperations	4	5,0
Exitus	1	1,3

Infections of the skin and subcutis (Szilagyi I), which are clinically manifested as deteriorated healing of operation wounds, were recorded in 15 patients (18.8 %) as early complications. Their relatively frequent occurrence can be explained by the fact that more than 40 % of our patients suffered from diabetes.

Two patients (2.5 %) suffered from infection (Szilagyi III) of their vascular prostheses. This value was within the range reported in the literature, which was 0.7–6.0 % *(2)*.

When the economic costs were compared, implantation of a RaK collagen vascular prosthesis was almost four times cheaper than implantation of any foreign-made prosthesis with comparable parameters.

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