THE ROLE OF PERIPHERAL VASCULAR RESISTANCE IN DETERMINING THE INFRAINGUINAL ARTERIAL RECONSTRUCTION PATENCY

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ABSTRACT

OBJECTIVE: To find if there is any correlation between the peripheral vascular resistance, its change following an intragraft prostaglandin infusion and the infrainguinal reconstruction patency.

PATIENTS AND METHODS: Ninety-seven patients with infrainguinal reconstructions were included in the study: in 48 patients they were compromised (32 with graft thrombosis and 16 with stenosis of the distal anastomoses); 49 patients had their bypasses patent for no less than 12 months.

Intraoperative flowmetry was performed on the target artery under the distal anastomosis, after declamping, and after a five-minute intragraft prostaglandin infusion.

We measured the peripheral vascular resistance (PVR) by two methods - as a ratio of the invasively measured average pressure to the average blood flow volume (mmHg/ml/min. = peripheral resistance unit [PRU]) and by using the readings by the flowmeter (ohms).

RESULTS: The decrease of peripheral resistance was calculated in the functioning and the compromised reconstructions after administration of prostaglandin. We found that if PVR decreases 4.5 times (in ohms) the prognosis is good; we can make the same positive prognosis when the ratio of the mean invasively measured pressure to the mean blood flow volume \((P_{mean}/Q_{mean})\) decreases more than four times.

Values greater than 1.07 ohms, after peripheral vasodilatation, are indicative of high peripheral vascular resistance, at a level of specificity of 86%, and values greater than 0.57 PRU – at a level of specificity of 87%.

CONCLUSION: Although PVR measurements cannot predict with absolute certainty that bypasses under the inguinal ligament shall stay patent for a long time, it is a valuable indicator showing the immediate outcome of reconstruction work carried out with the patient on the operating table. Finding any technical errors and dealing with them saves time and money, as well as prevents the stress on the part of patients caused by the required additional revisions and multiple operations.

Key words: intraoperative flowmetry, peripheral vascular resistance (PVR), prostaglandins

INTRODUCTION

The blood circulatory system is made up not of solid, firm pipes, but of elastic vessels. The elastic quality of the arteries allows them to adapt to the work of the heart, which leads to smooth, almost continuous blood flow through them.1-3

Peripheral vascular resistance (PVR) is defined as the ratio of perfusion pressure to blood flow in the vascular system. Ascer and other researchers measure it in their studies.4,5 They calculate the linear vascular resistance using Ohm’s law, known as Druck’s Quotient, and measure the flow speed while administering saline solution or blood in the artery at a constant speed of the perfusion and the pressure is measured. Some authors use constant pressure in injecting the solution and measure the speed of the flow.6

Ascer and Beard have shown that intraoperative measurement of the distal resistance is predictive for the outcome of femorodistal bypasses. Some authors define a cut-off point beyond which the femorodistal grafts tend to reocclude. Attempts have been made to establish the level of resistance over which surgeons must opt for amputation instead of artery reconstruction, and determine the levels at which the graft opening can be ignored in case
reocclusion occurs early in the postoperative period.

PATIENTS AND METHODS

Resistance (R) is a function of the entry pressure and the blood flow with the blood flow considerably easy to measure using echographic devices for transit time. The ratio of mean pressure and mean flow ignores the pulsatile character of the blood flow, yet provides a useful idea of the condition of the distal vascular bed.

The run-off artery resistance measured at the operating table after declamping is normally much higher than that in a wakeful patient, resulting from the vessel constringent effect of the surgical exposure, the ischemic condition and reperfusion. This constraint is compensated by measuring the PVR after stimulation with a vasodilatation agent: this is referred to as “induced resistance” or “flow reserve”. This manoeuvre shows clearly, and this was done by several researcher teams, that there is an evident correlation between vascular resistance and the reconstruction patency.

We included in the study 97 patients with infrainguinal reconstructions performed under spinal anesthesia over a period of 12 months. Forty-eight patients with compromised arterial reconstruction (32 with thromboses in their grafts and 16 with stenosis of their distal anastomoses) and 49 patients with preserved patency of their bypasses over a period of 12 months. The bypasses we studied had different levels of distal anastomoses and different material for the grafts. All studied grafts (16 made of polytetrafluorethylene, PTFE and 20 - of polyester) were 6 mm in diameter and 38 cm in length, three of the PTFE grafts having a length of 48 cm. In 48 patients we used VCM, and in 4 - v. parva, dividing them according to the vein diameter over and under 3.5 mm.

The intraoperative measurement of the blood flow was performed using a VeriQ flowmeter and perivascular probes of Medi-Sims AC, Oslo, Norway. The first measurement of the blood flow and peripheral pressure was performed after completing the distal anastomosis and declamping. The blood flow probe was positioned immediately under the distal anastomosis, and the pressure cannula - no more than 10 mm away. The mean values of the pressure and the volume of the blood flow were registered; then we infused for 5 minutes a solution of 10 μg of prostavasin or 7 μg of ilomedin. After their administration we again checked the pressure and blood flow.

Two methods were used in measuring the peripheral vascular resistance: the one was by the procedure described by Ascer as a ratio of the invasively measured pressure to the mean volume of the blood flow - R=P/Q (PRU) and the other – by using the readings automatically provided by the flowmeter (ohms).

STATISTICAL ANALYSIS

Statistical analysis of the flowmeter readings of the successfully functioning and the compromised reconstructions was performed using SPSS 12.0. The mean values and the standard deviations were calculated. The t-test was used to compare the significant differences at a level of significance of P = 0.0001 for two variables and ANOVA - for more than two variables. The graphic presentation utilised the Kruskal-Wallis analysis, and the receiver operating characteristics curves (ROC).

RESULTS

We compared the flowmeter readings for the functioning and the compromised reconstructions and calculated the decrease of the resistance after the prostaglandin administration (the ratio of the values before and those after infusion in two groups - R/Rv compromised and R/Rv functioning grafts). We found a significant difference between the two groups (t = 15.745; P = 0.00007) (Fig. 1), but there were values in the compromised grafts group that were 75% of the results in the functioning graft reconstruction group. This was the ground for our conclusion that the PVR decrease after prostaglandin administration
was 4.5 times more reliable prognostic criterion. The specificity of PVR read on the flowmeter (R/Rv-Ohm) in the two groups after the drug infusion was assessed using the receiver operating characteristics curve analysis (Fig. 2).

Values higher than 1.07 ohms, after peripheral vasodilatation, are highly prognostic for high PVR, at a level of specificity of 86%.

We calculated the PVR also as a ratio of the measured mean values of pressure and the volume of the blood flow under the distal anastomoses. We calculated the PVR decrease after prostaglandin infusion and compared the results of the two groups (Fig. 3). The difference was statistically significant (t = 22.756; p = 0.00000).

We found that the data in both groups overlap until the resistance decreased less than 2.5 times for 75% of the results of the compromised grafts and 3.6 times - for the functioning grafts. We believe that a decrease by more than 4 times is a more reliable prognostic criterion for permanently operating bypasses. The conclusion is valid only for the condition of the arterial segment under the distal anastomosis.

The specificity of PVR calculated as a ratio of the values of the measured pressure and volume of the blood flow (P/Q, PRU) in the two groups after the drug infusion was assessed using the receiver operating characteristics curve analysis (Fig. 4).

Values higher than 0.57 mPRU, after peripheral vasodilatation, are highly prognostic for high PVR, at a level of specificity of 87%.

![Figure 2](image_url)  
**Figure 2.** ROC curve analysis: Resistance of compromised grafts (+), Rv of functioning grafts (-); Area under the curve = 0.864; 95% CI: 0.799 - 0.929. Optimal cut-off point = 1.07 ohms.

![Figure 3](image_url)  
**Figure 3.** Decrease of PVR (P/Q, PRU) in the two groups after prostaglandin infusion.

To establish if there is any significant difference between the data for reconstructions with stenosis and those with thrombosis we compared separately the data with those for the functioning bypasses using ANOVA for comparison of more than two groups. We compared the changes in the ratios after the MB but found no significant differences between the reconstructions with stenoses and those with thromboses PQ/PQv(stenosis) / PQ/PQv(thrombosis) (P = 0.8377) (Fig. 5) and R/Rv(stenosis) / R/Rv(thrombosis) (P = 0.8377) (Fig. 5) and R/Rv(stenosis) / R/Rv(thrombosis) (P = 0.8377).

![Figure 4](image_url)  
**Figure 4.** ROC curve analysis: P/Q compromised (+), (P/Q)v functioning (-); area under the curve = 0.875; 95% CI = 0.816; 0.935. Optimal cut-off point = 0.57 PRU
Rv(thromboses) (P = 0.1388) (Fig. 6). The difference between the compromised bypasses and the functioning bypasses was statistically significant in the two methods of measurement of PVR.

**DISCUSSION**

The usual methods for assessing the peripheral outflow resistance are as a whole related to the worth noting here that in the two groups the results of the measurement showed, based on the great range of variation, a high overlap rate (between 0.5 and 1.2 PRU), so a prognosis whether a bypass is patent or occluded is impossible to make in some studies with small number of observations. Parvin et al.\(^{11}\) have shown that occlusion rate considerably rises if the peripheral resistance exceeds 0.45 PRU during the first 30 days.

Our results, presented here by the ROC curve analysis, showed that resistance greater than 0.57 PRU (Fig. 4, at a level of specificity of 87%) and more than 1.07 ohms (Fig. 2, with 86% specificity) after prostaglandin infusion indicate that PVR is high and the artery reconstructions may not last long.

As there is a large overlap of data from PVR for the compromised and the functioning infraintimal reconstructions we think that using the post-prostaglandin infusion change in PVR is of little prognostic value for the vascular reconstructions performed under the inguinal ligament.

And yet if PVR intraoperatively is greater than 0.57 ohms and 1.07 PRU after prostaglandin infusion it may suggest that there might be a technical fault or that there is a distal vascular segment seriously affected by the disease.\(^{12}\)

PVR depends on the degree to which the distal arterial segment has been affected by the disease and less so on the graft’s characteristics.\(^9\)

Lundell and Bergqvist reported that the increased peripheral resistance bears a higher prognostic value for an early graft occlusion than measuring the minute volume of the blood flow has. In patients with severe peripheral atherosclerosis one could expect a bit less increase of the prostaglandin flow\(^{13}\) as compared with patients with good run-off resistance. The graft patency and preservation of the limb, after femorodistal bypass, depend directly on the outflow resistance.

The difference in the patency of grafts with high and low PVR (in non-pulsatile flow) is not large. Although it is the bypasses with low PVR that perform better, the resistance’s prognostic value in determining the one-year patency of peripheral vascular reconstructions is rather small.

No changes in the studied parameters after intragraft administration of prostavasin and ilomedin suggest that there is a problem in the technical implementation of the reconstruction or that there is much more serious multisegment affection of the distal arterial segment by the atherosclerotic changes.\(^{14}\)

We found no differences in the prognostic value
for differentiation of the development of stenosis from that of thrombosis in the late post operative period considering the different severity of the lesion of the distal arterial segment.

Endothelial lesion during vascular surgery, the anastomoses and the gradient of blood flow tangential pressure (shear stress) are the major reasons for the development of intimal hyperplasia\textsuperscript{15}, leading to stenosis around the anastomoses. Wall shear stress\textsuperscript{16} is related to flow and inversely related to diameter. It seems that there is an optimal shear stress, whether it is absolute or a gradient, determined by the size of the flow, at which no intimal hyperplasia occurs.\textsuperscript{17} Further progression of the disease, changes in the size of the flow and intimal hyperplasia are the major causative factors for development of thrombosis in the bypass during late postoperative period.

CONCLUSIONS

The intraoperative measurement of flow and the invasive arterial pressure are like a screening study to find cases that need further investigation using Doppler, duplex or angiography.

As the PVR prognostic value (for non-pulsatile blood flow) in determining the one-year bypass patency of peripheral artery reconstructions is small, other parameters that are related to the pulsatile character of the blood flow should be used. However, if there is no or little change in the PVR caused by the administration of vasodilatation agents, as well as values greater than 0.57 ohms and 1.07 PRU, it is quite likely that there is a technical error, or wrong level of distal anastomosis or distal arterial segment affected by the disease. If it is impossible to make any corrections one thing to do is the assess how serious is the postoperative therapy and follow-up of the patients.

REFERENCES

ЗНАЧЕНИЕ ПЕРИФЕРИЧЕСКОГО СОСУДИСТОГО СОПРОТИВЛЕНИЯ ДЛЯ ОПРЕДЕЛЕНИЯ ПРОХОДИМОСТИ ИНТРАИНГВИНАЛЬНЫХ АРТЕРИАЛЬНЫХ РЕКОНСТРУКЦИЙ

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РЕЗЮМЕ

Цель: Изучить связь между периферическим сосудистым сопротивлением и его изменением после интраграфтовой инфузии простагландинов меди-каментов с проходимостью интрангилингвинальных реконструкций.

Пациенты и методы: Прослежено 97 пациентов с интрангилингвинальными реконструкциями (48 с компрометированными реконструкциями: 32 с тромбозами графтов и 16 со стенозом дистальных анастомозов) и 49 пациентов со сохраненной проходимостью не менее 12 мес.

Интраоперативная флюометрия проводилась на таргетной артерии под дистальным анастомозом после деклампажа и после пятиминутной интраграфтовой инфузии простагландинов.

Авторы проследили периферическое сосудистое сопротивление (ПСС) по двум методам: как отношение между инвазивно измеренным осредненным давлением и осредненным объемом кровотока (mmHg/ml/ min = PRU) и по данным, зарегистрированным автоматически флюометром (Ohm).

РЕЗУЛЬТАТЫ: Определен спад сопротивления между функционирующими и компрометированными реконструкциями после простагландиновой апликации. После измерения в омах авторы установили, что спад свыше 4.5 раз - ПСС с хорошим прогнозом, а относительное отношение между осредненным вазодилатацией и осредненным объемом кровотока (Pmean/Q mean) спад свыше 4 раза.

Стоимости свыше 1.07 Ohm после периферической вазодилатации показательны для высокого ПСС, при уровне специфичности 86%, как и стоимости свыше 0.57 PRU – специфичность 87% показательны для высокого ПСС.

ЗАКЛЮЧЕНИЕ: Измерение ПСС не дает 100% уверенности насчет продолжительной проходимости байпасов под интрангилингвинальным лигаментом, но является показателем, ориентирующим о непосредственном исходе проведенной реконструкции еще на операционном столе. Обнаружение и устранение технических ошибок экономит время и средства, как и уменьшает стресс пациентов от дополнительных ревизий и реопераций.