JUSTIFICATION OF OPTIMAL ANGLE FOR ANASTOMOSIS IN RECONSTRUCTIVE SURGERIES ON VESSELS

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Abstract. Reconstructive surgeries on femoral-popliteal vessels compose 60-70% of all surgery types on peripheral arteries. Dominant reconstructive method in the occlusion of femoral vessels is a bypass surgery. As a material for bypass shunt both auto-vein and synthetic vessel prostheses are used. The author created a vascular anastomosis model using two tubes, put on at the angle of 90°, 75°, 60°, 30° and 15°. Mathematical calculations are made and graph describing dependence of blood flow’s resistance coefficient on blood flow’s different angles is sketched. As a result of conducted experiments and calculations, optimum angle of vessel anastomosis is defined. It is defined that optimal angle of vessel anastomosis lies in the range of 30°-40°.

Keywords: optimal angle, peripheral arteries, reconstructive surgeries on vessels, vascular anastomosis, bypass.

More than half of ill people, obliterating by vessel diseases of lower extremities have an occlusion of arteries in femoral-popliteal areas, including together with lesion in other sites. Reconstructive surgeries on femoral-popliteal vessels compose 60-70% of all types of surgeries on peripheral arteries (Kazakov Yu. I., Khatipov M. G. and other, 2007). Dominant method of reconstruction in the occlusion of femoral arteries is bypass surgery. As a material for bypass shunt both auto-vein and synthetic vessel prostheses are used (Karo, et al., 1981; Kazakov et al., 2007; Lyashko et al., 2010).

Factors that influence on the duration of bypass shunt’s operation are the levels of laid distal anastomosis, condition of peripheral canal, type of bypassing material and implementation technique of surgery. All abovementioned factors can influence on the size of volume velocity of blood flow, drop of which lower 120 ml/min can lead to the occurrence of shunt thrombosis in the early and long-term post-surgical periods (Kazakov et al., 2007). Decrease in the resistance of blood flow through shunt and increase of volumetric flow velocity through it can improve the results of reconstructive surgery.

Purpose of Research
Development of optimal parameters for vascular anastomosis in reconstructive surgeries through bypass.

Materials and Methods
To define optimal angle of vascular anastomosis a model from rubber tubes was prepared. Model is made of two joining tubes – main and attachable, with external diameter on 5 mm. On the joint, attachable tube is connected with the main one under different angles: 15, 30, 60, 75 and 90 degrees and perimeter of the joint is drawn by steel needle (Fig. 1).

After detaching jointing tube on outlined line, thread is laid with the help of which the length of virtual seam is measured.

Experiment results are given in Table 1.

Table 1
Dependence of virtual seam’s length on turning angle

<table>
<thead>
<tr>
<th>Slope angle degree (α)</th>
<th>Sine angle (sin α)</th>
<th>Length of virtual seam, mm</th>
<th>Relative length of virtual seam</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>1</td>
<td>22</td>
<td>1</td>
</tr>
<tr>
<td>75</td>
<td>0,97</td>
<td>26</td>
<td>1,18</td>
</tr>
<tr>
<td>60</td>
<td>0,87</td>
<td>34</td>
<td>1,54</td>
</tr>
<tr>
<td>30</td>
<td>0,50</td>
<td>45</td>
<td>2,05</td>
</tr>
<tr>
<td>15</td>
<td>0,26</td>
<td>56</td>
<td>2,54</td>
</tr>
</tbody>
</table>
According to table, dispersion equation of absolute length dependence of virtual seam \( Y \) on angle sine \( \alpha \) is gained.

\[
Y = 42.4x + 67.2, \quad R^2 = 0.92.
\]  

(1)

More precise such dependence is approximated by square polynomial

\[
Y = -125.2x^2 + 141.7x + 54, \quad R^2 = 1.
\]  

(2)

However, to achieve an aim – definition of optimal angle of joining two arteries, dependence (1) is reasonable to present in relative numbers. Such dependence looks as following

\[
Y = -1.94x + 3.06, \quad R^2 = 0.92,
\]  

(3)

whereas \( Y \) – relative length of virtual seam.

In the movement of blood flow through arteries on sites where directions change, local hydraulic resistance occur which provoke additional loss of blood flow (Kazakov et al., 2007). For flow’s turn at the angle \( \alpha \), resistance coefficient is solved through Altshul equation (Chugaev, 1975; Karo et al., 1981; Kazakov et al., 2007; Kiselev, 1972; Lyashko et al., 2010).

\[
\xi = \xi_{90}(1 - \cos \alpha),
\]  

(4)

where \( \xi_{90} \) – resistance coefficient in flow’s turn at 90\(^0\).

For an artery of minor diameter, acceptance of \( \xi_{90} = 1.6 \) is recommended (Kazakov et al., 2007). Then, for different turning angles of the flow, we find the value of \( \cos \alpha \) and define the value of \( \xi \). Results of calculation is given in Table 2.

According to Table 1, 2, we build a dependence of a resistance coefficient on angle sine of flow turn. It is expressed by dispersion equation

\[
Y = 2.52x - 1.12, \quad R^2 = 0.88,
\]  

(5)

Where \( Y \) – resistance coefficient \( \xi \) (Table 2); \( x = \sin \alpha \) (Table1), \( x>0 \); \( R^2 \) – dispersion coefficient.

Fig. 1. Scheme of anastomosis put on under angle 90\(^o\), 75\(^o\), 60\(^o\), 30\(^o\) and 15\(^o\)

1 - main artery,
2 - bypass shunt,
3 - artery occlusion site,
4 - anastomosis type in view.
Table 2

<table>
<thead>
<tr>
<th>Angle of flow turn (α), degree</th>
<th>Angle cosine (cos α)</th>
<th>Resistance coefficient, (ξ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>0</td>
<td>1,60</td>
</tr>
<tr>
<td>75</td>
<td>0,26</td>
<td>1,18</td>
</tr>
<tr>
<td>60</td>
<td>0,50</td>
<td>0,80</td>
</tr>
<tr>
<td>30</td>
<td>0,87</td>
<td>0,21</td>
</tr>
<tr>
<td>15</td>
<td>0,97</td>
<td>0,05</td>
</tr>
</tbody>
</table>

There is one and the same argument on the right side of equations (3) and (5) – sinα. To find optimal angle of flow turn, it is necessary to add right parts of both equations –

\[
Y = -1,94x + 3,06 \\
Y = 2,52x - 1,12 \\
Y = 0,58x + 1,94. \quad (6)
\]

Attained equation (6) is equal to zero and derived. As a result, \(Y = 0,58\) or \(\sinα = 0,58\) is gained. Then, turn angle is equal to \(35°\). This task of choosing optimal turn angle is solved graphic way. For this, on X-axis value of blood flow’s turn angle sine is put, on Y-axis – value of relative length of seam, and on another Y-axis – value of resistance coefficient (Figure 2).

![Figure 2. Graph of relative dependence of bypass shunt length (y1) and hydraulic resistance coefficient in blood flow turn from artery to shunt (y2) on angle sine (x)](image)

Then, according to Table 1, 2, graphs of dependences of relative length of seam and resistance coefficient on angle sine of a turn are built – in the figure accordingly \(Y_1=f(x)\) и \(Y_2=f(x)\). After this, ordinates of both graphs are summed up, and, as a result, new graph \(Y_1+y_2=f(x)\) is gained. On this, minimum ordinate conforms to angle sine, equal to 0,58.

Conclusion

As a result of conducted experiments and calculations, optimal angle of vascular anastomosis is defined. In the same diameter of joining arteries, optimal angle of their joining lies within \(30°-40°\).
References