

ANALYSIS AND COMPARISON OF THE STRENGTH PROPERTIES OF THE PULMONARY ARTERY WALL AND POLYVINYLIDENE FLUORIDE MONOFILAMENT THREADS DURING THE FORMATION OF A VASCULAR SUTURE

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Introduction. Vascular suturing is a crucial stage in the reconstruction of any blood vessel. The creation of a vascular anastomosis is not merely a technical procedure, but a fundamental prerequisite upon which tissue survival, the success of the operation and the patient's overall well-being directly depend. The success of the operation is largely determined by the quality with which this step is performed.

A high-quality vascular anastomosis is achieved through the interaction of a number of factors. These include: a thorough understanding of the structural features and properties of the vessel wall being anastomosed, the correct choice of suture material, and the surgeon's possession of the necessary skills and equipment. Only when these elements are combined do they guarantee the formation of a vascular suture with sufficient strength and optimal haemodynamic properties.

In most cases, surgeons worldwide opt for monofilament sutures made of polypropylene or polyvinylidene fluoride when performing vascular anastomoses. Furthermore, suture material of size 5/0 or 6/0, according to the USP classification [1, p. 1694], [2, p. 876], is usually used to connect segments of the pulmonary artery or a conduit.

Aim. To investigate the tensile properties of the pulmonary artery wall and polyvinylidene fluoride monofilament sutures during the formation of a vascular suture.

Research methods. The study was conducted on 46 specimens of cadaveric pulmonary artery. Sections of the pulmonary vessels were obtained according to the following criteria: time since death not exceeding 12 hours; age between 18 and 68 years.

During the post-mortem examination, the researcher mobilised a section of the pulmonary artery from the bifurcation of the main trunk to the intrapulmonary segments of the vessel. A 10 mm wide section of the mobilised pulmonary artery was then excised. Prior to the assessment of biomechanical properties, the section of the pulmonary artery was stored in saline solution at room temperature for no more than 2 hours.

The biomechanical study was carried out in a laboratory setting. The edge of the cadaveric pulmonary artery wall was rigidly fixed in a machine and sutured with a monofilament thread made of polyvinylidene fluoride (Coralen, Ergonest, Belarus) in

sizes 3/0, 4/0, 5/0 and 6/0 according to the USP standard, at a distance of 1 mm from the edge, maintaining a spacing of 5 mm between sutures. The suture was then secured in a laboratory dynamometer (scale division – 0.1 H). After securing the surgical suture in the dynamometer, traction was applied by moving the dynamometer along the axis of the vessel at a speed of 1 mm/s. The breaking load was recorded at the moment of vessel wall delamination (F1), complete wall rupture (F2), and also when the suture fibre broke. The breaking load is expressed in newtons (N).

Results and discussion. During the investigation of the biomechanical properties of the pulmonary artery at the site of suturing with 3/0–6/0 suture, high elastic properties of the vascular tissue were observed, which virtually prevent its wall from stretching when the suture is pulled.

In our studies, the effect of the surgical suture on the wall of the pulmonary artery at the suture site occurred in two stages.

The first stage was delamination. Segmentation of the pulmonary vessel wall along the course of the circular fibres was observed, beginning at the sutured section of the vessel and spreading in a transverse direction.

The second stage is complete rupture. With a further increase in the tensile load exerted on the surgical suture, destruction was observed in the section of the vessel located between its free edge and the site of the sutured section of the pulmonary artery.

The data obtained showed that the initial signs of destruction of the pulmonary artery wall, in the form of its dissection at the site of suturing with a 6/0 suture, were recorded at a tensile load (F1) of 1.1 N (95% CI: 1.00–1.40), which increased with an increase in the fibre diameter of the surgical suture.

Analysis of the force required to cause dissection or complete rupture of the pulmonary artery wall revealed that the force needed to damage the vessel wall at the first stage (dissection) was, on average, 46.2% lower than the force required for complete rupture of the vessel wall (Mann–Whitney, $p < 0.001$).

As in the previous stage (dissection), the level of breaking load recorded for achieving a complete rupture of a section of the pulmonary artery wall depends on the diameter of the surgical suture fibre. Thus, complete rupture of the pulmonary artery wall at the suture site using a 6/0 suture was recorded at a rupture load (F2) of 1.90 N (95% CI: 1.7–2.2), and using a 3/0 suture – at 3.1 N (95% CI: 2.8–3.5).

When suturing the pulmonary artery wall with a 6/0 polyvinylidene fluoride suture, fibre rupture was recorded in 6 out of 46 cases (13.0%), and with a 5/0 suture – in 1 out of 46 experimental cases (2.1%). No instances of fibre breakage were recorded for similar sutures of sizes 4/0 and 3/0 prior to their delamination and rupture.

According to the results of our studies, fibre breakage of surgical suture under traction was observed in one (2.1%) and in 6 out of 46 (13.0%) cases when using 5/0 and 6/0 monofilament surgical sutures, respectively.

The breaking load when suturing the wall of the pulmonary artery using a 6/0 surgical suture, which leads to its delamination, is 1.1 N, which exceeds the maximum

load requirements for this type of suture material as specified by the FDA. The tensile strength of the 6/0 do not correspond to the maximum load that can be applied when forming an inter-vascular anastomosis without damaging the pulmonary artery wall, which will lead, in almost one in seven cases, to anastomotic failure due to suture breakage. When using a 5/0 surgical suture, the highest recorded tensile strength values are 2.7 N and fall within the range of 2.2–2.8 N, which in some cases exceed the values specified by the FDA requirements for this suture material. This also explains the possibility of a fibre in suture of this size breaking when forming a pulmonary artery suture.

When comparing the breaking loads leading to delamination (F1) or complete rupture (F2) of the pulmonary artery whilst suturing its wall with 4/0 and 3/0 Coralen monofilament sutures, no statistically significant differences were observed (Mann–Whitney, $p > 0.05$).

Conclusions. Analysis of the biomechanical properties of the pulmonary artery wall during the formation of a vascular suture and the strength of monofilament sutures (polyvinylidene fluoride, sizes 6/0 and 5/0) showed that their use is inadvisable due to the risk of suture rupture. Consequently, for the creation of a pulmonary artery vascular suture, it is recommended to use suture material with an optimal combination of strength characteristics and the smallest possible fibre diameter. Among monofilament sutures made of polyvinylidene fluoride, the 4/0 suture, which complies with USP standards, is the optimal choice to meet these requirements.

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