Creating a 90° curve in polyester grafts during thoracic aortic surgery using the pleat technique

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Video clip is available online.

Open surgical repair of ascending aorta and aortic arch pathology often requires replacement with polyester tubing. One of the difficulties of this procedure is manipulating the polyester graft so that it replicates a 90° curve from the ascending aorta to the arch without creating a kink in the graft. The avoidance of graft kinking is important because kinks can cause flow obstruction and increase the cardiac afterload. Although rare, graft kinking also can result in the serious complication of hemolytic anemia, both in the postoperative period and as a long-term sequela.^{1,2} We have developed a method of creating 90° curves in polyester grafts by shortening one side of the graft with simple suturing. This unilateral graft-pleating method is presented with a mathematical solution to illustrate how much polyester grafts of varying diameters need to be shortened to obtain a 90° curve.

Initial graft length is determined by the length of aortic arch that needs to be replaced. To create a 90° curve, one side of a polyester graft must be selectively shortened to a computed length. If we consider opposite sides of the graft as arcs of 2 independent circles, we can derive a formula and solve for the length that one side must be shortened to. We begin with the equation for arc length of a circle:

$$\text{Arc Length} = [(\text{Angle of Curvature}) \times (\text{Radius of Circle}) \times \pi] / 180^\circ$$

If we define s = Graft Length, θ = Angle of Curvature and r = Radius of Circle, then:

$$s = [\theta \times r \times \pi] / 180^\circ$$

Graft of predetermined length (s_1) and diameter (d_g) is shortened on one side to a calculated length (s_2) creating a 90° curve. The length to be reduced ($s_1 - s_2$) is determined using mathematics considering opposite sides of the graft as arcs of 2 independent circles each with a separate radius (r). All graft measurements are taken with the graft in a stretched state.

Central Message

We describe a simple mathematical solution for creating 90° curves in polyester grafts that avoid kinking by shortening one side of the graft with simple suturing.

See Editorial Commentaries pages 417 and 418.

If we solve for θ :

$$\theta = [s \times 180^\circ] / [r \times \pi]$$

Because both sides are undergoing a 90° curve, we can set the equations equal to each other.

$$\theta_1 = \theta_2 \rightarrow [s_1 \times 180^\circ] / [r_1 \times \pi] = [s_2 \times 180^\circ] / [r_2 \times \pi]$$

If we define d_g = diameter of the graft, then $r_1 = (r_2 + d_g)$. We can then substitute r_2 for $(r_1 - d_g)$ and eliminate terms:

$$s_1 / r_1 = s_2 / [r_1 - d_g]$$

Solving for s_2 :

$$s_2 = [s_1 \times (r_1 - d_g)] / r_1$$

s_2 represents the length of the lesser curve of the graft, or the length of the shortened side. For example, if we have a 28-mm-diameter graft that is 8 cm in length:

$$s_2 = [8.0 \text{ cm} \times (r_1 - 2.8 \text{ cm})] / r_1$$

FIGURE 1. A, Line drawn on graft to be shortened. B, A single suture passed through each pleat of the graft forming 2 rows. C, Two ends of the suture are tied together. D, Graft reduced to appropriate length with gradual curvature and no kinks. E, Pleated graft used in surgical repair. F, Magnetic resonance 3-dimensional reconstruction showing pleated graft.

We can solve for r_1 using the following formula:

$$s_1 = [\theta_1 \times r_1 \times \pi] / 180^\circ$$

$$\begin{aligned} r_1 &= [s_1 \times 180^\circ] / [\theta_1 \times \pi] \\ &= [8.0 \text{ cm} \times 180^\circ] / [90^\circ \times \pi] \\ &= 5.093 \text{ cm} \end{aligned}$$

$$\begin{aligned} s_2 &= [8.0 \text{ cm} \times (5.093 \text{ cm} - 2.8 \text{ cm})] / (5.093 \text{ cm}) \\ &= 3.602 \text{ cm} \end{aligned}$$

Therefore, we would have to shorten 1 side of a 28-mm-diameter graft that is 8.0 cm to 3.6 cm to create a 90° curve (Figure 2). When repair necessitates the graft be curved to an angle other than 90°, the graft length is calculated by substituting the desired angle for 90° when solving for r_1 .

TECHNIQUE

The appropriate length of polyester graft that is to be shortened by is first marked on the graft as shown in Figure 1, A. A polypropylene suture is then threaded along the surface of the graft forming a U around the mark (see Figure 1, B). The 2 ends of the suture are then cinched together, shortening 1 side of the graft to the desired length (Figure 1, C and D). The pleated graft is then subsequently used in the surgical repair as depicted in Figure 1, E. One limitation of this technique is the inability to reduce the graft down by more than half of the original length. An appropriate length must be chosen that is at least double the amount the graft is going to be shortened. In conclusion, our pleating technique is a feasible method to create a 90° curve in the graft and thus avoids kinks (Video 1). This technique may make surgical treatment of aortic dissections easier and safer for select patients who require the graft to curve to conform to their anatomy. An alternative approach exists that involves suturing an implanted,

FIGURE 2. Graft of predetermined length (s_1) and diameter (d_g) is shortened on one side to a calculated length (s_2) creating a 90° curve. The length to be reduced ($s_1 - s_2$) is determined using mathematics considering opposite sides of the graft as arcs of 2 independent circles each with a separate radius (r). All graft measurements are taken with the graft in a stretched state.

VIDEO 1. The suture has been passed through each pleat of the graft for the specified length and is subsequently tied down to create an even curve. Video available at: [http://www.jtcvsonline.org/article/S0022-5223\(17\)30182-4/addons](http://www.jtcvsonline.org/article/S0022-5223(17)30182-4/addons).

pressurized graft along the lesser curve. Although not explicitly addressed here, our solution may provide insight into why this alternative technique is successful by illustrating the mathematics involved. Last, we feel both approaches offer value and can be used in conjunction if necessary.

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