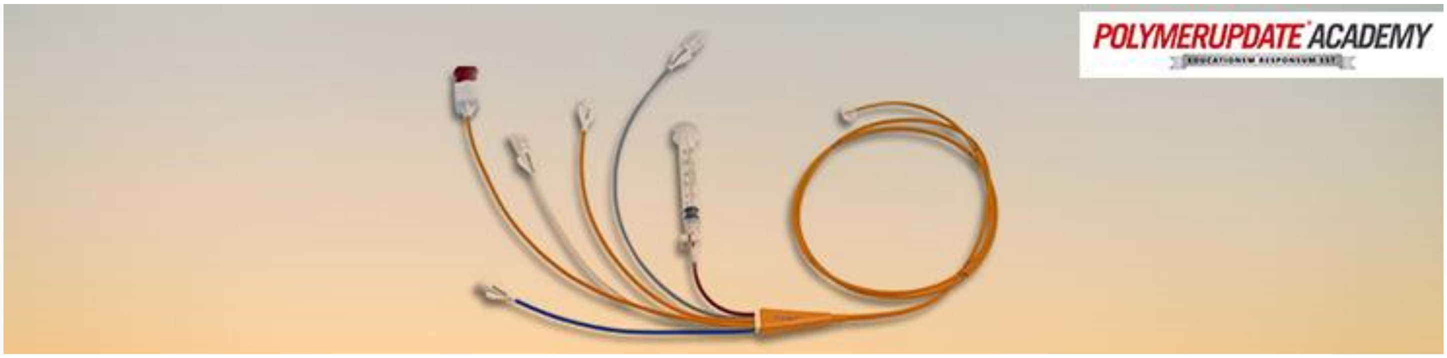

Medical Catheters and Plastics – Part III

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In the last blog (Part II of the series), we examined important parameters including the size of catheters, the selection of size and effect of the catheter dimensions on the flow of fluids through them. We shall further continue the series and focus on some of the important properties of catheters that will determine their applicability in the body. This part will concentrate on two widely used and important properties of catheters, pushability and torquability.

Pushability of catheters:

The ability of the catheter to easily navigate the complexities of the vascular system is expressed in terms of the degree of force required to push the catheter through. This degree of force is expressed as the pushability of the catheter. Catheter pushability refers to the response of a tube upon the placing of a longitudinal force along its axis. Pushability is also related to and sometimes referred to as the columnar stiffness of the catheter. Columnar stiffness is the ability to transmit force or movement from the proximal end to the distal end of a catheter. The proximal end of the catheter is defined as the portion of the catheter close to the point of attachment or insertion, whereas the distal end is the opposite of the proximal end and describes the portion furthest away from the point of insertion. The pushability of a catheter is related to longitudinal stiffness of the tube and for small deflections its behavior can be approximated as a spring system, it can be calculated as:

$$k_{long} = \frac{EA}{L} \qquad (1)$$

Where

k_{long} is the longitudinal spring constant,
E is the modulus of elasticity of the material of the catheter,
A is the cross-sectional area
L is the length of the catheter shaft.

For increased pushability, k_{long} must be increased. An examination of the above equation reveals that pushability is directly related to the material modulus and the catheter cross sectional area, whereas the pushability is inversely related to the length of the catheter. Accordingly, a maximization of k_{long} can be achieved in the following ways:

- Increasing the size of the catheter, i.e., increasing cross-sectional area of the tubing.
- Increasing material stiffness or elastic modulus
- Decreasing the overall catheter length

However, these variables are limited by the actual application, the size of the catheter is limited by the size of the blood vessel to be accessed, the stiffer the material of construction of the catheter the greater is the probability of causing injury to the vasculature and finally the length of the catheter is limited by the type of procedure and the distance between the point of insertion and the target area for diagnosis or intervention.

Torquability of catheters:

The maneuverability of the catheter through the vasculature depends upon the ability to transmit torque from the proximal end to the distal end of the catheter. Torque is the force that produces or tends to produce rotation. The degree of distal rotation is divided by the degree of proximal rotation to determine the torque ratio. The torque ratio must be such that the catheter material is able to provide sufficient rotation to the distal end of a catheter, in some case a lower torque ratio may be desirable as a lower torque ratio may provide better steering ability for the catheter.

The torsional stiffness of a catheter can be expressed by the 'Torquability' of the catheter. Again for small deflections, the catheter can be approximated as a spring system and the torquability of a catheter can be expressed as:

$$k_{torq} = \frac{GJ}{L} \tag{2}$$

Where

- k_{torq} is the torsional spring constant
- G is the shear modulus
- J is the polar moment of inertia
- L is the length of the catheter shaft

Maximizing the transmission of torque means an increase in the torquability of the catheter and this can be achieved by maximizing the torsional stiffness value, k_{torq}. One of the ways of increasing the k_{torq} value can be through maximization of the material polar moment of inertia, J.

For a tube, the governing equation for J is:

$$J = \frac{\pi}{32}(d_o^4 - d_i^4) \tag{3}$$

Where,

d_o = outer diameter of the catheter

d_i = inner diameter of the catheter

Maximization of J can be achieved through the maximization of the catheter's outside diameter as well as its wall thickness.

As the shear modulus is also directly proportional to the torquability, an increase in the shear modulus can also result in an increase in the k_{torq} value. The shear modulus is directly related to the elastic modulus of a polymer and generally expressed as:

$$E = 2G(1 + \upsilon) \quad (4)$$

Where,

E = Material elastic modulus

G = Shear modulus

ν = Poisson's ratio

Poisson's ratio is a dimensionless quantity and is generally between 0.3 – 0.5 for most plastics.

An increase in torquability can also occur with a corresponding decrease in the part length, L, as it is inversely proportional to k_{torq}. However, as with pushability, the degree of freedom with these variables in increasing the torquability is limited by the application site and the potential of injury to the blood vessels.