Introducing a polymeric device for the treatment of Abdominal Aortic Aneurysms: Design and *in vitro* performance

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Introuction: The formation of aneurysms is an extremely dangerous degenerative pathology of arterial tissues, especially common in adult and elderly populations, whereby the wall of the artery weakens locally and largely expands. In more than 80% of abdominal aortic aneurysms (AAA), the rupture of the aneurysmal sac is fatal.

Until 1991, the only treatment available entailed a fully open surgical procedure, whereby the dilated segment of the artery was replaced by an artificial vascular graft. An endograft was then implanted, consisting of a vascular prosthesis mounted on a stent and deployed intra-luminally at the aneurysmal site using a balloon.

This minimally invasive technique, called EndoVascular Aneurysm Repair (EVAR), represented a breakthrough in the field both conceptually as well as technologically. Unfortunately, though, there are various factors that restrict considerably the use of this technique, mainly the occurrence of renewed leakage into the aneurysmal sac (endoleaks), despite the presence of the stent/graft device and its migration downstream. Additionally, strict anatomical considerations pertaining to the dimensions of the artery both proximal and distal to the aneurysmal site, may prevent the use of the endograft.

This lecture will introduce a polymeric device for AAA treatment that will be deployed intra-luminally at the aneurismal site and then expanded so it tightly attaches to the aorta, proximally and distally to the aneurysm.

The implantation of these devices is divided into two parts: {a} the insertion through the iliac artery, the navigation to the site and the expansion stages, during which flexibility is critical, and {b} its performance at the aneurismal site, where the device is required to display appropriate mechanical properties.

Two strategies were pursued: (1) the device is thermally softened using a balloon filled with warm saline, so it can be easily brought to the site and then expanded, followed by its firm and conformable attachment to the arterial wall, proximally and distally to the aneurysm. While in its expanded configuration, the endograft is then cooled down to 37^{o}C and attains the mechanical properties and strong attachment required. (2) The endograft consists of an Expandable Component (EC) and a "Smart" Component (SC), with the latter being present within the former. The EC is responsible for the large change in dimensions the endograft undergoes during its deployment at the aneurysm. The SC is a low molecular weight, polymerizable or crosslinkable precursor that fulfills two different roles: {a} it acts as a plasticizer during the early stages of the procedure (navigation and expansion), rendering it with the required flexibility, and, {b} it stiffens the device after its expansion and snug attachment to the vessel wall, once it polymerizes or crosslinks, imparting to the endograft the necessary mechanical properties.

Materials and Methods: PEU thermoplastic elastomers softening between 50 and 60 degrees were used when following the first strategy, while poly(meth)acrylates and PEsUs performed as the EC, and methacrylates such as hydroxyethyl methacrylate (HEMA) were used as the SC. The various polymers were characterized by NMR, DSC, GPC and their mechanical properties were determined using an Instron Universal Testing Machine. Their *ex-vivo* performance was assessed in a cadaveric pig aorta segments and the acute *in vivo* feasibility of the device was evaluated by implanting it in a pig for eight hours.

Results: Following the basic working concept of this study, various expandable conduits were generated, differing in their composition, their mechanical properties, their expandability ratio, and the technique used to produce them. As an example, an elastomeric PEsU was blended with hydroxyethyl methacrylate (HEMA) at different concentrations. HEMA molecules soften the PEsU expandable component during the early stages of the implantation procedure, and remarkably stiffens it when polymerization takes place (Fig. 1), after the device is expanded and tightly attached to the aortic wall, proximally and distally to the aneurismal sac.

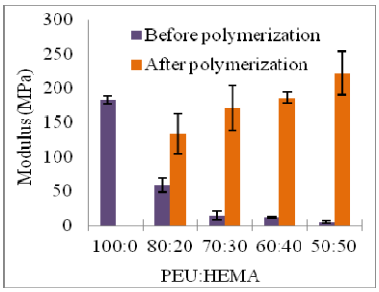

Figure 1. Mechanical behavior of a PEsU/HEMA device.

The expandability of the devices created was demonstrated in both cadaveric pig aorta sections and in an acute *in vivo* experiment in a pig. The diameter of the conduits increased more than three times and they became tightly attached to the luminal surface of the vessel. This was also demonstrated by measuring the displacement force required to pull out our device (~45N), well above devices presently in clinical use (4.5-25 N)[1].

Conclusions: The *in vivo* Proof of Principle of these devices, namely their ability to be deployed and inflated at the site following minimally invasive procedures that are routinely used in the clinic, and generate a stable and safe conduit, was demonstrated *in vitro* and acutely (eight hours) in the abdominal aorta of pigs.

References:

1. Resch, T. *et al Eur. J. Vasc. Endovasc. Surg.*, **2000,** *20*, 190-195.