Replacing diseased arteries: are we close enough?

Medical device technology has advanced to an extent that artificial heart, kidney, arteries, and prosthetic limbs are available as commercial market products. It is now a matter of choice for the patient and the surgeon to choose among a range of available options. Among these, vascular implants intended for replacing narrowed or blocked arteries constitute a multi-billion dollar cardiovascular implant market. A significant percentage of western world population is diagnosed with cardiovascular diseases every year. Most commonly treated artery is the coronary artery – an artery (diameter: 3.5 – 4.5 mm) supplying blood to the heart itself (Fig. 1). Another major supply artery from heart to various body organs (kidneys, brain and limbs) is the aorta (diameter: 25 – 30 mm) which is often diagnosed with an aneurysm condition – abnormal permanent ballooning of an artery. The two main strategies generally used to repair diseased arteries are either opening up the blocked region (with a stent) or bypassing the diseased segment internally (with a stent-graft). In other cases the artery is replaced as a whole (with a vascular graft) if the patient's health permits a surgery and disease severity is high. All these three categories of implants (stent, stent-graft, vascular graft) are manufactured by big medical device companies which compete to launch an improved implant every year with claims to be the next generation design. However, it does not take long to find structural similarities between current market implants from those introduced decades ago.

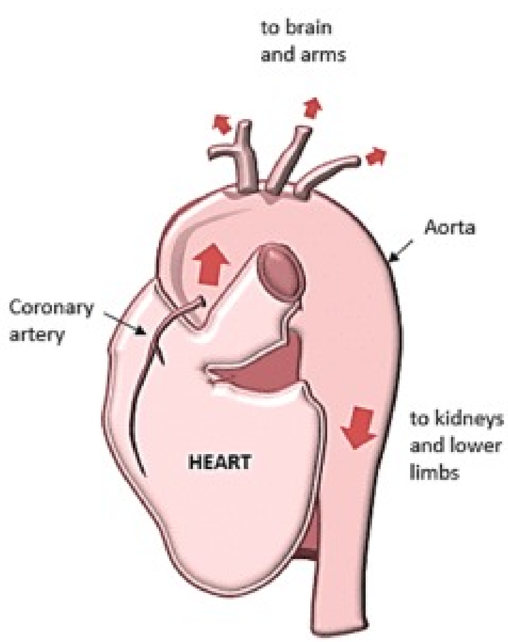

Fig. 1. Structural anatomy of heart and its main supply vessels.

Textiles have been an integral part of human society primarily due to their flexibility and softness (provides comfort), and drapability (fits body posture). This also led early surgeons (in 1950s) to think of using textiles for replacing or repairing internal body organs like arteries. The successful initial trials on animals led to exploration of new types of fibres (polyester, nylon, Teflon, spandex) and structures (woven, knitted, braided) for making tubular grafts. Polyester became the fibre of choice owing to its non-degradable property and is still the most commonly used graft material. Stents began to be manufactured as tubular metal wire (stainless steel, nickel-titanium alloy, cobalt-chromium alloy) meshes. Over the next few decades long-term clinical studies and extensive research in vascular biomechanics provided key insights into the critical design features deciding performance of these implants. However, if we select the implants available currently in market and analyse their structure and components, we find them to be still very similar to their predecessors. Furthermore, their design is far from resembling an artery's natural structure, a composite of elastic and stiff fibres embedded in a pliable matrix, which imparts unique pulsatile characteristic to the artery. On the contrary, woven and knitted structure of a commercial graft is quite similar to our dress garments, namely, windcheater and T-shirt, respectively (Fig. 2). Also, it is not difficult to imagine that stiffness of a metal stent is 8-10 times higher than an artery. The outcome of such dissimilarities is disturbed blood flow and increase blood pressure levels which ultimately affects patient health in long-term. The performance gets worse in small diameter arteries (coronary artery, cerebral artery) as flow dynamics are critical in deciding the re-blockage incidences.

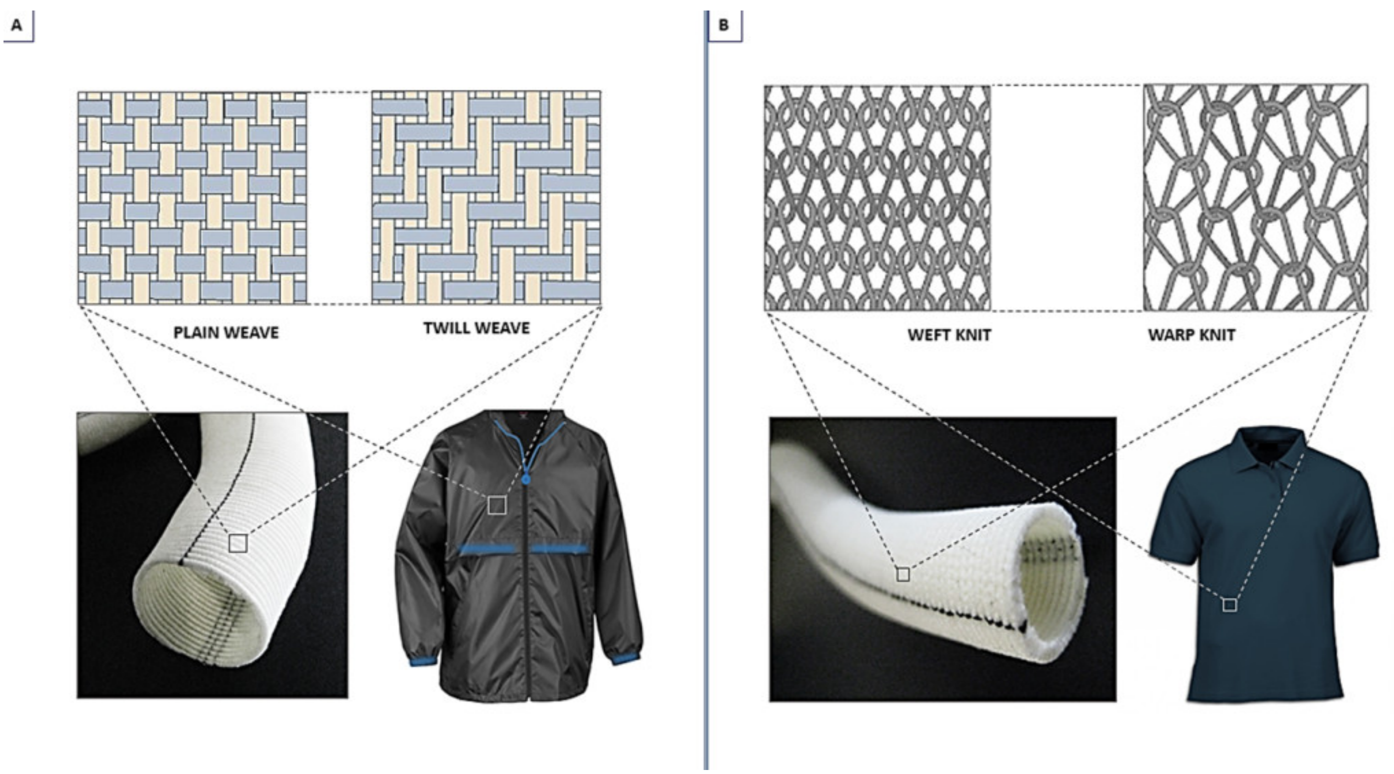

Fig. 2. Macroscopic structural comparison of (A) woven, and (B) knitted vascular graft with basic textile garments.

There is no denial that introduction of vascular implants and improvement in their implantation procedure (from open surgery to non-invasive treatment) has saved many patient lives but the focus still lacks on improving their structural design by learning from our own body. Our arteries are soft, pliable, and composite structures while our implants are still basic textiles from a structural context. This makes us question if our vascular spares are close enough to replace their natural counterparts?

Publication

Medical Textiles as Vascular Implants and Their Success to Mimic Natural Arteries.
Singh C, Wong CS, Wang X
J Funct Biomater. 2015 Jun 30