Chair: Physics of Fluids group

Steps towards understanding thrombus growth dynamics after endovascular aneurysm repair

Goal

The goal is to investigate what triggers a thrombotic event in an endograft limb. Using an in vitro setup with pulsating circulating pig blood the accumulation of thrombus in the endograft can be simulated over time. The use of ultrasound particle imaging velocimetry (echoPIV) allows for a unique opportunity to image opaque fluids (i.e. blood) through endografts. Furthermore, the addition of microbubbles allows for the distinction between flowing blood and thrombus and thus thrombus growth over time. The results could be used to identify patients at risk during follow-up and adapt the instructions for use of the Anaconda endograft.

Description

Endovascular aneurysm repair (EVAR) is the dominant treatment strategy for infrarenal abdominal aortic aneurysms (AAA). Despite the good short term results, the success of the procedure is impeded in 1.2% to 6.4% of the cases by endograft limb thrombosis (LT) [1]. Patients suffering from LT may be asymptomatic but do often develop symptoms such as intermittent claudication or acute limb threatening ischemia, impacting the quality of life and therefore LT regularly requires a reintervention [2]. Therefore, predictors for LT are necessary to prevent the need for such extreme measure and currently entirely lacking, despite rigorous follow-up procedures.

The Anaconda endograft (Terumo Aortic, Inchinnan, Scotland, UK), Fig. 1, has been used since 1998 and has been related to a LT rate between 3.5% and 9.8%. The Anaconda limb design has been improved over the years by having multiple independent rings to enhance its flexibility and prevent kinking, which reduced its LT rate. However, the underlying potential unfavorable factors that could cause LT are not yet fully known. Previously, Simmering et al. elaborated on a concertina effect hypothesis as a potential risk factor for LT, stating that neighboring stent rings distances decrease in tortuous and/or shortened Anaconda limbs, which may cause inward folding of the graft-fabric between them [3]. The independent rings, with their cribs and valleys design may lead to local endograft invagination in tortuous anatomy. These situations, in turn, may induce unfavorable local flow patterns, that could lead to blood stasis, thrombus formation, and eventually LT [3]. High shear (Fig. 1, B) and fluid stasis (Fig. 1, C) are in particular known to increase the platelet activation potential (PAP) [4]. PAP is a novel parameter that, together with blood stasis, has been linked to the formation of thrombus that could eventually cause LT.

Given the current hypothesis, new techniques are needed to visualize blood flow to quantify the PAP and areas of fluid stasis. The most widely known in-vivo flow measurement technique is ultrasound Doppler (DUPLEX) which, however, only provides 1D flow information within a small sample volume (Figure 1, C, left) [5] and is therefore insufficient to address the present challenge. In our most recent in-vitro study, we used echoPIV; a high frame rate ultrasound technique to quantify the limb flow fields after EVAR [6]. The unfavorable hemodynamics were noticed in the limb that thrombosed during follow-up, being in-line with our initial hypothesis. Furthermore, our previous MSc student (C.W. Verveld) designed an in-vitro flow setup to mimic and visualize the thrombus growth using

pig blood as the working fluid and 3D printing models, representing limb anatomy. In that study, thrombus formation has been realized repeatedly at the inlet, outlet and fabric of the Anaconda stent limbs. However, in the context of this project, we are aiming to fully quantify the thrombus growth dynamics by further optimizing our in-vitro flow setup.

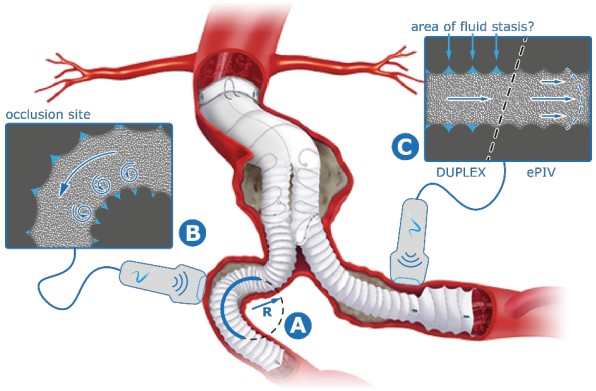

Figure 1: Abdominal aortic aneurysm treated with Anaconda endograft. Vascular anatomy in red, endograft in white. A) flexibility of Anaconda limb graft, B) Potential local recirculation zones, C) Comparing 1D DUPLEX and 2D echoPIV ultrasound velocimetry techniques

Assignment

Within the context of this project, you will be involved in designing new in-vitro flow setup, and fabricating various flow phantoms using 3D printers (Fig. 2), starting from simple pipe models towards more complex anatomical structures. The major tasks within this project can be divide in three major phases:

- Phase 1: What flow structures promote thrombotic event?
- Phase 2: Design motorized device to be able to perform 2D scanning echoPIV measurements. This enables us to capture complex flow structure in a 3D domain.
- Phase 3: What triggers a thrombotic event in an endograft limb?

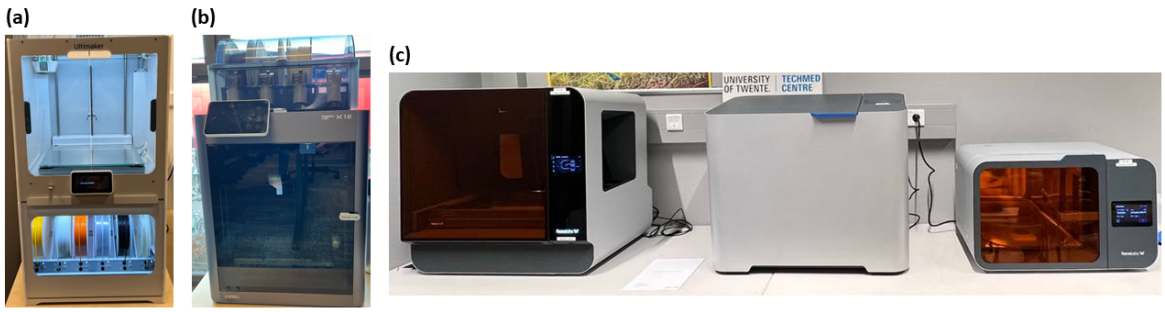

Figure 2: 3D printing facilities at TechMed center: (a) Ultimaker filament printer.; (b) Bambu lab filament printer.; (c) Formlabs resin printer.

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