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Case report

High shear stress on the background of clinical restenosis at the site of step-down phenomenon after drug eluting stent implantation

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ABSTRACT

A retrospective modeling was performed in a case with restenosis after 6 months of a DES implantation to investigate the effect of the step-down at the distal edge of the stent on the wall shear stress (WSS) using 3D coronary angiography reconstruction and the intracoronary pressure traces during a cardiac cycle. The kinetics of the WSS was calculated through the cardiac cycle along the reconstructed vessel by fluid dynamic analysis. Contrary to the previous reports the greatest amplitude and average of the arterial WSS was detected where the restenosis developed later at the site of the step-down.

Introduction

It is generally accepted that low or/and oscillating wall shear stress (WSS) has a role in the development of restenosis after coronary stent implantation but there is only a limited amount of data about systematic follow-up investigation of clinical endpoints and WSS calculation in clinical population after stent implantation.

Description of the case

A 49-year-old female diabetic patient who had stent implantation in the left circumflex coronary (LCx) artery was admitted because of recurrent anginal symptoms. Coronary angiography revealed a patent LCx stent while a long 50–60% stenosis was detected in the medial segment of the left anterior descending artery (LAD). Fractional flow reserve (FFR) measurement during maximum vasodilatation proved the

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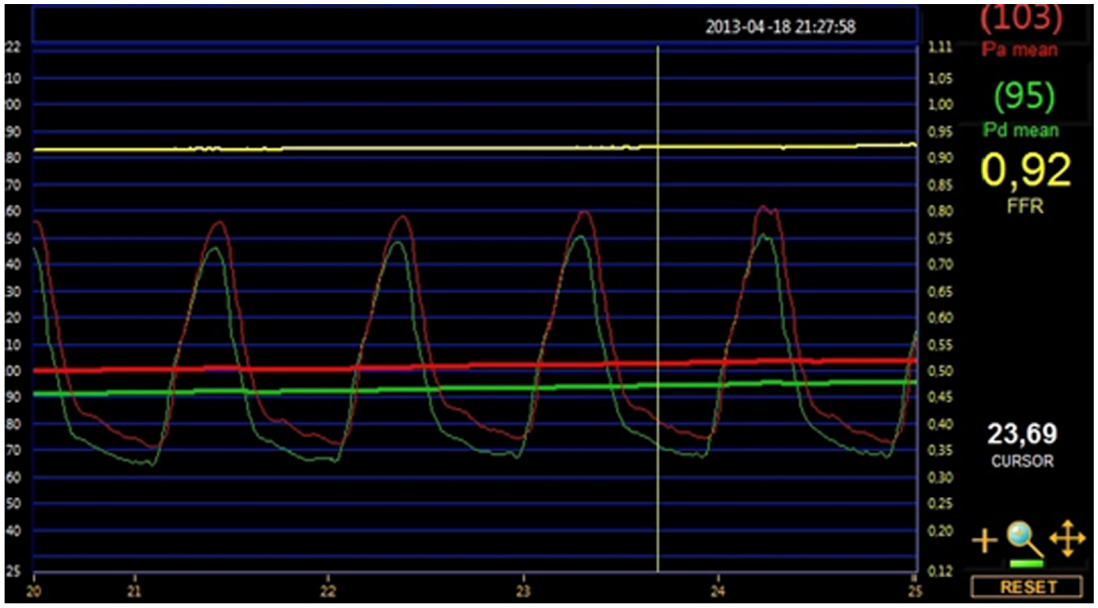

Fig. 1 – Resting intracoronary pressure trace (green line) after the DES implantation in the LAD. The ratio of the distal pressure and the proximal one (in the aorta: red line) was 0.92.

hemodynamic significance of the lesion (FFR: 0.77). Therefore, a drug eluting stent (DES) was implanted (3.5/28 mm Promus Element) which improved the FFR to 0.86. The resting pressure ratio was detected to be 0.92 (Fig. 1).

After 6 months repeated coronary angiography was performed because of reoccurrence of the symptoms of effort angina pectoris showing severe restenosis at the distal edge of the DES (Fig. 2A and B). This lesion was successfully treated by another DES implantation. A retrospective modeling was performed to investigate the possible effect of the step-down at the distal edge of the previous DES on the wall shear stress (WSS) conditions (Fig. 2A and C) using fluid dynamic analysis by the ANSYS CFX 15.0 software. The investigated vessel geometry was generated on the basis of the 3D anatomical reconstruction of the target vessel segment by a dedicated 3D QCA software package (QAngio XA 3D Research Edition 1.0, Medis Specials bv, Leiden, the Netherlands) software and the pressure traces during a cardiac cycle after the previous DES implantation at resting condition.

Blood was considered as a homogeneous, non-Newtonian fluid modeled by the Carreau-Yasuda shear dependent viscosity equation with the same parameters as in Boyd et al. [1,2], and a density of 1050 kg/m^3. Blood flow was assumed to be laminar and incompressible. The arterial wall was considered to be rigid and no-slip conditions were applied at the baseline luminal surface. Shear stress at the reconstructed poststent luminal surface was calculated as the product of blood viscosity and the gradient of blood velocity at the wall during the cardiac cycle (Fig. 3).

The kinetics of the WSS was calculated along the cardiac cycle (Video 1). The changes in direction and magnitude of WSS could be approximated by the oscillatory shear index OSI (its values may range from 0 to 0.5 – 0 being a total unidirectional WSS, and 0.5 being a total bidirectional shear flow) [2]. The OSI and the average WSS were calculated at 5 points of the reconstructed vessel (1–3: within the stent, 4–5 distal to the stent) (Fig. 2C and Table 1).

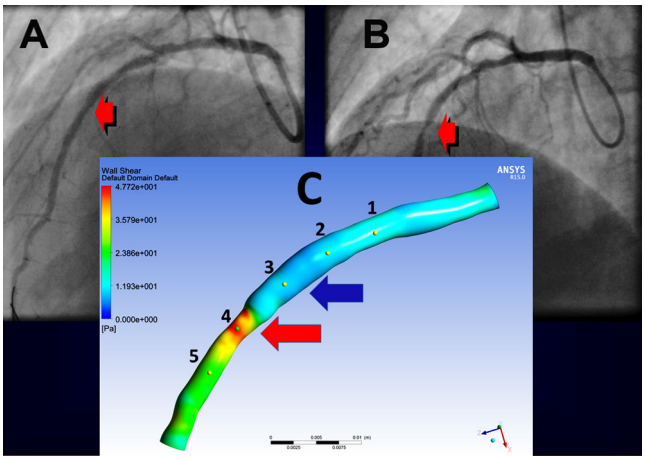

Fig. 2 – Coronary angiography from lateral view of the LAD after the DES implantation (A), and 6 months later (B). The computation by the ANSYS CFX software shows the greatest the arterial wall shear stress at the site of the step-down (C) where the restenosis has developed (B). The 3D reconstruction of the wall shear stress is shown at the early diastole (C). The 5 points indicate the sites of the kinetic analysis of the shear patter during the cardiac cycle. The results at the points 3 and 4 (blue and red arrow) shown in Fig. 3, while the average WSS and the OSI are summarized in Table 1.

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