New insight into the aortic microcirculation in coronary disease: Intraoperative laser Doppler flow measurement and vasa vasorum imaging

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Surgical coronary artery bypass grafting (CABG) is the standard procedure in coronary revascularization. Compared to on-pump CABG, the off-pump CABG (OPCABG), or beating heart surgery without cardiopulmonary bypass, provides a less invasive technique as it does not require ascending aorta or right atrium cannulation. This approach is favorable in high-risk patients with extensive atherosclerotic plaques in the aorta, which could be mechanically disrupted during cannulation or cross-clamping, leading to subsequent embolization [1]. However, OPCABG is not devoid of complication risks. In particular, it is associated with an elevated risk of aortic dissection due to frequently required lateral aortic clamping and the pulsatile pattern of arterial pressure [2].

Although the predisposing factors for perioperative aortic dissection remain ill-defined, recent studies suggest that the function of the vasa vasorum (VV) may play a role. It has been demonstrated that disturbances in VV flow led to an acute decrease in the distensibility of the ascending aorta. Similarly, structural changes in the aortic wall have been found to be a direct consequence of decreased VV density [3]. Thus, we suggest a routine intraoperative evaluation of the ascending aorta VV perfusion to indicate the appropriate surgical technique and predict possible complications.

Our recent study showed that laser Doppler flowmetry (LDF) can effectively monitor changes in myocardial perfusion during CABG [4]. LDF uses a fiber-optic probe to emit 780 nm laser light, which shifts in wavelength upon meeting moving blood cells. Single point LDF measures blood flow in a small volume (around 1 mm^3) detecting quick microvascular perfusion changes and presents the readings in arbitrary perfusion units (APU).

A 67-year-old woman with diabetes and coronary artery disease was referred for CABG surgery for two-vessel disease. During beating-heart CABG, we provided the measurements of microvascular perfusion of the ascending aorta adventitia assessed continuously by LDF (Periflux System 5000, Perimed, Järfälla, Sweden) (Figure 1A–B). In addition, we collected the biopsy material (0.5 cm^2) of the ascending aorta. The material was formalin-fixed, paraffin-embedded, and used for imaging of aortic microvessels. Cross sections (3 μm) were stained with hematoxylin and eosin to show aortic layers and VV (Figure 1C). Then, the sections were processed for endothelial cell immunolabeling [5]. The results exposed a considerable density of adventitial VV and individual microvessels in the media. In addition, positive staining for endothelial nitric oxide (NO) synthase in the microvascular endothelium underlined the significant role of adventitial aortic tissue as a source of NO that plays a critical role in vascular homeostasis.

To the best of our knowledge, the presented case is the first involving noninvasive real-time microcirculation monitoring in an ascending aorta during surgery on the beating heart in patients with coronary disease supplemented by evaluation of the VV distribution and functional role in NO production. In the future, we expect to find a strong

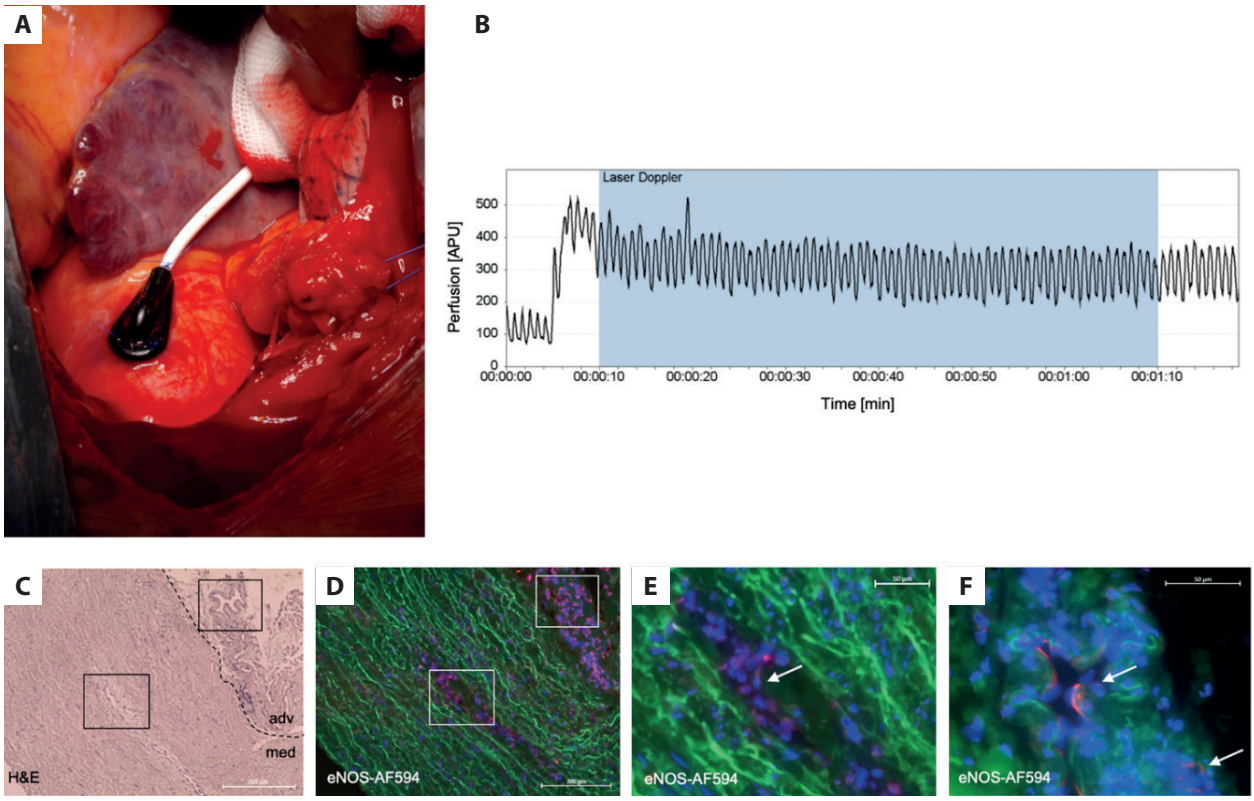

Figure 1. A. Intraoperative image of the laser Doppler probe stitched to the ascending aorta; **B.** Representative image of laser Doppler flowmetry recording in arbitrary perfusion units (APU) **C.** The ascending aorta stained with hematoxylin and eosin (H&E). The border between the adventitia (adv) and the media (med) is denoted by a dashed line. **D–F.** Immunofluorescence (IF) staining of the endothelium in the vasa vasorum. Endothelial cells are labeled by staining against endothelial nitric oxide synthase (eNOS-AF594, red). Cell nuclei are counterstained with DAPI (blue). Elastin fibers autofluorescence (green). Squares indicate zoom areas. White arrows point to the vasa vasorum

correlation between the hyperperfusion of the aortic wall and the severity of atherosclerotic plaques in histochemical findings in a larger group of patients.

Article information

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REFERENCES

1. Singh A, Mehta Y. Intraoperative aortic dissection. Ann Card Anaesth. 2015; 18(4): 537–542, doi: 10.4103/0971-9784.166463, indexed in Pubmed: 26440240.
2. Stanger O, Schachner T, Gahl B, et al. Type A aortic dissection after nonaortic cardiac surgery. Circulation. 2013; 128(15): 1602–1611, doi: 10.1161/CIRCULATIONAHA.113.002603, indexed in Pubmed: 24025592.
3. Stefanadis C, Vlachopoulos C, Karayannacos P, et al. Effect of vasa vasorum flow on structure and function of the aorta in experimental animals. Circulation. 1995; 91(10): 2669–2678, doi: 10.1161/01.cir.91.10.2669, indexed in Pubmed: 7743631.
4. Łoś A, Hellmann M. Real-time microcirculation imaging during beating-heart coronary artery bypass grafting. Kardiol Pol. 2020; 78(7–8): 780–781, doi: 10.33963/KP.15322, indexed in Pubmed: 32347087.
5. Chisci E, De Giorgi M, Zanfrini E, et al. Simultaneous overexpression of human E5NT and ENTPD1 protects porcine endothelial cells against HO-induced oxidative stress and cytotoxicity in vitro. Free Radic Biol Med. 2017; 108: 320–333, doi: 10.1016/j.freeradbiomed.2017.03.038, indexed in Pubmed: 28389406.