Assessment of the MAFA ratio as a quantitative prognostic marker of aneurysm occlusion after flow diverter treatment. V. Mendes Pereira1,2, O. Brina2, P. Bouillot2, F. van Nijnatten3, H. Yilmaz2, R. Ouared2, O. Bonnefous3, D. Ruijters3, T. Krings1, Z. Kulcsar2, T. Grünhagen3, K.O. Lovblad2

Background and purpose
Flow-diverter stents (FDSs) have been used effectively to treat wide neck and complex intracranial aneurysms (IAas) [1]. However, treatment strategies—such as single or layered FD stenting and/or adjunctive coiling—vary significantly and are inconsistent between different centers, largely due to the absence of reliable angiographic endpoints [2].

Preferably, the normalized mean aneurysm flow amplitude ratio (MAFA-R) has been described as a novel metric to quantify aneurysm flow reduction that occurs as a result of FD stenting [2-4]. The aim of this study was to analyze the potential value of measuring per-operative hemodynamic changes to evaluate FDS treatment outcome in a large prospective and consecutive series.

Materials and methods
We included consecutive patients harboring unruptured sacular sidewall IAs of the internal carotid artery (ICA) eligible for FDS placement. Data was acquired with a flat-panel angiographic C-arm system (Artis FG2000, Philips Healthcare). First a 3D rotational angiography (RA) was acquired. Then, two high frame rate DSA sequences (60 fr/sec) were acquired before and right after the implantation of the FDS with a contrast injection of 1.5 ml/s for a duration of 4 sec.

Flow reduction was assessed using dedicated software based on optical flow principles (AnysysFlow, Philips Healthcare). First, the volumetric flow rate was measured in the upstream artery through the joint registration of the 2D DSA images with the 3D geometry of the vessel. Secondly, the aneurysm velocity fields projected in the line of sight of the detector were measured from which the time- and space-averaged velocities (MAFA) values are derived (Figure 1). The flow modification induced by the stent was assessed by the post-stent-over-pre-stent ratio of MAFA-R, normalized to the parent vessel volumetric flow rates (Q), respectively, taking into account any occurrence of new physiological conditions during the procedure.

Results
We included 71 patients harboring 72 unruptured sacular aneurysms. All patients included in the study were successfully treated with FDS without coiling. For 2 patients, the 12 months imaging follow-up was not available. From the 72 aneurysms, 18 were excluded from the ROC analysis because the MAFA-R could not be calculated reliably. Main issues with optical flow imaging were related to a low confidence measurement of the vascular area due to 2D-3D registration failure or an insufficient pulsatile behavior of the CA-blood mixing flow in the vessel.

Results of the ROC analysis for the complete aneurysm cohort are presented in Table 1. At 12 months follow-up, 39 out of 52 aneurysms occluded (75%). The MAFA-R threshold for prediction of aneurysm occlusion was 0.89 (AUC=0.66, p<0.002081).

For the large (>10mm) aneurysm subgroup, the results of the ROC analysis are presented in Figure 2 and Table 2. At 3 months follow-up, 2 out of 19 aneurysms occluded (11%). The MAFA-R threshold was found to be 0.64 (AUC=0.97, p>0.0001). At 6 months, 7 out of 19 aneurysms occluded (37%) with a MAFA-R threshold of 0.93 (AUC=0.82, p<0.001080). At 12 months follow-up, 11 out of 18 aneurysms occluded (61%) with a MAFA-R threshold of 0.89 (AUC=0.91, p<0.0001).

Discussion
Our study describes a DSA-based method using optical flow imaging that was successfully used to predict complete aneurysm occlusion after treatment with FDS. The method was particularly accurate for a subgroup population of large IAs (>10mm). The accuracy of the ROC performance test was increasing from 67% for all aneurysms, to 91% for large-sized aneurysms.

Conclusion
Aneurysm occlusion after flow diverter stenting will depend on multiple factors including location, hemodynamics, patient healing peculiarities, aneurysm neck size, anti-aggregation response, etc. Nevertheless, we demonstrated that measuring the intra-aneurysm flow during the procedure with a method that takes into consideration the upstream vessel volumetric flow rate is able to predict independently the outcome by establishing a threshold for further clinical investigation.

This prospective series of systematically treated, evaluated and followed aneurysms, confirms that MAFA-R may be a potential useful indicator of successful treatment in the current clinical framework of FDS endovascular procedures.

References

Figure 2 ROC performance curves for MAFA-R for the large aneurysm cohort corresponding to follow-up at 3 months (A), 6 months (B) and Row 12 months (C).

Table 1: Results of the ROC analysis for determination of the optimal MAFA-R threshold for the complete aneurysm cohort. The number of cases considered, the rate of full aneurysm occlusions, the area under curve (AUC), p-value and thresholds at 3, 6 and 12 months.

Table 2: Results of the ROC analysis for determination of the optimal MAFA-R threshold for the large (>10mm) aneurysm cohort. The number of cases considered, the rate of full aneurysm occlusions, the area under curve (AUC), p-value and thresholds at 3, 6 and 12 months.