INTRODUCTION: We report here on an ongoing study of unruptured aneurysms that are followed over time. Intracranial aneurysms pose a substantial risk for subsequent neurological events. These can result from aneurysm rupture resulting in hemorrhagic stroke or from mass effect generated by the enlarging aneurysm pressing on critical brain structures. We report here on the use of 3D MRA/I methods that were used to evaluate the progression of disease in patients with intracranial aneurysms where no intervention was planned, either because of size, unfavorable treatment options, or because of patient choice. In addition to MRA of the lumen and MRI of the wall, MR velocimetry was acquired to assess the intra-aneurysmal flow conditions. The use of MRI provides a non-invasive option to evaluate serial changes over time and to correlate those changes with hemodynamics.

METHODS: 59 patients with 67 aneurysms of the intracranial circulation were recruited for serial imaging using an IRB-approved protocol. Patients were imaged at baseline and then in intervals that ranged between 6 months and 1 year. Of the 67 aneurysms, 2 had 8 follow-up studies, 6 had 7 follow-up studies, 5 had 6 follow-up studies, 6 had 5 follow-up studies, 12 had 4 follow-up studies, 13 had 3 follow-up studies, 12 had 2 follow-up studies, and the remaining 23 had one follow-up study. This results in a total of 164 interval measurements. At each imaging session MRA and MRI studies were conducted to assess the lumenal volume and whether there was any thrombus present in these aneurysms [1,2]. The MRA study used was a contrast-enhanced 3D acquisition with a parallel acceleration factor of 2 resulting in high-resolution (0.6 x 0.63 x 1.2 mm) CE-MRA images of the cerebral vessels. The MRI study used was a 3D balanced steady state free precession sequence with orientation and resolution selected to match the CE-MRA study. Serial MR studies were co-registered using internal fiducial markers. Consistent thresholding was imposed by requiring that a reference segment of undiseased vessel maintained the same lumenal volume over time. The lumenal volume of the aneurysmal segment was then assessed on the CE-MRA studies for regional and global changes (Figure 1). In addition, velocity fields were computed and wall shear stress was determined (Figure 2). Changes in volume of the aneurysmal segment were calculated as a percentage of the baseline volume and were normalized on an annualized basis. If measured differences were between -5% to 5% of baseline, aneurysms were considered unchanged, as that corresponds to measurement error.

RESULTS: Of the aneurysms that were followed, 6 of 67 showed growth that was significant beyond measurement error. Four of the 67 showed significant lumenal reduction reflecting the deposition of thrombus. In cases where growth was observed, large lumenal surface areas of low wall shear stress were noted. In regions of thrombus deposition, the calculated velocity fields showed slow recirculating flow with low fluid shear stress.

DISCUSSION: MR provides a minimally invasive means to monitor intracranial aneurysms affording the opportunity to determine their natural history in ways that have not been possible before. In particular, 3D analyses remove the limitations of traditional methods that utilize measurements of linear dimensions: MRA together with MRV provides the necessary boundary conditions for calculating the intra-aneurysmal flow field. Those computed fields are shown to provide hemodynamic descriptors (wall shear stress and blood shear stress) that correlate with changes in aneurysm lumen and wall over time. We continue to recruit subjects to expand our statistical power, and to permit more definitive statements on the relationship of hemodynamics to aneurysm evolution in general, and as a function of other variables, such as size and location of the aneurysms.