# Point: CFD––Computational Fluid Dynamics or Confounding Factor Dissemination

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EDITORIAL

# Point: CFD—Computational Fluid Dynamics or Confounding Factor Dissemination

Stimulated by our ongoing uncertainty about which unruptured cerebral aneurysms to treat brought about by a near-complete lack of meaningful clinical trial data, facilitated by substantial increases in computing power, and promulgated by scientists and engineers facile in generating massive amounts of data on estimated flow in virtual tubes, computational fluid dynamics (CFD) now holds a prominent position in the endovascular research community. Physicians see color displays generated by CFD and hope that we are starting to gain insight into why some aneurysms rupture and others do not. Journal editors have welcomed the field of CFD because of its captivating color schemes perfect for cover material, prompting some observers to propose that "Color For Doctors" represents the true meaning of CFD in the clinical realm.[1] I, on the other hand, propose a different perspective on the emerging field of CFD: confounding factor dissemination.

By way of full disclosure, I am not a professional computational scientist. However, I did learn in college how to calculate a Reynold's number. By way of a little investigating, I also know the following: 1) that most published CFD articles apply boundary conditions on the basis of idealized flows from articles published in the late 1980s (rather than individualized patient flows), 2) that the walls of the vessels are assumed to be rigid, and 3) that estimated numeric outputs can vary as much as 50% on the basis of whether geometries used CTA or 3D rotational angiography.[2] Finally, I know that the simple mathematic definition of wall shear stress (WSS) is simply the slope of the line from a curve plotting velocity as a function of distance from the vessel wall.

I have been told by computational scientists that we clinicians do not really need to know all of the gory details anyway, just as we do not really need to know all of the details about how the x-ray equipment works to perform angiography. I beg to differ. For example, many or most computational articles at least mention WSS, and in numerous articles, WSS represents the prime focus and the potentially "bad actor" in aneurysm rupture. However, there are as many, or more, definitions of "WSS" as there are types of intracranial aneurysms. WSS can be averaged with time ("time averaged" WSS) or over an area (the inlet zone, outlet zone, or dome) or can be maximal (typically at peak systole) or minimal (at end diastole). It can be oscillatory (oscillatory shear index), can be normalized to the parent artery flow or not, or can be a difference of 2 WSSs (WSS gradient). Thus, to say that WSS is correlated with a specific phenotype may mean a lot of different things to different people, and it is no wonder that, in turn, both elevated and diminished WSS has been associated with rupture in various studies.[3,4] Moreover, of course, correlation does not always equate to causation.

Unfortunately, defining WSS is just the beginning of the confusion. Each new computational article seems to introduce a new index or 2. We now need to learn, in addition to WSS, terms related to kinetic energy, vorticity, impact zone size, aneurysm-size ratio, aspect ratio, nonsphericity index, relative residence time, energy loss, and gradient oscillatory number[5]—and the list goes on and likely will continue to get longer. Given the rapid expansion of the number of potential CFD "outcomes," it is highly likely that many new "correlations" between these outcomes and rupture will be found—that is, the more comparisons you do, the more likely you are to find a spurious difference.

Perhaps a key problem with CFD research is that it is generally performed by isolated groups analyzing data from a very small number of cases. Relatively small studies provide substantial value in screening potential indices but, in my opinion, are as likely as not to identify confounding variables rather than the true agents of harm. Moreover, this is even assuming that aneurysm rupture is hemodynamic rather than biologic, which remains unclear to say the least. To really figure out what, if any, clinical utility CFD has, we need collaboration across specialties, including but not limited to statisticians, endovascular therapists, and clinical trialists. Performing statistical correlations between dozens (now) and hundreds (soon) of computational indices with aneurysm phenotype (typically ruptured versus unruptured) likely will require extremely large clinical datasets and sophisticated tools such as machine learning.

Until now, neurointerventionalists have marveled at the aesthetically pleasing color images that CFD provides, hoping that someday soon they would lead to clinical application. Clinicians would love to have a CFD button to push that provides a "treat/do not treat" decision for a given patient, but that is probably not going to happen soon. To help define what, if any, flow-related parameters really matter clinically, CFD researchers will need to do a lot more work to close the gaps in information and address the conflicting information and confounding variables.

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