Correspondence

Blood flow patterns in the human aorta studied by magnetic resonance

Sir,

It was fascinating to see the measurements of aortic blood flow velocity obtained with magnetic resonance by Klipstein *et al* (1987;58:316-23). In the early 1970s a number of us struggled at the limits of the then available technology (mainly hot-film anemometry) to make measurements of this kind, and it is satisfying to see those results so elegantly confirmed and extended.

In only one respect are these new results at odds with previous work, and that is in the authors' conclusion that turbulence was absent. Turbulence was seen in several studies in the ascending aorta of man and several other mammalian species¹⁻³ and this is to be expected on the basis of fluid mechanics. I wonder whether this discrepancy is a matter of measurement technique?

Turbulence consists essentially of a disorganised collection of small eddies moving with the bulk flow. These cause high frequency small amplitude fluctuations in velocity that are very easily missed unless the sensing technique samples local flow and is sensitive to high frequencies. The energy content of the turbulence is small (typically less than 0.5% of the total kinetic energy in the flow) and the frequencies are high (up to several hundred Hz). Hot-film anemometer probes are ideally suited to detecting such turbulence because they are tiny and have a very high frequency response. Klipstein *et al*'s suggestion that the presence of such probes actually caused the turbulence seen in the earlier work is not, I think, plausible—flow turbulence caused in that way would only be detectable downstream, in the wake of the probe. Could an alternative explanation be that the magnetic resonance technique requires a degree of spatial or time averaging that makes it insensitive to low level turbulence?

W A Seed,
Department of Medicine,
Charing Cross and Westminster Medical School,
Fulham Palace Road,
London W6 8RF.

References

- 1 Falsetti HL, Carroll RJ, Swope RD, Chen CJ. Turbulent blood flow in the ascending aorta of dogs. *Cardiovasc Res* 1983;17:427-36.
- 2 Yamaguchi Y, Kikkawa S, Yoshikawa T, Tanishita K, Sugawara M. Measurement of turbulence intensity in the center of the canine ascending aorta with a hot-film anemometer. *J Biochem Eng* 1983;105:177-87.
- 3 Paulsen PK, Hasenkan JM. Three-dimensional visualization of velocity profiles in the ascending aorta in dogs, measured with a hot-film anemometer. *J Biomech* 1983;16:201-10.

This letter was shown to one of the authors, who replies as follows:

Sir,

I note with interest the comments of Dr Seed, and agree with them. Despite the many advantages that we discuss in the paper, magnetic resonance velocity mapping does require both spatial and temporal averaging.

The spatial averaging is based on a typical voxel size in the region of 50 mm³ (the precise value varying both with the field of view and slice thickness). The temporal averaging arises because acquisition of the data for a series of frames takes several minutes, the images being reconstructed afterwards. The only detectable turbulence (seen as signal loss) is that which occurs repeatedly in the same place with every heart beat. High frequencies as such are not a problem because they increase the likelihood that the resultant of all velocities in the voxel over the 12 ms of data acquisition will be zero, and therefore that signal loss will occur.

The even echo rephasing that we use to retain the signal from moving blood (even though there may be a wide range of velocities passing through a single voxel) would be enough to eliminate the expected signal loss from small degrees of turbulence (as we mention at the end of the section on the principles of