Are villi rigid structures during lumen flow?

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The rigidity of the shafts of the villi and their attachment to the mucosa have important implications for intestinal mixing. A rigid villus projecting into the intestinal lumen may induce vortex formation. Rigidity may also allow the tips of villi to reflect mucosal movements and hence to approximate during mucosal micro-folding.

In this work, the movements and rigidity of villi were determined. Mucosal samples from the terminal ileum of the brushtail possum (*Trichusurus vulpecula*) were maintained *ex vivo* in an organ bath that was mounted in the visual field of an inverted microscope. The organ bath comprised a specially designed flow cell that allowed physiological and supraphysiological levels of shear stress to be reproduced in proximity to the villi. Velocities of fluid flow in the perivillous space were determined by microparticle image velocimetry (mPIV). The movements and rigidities of villi were quantified during fluid flow by video image analysis. Gradients in the velocities of microbeads at right angles to and parallel to the long axes of villi were also determined.

No changes were observed in the profiles of villi that could indicate bending either at physiological or supraphysiological fluid flow rates. There was little movement of fluid in regions >150μm below the tip of the villus. A lattice Boltzmann model of flow incorporating the mPIV findings in an array of static and rigid villi showed that flow within the lumen could only generate vortices of very low velocity between adjacent villi such that the rate of convective mixing would approach that of simple diffusion. Hence without additional mechanisms such as mucosal micro-folding, significant convective mixing in the intervillous space cannot occur.