# The influence of aortic root diameter on wall shear stress in the mouse aortic arch


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## Introduction

In recent studies wall shear stress (WSS) in the mouse aortic arch has been investigated and values up to 30 times higher then in humans have been reported. However, mice experience a significant change in aortic root diameter in a relatively short time span due to a gain in body weight. The effect of the change in aortic dimensions on the resulting WSS is investigated here.

## Methods

A twelve-week-old wild type mouse was euthanized and a corrosion cast of its vascular system was produced with Batson's no. 17 Plastic replica kit using standard techniques. The cast was scanned using micro CT. The resulting images were segmented and meshed in Mimics (Materialise, Leuven, Belgium) to produce a 3D model of the aortic arch. Fluent (Ansys, Canonsburg, Pennsylvania) was used to numerically solve the Navier-Stokes equations for the flow. The resulting velocity field was post processed to yield wall shear stress. Blood was modelled as a Newtonian fluid with a density of 1060 kg/m³ and a dynamic viscosity of 3.5 mPas. A blunt inlet velocity profile was imposed at the aortic root and outflow was imposed at the outlets. The flow split at the side branches was taken from literature since no measurements were available. For the time-dependent simulations a flow profile measured in a human ascending aorta was rescaled to match the flow magnitude and frequency typical for mice. The original model (aortic root diameter of 0.8 mm) was then rescaled to obtain 4 extra models based on a set of rules. According to [1] mouse body weight is linearly related to aortic root diameter measured from casts by $D = 0.0284\,M + 0.008$ ($r^2=0.86$). The cardiac output for conscious mice as a function of their body weight was measured by [2] to be 500 ml/min·kg over a range of different body masses. Combining these results allowed us to compute the mean inlet velocity for aortic root diameters varying between 0.7 and 1.5 mm.

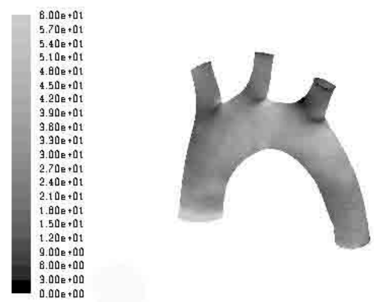


**Figure 1: WSS for steady flow (D=0.8 mm). Ventral view, ascending aorta shown left.**

## Results

The distribution of wall shear stress over the surface of the original model is shown for steady flow (figure 1). The WSS reaches a peak value of around 60 Pa. The averaged WSS values over the arch surface in steady flow and the hemodynamic parameters used at the inlet are summarized in Table 1. The WSS values decrease with a factor 4 when the aortic root diameter increases from 0.7 to 1.5 mm. This variation in aortic dimension should cover the range that occurs throughout different stages in the mouse life cycle (also depending on the mouse strain and sex). The observed WSS values are rather high when compared to average values published in literature ([1]), especially for the lower diameters. WSS in pulsatile flow, averaged over one cardiac cycle, was a factor 2-3 higher than in steady flow.

| D (mm) | M (g) | $V_{inlet}$ (m/s) | $Re_{inlet}$ | WSS (Pa) |
|---|---|---|---|---|
| **0.7** | 21.8 | 0.47 | 94 | 33.05 |
| **0.8** | 25.3 | 0.42 | 96 | 25.99 |
| **1.0** | 32.4 | 0.34 | 98 | 17.10 |
| **1.3** | 43.0 | 0.27 | 100 | 10.90 |
| **1.5** | 50.0 | 0.24 | 101 | 8.58 |

**Table 1: Hemodynamics vs Diameter**

## Conclusions

With the limitations mentioned, the results of this study point out that WSS in the mouse aortic arch can vary significantly during the mouse lifetime. It is therefore recommended to take into account the mouse age and body weight when interpreting results from simulations and to be cautious mentioning 'generally applicable' values for hemodynamic parameters sensitive to body size, such as WSS.


[1] Feintuch et al. Hemodynamics in the mouse aortic arch as assessed by MRI, ultrasound and numerical modelling. *Am J Physiol Heart Circ Physiol* 292, pp 884-892, 2007.

[2] Janssen et al. Chronic measurement of cardiac output in mice. Am *J Physiol Reg Int Comp Physiol* 282, pp 928–935, 2002.