Introduction
You always hear about the pitfalls of driving. Mentions of fender-benders, DUs, and road rage saturate the airwaves. All this talk of danger and even the possibility of death, and we never stop to ask ourselves: what actually kills us? Statistics will tell you that blunt force trauma to the head is the leading cause of death. This is understandable, but the second leading cause of death is something of a mystery to most: Blunt Traumatic Aortic Rupture (BTAR) [1].

A condition classified as the rupture of the aorta (the main artery that acts as the exit for blood from your heart) due to blunt force trauma, BTAR causes 15% of all fatalities in auto accidents [1] [2]. Yet, oddly enough, a large number of these induced deaths happen after the patient has been taken to hospital due to the difficulty of diagnosis. Even with all the medical technology we have available to us, 30% of people who survive to reach hospital die within 24h, and 50% die within 48h [3]. To make matters worse, we are not exactly sure why BTAR occurs. While the general cause for BTAR is understood to be high-speed impact, the physiological causes are scarcely understood due to the clinical and ethical constraints of human testing for such a condition [4]. As such, we have decided to develop a method for analyzing the response of blood (pressure, flow rate, etc...) in the human aorta during high speed collision. Working under the hypothesis that high speed impact will cause a large increase in pressure due to the resulting forces and possible cause rupture, we hope that this system, dubbed OSCAR (Ongoing Search for Counteracting Aortic Rupture), will allow us to gain insight into one of the possible causes of BTAR, as well aid in the possibility of preventing it.

Materials and methods
The OSCAR system consists of a cart carrying an experimental synthetic aorta with an attached heart valve (mechanical or porcine). The synthetic aorta is anatomically correct, and is surrounded by a 3D printed ribcage to allow for a more realistic recreation of real life conditions. Water is pumped through the system continuously (in place of blood). The internal conditions of the aorta are rigidly governed to produce an approximate flow rate and pressure waveform consistent with the average adult (5 L/min and 120/80 mmHg respectively). The cart is pulled along a track using a motor and is stopped by a shock absorber. At this moment, the cart begins accelerating. As we approach 7 seconds, the cart impacts with the shock absorber and a massive spike is recorded. After approximately 10 seconds (4 seconds after impact), we can clearly see that the pressure waveform returns to normal.

Results

Our results showed a significant increase in pressure during impact compared to at rest. On average, the peak pressure was found to be 250 mmHg, or a bit more than double the normal “high pressure” (systolic pressure) of the heart. The results shown were acquired while using a porcine valve, similar results were seen with a mechanical valve.

Conclusions

Though our hypothesis was verified, and a significant pressure spike was recorded (120 mmHg to 250 mmHg), we are unable to say with any certainty that the pressure response is the sole reason for BTAR.

According to the literature, the threshold for rupture of aortic tissue is at a minimum 1.58 MPa (approximately 11 800 mmHg) [5]. Though these results are a product of biaxial stress testing, a different mechanism of rupture than ours, they are still a useful guideline for the strength of human aortic tissue. Furthermore, these results are orders of magnitude higher than our value of 250 mmHg, and this allows us to deduce that though our pressure response does have an effect, it should not be considered a standalone mode of failure.

Our next step is to improve the system in such a way as to gain even more accurate results. This will be done by:

• Adding an accelerometer to the system.
• Using Particle Image Velocimetry (PIV) to analyze fluid flow at impact.
• Undergoing tests with different synthetic aortae to verify results.
• Modification of the system to allow for different aorta configurations (frontal vs side impact)

Literature cited

Mark Cohen and Lyes Kadem
Laboratory for Cardiovascular Fluid Dynamics, Concordia University