



Determination of the Relationship between Pressure and Injury by Impacting *Ex Vivo* Perfused Spleens

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INTRODUCTION

- Automotive crashes result in injury to different body regions, but in particular, the abdomen is a site of potential life-threatening injuries due to housing vital body organs [1].
- The spleen is the second most injured organ following the liver; splenic injuries are estimated to be 23.1% while those to the liver are 39.2% of all abdominal organ injuries [2].
- Blunt impacts to the abdominal region in automotive crashes are the main cause of liver and spleen injuries.
- However, less research has focused on injury mechanisms to the spleen than to the liver.
- There is a need to define the injury mechanism of splenic injuries in automotive crashes.
- This study investigated the correlation between injury to the spleen and pressure changes in spleen due to blunt impacts.
- A series of experiments was conducted to evaluate whether pressure change is significantly associated with spleen injury.

METHODS [3]

- Obtain *ex vivo* spleens from autopsies and inspect for any visible damage prior to testing
- Test fixture
 - Free-fall drop tower—which includes a load plate (23.4 kg) attached to the guide rails with two load cells to measure force applied to the spleen [Figure 3]
- Prepare and instrument the spleen
 - Identify the splenic artery (a) and vein (v)
 - Insert foley catheters into the artery and vein [Figure 1b] Insert pressure sensors [Figure 1c] to splenic a. & v. through foley catheters
 - Connect foley catheters to saline reservoirs for spleen perfusion [Figure 2]
- Apply blunt impacts to the *ex vivo* spleen by varying the drop height of the load plate [Table 1]
- Data analysis
 - Injury analysis [Table 2]
 - Pressure analysis
 - Pressure vs. Time
 - Force vs. Time

Table 1. Test matrix

Subject	Trial 1	Trial 2	Trial 3
N ↓ 1	Low velocity impact	Median Velocity impact	High Velocity impact
	1 m/s (height of 8 cm)	2 m/s (height of 23 cm)	3 m/s (height of 47 cm)

Table 2. Abbreviated Injury Scale [4]

Injury	AIS Score	Description
2	Moderate	Laceration <1cm
3	Serious	Laceration >3cm
4	Severe	Laceration producing major devascularization
5	Critical	Ruptured spleen

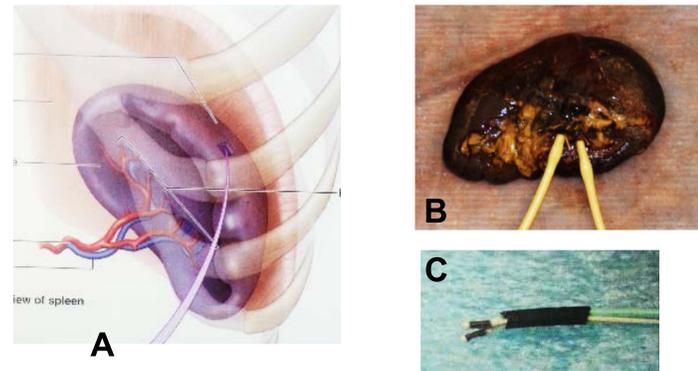


Figure 1. (a) Spleen with splenic a. and v.; (b) spleen with foley catheters; (c) pressure sensors

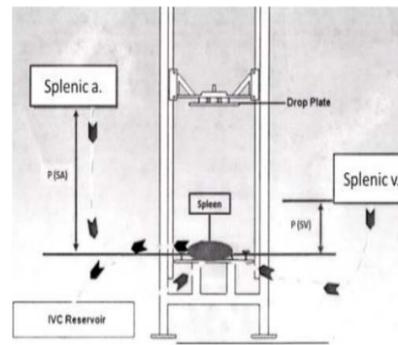


Figure 2. Perfusion system setup



Figure 3. Drop Tower setup

RESULTS & DISCUSSION

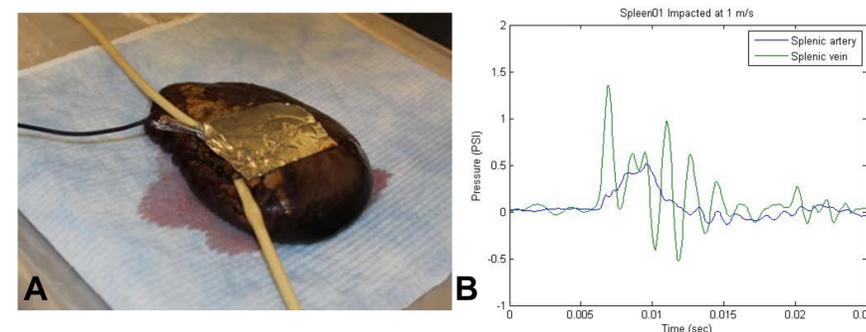


Figure 4. Spleen01 blunt impact at 1 m/s (a) Spleen01 post-test image (b) Splenic artery and vein pressures vs. time

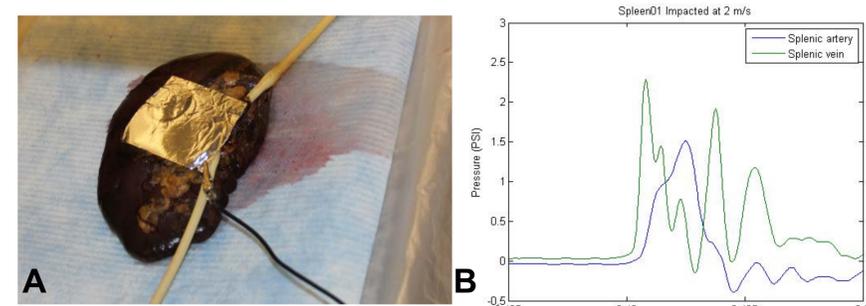


Figure 5. Spleen01 blunt impact at 2 m/s (a) Spleen01 post-test image (b) Splenic artery and vein pressures vs. time

- Only the splenic a. was instrumented with a foley catheter and a pressure sensor due to the size of the splenic vein.

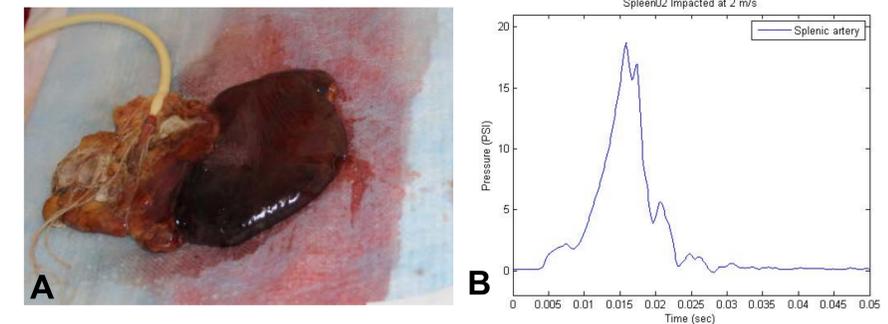


Figure 6. Spleen02 blunt impact at 2 m/s (a) Spleen02 post-test image (b) Splenic artery and vein pressures vs. time

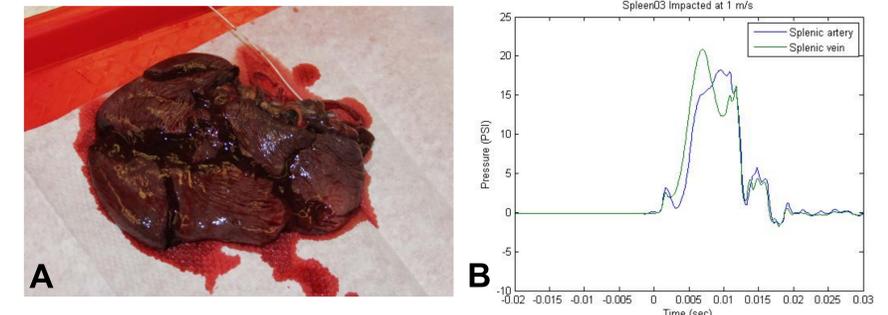


Figure 7. Spleen03 blunt impact at 1 m/s (a) Spleen03 post-test image (b) Splenic artery and vein pressures vs. time

Table 3. Summary of the test results

Test Number	Velocity (m/s)	Peak Pressure (PSI)	Peak Force (N)	Damage
Spleen01	1	0.61 (A); 1.81 (V)	1916	No damage
Spleen01	2	1.56 (A); 2.91 (V)	2816	AIS 2
Spleen02	2	19.3 (A)	7680	AIS 3
Spleen03	1	19.7 (A); 20.9 (V)	1890	AIS 5

CONCLUSIONS

- 3 *ex vivo* spleens were tested and vascular pressures were measured from impact-induced hydrostatic pressure changes inside the spleen.
- The hydrostatic pressure changes in spleen showed correlation with injury.
 - Severely injured spleens had higher peak pressure [Table 3].
- These initial experimental blunt spleen injuries produced in this testing compared well with those observed in motor vehicle crash victims.
- Further testing of *ex vivo* spleens is needed to verify these initial findings. If this trend continues, whole body post-mortem human surrogate (PMHS) testing with pressure transducers in the splenic vasculature should be conducted.

REFERENCES CITED

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ACKNOWLEDGEMENTS

The students and staff of the IBRC