XSENSOR High-Speed Impact System in PMHS Thoracic Impact Testing.

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I. INTRODUCTION

Past thoracic research has relied on instrumentation and technology like chestbands, strain gages, and accelerometers to define the biofidelic response and injury threshold of the thorax to blunt impacts [1-4]. All instrumentation has strengths and weaknesses, but a common weakness across these examples is that they sense the loading at a single point, or in the case of the chestband, at a single cross-section of the thorax. This limitation does not allow researchers to understand how the thorax as a whole is interacting with the impacting surface. The XSENSOR High-Speed Impact System (XSENSOR, Calgary, Canada) is technology which allows researchers to record pressure profiles of the impacting load to a broad area of the thorax.

The goal of this research was to use the XSENSOR High-Speed Impact System in a series of PMHS thoracic impacts to investigate the potential of the XSENSOR system to measure thoracic response to blunt loading.

II. METHODS

This testing was completed with a single PMHS who fit the 50th percentile male criteria for age, weight, BMI, and had a “normal” aBMD score. Instrumentation for the impact series included a mix of strain gages to determine fracture timing, 6dx blocks to measure spinal kinematics, and a XSENSOR pressure pad (10”x10”) to measure the pressure profile during each impact. The strain gages were located on the sternum along with both an anterior and an anterior-oblique location on ribs 2-8 on both right and left sides. The 6DX motion blocks were placed on the manubrium, 1st thoracic (T1), 4th thoracic (T4), 12th thoracic (T12), and 1st sacral (S1) vertebral levels, and the XSENSOR pad location varied between tests, but was placed over the thoracic region of interest. The XSENSOR data was collected at 2,383 Hz, while all other channels were collected at 20,000 Hz using a SlicePro data acquisition system (DTS, Seal Beach, CA).

The series of impact tests conducted on the PMHS were based on previous impact testing conducted in the Injury Biomechanics Research Center (IBRC), thus allowing for comparison between XSENSOR and traditional measurement techniques [1-3]. The PMHS was seated in an upright position, with the arms raised until they were parallel to the ground (Figures 1-3). A series of seven thoracic impacts were conducted including: impacts to the front, left, and right aspects of the thorax, two different impactor faces and three different energy levels. The test matrix, including the testing order and boundary conditions used for each impact, is shown in Table 1. After the impacts, the strain gage data was plotted to determine whether a fracture occurred, and if so when it occurred. This data was then compared to both the anatomical fracture location after dissection, and the XSENSOR pressure map during that time of fracture to determine if there was any correlation between the pressure map, fracture timing, and fracture location.

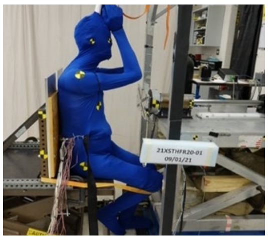

Figure 1: Impact 01 Set-up

Figure 2: Impact 02 Set-up

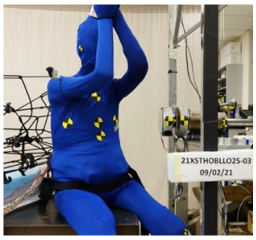

Figure 3: Impact 03 Set-up

	Impact 01	Impact 02	Impact 03	Impact 04	Impact 05	Impact 06	Impact 07
Impact Aspect	Frontal	Lateral	Oblique	Lateral	Lateral	Oblique	Lateral
PMHS Side	-	Left	Left	Left	Right	Right	Right
Impactor Face	Rectangle	Rectangle	Circle	Circle	Rectangle	Circle	Circle
Speed (m/s)	2.16	2.56	2.49	4.54	2.52	2.52	4.43
Rib Fxs	Right 5	-	Left 3, 4, 5	Left 6, 7	-	Right 4, 6, 7	-

Table 1: Test Matrix

III. INITIAL FINDINGS

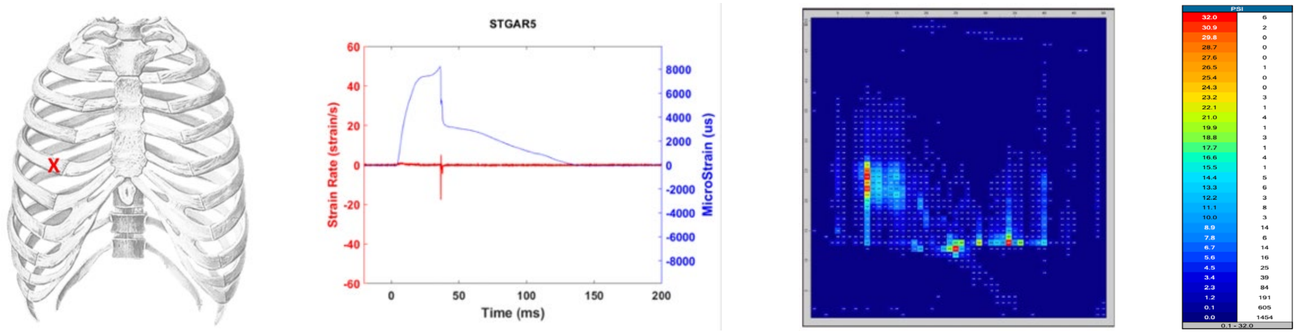

Figure 4: Impact 01 Injury Location, Right Rib 5 Strain Data, Pressure Map, and Pressure Map Scale

A summary of the rib fractures which occurred during the seven impacts can be found in Table 1. Figure 4 shows the key findings from Impact 01, which resulted in a fracture to rib 5 on the right side (shown by the red "x"). The time of fracture is determined using both strain and strain rate data from the anterior strain gage on rib 5. Finally, the XSENSOR pressure map still photo reveals the corresponding pressure across the front of the thorax at the exact time at which rib 5 fractured. Figures 5 and 6 contain two additional injury and pressure maps (Impact 03 & Impact 06), which both produced fractures during their respective impacts.

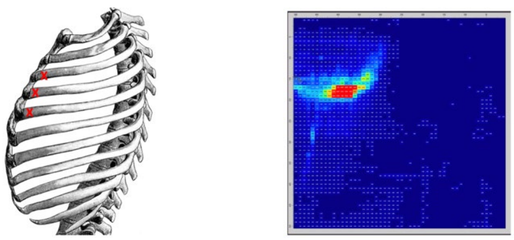

Figure 5: Impact 03 Injury and Pressure Map

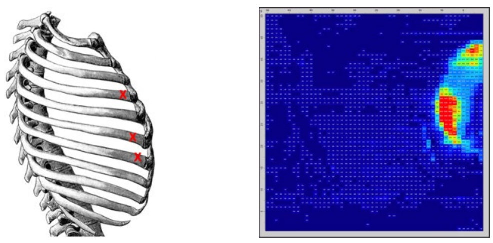

Figure 6: Impact 06 Injury and Pressure Map

IV. DISCUSSION

To date, findings from each impact focused on comparing the dynamic pressure profiles of the impacted thorax to the recorded strains from the attached gages on each rib, and to any injury locations that were documented during autopsy. The timing of each fracture, as determined from the strain gages, were also compared to the timing of the peak pressures from the XSENSOR output in each given region of interest. The pressure maps revealed that the XSENSOR High-Speed Impact System identified that the highest-pressure areas were aligned with the anatomic locations of the resulting fractures. In addition, the pressure map showed areas of high pressure during the time of fracture found by the strain gages. It is important to note that these conducted tests did match the historical PMHS impacts from a spinal kinematics standpoint.

A limitation of the testing was that a single PMHS was impacted multiple times to collect a large quantity of comparable data between instrumentation techniques. Also, while the conducted impacts did mimic historical thoracic impact tests, the tests were performed under simplified boundary conditions compared to car crash scenarios. One area of improvement to consider in future PMHS testing with the XSESNSOR system is to conduct a CT on the PMHS following the placement of the XSENSOR pad to obtain exact anatomical positioning coordinates of the pad instead of having to rely on x-rays. Also, further investigation should be conducted with the XSENSOR High-Speed Impact System in a dynamic sled environment to test the system's durability and ability to document interaction between a PMHS and typical safety devices.

Given the findings from this laboratory setting, it appears that the XSENSOR High-Speed Impact System has the ability to map pressure distributions during dynamic impacts that could help to identify injuries in blunt impact scenarios.

V. References

[1] Shaw J *et al.*, Stapp J, 2006. [2] Rhule H *et al.*, Stapp J, 2011. [3] Murach M *et al.*, Stapp J, 2018. [4] Shurtz B *et al.*, SAE Tech Paper, 2018.

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