INTRODUCTION
Two case studies are presented that involve interactions between the occupant and the steering wheel during a collision. In one case the occupant sustained a shoulder injury and in the other the occupant sustained a facial/head injury. These case studies will focus on the nature of the evidence (vehicle interior and occupant) with some limited development of quantitative data. It is hoped that the reader will appreciate the attention to detail required to establish the injury mechanisms in these cases.

METHODS
The cases presented here are typical of intersection and head-on collisions that occur regularly on roadways. For each case study presented detailed exterior and interior inspections were conducted for the vehicle of interest. Additionally, thorough medical record reviews were conducted for each driver.

Crash severity was defined based on the exterior inspection and expressed as a velocity change ($\Delta V$) along a Principal Direction of Force (PDoF). Interior contacts/interactions for the driver were developed through a detailed interior inspection focusing on the clearly damaged steering wheel. Finally, the crash environment, the driver’s interactions with the interior, and the injuries sustained by the driver were correlated to determine a case-specific mechanism of injury.

RESULTS
Case 1 – This case involved a 1991 Hyundai Excel 2-door hatchback and a 1983 Mercury Cougar 2-door coupe. The Cougar ran a stop sign at an intersection and the Excel struck the left side of the Cougar with its front end. As a result of the impact the Excel sustained an ~20 mph $\Delta V$ with a PDoF range from 12 to 1 o’clock. An inspection of the passive restraint revealed evidence of loading on the torso portion in the form of web-grabber marks. The steering wheel ring was heavily deformed (Figure 1), there were depressions/indentations to the trailing aspect of the instrument cluster shroud, and there was also deformation of the driver’s knee bolster. The 78 year old male driver had signs of torso belt usage, without signs of lap belt usage. He also sustained a full thickness tear of the supraspinatus tendon of his right shoulder along with, a mid-body sternal fracture, and multiple left and right rib fractures.

Case 2 – This case involved a 2001 Ford Taurus 4-door sedan that was impacted nearly head-on by a 1992 Mazda Miata 2-door roadster. As a result of the collision the Taurus sustained an ~30 mph $\Delta V$ with a PDoF of between 11 and 12 o’clock. The driver’s airbag did not deploy. There was heavy evidence of occupant loading on the driver’s restraint. Further, the hub-to-column bracket was fractured. A peculiar inverted u-shaped cut was found on the steering wheel ring (Figure 2). The 55 year old male driver had signs of restraint usage and had sustained a facial injury with exposure and truncation of the nasal bone. Additionally, a small intraparenchymal brain hemorrhage was noted along with diffuse chest wall pain and two right rib fractures.

DISCUSSION
Case 1 – Careful correlation of the evidence on the restraint, knee bolster, steering wheel ring, and instrument cluster shroud demonstrated that the driver was in a normal seated position with both hands near the top of the steering wheel ring and bracing for impact. During the impact his failure to use the lap belt allowed his pelvis and lower extremities to move forward engaging the knee bolster. Use of the passive torso belt resulted in the mid-body sternal fracture and bilateral rib fractures. By bracing against the upper portion of the steering wheel ring the driver forced the ring to bend forward about the spokes (Figure 1), which allowed his knuckles to indent the instrument shroud. Moreover, the forces required to bend the ring (~ 200 to 300 lbs based on a component test) overloaded the supraspinatus tendon in the driver’s right shoulder.

Case 2 – As a result of the significant crash forces the driver heavily loaded his three point restraint and applied substantial load to the steering wheel through his arms and torso. As a result his head and neck were flexed forward to the point where the steering wheel ring engaged his face across the bridge of his nose. The soft-tissues and cartilage overlying the nasal opening were displaced toward the left side of his face and the upper portion of the nasal opening cut through the soft-tissues and cut the steering wheel ring. The u-shaped cut to the steering wheel ring (Figure 2) matched the size and shape of the upper portion of the nasal opening. On close examination a fragment of bone was found embedded in the ring, consistent with the truncation of the nasal bone.

Figure 1: Photo of the deformed steering wheel for Case 1.

Figure 2: Photo of the peculiar u-shaped cut in the steering wheel ring from Case 2.