Title:

Comparison of visual and CT 3D reconstructed abdominal seat belt sign locations

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ABSTRACT

Objective - Occupants in high-speed motor vehicle collisions often show subcutaneous adipose tissue enhancement on 3D reconstruction CTs that appears consistent with the path of the seat belt. These subcutaneous adipose beltmarks (SABs) may aid in clinical and biomechanical research. The goal of this project was to provide an initial proof-of-concept for SAB identification. This was achieved by determining the level of agreement between locations of SAB and visible injury. A secondary objective was to determine if independent evaluators agreed on the presence and location of SABs.

Methods - A retrospective study was performed using the Crash Injury Research and Engineering Network (CIREN) database to select cases with external trauma from seat belt use in frontal impact collisions. The inclusion criteria were high-speed (>40 kph), frontal impact, occupants age ≥15 years, seat belt in use, patient photos showing abdominal bruising, and abdominal CT DICOMs available. For each case, patient photos and CT 3D reconstructions with fat enhancement were de-identified. The location of suspected seat belt injuries on photos and CT renderings were described using a newly-designed metric, which divided the abdomen into four zones. Two medical doctors evaluated each image independently. Inter-rater reliability was calculated separately for photos and CT renderings. When disagreement over location existed, the image was discussed and a consensus was achieved. The location of the visible injury was then compared to the location of the SABs for each case to determine agreement.

Results - Twenty-two CIREN cases met the inclusion criteria. The 3D renderings of the fat-enhanced CTs revealed subcutaneous enhancement consistent with a SAB in 20 of 22 cases (95%). Evaluators agreed on the location of injury based on photos in 19/22 cases (86%, kappa 0.72) and CT renderings in cases 21/22 (95%, kappa 0.93) of cases. Within the group containing SABs, 15 of 20 (75%, kappa 0.56) cases matched the location of the SAB to the same zone as the visible seat belt mark. In one instance, the SAB was one zone inferior to the visible mark, while the SAB in four cases was one zone superior. Injuries were in the same or adjacent zones in all cases when a SAB was identified.

Conclusions - SABs identified on fat-enhanced 3D reconstructions abdominal CT were shown to be correlated with visible seat belt injuries. This study indicated SABs may be caused by subcutaneous injury by compression from the seat belt during frontal impact motor vehicle collisions. Further investigation correlating SABs with intra-abdominal injury and sensitivity/specificity analysis is warranted.

INTRODUCTION

The presence of visible abrasions or contusions from seat belts on occupants of motor vehicle collisions (MVCs) has long been known to increase the likelihood of intra-abdominal injury (Chandler et al. 1997, Doersch et al. 1968). Recently, the CT scans of victims of high-speed motor vehicle collisions have been noted to show signs of subcutaneous injury when reconstructed in 3D and enhanced for adipose tissue (Hartka et al. Pub Pending). These subcutaneous injuries appear consistent with the path of the seat belt and may have clinical importance in predicting intra-abdominal injuries. It is important to confirm that these subcutaneous fat enhancements are indeed caused by injury from the seat belt and not an artifact of the CT. The objective of this project was to provide an initial proof-of-concept for SAB detection with a specific research question: if a seat belt sign is visible on an occupant in a frontal impact collision, will a SAB be detected in an equivalent location on CT? This study aimed to determine the level of agreement between locations of SAB and visible injury. A secondary objective was to determine if independent evaluators agreed on the presence and location of SABs.

METHODS

A retrospective study was performed using the Crash Injury Research and Engineering Network (CIREN) database to identify cases with external trauma from seat belt use in frontal impact collisions. The CIREN network performs in-depth engineering and medical analysis on select MVCs. Cases are well documented with crash, vehicle, and occupant details; additional supporting information for each case can include occupant photos and CT scans. The database was queried for cases meeting the following criteria: high-speed (>40 kph), frontal impact collisions, occupant age ≥15 years, 3-point seat belt in use, and auxiliary information including patient photos and CT DICOMs available. Abdominal CT scans were rendered in 3D with subcutaneous fat enhancement, and then a screenshot was saved. When applicable, a transverse slice indicating bony landmarks was included on the 3D rendering and the image resulting was also saved. A random key was generated for photos and CT images separately and images were de-identified from their CIREN case number.

The location of abdominal injuries along the longitudinal axis of the body was determined using a newly developed metric for this study that locates the injury into one of four zones (Figure 1). These zones were chosen to approximate the belt path across the abdomen based on bony landmarks that could be reliably identified on photos and CT. Two Emergency Medicine trained physicians familiar with seat belt signs and SABs then independently evaluated each photo and CT rendering to determine the zone containing the external injuries (see example - Figure A1). When injuries were present in multiple zones, the zone encompassing the majority of the markings was selected. Evaluators could also choose to grade an image as "unknown" if no clear injury could be identified or the location could not be determined. A Kappa value, used for describing inter-rater reliability, was then determined using Stata/SE 12.1. When primary zones differed between evaluators, each case was discussed and a consensus zone was determined. The consensus zones for photos and 3D renderings were then compared for agreement.

RESULTS

The inclusion criteria identified 107 case occupants. Of these, 35 (32.7%) contained photos of the abdomen with seat belt abrasions or contusions. Further, 22 of the 35 cases had full abdominal CT scans available. Among the 22 cases with CT scan available, 16 occupants were female (73%) and the mean age was 52 years (range 15-84). The mean height was 169 cm (range 147-188) and weight was 84 kg (range 49-154), resulting in a mean BMI of 29 (range 18-57). The mean Delta V was 56 km/h (range 31-95, one case unknown). The 3D rendering of the fat-enhanced CTs revealed subcutaneous enhancement consistent with a SAB in 20 of 22 cases (95%). There was no evidence of SAB on CT in one case, while the second case had multiple areas of enhancement for an unknown reason and no SAB could be differentiated from the artifacts. Evaluators agreed on the location of injury based on photos in 19 of 22 cases (86%, Kappa 0.72) and CT renderings in 21 of 22 cases (95%, Kappa 0.93) cases. Within the group containing SABs, 15 of 20 (75%, Kappa 0.56) cases matched the location of the SAB to the same zone as the visible seat belt mark identified on photo. In one instance, the SAB was one zone inferior to the visible mark

(Photo: Zone III, CT: Zone II). The SAB was one zone superior to the visible mark in four cases. In these four cases, the visible injury was identified on the leg or lateral abdomen, while the SAB was identified over the mid-abdomen (Photo: Zone I, CT: Zone II). Injuries were in the same or adjacent zones in all cases when a SAB was identified on CT (100%).

DISCUSSION

SAB analysis has the potential to be incorporated into clinical treatment guidelines and collision reconstruction. Although SABs were considered to represent subcutaneous tissue injury caused by seat belts, this relationship has not been definitively demonstrated. This study was the first attempt to validate SABs using a retrospective analysis. There was good and excellent inter-rater reliability between evaluators for photos and CT renderings respectively based on Kappa (Photos 0.72 vs. CT 0.93). The lower inter-rater reliability for photos was likely due to inconsistency in photo technique and difficulties identifying visual landmarks in obese patients. CT scans had the advantage that bony landmarks could be definitively identified and marked. This set of CT images was carefully selected for a high likelihood of having subcutaneous injury on CT, yet it was promising that SABs could be identified in all but two cases. The SAB was located in the same abdominal zone as the visible seat belt marks in the large majority of cases. In cases that did not match, the location of the SABs zone was offset by one adjacent zone. Further analysis revealed that in four of these cases the seat belt path likely traversed two zones. In these cases, photos identified contusions or abrasions on the leg while the SAB was located on the mid-abdomen. Due to reliance of the abdominal zone metric on easily recognized physical landmarks, the upper leg and mid-abdomen were in separate zones. However, a properly placed seat belt may course through both of these zones.

SABs are consistent with subcutaneous edema and microhemorrhage. The pressure needed to damage the subcutaneous tissue may be less than the threshold to cause external injury. Therefore, SABs may be more sensitive predictor of intra-abdominal injury than visual inspection. The next step in this analysis will be to correlate SABs with hollow or solid organ intra-abdominal injury. This study was limited by the retrospective nature of the study design and availability of cases that met the selection criteria. Measuring the sensitivity and specificity of SABs between those with and without visible injury from the CIREN database is difficult because most cases do not include abdominal photos and minor external injuries may not be noted in all cases. A prospective trial specifically investigating this method is needed to improve discrimination of abdominal zones and to perform a sensitivity and specificity analysis.

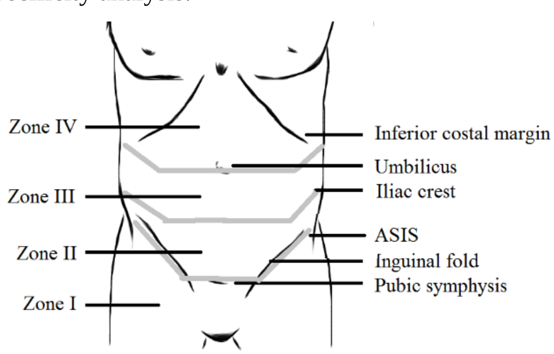

Figure 1 – Abdominal zones for seat belt mark location determination.

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APPENDIX

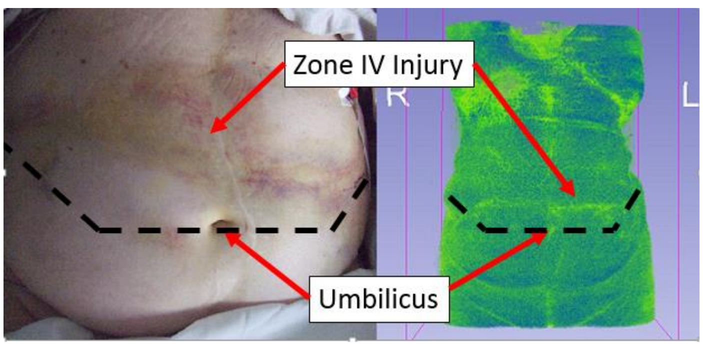

Figure A1 – Example of zone determination for an occupant photo and CT three-dimensional rendering.