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Neck seatbelt sign suspicion of injury score derived from emergency physician diagnostic imaging practice

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Abstract

Introduction: Neck abrasion/contusions from seatbelts after motor vehicle collisions may be associated with underlying bony or vascular injury. The decision to order imaging is highly subjective, and the yield is low. To date, there is no objective guidance in the literature regarding which patients need imaging. The aim of this study was to derive a scoring system from physical characteristics of seatbelt contusion photographs, based on emergency physician (EP) decisions to order imaging.

Methods: A survey of a convenience sample of practicing and academic EPs, given five photographs of a spectrum of seatbelt contusions and a standard brief patient description. Respondents were asked whether and which imaging they would perform for each photo. Respondents rated photos for overall clinical concern for underlying injury and for concern regarding color, size, depth, texture and location on a five-point Likert scale. Logistic regression to assess associations between these five features and overall clinical concern, and the strength of association between features, overall concern, and decision to image was conducted.

Results: Overall, 97 respondents (24% of those surveyed) provided 425 imaging decisions and 95% would image at least one hypothetical patient. However, 40% would not image at least one of the five patients. Decision to image for five photos ranged from 20.0% to 90.6%. Intra-class correlation coefficient for decision to image was fair (0.31, 95% CI 0.13–0.79), indicating variability in practice, and highlighting need for a scoring system. Computed tomography (CT) and CT angiography were used most often for bony and vascular imaging. A 12-point severity scoring system based on location, depth, size and color is proposed. This scale had strong correlation with decision to image (Pearson r = 0.94).

Conclusion: Physician practice shows variability in decision to image patients with neck seatbelt contusions after motor vehicle trauma. A proposed severity scoring system may begin to promote evidence based practice

Introduction

Contusions or abrasions may be useful indicators of underlying injury in victims of motor vehicle collisions (MVC). While seatbelts significantly decrease injury and mortality in MVCs, ‘seatbelt signs’ are also associated with injuries in their anatomical location, including intra-abdominal injury,1 and cervical vascular injury.[2] Their presence should raise a clinician’s suspicion of underlying injury.

A neck seatbelt sign (SBS) without neurological deficit is an inadequate justification for vascular imaging;[3] routine CT angiogram (CTA) for those with a neck SBS revealed vascular injury in only 11 of 418 (2.6%) of cases with blunt carotid artery injury in only 2 of 418 (0.5%) – all cases of vascular injury had other obvious hard/soft tissue injuries or positive findings on standard trauma imaging, suggesting that CTA be reserved for SBS with other injuries or positive imaging.[4] The severity of seatbelt contusion was not well-described in these studies however.

There have been no published attempts to classify SBSs by severity and clinical import, but without this, correlation with internal injury and recommendations for diagnostic work-up appear specious. This study assesses emergency physicians' (EP) perceive clinical relevance of the size, location, depth, color and texture of a neck seatbelt contusion, based on planned diagnostic imaging. It sought to develop a quantitative scoring system based on physical characteristics for SBS classification, which would need validation against underlying injury. Specifically, this study does not suggest specific management based on a given SBS, and is not therefore a decision instrument, rather it seeks to derive a scoring system based on current practice.

Materials and methods

We surveyed a convenience sample of practicing EPs, from March 2012 to January 2013, regarding five photographs of neck seatbelt contusion/abrasions. We used a five-point Likert scale of 'clinical concern,' and asked them whether, and which, imaging studies they would order for each photo.

We obtained study photographs, after patient consent, from alert, hemodynamically stable, adult MVC victims with a neck SBS cared for at a Level I Trauma Center Emergency Department (ED). Out of 15 candidate photographs, three EPs chose five with a spectrum of severity and various qualities (Figure 1a–e). To isolate the effect on clinical judgment, we used the same clinical scenario for all five photographs:

> *'A 35 year old, non-intoxicated restrained driver is brought in by medics 30 minutes after a motor vehicle collision. The patient has stable vital signs and GCS 15. To what degree does the image above of this patient affect your suspicion that the patient has a clinically relevant cervical-vascular injury?'*

The photograph presentation order was computer randomized initially but remained constant for all respondents.

The five-point Likert scale ranged from 1 ('not concerned') to 5 ('very concerned') with a neutral and a 'don't know' choice. Respondents were asked to rate their 'overall concern' of the photo, and then based only on individual characteristics of color, size, depth, texture and location producing five 'characteristic ratings' for each photo. These values were reported using descriptive statistics.

Stata (College Station, TX. version 12.1) was used to assess the linear association between 'overall' and 'characteristic ratings,' (for color, size, depth, text and location) conditional on the photograph, in a random-effects model. This model is appropriate because the raters and photographs are a sample of all raters and photographs of interest.

Additionally, subjects were asked if they would order diagnostic imaging based on their concern for each scenario, and if so, which modality(ies): Computed tomography (CT) of the cervical (C)-spine, CTA of the neck, conventional cervical angiogram, plain cervical x-ray, carotid artery Doppler ultrasound or magnetic resonance-angiogram, or they could specify other imaging in free text.

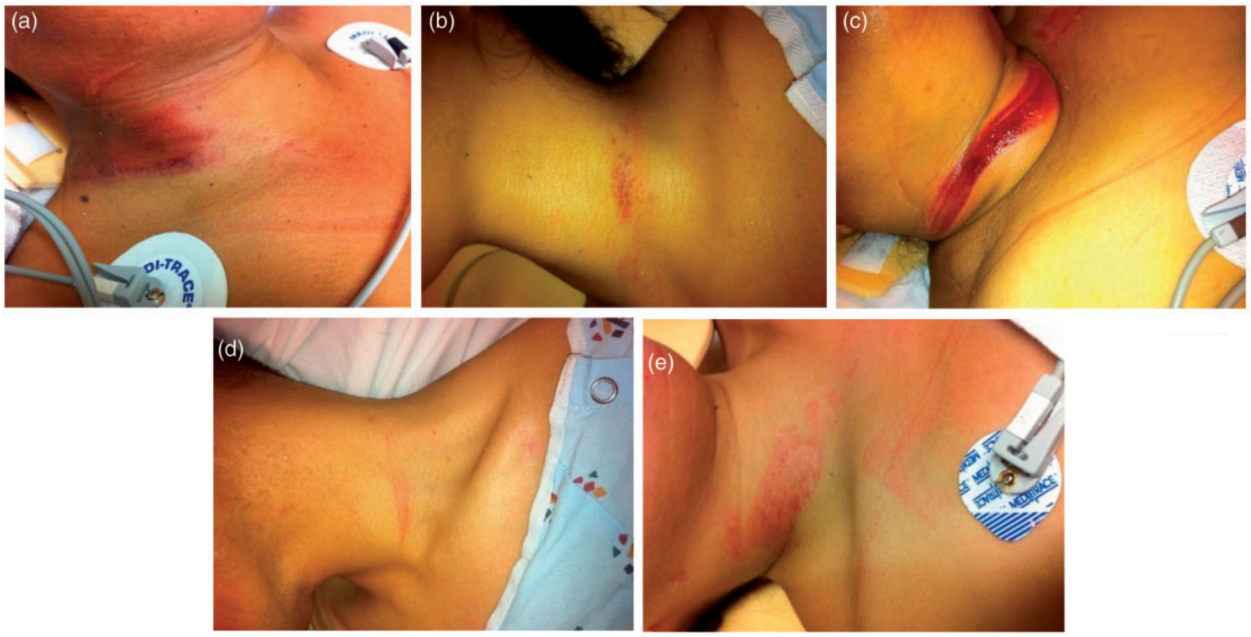

Figure 1. (a–e) Photos of seatbelt signs used for the five different clinical scenarios as described in the survey.

Logistic regression was used to determine the relative contribution of each characteristic, if significant, in determining whether the physicians would order imaging for each of the five patients, which derived a weighted numerical scoring system to reflect severity based on physical characteristics alone. To measure reliability, intra-class correlation coefficients were calculated using a two-way random effects analysis of variance model. The intra-class correlation coefficient is the proportion of variance of an observation due to between-subject, rather than between-rater, variability; thus it is a function of the variability in the data. The values are the multi-rater analogue of Cohen's kappa for two raters.

The survey was administered at a regional professional meeting in California to EPs who attended a booth in the exhibit hall, recruiting a near 100% response rate there. In addition, a single e-mail survey, using surveymonkey. com (Palo Alto, CA) was sent to each of 350 practicing EPs around the US who review for a professional journal, for a total potential sample of 400. The study was approved by the local institutional review board.

Results

We received 97 responses from 400 e-mail queries, giving a 24% response rate; 85 of 97 (88%) responses were complete for all five photos. Most participants worked in academic hospitals (72%), and Level I Trauma Centers (51%); 80% were board certified with the remainder in residency.

Overall level of concern

On the five-point scale, mean 'overall concern' ranged from a low of 2.09 (Photo D) to a high of 4.45 (Photo C). The order of concern from lowest to highest was Photo D, B, E, A and finally C with highest concern (Table 1). Figure 2 is a histogram of concern for each photo, again with lowest concern first.

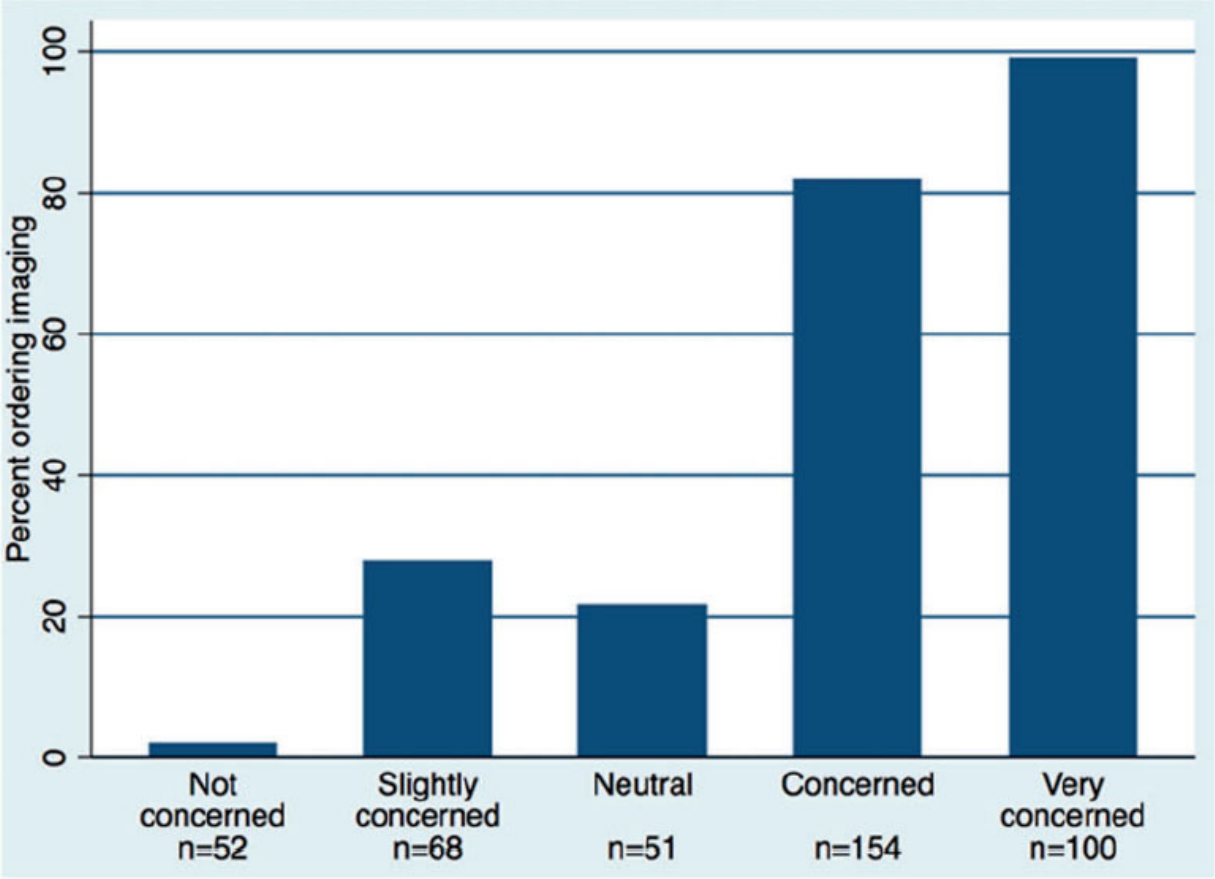

Figure 2. Percent of physicians (n = 85) ordering any imaging by level of concern across all five photographs.

Table 1. Mean overall level of concern for each photo from least to most where 1 = not concerned to 5 = very concerned ($p < .00005$) and number of physicians ordering any imaging ($p < .00005$). Comparisons are for concern and image ordering between all five photographs.

Photo	Overall concern: mean (±SD)	% of physicians ordering imaging
D	2.09 (±1.15)	20.0
B	3.18 (±1.24)	43.5
E	3.45 (±1.05)	69.4
A	3.98 (±1.05)	77.6
C	4.45 (±0.08)	90.6

Seatbelt sign characteristics vs. overall concern and decision to image

Each of the five characteristic ratings were strongly related to the corresponding 'overall concern' (regression coefficients = 0.60–0.88, thus approaching a direct correlation, $p < .0005$). In a multiple regression model, mutually adjusted and conditional on the photograph, each of the characteristics, except texture, were related to the 'overall concern.' Location had the strongest relationship to the 'overall concern' (Table 2).

Table 2. Multiple regression of each characteristic rating as a predictor of 'overall concern' (concern) and decision to image (DTI) using random effects model conditional on respondent. $N = 85$ for each characteristic. NS: not significant.

Characteristic	Coefficient (95% confidence interval)	*p*
Location		
Concern	0.44 (0.37–0.52)	<0.0005
DTI	0.08 (0.04–0.13)	<0.0005
Size		
Concern	0.20 (0.11–0.30)	<0.0005
DTI	0.07 (0.01–0.13)	0.028
Color		
Concern	0.19 (0.10–0.29)	<0.0005
DTI	0.03 (−0.03–0.09)	0.39 (NS)
Depth		
Concern	0.14 (0.03–0.24)	0.012
DTI	0.08 (0.01–0.14)	0.023
Texture		
Concern	0.03 (−0.08–0.14)	0.57 (NS)
DTI	0.01 (−0.05–0.08)	0.66 (NS)

Table 2 also shows the regression coefficients for each characteristic vs. the decision to image (DTI). Location, size and depth were significantly related to DTI.

Together, these two statistical comparisons show which characteristics of the SBS photos are related to both clinical concern and decision making (DTI). We will present a score that considers the relative strengths of association of the SBS characteristics in these two domains

Degree of agreement between respondents

Respondents agreed with each other to a moderate degree regarding 'overall concern' for underlying injury across the five photos, as shown by the intraclass correlation coefficient (ICC) of 0.41 (95% CI 0.19–0.85). The ICCs for the individual 'characteristic ratings' ranged from 0.29 to 0.45, indicating fair to moderate agreement among raters. The ICC for decision to image was lower at 0.31(95% CI 0.13–0.79), indicating fair agreement. This suggests that there was more agreement regarding 'overall concern' than there was on DTI. These levels of agreement reflect face validity that subjects indeed applied similar judgment to the survey questions and evaluation of photos.

Diagnostic imaging in relation to level of concern

There were 85 respondents each making a DTI for five photos, giving 425 imaging decisions. Eighty-one of the 85 respondents (95%) said they would order diagnostic imaging for at least one of the five photos, with CT angiography and CT C-spine being most common at 47% and 20%, respectively. However, 169 of 425 (40%) responses were to not order imaging for a given photo. The 'no imaging' response for each photo was as follows: photo A (22.4%), photo B (56.5%), photo C (9.4%), photo D (80.0%) and photo E (30.6%). For bony imaging, respondents favored CT in 87 cases (20% of all patient decisions, 84% of those imaging bones), but plain radiography in only 17 cases (4%). For vascular imaging, respondents chose CT angiography in 198 cases (47% of all patient decisions, 85% of those imaging vessels) but carotid duplex Doppler ultrasound in only 35 cases (8%).

The number of respondents who would order imaging was strongly related to the 'overall concern' rating. Respondents said they would order imaging for only 1 of 52 (2%) images they rated 'not concerned', and for 99 of 100 (99%) of images rated 'very concerned.' Figure 2 displays the percentage of EPs who would order imaging, by 'overall concern.' There was a strong correlation of imaging ordered with increasing level of concern, with a point-biserial correlation coefficient of 0.70, $p < .00005$. Among EPs ordering imaging, random-effects linear regression identified that CTA was increasingly preferred as 'overall concern' increased, while plain cervical films were thought less useful. The use of other imaging modalities did not vary by 'overall concern.'

Table 3. Seatbelt sign suspicion of injury score point distribution, as derived from EP concern and decision to image (4–12 scale).

	Severity points			
Characteristics	1	2	3	4
Location (relative to vascular bundle)	Not touching	Touching		Spanning
Depth	Epidermis	Dermis	Deeper	
Size (greatest dimension)	<3 cm	3–6 cm	>6 cm	
Color	Pink	Red		
Total possible points: 12				

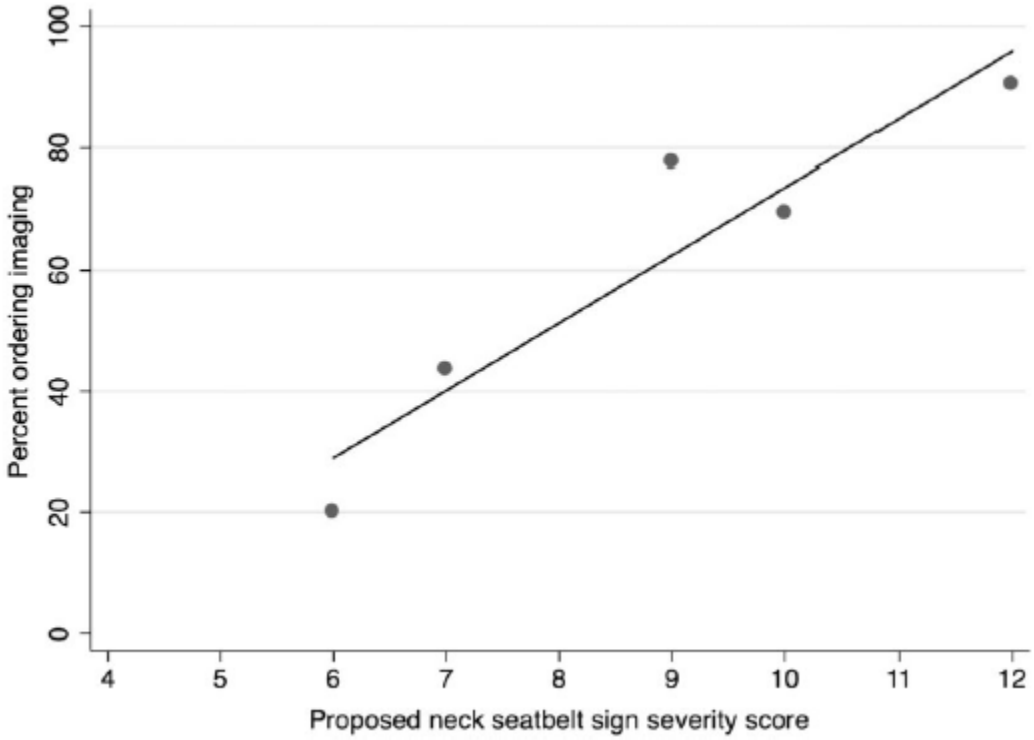

Figure 3. Relation between proposed seatbelt sign suspicion of injury score (0 = no abrasion/contusion at all, and 4–12 for severity) and proportion of emergency physicians who reported they would order any cervical imaging. Solid line depicts regression with Pearson r = 0.94.

SBS suspicion of injury score

Given the agreement between respondents for 'characteristic ratings' (location, depth, size and color ICC = 0.29–0.45), as well as regarding decision to image (ICC = 0.31), we propose a 'suspicion of injury score' that grades neck SBSs by severity as given in Table 3. To illustrate application of this score, the five photographs were then graded using the suspicion of injury score: in descending order of severity score: photo C (12 points), photo E (10 points),

photo A (9 points), photo B (7 points) and photo D (6 points). These scores show a strong correlation to DTI (Pearson r = .94) and there was an increasing intent to order imaging by our respondents by increasing suspicion of injury score (Figure 3), adding face validity to the proposed scoring system.

Discussion

Despite the evidence that SBSs, whether abdominal or cervical, have clinical relevance to predict underlying injury,[1,2] there are no studies that classify seatbelt contusions by severity or correlate physical characteristics with decisions to image.

The only prospective study to date included 88 patients with neck seat belt signs (131 total patients with the remainder thoracic seat belt contusions). It tested the safety of an imaging algorithm for both locations for discovery of vascular injuries with an otherwise-unqualified, 'obvious seat belt sign.'[2] In the algorithm, all patients apparently had imaging, but those with a normal neurovascular examination and Glasgow Coma Scale score were allowed to delay evaluation to within 24 h of admission. Patients with either feature underwent immediate arteriography. Specifically, there was no description of what severity of seat belt sign triggered application of the algorithm.

The study[2] found four of these 88 patients with carotid injuries (4.6%). One had a SBS over the clavicle rather than the neck and had a middle cerebral artery stroke from occluded carotid (on angiogram), and died. There was no description of this or the other patients' severity of seat belt contusion.

Although seat belt signs across the abdomen and chest were associated with internal injuries, Velhamos et al. found no neck injuries among the seven patients with a cervical SBS out of the 650 patients in the study.[5] The authors recommended a high index of suspicion and low threshold for diagnostic evaluation, mostly to detect underlying myocardial contusion and mesenteric/bowel injury. No attempt is made to quantify the severity of the seat belt sign.

A large retrospective study (35,000 patients) from two trauma centers identified 17 patients (0.05%) with blunt carotid injury.6 Patients were evaluated based on published risk factors including cervical hyper-extension or -flexion, a direct blow to the head and neck, cervical seat-belt sign, GCS less than 7, diffuse axonal brain injury, cervical spine, skull, midface or mandibular fracture.7 Overall, 6 of 17 patients showed no signs of blunt carotid artery injury and 11 of 17 had a stroke, nine of which were within 2 h. The authors question the wide application of imaging for screening of patients with these common injuries as only one patient may have had an undiagnosed, clinically occult blunt cerebrovascular injury detected. Again, the 'seat-belt' sign used in these trauma centers to raise suspicion for carotid injury is not described.

In the trauma center from which this study originated, the use of the subjective seat belt sign criterion to trigger vascular imaging resulted in a 2.6% rate of discovery of vascular injuries (11/418 patients over 11 years), including a 0.5% incidence of blunt carotid artery injury (two patients).[2] This low yield suggests the need for additional criteria beyond the mere presence of the seat belt sign to improve the yield of expensive and radiation-intensive imaging.

Overall level of concern

This study has shown that there is an intuitive hierarchy of severity among EPs when evaluating seatbelt contusions of the neck. The mean 'overall' rating of concern for each of the

five SBS photos shows consensus, as evidenced by differing point estimates and relatively narrow standard deviations (Table 1). Furthermore, the ICC of 0.41 for 'overall concern,' but a lower ICC of 0.31 for DTI, indicates more agreement on perceived severity than imaging. This supports the development and validation of a suspicion of injury score to better inform the decision to image.

Level of concern for SBS characteristics

We found that, of five SBS characteristic studied, Eps considered 'location' most important, followed by 'size' and 'depth' (approximately equivalent), followed by 'color' as least important but still significantly associated with 'overall concern,' but not DTI (Table 2); 'texture' was not associated with either 'overall concern' or DTI. Therefore, we propose a suspicion of injury score which assigns four potential points to location with the strongest association, three each for size and depth, and only two to color with the weakest association.

Diagnostic imaging

We found that EPs are more likely to order imaging with increasing concern, adding face validity to our results. CTA was preferred, regardless of level of concern, with CT neck and Doppler ultrasound as second and third preferences, respectively. While Doppler ultrasound has adequate sensitivity (93%) for cervical vascular injury,8 CTA better evaluates vessels, as well as bony cervical spine.9 Therefore regardless of concern, EPs studied here prefer CTA for vascular evaluation.

Variation in practice. We found wide variation in practice regarding DTI at all, as well as which modality to use. While 40% of all respondents would not image patients with one of the five SBSs at all, 90% would image the most concerning one. Furthermore, it appears some physicians are quite concerned for underlying injury, as 17.6% would image patients with the entire spectrum of SBS presented, while 4.7% would image none. This again highlights the importance of developing a suspicion of injury score.

Scoring systems, however valid, should not be used in isolation from other clinical findings. Neck hematoma, neurologic deficit, bruit or active bleeding, are independent indications for imaging, but these are uncommon.[10]

Clearly, this proposed suspicion of injury score needs to be validated prospectively and correlated with presence and severity of underlying injury. With every analysis of this data set, we have found practice variation and uncertainty and we view this study as a first step to bring evidence to this highly subjective clinical judgment.

Limitations

The suspicion of injury score derived here does not inform whether an EP should order imaging or what type, only that EPs would have ordered imaging in these hypothetical cases. Further studies would be needed to determine the threshold for, and yield of diagnostic imaging.

The study reports a small convenience sample with a relatively low response rate. Photographs were chosen to depict a spectrum of seatbelt contusions, but were neither chosen nor thought to represent the entire spectrum of severity. Of the five characteristics, texture is difficult to determine in a two-dimensional photograph. Respondents may have been confused

regarding the 'neutral' choice in the five-point Likert scale, but we provided this to avoid obvious severity bias. Our 'location' quality may not have had sufficient variety to determine level of concern, as all photographs have similar neck locations. Our respondents' experience may not reflect community opinion as academic centers were overrepresented and have ready access to advanced imaging. We did not assess potential or concern for thoracic injury. Finally, our classification scheme must be viewed as exploratory and requires validation before use.

Conclusion

EPs show moderate agreement in their level of concern regarding seatbelt contusions of the neck, but wide variation in decision to image these. They are more concerned when the contusions are located over the vascular bundle, are large and deep, and red. They prefer CT angiography to plain x-ray, MR angiography and Doppler ultrasound for evaluating underlying injury. A simple 12-point suspicion of injury score, if validated, may aid decisions to order imaging and discover underlying bony or vascular injury.

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