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Authors
Yu, Louis
Baumann, Brigitte M
Raja, Ali S
et al.

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Louis Yu, MD, [1] Brigitte M. Baumann, M.D., M.S.C.E.,[2] Ali S. Raja, M.D., M.P.H.[3], William R. Mower, M.D., Ph.D.,[4] Mark I. Langdorf, M.D.,[5] Anthony J. Medak, M.D.,[6] Deirdre R. Anglin, M.D. MPH,[7] Gregory W. Hendey, M.D.,[4] Daniel Nishijima, M.D.[8], Robert M. Rodriguez, M.D[1]

[1]Department of Emergency Medicine, The University of California San Francisco

[2]Department of Emergency Medicine, Cooper Medical School of Rowan University

[3]Department of Emergency Medicine, Massachusetts General Hospital/Harvard Medical School

[4]Department of Emergency Medicine, University of California Los Angeles

[5]Department of Emergency Medicine, University of California Irvine

[6]University of California San Diego School of Medicine

[7]Department of Emergency Medicine, Keck School of Medicine, University of Southern California

[8]Department of Emergency Medicine, University of California Davis School of Medicine

Corresponding Author: Robert M. Rodriguez, MD

Professor of Emergency Medicine

Department of Emergency Medicine

University of California San Francisco

1001 Potrero Ave, San Francisco, CA 94110

Email: robert.rodriguez@ucsf.edu

Phone: (415) 206-5875

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DR. DANIEL KIDEN NISHIJIMA (Orcid ID : 0000-0003-4952-8212)
DR. ROBERT M RODRIGUEZ (Orcid ID : 0000-0003-1354-1773)

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ABSTRACT

Background: In the era of frequent head-to-pelvis CT for adult blunt trauma evaluation, we sought to update teachings regarding aortic injury by determining 1) the incidence of aortic injury; 2) the proportion of patients with isolated aortic injury (without other concomitant thoracic injury); 3) the clinical implications of aortic injury (hospital mortality, length of stay, and rate of surgical interventions); and 4) the screening value of traditional risk factors/markers (such as high-energy mechanism and widened mediastinum on chest x-ray [CXR]) for aortic injury, as compared to newer criteria from the recently developed NEXUS Chest CT decision instrument.

Methods: We conducted a pre-planned analysis of patients prospectively enrolled in the NEXUS Chest studies at ten level 1 trauma centers with the following inclusion criteria: age > 14 years, blunt trauma within 6 hours of ED presentation, and receiving chest imaging during ED trauma evaluation.

Results: Of 24,010 enrolled subjects, 42 (0.17%, 95% confidence interval [CI] 0.13-0.24%) had aortic injury. Most patients (79%, 95% CI 64-88%) had an associated thoracic injury, with rib fractures, pneumothorax/hemothorax and pulmonary contusion occurring most frequently. Compared to patients without aortic injury this cohort had similar mortality (9.5%, 95% CI 3.8-22.1%] versus 5.8%, 95% CI 5.4-6.3%]), longer median hospital length of stay (11 versus 3 days, p < 0.01) and higher median injury severity score (29 versus 5, p < 0.001). High-energy mechanism and widened mediastinum on CXR had low sensitivity for aortic injury (76% [95% CI, 62-87%] and 33% [95% CI, 21-49%] respectively), as compared to the NEXUS Chest CT decision instrument (sensitivity 100% [95% CI, 92-100%]).

Conclusions: Aortic injury is rare in adult ED blunt trauma patients who survive to receive imaging. Most ED aortic injury patients have associated thoracic injuries and survive to hospital discharge. Widened mediastinum on CXR and high-energy mechanism have relatively low screening sensitivity for aortic injury, but the NEXUS Chest decision instrument detected all cases.

INTRODUCTION

The desire to detect (or not miss) significant injury and the broad availability of rapid computed tomography (CT) have ushered in the era of frequent head-to-pelvis CT (pan-scan) in adult blunt trauma patient evaluation over the past two decades. Although major injury prevalence in the US remained stable, the proportion of CT scans performed per injury-related visit more than doubled from 1998 to 2007 (1), and currently, 245 CT scans are performed per 1000 patients annually -- more than any other high-income country by a wide margin (2). Aortic injury is one of the gravest thoracic complications of blunt trauma, and the need for its detection may be a major driving force for increased chest CT utilization.

The incorporation of frequent chest CT in the evaluation of blunt trauma patients mandates a need for reassessment of traditional teachings about injuries detected. Using data from our large, prospectively derived database of adult blunt thoracic injuries (the NEXUS Chest studies), we have previously updated and revised classic teachings regarding pulmonary contusion, sternal fracture, rib fracture, scapular fracture, and pneumothorax/hemothorax in the modern era (3-7). In this analysis, we seek to similarly update teachings about aortic injury. Specifically, we sought to determine 1) the incidence of aortic injury in adult blunt trauma patients who receive imaging, 2) how often aortic injury occurs in isolation (without other thoracic injury), 3) the clinical implications of aortic injury (mortality, hospital length of stay, and rate of surgical interventions), and 4) the screening value of traditional risk factors and markers for aortic injury (high-energy, rapid deceleration mechanism and widened mediastinum on CXR) as compared to newer criteria from the recently developed NEXUS Chest CT decision instrument (DI).

METHODS

Study Design

We conducted a planned secondary analysis of data from two prospective, observational studies of four cohorts of adult blunt trauma patients: derivation and validation cohorts in the NEXUS Chest study (conducted from January 2009 to December 2012) and in the NEXUS Chest CT study (conducted from August 2011 to May 2014) (8-10). We obtained Institutional Review Board approval at all study sites prior to enrollment.

Setting and Participants

The specifics of these parent studies have been previously described (8-10). Briefly, we conducted both studies at ten urban United States Level 1 trauma centers, prospectively enrolling blunt trauma patients with the following inclusion criteria: 1) patient age >14 years; 2) presenting to the Emergency Department (ED) within 6 hours of blunt trauma; and 3) receiving chest imaging (CXR and/or chest CT ordered at the discretion of providers) during their ED evaluation. All injuries in this analysis were identified from ED imaging with the index CXR preceding chest CT in all cases.

Measures and Outcomes

Our primary outcome measures were 1) the incidence of aortic injury in adult blunt trauma patients, 2) the proportion of patients whose aortic injury occurs in isolation (without other thoracic injury on chest imaging), 3) aortic injury associated hospital mortality, length of stay, and rate of surgical interventions, and 4) the sensitivity of a) high energy mechanism (defined a priori as fall > 20 feet, MVC > 40 miles per hour, or pedestrian hit by motorized vehicle), b) widened mediastinum on CXR, and c) NEXUS Chest CT DI criteria for aortic injury – see Box.(8)

Box. NEXUS Chest CT Criteria to guide selective chest CT

1) Rapid deceleration mechanism
2) Distracting injury
3) Chest wall tenderness
4) Sternal tenderness
5) Thoracic spine tenderness
6) Scapular tenderness
7) Abnormal CXR defined as any injury or widened mediastinum seen on CXR

Data management and analysis

We managed input data using Research Electronic Data Capture (RedCAP) hosted by the University of California, San Francisco and exported completed data to Microsoft Excel for sorting and STATA v14 (College Station, TX) for analyses. For age, ISS and LOS, we determined medians and interquartile ranges (IQRs). For the incidence of aortic injury, mortality, rate of isolated aortic injury, sensitivity and other proportions, we calculated 95% confidence intervals (CIs). Because aortic injury is considered to be a grave, highly lethal injury and because the low prevalence of disease would artificially inflate negative predictive value (NPV), sensitivity was chosen as the screening parameter of choice (instead of specificity and NPV). To compare sensitivities we calculated difference in proportions with 95% CIs that did not cross zero indicating significant difference. In terms of reporting our work, we followed the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines.

RESULTS

Of 24,010 enrolled subjects, 42 (0.17%; 95% CI 0.13- 0.24%) had aortic injury. See Table 1 for characteristics of aortic injury versus non-aortic injury patients. Nine patients (21%, 95% CI, 12-36%) had isolated aortic injury. The most common associated thoracic injuries were rib fractures (57%), pneumothorax (45%), pulmonary contusion (31%), hemothorax (24%), and sternal fracture (12%).

Compared to patients without aortic injury, the aortic injury group had statistically similar mortality (9.5% versus 5.8%, difference 3.7% 95% CI -2.0 to 16.3%), longer median hospital LOS (11 days versus 3 days) and higher median ISS (29 versus 5). The four deaths in aortic injury patients were attributed to traumatic brain injury and not to the aortic injury itself. Most aortic injury patients (57%) had surgical interventions – exclusively endovascular repair.

The sensitivities of high-energy mechanism and widened mediastinum on CXR for aortic injury were 76.2% (95% CI 61.5-86.5%) and 33.3% (95% CI 21.0-48.5%), respectively – both significantly lower than the sensitivity of the Nexus Chest CT decision instrument (100% [95% CI 91.6-100%]). See Table 2.

LIMITATIONS

Our greatest limitation in this study is that we only captured patients who survived in the ED long enough to have chest CT (not patients who died in the field or immediately in the ED), and we therefore cannot assess the true incidence of aortic injury and its true overall mortality. Although we conducted follow-up procedures to detect work-up bias, we could not completely rule out aortic injury in patients who did not receive chest CT (only received CXR). We also conducted this study at high-volume, urban Level 1 trauma centers, which may introduce spectrum bias limiting generalization of our findings to lower acuity trauma centers. We did not fully account for confounding factors, such as injury to other organ systems that likely affected the outcomes of admission rates, LOS and mortality. Finally, even though we had a large total sample size of over 24,000 patients, the low number of aortic cases led to wide confidence intervals in many of our analyses that may have precluded finding significant differences where they truly exist -- especially with regards to mortality.

DISCUSSION

The evolution of trauma imaging practice toward more CT utilization mandates reconsideration of traditional teachings about traumatic injuries. As such, we present a number of notable findings regarding aortic injury in the era of frequent chest CT for blunt trauma. First, the incidence of aortic injury in ED blunt trauma patients is low, especially considering that we only included trauma patients who had chest imaging – a more injured group of patients than all-comers who did not receive chest imaging. The incidence in an unselected group of ED blunt trauma patients would almost certainly be lower. Using ICD 9 codes from the 2000-2005 National Trauma Databank, Arthurs et al found that 0.3% of blunt trauma admissions had aortic injury (11); when removing the 23% of these patients who died on ED arrival or in triage (presumably prior to imaging), the resultant 0.22% incidence of aortic injury closely approximates ours.

Second, we found that isolated aortic injury is even rarer – 9/24010 (0.03%) of all patients in this study. Aortic injury more commonly occurs as part of a thoracic injury complex associated with other injuries. As such, management for these cases often involves a multi-modal approach with stabilization of thoracic injuries beyond the aortic repair, as well as treatment of injuries outside of the thorax.

Third, mortality was low and death in the few patients who died was attributed to other injuries. Given that this was an observational study, we cannot determine whether this low mortality resulted from early detection and surgical intervention or other factors. Additionally, as noted above, we did not evaluate patients who died in the field or before imaging, and therefore overall mortality from aortic injury is higher. Our research supports a body of evidence suggesting that inpatient mortality from aortic injury has steadily declined in the past few decades (12-15). Examining blunt aortic injury patient data from 1977-1985, Cowley et al reported inpatient mortality of 33%, while later studies in 1997 and 2007 found aortic injury mortality of 22% to 13% (12-14), respectively. These reductions in morality were associated with a transition in diagnostics from aortography to CT scan, higher rates of endovascular repair instead of open surgical techniques, and increased use of cardiovascular bypass (14,15).

Finally, we have several findings regarding screening markers that may inform decisions for the ordering of chest CT to detect aortic injury. Counter to classic teachings (16-19), widened mediastinum and abnormal CXR had low sensitivity for aortic injury. The sensitivities of high-energy mechanism and distracting injury are higher, but still insufficient for use as rule out criteria. Thus, none of the three components of blunt thoracic trauma evaluation (history [mechanism of injury], physical exam [thoracic tenderness and distracting injury], or imaging [CXR]) had high sufficiently high sensitivity for aortic injury as criteria by themselves. The gravity of aortic injury mandates that a screening tool should have perfect or near-perfect sensitivity, and we therefore recommend use of the NEXUS Chest CT decision instrument, which incorporates all three trauma evaluation components, and detected all cases**.**

CONCLUSIONS

Aortic injury is rarely diagnosed in the current era of frequent chest CT for adult blunt trauma patient evaluation. Aortic injury is usually seen as part of a thoracic injury complex and inpatient mortality (for those who survive long enough to be imaged) is low. Classic risk stratification markers of widened mediastinum and high-energy mechanism are insensitive predictors of aortic injury, while the NEXUS Chest CT DI detected all cases.

REFERENCES

1. Korley FK, Pham JC, Kirsch TD. Use of Advanced Radiology During Visits to US Emergency Departments for Injury-related Conditions, 1998–2007. *JAMA*. 2010 Oct 6; 304(13):1465–71. DOI: 10.1001/jama. 2010.1408 PMID: 20924012
2. Papanicolas I, Woskie LR, Jha AK. Health Care Spending in the United States and Other High-income Countries. *JAMA*. 2018 March 13; 319(10): 1024-39. DOI: 10.1001/jama.2018.1150.
3. Perez MR, Rodriguez RM, Baumann BM, et al. Sternal Fracture in the Age of Pan-scan. *Injury*. 2015; 46:1324-7. DOI: 10.1016/j.injury.2015.03.015.
4. Rodriguez RM, Friedman B, Langdorf MI, et al. Pulmonary Contusion in the Pan-scan Era. *Injury*. 2015. DOI: 10.1016/j.injury.2015.11.043.
5. Murphy CE, Buamann BM, …Rodriguez RM (senior author). Rib Fracture Diagnosis in the Pan Scan Era. *Ann Emerg Med*. 2017 May 27. DOI: 10.1016/j.annemergmed.2017.04.011.
6. Brown C, Elmobdy K, Raja AS, Rodriguez RM. Scapular Fractures in the Pan-scan Era. *Acad Emerg Med.* 2018 Jan 11. DOI: 10.1111/acem.1337.
7. Rodriguez RM, Canseco K, et al. Pneumothorax and Hemothorax in the Age of Frequent CT Scan for Blunt Trauma. *Ann Emerg Med*. DOI: 10.1016/j.annemergmed.2018.08.423.
8. Rodriguez RM, Langdorf MI, Nishijima D, et al. Derivation and Validation of Two Decision Instruments for Selective Chest CT in Blunt Trauma: A Multicenter Prospective Observational Study (NEXUS Chest CT). *PLoS Med.* Oct 6, 2015;12(10):e1001883. DOI: 10.1371/journal.pmed.
9. Rodriguez RM, Hendey GW, Mower W, et al. Derivation of a Decision Instrument for Selective Chest Radiography in Blunt Trauma. *Jour of Trauma.* 2011; 71:549-53. DOI: 10.1097/TA.0b013e3181f2ac9d.
10. Rodriguez RM, Anglin D, Langdorf MI, et al. NEXUS Chest: Validation of a Decision Instrument for Selective Chest Imaging in Blunt Trauma. *JAMA Surg*. 2013; 148(10): 940-946. DOI: 10.1001/jamasurg.2013.2757.

11. Arthurs ZM, Starnes BW, Sohn VY, Singh N, Martin MJ, Andersen CA. Functional and survival outcomes in traumatic blunt thoracic aortic injuries: An analysis of the National Trauma Databank. *J Vasc Surg*. 2009; 49(4): 988-94. DOI: 10.1016/j.jvs.2008.11.052.

12. Cowley RA, Turney SZ, Hankins JR, Rodriguez A, Attar S, Shankar BS. Rupture of Thoracic Aorta Caused by Blunt Arauma: A Fifteen-year Experience. *J Thorac Cardiovasc Surg*. 1990 Nov;100(5):652-660; 660-1.

13. Fabian TC, Richardson JD, Croce MA, et al. Prospective Study of Blunt Aortic Injury: Multicenter Trial of the American Association for the Surgery of Trauma. *J Trauma*. 1997;42:374-380. DOI: 10.1097/00005373-199703000-00003.

14. Demetriades D, Velmahos GC, Scalea TM, et al. Operative repair or endovascular stent graft in blunt traumatic thoracic aortic injuries: results of an American Association for the Surgery of Trauma Multicenter Study. *J Trauma*. 2008;64:561-570. DOI: 10.1097/TA.0b013e3181641bb3.

15. Demetriades D, Velmahos GC, Scalea TM, et al. Diagnosis and treatment of blunt thoracic aortic injuries: changing perspectives. *J Trauma.* 2008; 64(6): 1415-8. DOI: 10.1097/TA.0b013e3181715e32.

16. Kram HB, Wolmuth DA, Appel PL, Shoemaker WC. Clinical and Radiographic Indications for Aortography in Blunt Chest Trauma. *J Vasc Surg*. 1987 Aug;6(2):168-76. DOI: 10.1067/mva.1987.avs0060168.

17. Wong YC, Ng CJ, Wang LJ, Hsu KH, Chen CJ. Left Mediastinal Width and Mediastinal Width Ratio are Better Radiographic Criteria than General Mediastinal Width for Predicting Blunt Aortic Injury. *J Trauma*. 2004 Jul;57(1):88-94. DOI: 10.1097/01.ta.0000082158.49654.e7.

18. Mirvis SE, Bidwell JK, Buddemeyer EU, *et al.* Value of Chest Radiography in Excluding Traumatic Aortic Rupture. *Radiology*, 163 (1987), pp. 487-493. DOI: 10.1148/radiology.163.2.3562831.

19. Marnocha KE, Maglinte DD, Woods J, et al. Blunt Chest Trauma and Suspected Aortic Rupture: Reliability of Chest Radiograph Findings. *Ann Emerg Med*. 1985 Jul;14(7):644-9. DOI: 10.1016/s0196-0644(85)80879-9.

Characteristic	Aortic injury (n=42)	No aortic injury (n=23,968)
Male, n (%)	32 (76)	14,853 (62)
Age in years, median (IQR)	49 (37-68)	45 (29-61)
GCS score, median (IQR)	15 (14-15)	15 (15)
ISS, median (IQR)	29 (17-44)	5 (1-10)
Hospital LOS, median (IQR)	11 (4-23)	3 (1-5)
Admitted n (%)	42 (100)	12,629 (53)
Mechanism of Injury:		
Motor vehicle accident	23 (55)	8,453 (35)
Pedestrian struck by vehicle	8 (19)	2,508 (10)
Fall > 20 feet	4 (10)	6,406 (27)
Bicycle crash	3 (7)	1,650 (7)
Fall from standing	0	3,591 (15)
Stuck by object or assault	0	1,475 (6)
Other or unknown	2 (5)	1,287 (5)

Table 1. Characteristics of aortic injury patients versus non-aortic injury patients

GCS = Glasgow Coma Score, ISS = Injury Severity Score, IQR = interquartile ratio, LOS = length of stay

Table 2. False negatives and sensitivity of criteria for aortic injury

Criteria	False Negatives (n=42)	Sensitivity
Widened mediastinum on chest x-ray	28	33% (95% CI 21-49%)
High energy mechanism	10	76% (95% CI 61-87%)
Chest, sternal, thoracic spine, or scapular tenderness to palpation	20	52% (95% CI 38-67%)
Distracting injury*	9	79% (95% CI 64-88%)
Abnormal CXR#	14	67% (95% CI 52-79%)
NEXUS Chest CT DI	0	100% (95% CI 92-100%)

CT = computed tomography, DI = decision instrument, CI = confidence interval, CXR = chest x-ray

*Distracting injury was defined a priori as any condition thought by the clinician to produce pain sufficient to distract from a second injury, including, but not limited to long bone fracture, visceral injury requiring surgical consultation, large laceration, degloving injury, crush injury, large burns, or any injury causing acute functional impairment.

#Abnormal CXR was defined as any injury (including clavicle fracture) or widened mediastinum seen on CXR

Figure: Enrollment and Classification