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Upper Extremity Trauma Resulting From Agricultural Accidents: Mechanism and Severity for Patients With and Without Upper Extremity Injury

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Abstract

Background: Farming remains the most dangerous occupation in the United States and upper extremity (UE) injuries occur frequently in agricultural accidents. The purpose of this study is to describe the injury mechanisms, severity, and health care costs of UE injuries resulting from agricultural accidents and to compare patients with and without injuries to the UE. **Methods:** We performed a 6-year retrospective review of our level I trauma center registry from January 2006 to May 2013, identifying all patients injured in an agricultural accident. Data collection included baseline demographics, injury type and mechanism, costs and treatment. Patients with UE injuries were compared with those without UE injuries. **Results:** Ninety-six of 273 patients (35%) sustained an UE injury with fractures of the phalanx and radius/ulna occurring most frequently. Patients with UE injuries were more likely to be injured from table saws ($P = .0003$) and farm machinery ($P < .0001$). Twenty-one percent with UE injuries sustained a mangled extremity. Patients with UE injuries were more likely to require surgery (68% vs 36%, $P < .0001$) and were more likely to be readmitted (17% vs 5%, $P = .0007$) with risk factors for readmission including age >18 years, falls from height, and surgery. Mean hospital charges were $95 147. **Conclusions:** Patients sustaining agricultural UE injuries have longer lengths of stay and more frequently require surgery despite similar hospital charges compared with non-UE injured patients. Hospital readmissions occur frequently for patients with UE injuries. Understanding injury mechanisms and the epidemiology of these potentially devastating and costly injuries may help guide agricultural injury prevention programs.

Keywords: upper extremity, epidemiology, agricultural accidents, trauma, health care costs

Introduction

Farming remains the most dangerous occupation in the United States.[4] The morbidity and mortality associated with this vocation has been well documented.[2,8,10,14] The upper extremity (UE) is the most commonly involved region for injuries that result from agricultural accidents.[7] These injuries can result from a variety of mechanisms. Tractor accidents, mechanical corn pickers, hay bailers, and grain augers have all been described in the literature.[1,3,5,6,9,13] Farm-related injuries can be expensive for patients when considering both associated health care costs as well as loss of income from sick leave.

The treatment of UE injuries resulting from agricultural accidents requires unique management considerations. Patients from rural farming communities may have prolonged prehospital transport times or be transferred from outside institutions for definitive care, particularly when treatment at a tertiary center is required. Contamination of soft tissue wounds can complicate management. Furthermore, a multidisciplinary approach may be required, particularly in higher energy mechanisms involving multisystem trauma when decisions regarding limb salvage or amputation are required. Understanding the epidemiology of these injuries may help develop injury prevention strategies, reduce hospital costs, and prevent readmissions.

In our experience, some of the most complex UE trauma treated at our institution has occurred from farm-related injuries. Anecdotally, we have observed that the UE, when

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involved, was more consistently injured to a more severe nature and frequently required multiple procedures (both acute and delayed) and additional soft tissue coverage. The purpose of this study is to describe the injury mechanisms, severity, and health care–related costs of UE injuries resulting from agricultural accidents. In addition, we aim to compare injury mechanisms, treatments, and injury severity for patients who sustained agricultural-related accidents with and without injuries to the UE.

Materials and Methods

Institutional review board approval was obtained. Our trauma registry allows for identification of patients injured as a result of agricultural or farming accidents. Patients identified through our registry who presented to the emergency department at our rural level I trauma center between January 2006 and May 2013 with any injury related to an agricultural accident were included in our analysis. We retrospectively reviewed the electronic medical records of all patients included in the study.

Data collection included age, sex, insurance status, admission date, length of hospital stay, intensive care unit (ICU) admission, mechanism of injury, Glasgow Coma Score (GCS), injury severity score (ISS), and trauma-related injury severity score (TRISS). After identifying the injury complex by reviewing radiographs, physician notes, and *International Classification of Diseases, Ninth Revision* (*ICD-9*) codes for each patient, we further identified patients who had sustained an UE injury. UE injuries were defined as any soft tissue or osseous injury involving the upper limb from the scapula to the fingertips.

The type of treatment and operative intervention were recorded for each patient including the number and type of procedures performed. Of note, open fractures with gross contamination were treated on an emergent basis. Open fractures without gross contamination (and without an indication for emergent intervention) were treated in the operating room within 12 hours of presentation as urgent injuries. We utilize a multidisciplinary approach to treating these injuries. Orthopedic surgery is the primary service involved in the operative management of extremity injuries, and general trauma surgery will often admit and help manage multiply injured patients. Plastic surgery is involved in soft-tissue coverage procedures and vascular surgery functions as a consulting service. Additional data were recorded for each patient, including in-hospital mortality, Functional Independence Measure (FIM) score, disposition at time of discharge, and total hospital charges.

All statistical analysis was performed using SAS software (SAS 9.3, Cary, North Carolina) with differences of $P < .05$ considered statistically significant. The patients with and without UE injuries were compared using Student *t* testing (for comparison of means) or chi-square testing (for percentages). Injury severity scores follow a discrete Poisson distribution; thus, *P* value was calculated from a Poisson regression comparison of mean ISS scores.

Results

A total of 273 patients met inclusion criteria. Ninety-six patients (35%) sustained UE injuries as a result of an agricultural accident. Table 1 outlines the baseline demographics and injury characteristics for patients with and without UE injuries. While patients with UE injuries required longer hospital length of stay (5.7 vs 4.8 days, $P = .001$) compared with patients without UE injuries, they were less likely to require admission to the ICU (10% vs 24%, $P = .006$). Patients with UE injuries were significantly more likely to be uninsured (42% vs 17%, $P < .0001$). There were significant differences with respect to injury mechanism, as patients with UE injuries were more likely to be injured as a result of table saw accidents ($P = .0003$) and farm machinery ($P < .0001$) than patients without UE injuries.

The specific types of UE injuries sustained are presented in Table 2. Phalanx fractures were the most common UE fractures (30%) followed by fractures of the radius or ulna (20%) and clavicle (14%). While 32% of these patients had an isolated hand injury, 21% of patients with UE injuries sustained a mangled UE defined as including all or nearly all of the major functional systems of an extremity including skin/soft tissue, vascular, nerve, muscle/tendon, bone, and joint. Of the 21 patients who sustained a mangled extremity, 62% resulted from farm machinery accidents ($P < .0001$).

Table 3 outlines the operative interventions between the 2 groups. Sixty-eight percent of patients with UE injuries required an operative procedure compared with 36% of patients without UE injuries ($P < .0001$). Sixty-seven percent of UE injured patients required orthopedic operative intervention versus 29% of patients without UE injuries ($P < .0001$). Table 4 provides details for the types of UE operative procedures performed. The most common procedure was debridement and irrigation (42%) followed by ORIF (26%) and soft-tissue coverage procedures (9%).

Table 5 illustrates the functional outcomes associated with treatment. Inpatient mortality was 3%. Mean total hospital charges were $90 594 for all patients, and no statistically significant difference was found between patients with and without UE injuries ($95 147 vs $88 125, $P = .54$). Patients with UE injuries were more likely to be readmitted (17% vs 5%, $P = .0007$), and Table 6 outlines risk factor for readmission for patients with UE injuries, including adult patients ($P = .009$), patients who sustained falls from height ($P = .04$), and patients who required operative intervention ($P = .002$). Of the 16 patients (17%) with UE injuries who were readmitted, 2 were unplanned (poor pain control after

Table 1. Baseline Demographics and Injury Characteristics for Patients With and Without UE Injuries.

	Patients without UE injury	Patients with UE injury	*P* value
Total patients, No.	177	96	—
Male, No. (%)	148 (84)	81 (84)	.87
Age in years, mean (SD)	41.9 (25.7)	37.9 (24.8)	.22
Pediatric patients <18years, %	25	26	.83
Uninsured, No. (%)	30 (17)	40 (42)	<.0001
Transfer from outside hospital, No. (%)	83 (47)	34 (35)	.07
Mean length of stay, days (range)	4.8 (1-32)	5.7 (1-56)	.001
Season of admission, No. (%)			.46
Winter	22 (12)	14 (15)	
Spring	50 (28)	28 (29)	
Summer	56 (32)	22 (23)	
Fall	49 (28)	32 (33)	
ICU admission, No. (%)	43 (24)	10 (10)	.006
Length of ICU stay, mean days per patient admitted to ICU (range)	4.6 (1-20)	8.8 (1-39)	<.0001
Readmitted, No. (%)	8 (5)	16 (17)	.0007
Length of readmission, mean days per patient readmitted (range)	1.4 (1-2)	3.1 (1-18)	.02
GCS, mean (range)	14.1 (3-15)	14.1 (3-15)	.53
ISS, mean (range)	13.5 (1-50)	11.8 (1-43)	.0001
TRISS, mean (range)	93.8 (4-99)	92.5 (3-99)	.008
Orthopedic injuries, No. (%)	100 (57)	96 (100)	<.0001
Mechanism of injury, No. (%)			
Animal	38 (22)	4 (4)	.0001
Falls	64 (36)	26 (27)	.13
Table saw	0 (0)	7 (7)	.0003
Machine	22 (12)	34 (35)	<.0001
Farm vehicle	53 (30)	25 (26)	.50
Associated injuries, No. (%)			
Abdomen	26 (15)	8 (8)	.13
Chest/thorax	46 (26)	25 (26)	.99
Face	56 (32)	15 (16)	.004
Head	58 (33)	18 (19)	.01
Rib Fracture	39 (22)	21 (22)	.98
Patients with any fracture, No. (%)	93 (53)	85 (89)	<.0001
Patients with UE fracture, No. (%)	0 (0)	82 (85)	<.0001
Patients with lower extremity fracture, No. (%)	67 (38)	13 (14)	<.0001
Patients with spine fracture, No. (%)	34 (19)	11 (12)	.10

Note. UE = upper extremity; ICU = intensive care unit; GCS = Glasgow Coma Score; ISS = injury severity score; TRISS = trauma-related injury severity score.

discharge and postoperative infection, respectively). The remaining 14 patients were readmitted for additional operative procedures (staged or delayed fixation and hardware removal).

Discussion

Agricultural injuries are associated with substantial morbidity, mortality, and cost. According to the U.S. Bureau of Labor Statistics, fatal occupational injuries occurred at a rate of 25 per 100 000 workers in the farming industry compared with 13 per 100 000 workers in construction.[4] In our analysis of the epidemiology of agricultural accidents at a rural level I trauma center, we note a 3% inpatient mortality rate and 35% of our patients with agricultural injuries sustained an injury to their UE. This compares well to a series of 260 farm-injured patients reported by Hansen and Carstensen where 45% of patients injured on the farm sustained an UE injury.[8]

Upper extremity injuries from farm machinery accidents are the most common injury mechanism, accounting for 35% of all UE injuries. Previous authors have described a variety of machinery injuries resulting from tractors, mechanical corn pickers, hay bailers, and grain augers.[1,3,5,6,9,13] In addition to being the most common mechanism, farm machinery injuries resulted in significantly more mangled extremities in

Table 2. Description of UE Injuries Sustained.

Total number of patients with UE injuries	96
Total number of UE fractures	117
Total number of UE open fractures	54
Total number of other UE (non-fracture) injuries	63
Patients with at least one UE fracture, No. (%)	82 (85)
Patients with at least one UE open fracture, No. (%)	35 (36)
UE open fracture grade, mean	2.7
Patients with isolated hand injury only (carpus and distal), No. (%)	31 (32)
Patients with a mangled extremity, No. (%)	21 (22)
Fractures by bone, No. (% of total UE fractures)	
Scapula	15 (13)
Clavicle	16 (14)
Humerus	13 (11)
Proximal humerus	4 (3)
Humerus shaft	3 (3)
Distal humerus	6 (5)
Forearm	23 (20)
Proximal forearm	1 (1)
Forearm shaft	12 (10)
Distal forearm	10 (9)
Carpus	3 (3)
Metacarpal	13 (11)
Phalanx	34 (30)
Non-fracture UE injuries, No. (% of total non-fracture injuries)	
Digital amputation	17 (27)
Limb amputation	1 (2)
Dislocation	4 (6)
Flexor tendon injury	6 (10)
Extensor tendon injury	11 (18)
Nerve injury	11 (18)
Ligament injury	4 (6)
Compartment syndrome	2 (3)
Other soft tissue injury	7 (11)

Note. UE = upper extremity.

Table 3. Operative Treatments for Patients With and Without UE Injuries.

	Patients without UE injury	Patients with UE injury	*P* value
Total patients, No.	177	96	
Underwent operative procedure, No. (%)	64 (36)	65 (68)	<.0001
Underwent orthopedic procedure, No. (%)	52 (29)	64 (67)	<.0001
Underwent non-orthopedic procedure, No. (%)	12 (7)	5 (5)	.61
Abdominal surgery	7 (4)	3 (3)	.73
Thoracic surgery	1 (1)	1 (1)	>.99
Neurosurgery	3 (2)	0 (0)	.55
Vascular surgery	1 (1)	1 (1)	>.99
Total trips to OR for patients with orthopedic procedures, No. (mean per patient)	75 (1.4)	118 (1.8)	.10

Note. UE = upper extremity; OR = operating room.

our series when compared with other mechanisms. We have observed that grain augers and mechanical corn picker injuries can create particularly devastating UE crush injuries with substantial soft tissue contamination.

Table 4. Operative Procedures for the 96 Patients With UE Injuries.

Underwent at least one operative procedure, No. (%)	57 (59)
Total trips to OR for UE procedures, No. (mean per operative patient)	98 (1.7)
Total number of UE operative procedures, No. (mean per operative patient)	212 (3.7)
Type of UE procedure performed, No. (% of UE procedures)	
Nail bed repair	3 (1)
Debridement and irrigation	89 (42)
Open reduction, internal fixation	54 (26)
Arthroplasty or fusion	6 (3)
Digital amputation	10 (5)
UE/limb amputation	2 (1)
Tendon repair	17 (8)
Nerve repair	7 (3)
Soft-tissue coverage procedure	18 (9)
Other	6 (3)

Note. UE = upper extremity; OR = operating room.

Table 5. Outcomes Associated With Injuries for Patients With and Without UE Injuries.

	Patients with UE injury	Patients without UE injury	*P* value
Total patients, No.	96	177	—
Inpatient mortality, No. (%)	3 (3)	6 (3)	>.99
FIM Total, mean (range)[a]	17.8 (7-20)	17.5 (5-20)	.26
FIM Feeding, mean (range)	3.7 (1-4)	3.6 (1-4)	.62
FIM Locomotion, mean (range)	3.1 (1-4)	3.2 (1-4)	.45
FIM Expression, mean (range)	4.0 (2-4)	3.8 (1-4)	.11
FIM Mobility, mean (range)	3.1 (1-4)	3.2 (1-4)	.38
FIM Interaction, mean (range)	3.9 (2-4)	3.7 (1-4)	.26

Note. UE = upper extremity; FIM = Functional Independence Measure.
[a]FIM data available for 202 of 273 patients.

Pediatric patients appear to be at particular risk for sustaining agricultural injuries to the UE, with 26% of the patients in our series under the age of 18 years. Lubicky and Feinberg analyzed 292 children who sustained injuries from agricultural accidents, noting that 88% were male with an average age of 12 years.[12] Thirty-four percent of these injuries involved the UE, which compares to our findings. A multidisciplinary approach incorporating pediatric trauma, orthopedics, and pediatric critical care is requisite when treating agricultural injuries in this younger population.

Agricultural injuries cost the United States an estimated $4.57 billion in 1992 when considering both direct and indirect costs.[11] The average direct health care costs in our series was $95 147 per patient with an UE injury. Of additional concern with respect to cost, 17% of patients with an UE injury were readmitted in our series, significantly higher than for patients without UE injuries. While the costs for readmission were not assessed, hospital readmissions account for more than $17 billion in avoidable Medicare spending.[15] Recognizing the risk factors for readmission in this population, including adult patients, patients who sustain falls from height, and those who underwent operative procedures, may aid in decreasing readmission rates and overall health care costs. Furthermore, 42% of patients with UE injuries in our series were uninsured with prolonged hospitalizations representing an increased financial burden. In our experience, uninsured patients often inquire about the cost of their hospitalization, and our financial data can be used as a guide to help counsel these patients on health care–related costs during their admission.

Limitations of this study include a single institution in a rural northeastern US population. Our results may not be generalizable to agricultural injuries at institutions nationwide. Our data are retrospective and rely somewhat on the accuracy of trauma registry documentation. However, we performed individual chart reviews for each patient, and the data are from an institution with an electronic medical record system, making it easily verifiable.

Farming accidents resulting in UE injuries have substantial morbidity and financial implications for both patients and health care systems. Agricultural accidents resulting in UE injuries occur more frequently in association with

Table 6. Patients With UE Injuries Who Were Readmitted Versus Those Who Were Not Readmitted.

	Readmitted	Not readmitted	*P* value
Total patients, No.	16	80	—
Male, No. (%)	15 (94)	66 (83)	.26
Pediatric patients <18years, No. %	0 (0)	25 (31)	*.009*
Uninsured, No. (%)	8 (50)	32 (40)	.46
Transfer from outside hospital, No. (%)	6 (38)	28 (35)	.85
Mean length of stay, days	4.9	5.9	.32
ICU admission, No. (%)	1 (6)	9 (11)	.55
GCS, mean	14.9	13.8	.11
ISS, mean	9.75	12.2	.19
TRISS, mean	98.2	91.37	.11
Mechanism of injury, No. (%)			
Animal	0 (0)	4 (5)	.36
Falls	1 (6)	25 (31)	.04
Table saw	2 (13)	5 (6)	.38
Machine	9 (56)	25 (31)	.06
Farm vehicle	4 (25)	21 (26)	.92
Associated injuries, No. (%)			
Abdomen	0 (0)	8 (10)	.19
Chest/thorax	2 (13)	23 (29)	.18
Face	2 (13)	13 (16)	.70
Head	2 (13)	16 (20)	.48
Rib Fracture	2 (13)	19 (24)	.32
Patients with any fracture, No. (%)	14 (88)	71 (89)	.89
Patients with lower extremity fracture, No. (%)	2 (13)	11 (14)	.89
Patients with spine fracture, No. (%)	2 (13)	9 (12)	.89
Required operative procedure, No. (%)	16 (100)	49 (61)	*.002*

Note. UE = upper extremity; ICU = intensive care unit; GCS = Glasgow Coma Score; ISS = injury severity score; TRISS = trauma-related injury severity score. Italic values signifies $P < 0.05$.

machinery and table saw injuries. Pediatric patients are at particular risk for sustaining these potentially devastating injuries. Understanding injury mechanisms and the epidemiology of these injuries may help guide agricultural injury prevention programs.

Ethical Approval

This study was approved by the Geisinger Health System IRB (reference No. 2012-0433).

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

Not applicable.

Declaration of Conflicting Interests

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