Journal of Agromedicine

ISSN: 1059-924X (Print) 1545-0813 (Online) Journal homepage: https://www.tandfonline.com/loi/wagr20

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To cite this article: Randeep S. Jawa MD , David H. Young MD , Joseph C. Stothert MD , Diane Yetter RN , Robbie Dumond RN , Valerie K. Shostrom MS , Samuel Cemaj MD , Risto H. Rautiainen PhD & David W. Mercer MD (2013) Farm Machinery Injuries: The 15-Year Experience at an Urban Joint Trauma Center System in a Rural State, Journal of Agromedicine, 18:2, 98-106, DOI: 10.1080/1059924X.2013.766145

To link to this article: https://doi.org/10.1080/1059924X.2013.766145

Published online: 29 Mar 2013.

Journal of Agromedicine, 18:98–106, 2013

ISSN: 1059-924X print/1545-0813 online
DOI: 10.1080/1059924X.2013.766145

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ABSTRACT. Farm machinery is a major source of injury. The objective of this study is to characterize the incidence, injury characteristics, and outcomes of patients admitted with farm machinery injuries (FMIs) to an urban joint trauma system in a rural state. A retrospective 15-year review of the trauma registries of the two trauma centers that function as a single state-designated Level I joint trauma center system was conducted. There were 65 admissions for FMIs at hospital A and 41 at hospital B; this represents under 0.4% of total trauma admissions. The patients ranged in age from 2 to 87 years. At hospital A, 89% of admitted patients sustained extremity injuries, 16% sustained torso trauma, 92% required surgical intervention, and the mortality rate was 0%. At hospital B, 60% of admitted patients sustained extremity injuries, 36.6% of patients sustained torso trauma, 63% required surgical intervention, and the mortality rate was 14.6%. Tractor-related injuries were responsible for 17% of admissions at hospital A and 69% at hospital B. Of the six fatalities, five were tractor related.

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This research was presented, in part, at the 7th annual Academic Surgical Congress in Las Vegas, Nevada, on February 14–16, 2012.

The farm injury incidence data have been provided by the Nebraska Trauma Registry, which was supported by Nebraska Fifty-Cent for Life Cash Fund from Nebraska Department of Health and Human Services (NDHHS). Its contents are solely the responsibility of the authors and do not necessarily represent the official view of NDHHS.

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The data demonstrate that FMIs affect people in nearly all decades of life. FMIs at the two hospitals had differing injury characteristics and outcomes, in large part secondary to the differing frequency of tractor-related injuries. FMIs frequently required surgical intervention.

KEYWORDS. Farm, farm machinery, injury, tractor, trauma

BACKGROUND

Agriculture is a dangerous industry, based on occupational injury and fatality rates and related costs.[1–3] In 1980, it had a fatality rate of 61 per 100,000 workers, as compared with 13 per 100,000 workers for all other occupations combined.[2] In 2010, the fatality rate for agriculture was 27.9 as compared with 3.6 per 100,000 workers for all other industries.[3] In order of frequency, the next highest fatality rates in 2010 were in mining (19.9), transportation and warehousing (13.7), and construction (9.8).[3] Of note, these Bureau of Labor Statistics rates also include forestry, hunting, and fishing under the agriculture heading. The economic cost of agricultural injuries in the United States is substantial, with an average annual direct and indirect cost of nearly $4.6 billion.[4] Whereas other industries, such as mining and construction, have made progress in injury prevention, agriculture retains one of the highest occupational fatality rates.[2,5]

A major source of injuries and fatalities in agriculture is farm machinery. There is limited available literature on farm machinery injuries seen by trauma centers. The objective of this study is to characterize the incidence, injury characteristics, and outcomes of patients admitted with farm machinery injuries (FMIs) to our urban joint trauma center system in a rural state. Nebraska has over 47,200 farms, covering 92.7% of its 49.2 million acres.[6,7] According to United States Department of Agriculture (USDA) statistics, which count a maximum of three operators per farm, there are at least 71,000 farmers in Nebraska, which has an overall population of about 1.8 million.[6] We hypothesized that the incidence of admissions for farm machinery accidents to our trauma system was quite low, but these patients had a higher mortality than patients admitted for non-FMI injuries.

METHODS

A retrospective review was performed of the trauma registry of each hospital in our urban joint trauma center system from late 1994 to the end of 2008, i.e., since the inception of the joint trauma program. These two otherwise competing medical centers, situated only 2 miles apart, function together to form a single state-designated Level I (comprehensive) trauma center system, i.e., the Omaha Trauma System. The two trauma centers have perennially alternated the same days of trauma call coverage (Tuesday, Friday, and Sunday at hospital A and the other 4 days at hospital B) for emergency medical services (EMS) and most hospital transfers. A referring hospital, however, may request transfer to a particular physician/facility. Each facility is responsible for its own walk-ins. Our catchment area also includes neighboring states, especially western Iowa.

We analyzed the trauma registry at each institution for injuries that occurred on a farm and were secondary to agricultural machinery. This study was granted exempt status by the institutional review board at each institution. To capture all injuries, we used the E-code 849.1, a location code that indicates a farm as the site of injury, and International Classification of Diseases Ninth Revision (ICD-9) E-code (external cause of injury code) 919.0, indicating injuries caused by agricultural machinery. Hence, injuries secondary to falls unrelated to machinery, animals, and all-terrain vehicles were excluded. Grain bin injuries were also excluded. To ensure an accurate number of admissions, readmissions for the same injury were not counted. Because all data points were not available for all patients, the number of patients was reduced, as indicated in the tables for the missing characteristics. To capture admissions at other trauma facilities in the state,

we also evaluated the trauma registry of the state of Nebraska for FMIs over the same time period. Only Level I and II trauma centers were included in this data set because data from lower-level trauma centers was not available in the state registry for the full duration of the study period. Besides our Level I joint trauma system, there are three Level II trauma centers in Nebraska during this time frame.

We evaluated the severity of injuries by the Injury Severity Score (ISS). The ISS ranges from 0 to 75, with an ISS greater than 15 indicating major trauma. It is calculated by squaring the abbreviated injury score (0–6) in each of the three worst injured body regions.[8] We specifically evaluated for traumatic brain injury via the Glasgow Coma Score (GCS). The GCS ranges from 3 to 15, with 6 points for best motor response, 5 points for best verbal response, and 4 points for eye opening.[8] A GCS of 8 or less indicates coma.

Statistical analyses were performed by our biostatistics department using SAS version 9.2 (SAS Institute, Cary, NC). Nonparametric tests, Wilcoxon rank sum or chi-square were used. A p value of less than or equal to .05 was considered as statistically significant.

RESULTS

Characteristics of Admissions at Hospital A

Between 1994 and 2008 only 65 patients, of 15,174 admissions for trauma, had FMIs (Table 1). FMI patients were overwhelmingly male, 97%. These patients had a comparable median age of 44 and ISS of 9 as the non-FMI trauma admissions. The age range for FMI patients was 2.6 to 85.9 years. Of note, 15% were under the age of 19 and 14% were age 65 or older. Median intensive care unit (ICU) length of stay was 0 days for FMI admissions. Significant differences arose when we compared Glasgow Coma Score (GCS), hospital length of stay, and disposition to home in comparison with non-FMI admissions; these were significantly higher in FMI patients. There were no deaths from FMIs.

TABLE 1. Fifteen-Year Hospital A and B Data

	Hospital A		Hospital B	
	FMI	All other traumas[a]	FMI[d]	All other traumas[e]
Admitted patients (n)	65	15,174	41	13,004
Age	43.9 (30.7, 59.2)	40.3 (22.9, 64)	54 (37.1, 67.0)	34.5 (21.3, 52.1)*
Glasgow Coma Score (GCS)	15 (15, 15)#	15 (15, 15)[b]*	15 (15, 15)	15 (15, 15)
Injury Severity Score (ISS)	9 (4, 9)#	9 (4, 14)[c]	9.5 (6, 22)	9 (4, 13)[f]*
Hospital Length of stay (days)	5 (2, 9)	3 (1, 6)*	5 (2, 8)	2 (1, 6)*
ICU length of stay (days)	0 (0, 2)#	0 (0, 1)	1 (0, 2)	0 (0, 2)
Discharge to home (%)	89.2%#	67.4%*	61%	73.6%
Mortality (%)	0%#	4.6%	14.6%	5.6%*

Note. Values are presented as medians with interquartile ranges. In statistical calculations, the number of patients was reduced if there were incomplete data for the statistic being examined, as indicated below.

#$p \leq .05$ between hospitals A and B.

*$p \leq .05$ between FMI and all other trauma admissions.

Hospital A:

[a]All other trauma patients: age, $n = 15{,}144$; GCS, $n = 15{,}162$; ISS, $n = 13{,}941$; hospital length of stay, $n = 14{,}679$; ICU length of stay, $n = 15{,}173$.

[b]The mean GCS for farm injury patients was 14.7 ± 1.9 vs. 13.8 ± 3.1, hence the significant difference.

[c]The mean ISS for farm injury was 9.4 ± 8.5 vs. 11.5 ± 11.2 for other trauma admissions.

Hospital B:

[d]FMI patients ISS, $n = 38$; hospital length of stay, $n = 38$; ICU length of stay, $n = 34$.

[e]All other trauma patients: age, $n = 12{,}970$; GCS, $n = 13{,}044$; ISS, $n = 11{,}898$; hospital length of stay, $n = 12{,}375$; ICU length of stay, $n = 10{,}495$.

[f]The mean ISS for farm injury patients was 16.8 ± 7.2 vs. 11.0 ± 11.3 for other traumas, hence the significant difference.

TABLE 2. Types and Anatomical Sites of Farm Machinery Injuries

Farm machinery mechanism	Hospital A ($n = 59$)	Hospital B ($n = 35$)
Tractor rollover/runover/fall/trapped	6 (10.2%)	19 (54.3%)
Tractor other	4 (6.8%)	5 (14.3%)
Combine rollover/trapped	2 (3.4%)	1 (2.9%)
Combine-penetrating	3 (5.1%)	1 (2.9%)
Auger	13 (22.0%)	5 (14.3%)
Baler	9 (15.2%)	2 (5.7%)
Other (picker, grinder, power takeoff, feeder, etc.)	22 (37.3%)	2 (5.7%)
Injury location/characteristics	**Hospital A ($n = 63$)**	**Hospital B ($n = 38$)**
Upper extremity (n)	46	15
Hand/wrist	42	4
Amputations	28	6
Lower extremity (n)	12	7
Amputations	4	6
Skull/facial fractures/scalp injury (n)	4	5
Intracranial injury (n)	2	2
Eye injury (n)	1	1
Spine fracture (n)	2	5
Pelvic fracture (n)	3	5
Chest injury (n)	5	8
Abdomino-pelvic visceral injury (n)	1	2
Injuries in noncontiguous sites (n)	4	12

Note: Patients with incomplete information were excluded from the *n* value given in Table 1. Patients may have had injuries in more than one location. Noncontinguous site refers to major body regions, i.e., head/neck, chest, abdomen, pelvis, and extremities.

The overwhelming majority of hospitalized FMI patients (89%) sustained injuries to the extremities, including one scapular and one brachial plexus injury (Table 2). This was followed by torso trauma (chest/abdomen/pelvis visceral injuries or fractures) in 16.4% injured patients. Spine and intracranial injuries were infrequent, occurring in two patients each. Only four admitted patients had injuries at one or more noncontiguous location. Admissions for FMIs were resource intensive, as 92% of admissions required surgical intervention; 59 of the 60 admitted patients undergoing surgery had a procedure on the extremities.

Characteristics of Admissions at Hospital B

FMIs accounted for 41 of 13,004 admissions (Table 1). The vast majority of FMI patients were again male (95%). The median age of FMI patients at hospital B was significantly higher than non-FMI admissions (54 vs. 34.5 years). The age range for FMI patients was 12.8 to 87 years. There were five (12.2%) patients under the age of 19, and 13 (31.7%) patients aged 65 years or older. Median ISS (9.5) was significantly higher than that of other trauma patients (ISS = 9). The mean ± SD ISS was 16.8 ± 17.2 vs. 11.0 ± 11.3 in the other trauma patients. FMI patients had a median GCS of 15 in the emergency department (ED). The median hospital length of stay (5 vs. 2 days) and mortality rate (14.6% vs. 6.4%) were significantly higher in FMI patients than other trauma admissions. Correspondingly, disposition to home was lower at 61% vs. 73.6% for the other, non-FMI trauma patients, but $p = .066$.

The majority of hospitalized FMI patients (60%) at hospital B also suffered from extremity injuries (Table 2). They had a high proportion (36.6%) of torso (chest/abdomen/pelvis) trauma and 13% suffered from spinal trauma. Nearly 32% had injuries at one or more noncontiguous locations. A majority (63.4%) of FMI patients at hospital B also required operative intervention. Fifteen of the 26 patients having an operation underwent extremity procedures; one additional patient had a procedure on the buttocks.

Comparison of Hospital A and B Farm Machinery Injury Admissions

In comparing the FMI data between the facilities, we were surprised by the different injury characteristics, as the two centers are located less than 2 miles apart and alternate days for trauma call. Specifically, patients at hospital B, as compared with hospital A, were more severely injured (lower GCS and higher ISS), and accordingly had a longer ICU length of stay, a lower frequency of discharge to home, and a higher mortality rate. We hypothesized that the differences were secondary to the types

of farm equipment being used. As seen in Table 2, rollovers, falls, and entrapment by tractors occurred in 10% of patients at hospital A as compared with 54% of patients at hospital B. The addition of other tractor-related injury mechanisms implicates tractors in 17% of admissions at hospital A and 69% of admissions at hospital B; the reason for this difference is not clear. Tractors have the potential for causing multisystem trauma. Meanwhile, 22% of patients were injured by augers at hospital A as compared with 14.3% at hospital B.

Direct referral from an outside facility to a particular hospital for certain injuries, such as hand injuries, may also explain disparities. In this regard, whereas 88% of admissions at hospital A were transfers from an outside facility, only 54% at hospital B were transfers. Although not reaching statistical significance ($p = .054$), the median age of patients at hospital A was lower than at hospital B. Finally, although the facilities alternate days of call, they differ in the actual days of week that they cover trauma. Had only the aggregate trauma center data presented in Table 3 been used, the influence of type of farm machinery on outcomes would have been difficult to discern, especially as compared with other trauma admissions.

TABLE 3. Aggregate 15-Year Data Comparing Farm Machinery Injuries Versus Nonfarm Machinery Injuries at the Urban Joint Trauma Center System

Characteristics	FMI injuries	Non-FMI injuries
Patients (n)	106	28,178
Mortality (%)	5.7%	5.1%
Age	47.2 (32.3, 63.1)	37.5 (22, 58.2)*
Glasgow Coma Score	15 (15, 15)	15 (15, 15)*
Injury Severity Score	9 (4, 13)	9 (4, 13)
Hospital Length of stay (days)	5 (2, 8)	3 (1, 6)*
ICU length of stay (days)	0 (0, 2)	0 (0, 1)
Discharged to home (%)	78.3%	70.3%

Note. Values are presented as medians with interquartile ranges except as indicated. Please note that the total numbers of patients were reduced secondary to incomplete data as described in Table 1.

*$p \leq .05$ between FMI and all other trauma admissions.

TABLE 4. 15-Year State of Nebraska Data†

Admitted patients	$N = 241$
Mortality	4.98%
Age (median, interquartile range in years)[a]	49.4 years (35.4, 64.9)
Glasgow Coma Score (GCS)[b]	Median = 15.0, mean ± $SD = 14.15 \pm 2.95$
Injury Severity Score (ISS)[c]	Median = 9.0, mean ± $SD = 11.36 \pm 10.57$
Hospital length of stay (days, mean ± *SD*)	6.88 ± 7.32
ICU length of stay (days, mean ± *SD*)	5.44 ± 6.20
Disposition to home (*n*, %)	169 (70.1%)
Underwent operation (ICD-9 procedure codes 01.0–86.9)	74.3%
Trauma system regions‡	
Northeast	41.5%
Southeast	30.3%
Central	19.9%
Panhandle	8.3%

†This includes data from the Omaha Trauma System.
[a]Age range was 2.6 to 94.8 years.
[b]$n = 235$.
[c]n = 201.
‡There are four trauma regions in the state of Nebraska. The regions where patients were treated at Level I or II trauma centers are as indicated.

State of Nebraska Level I and II Trauma Center Data

We evaluated the trauma registry data for the state from 1994–2008 (Table 4). Only one Level I joint trauma system and three Level II trauma centers are included in this database. Level I and II centers represent the highest echelons of trauma care. The data from our joint trauma center system form a fraction of this data set. Since our system is located on the eastern border of Nebraska, 35% of our patients came from neighboring states, with Iowa having the overwhelming majority. In Nebraska, the vast majority (71.8%) of farm machinery injuries were treated at trauma facilities in the eastern part of the state.

DISCUSSION

The morbidity and mortality rates in agriculture are high. In 2008, there were 5.3

occupational injury or illness cases per 100 full-time US agriculture, forestry, fishing, and hunting workers.[5] A Canadian study in 2003 found that farm workers had nearly twice the number of nonfatal, activity-limiting injuries, at 7.3%, as compared with the overall employment injury rate.[9,10] Important reasons for the high morbidity and mortality rates are that farm workers live in rural environments, work in isolation, work with hazardous machines, chemicals, and animals, and have less effective localization by/notification of EMS personnel. This impedes timely access to prehospital care or a medical facility.[11–15]

Farm machinery is a leading source of injuries on a farm. It is responsible for 23–50% of fatalities and approximately 50% of hospitalizations from nonfatal injuries.[13–16] Reasons for these injuries include use of older equipment that lacks safety mechanisms, failure to use or dismantling of protective guards on equipment, having children perform complex tasks, and allowing children to accompany adults.[2,13,17]

A particularly concerning finding of our study is that 9.3% of admitted patients were under age 19. These findings are congruent with other North American FMI studies that reported that 1–8% of injuries and 16% of fatalities occurred in children or adolescents.[9,17,18] In the United States, over 50% of the 1.03 million children aged under 20 living on a farm work on a farm; an additional 0.2 million youth are hired help.[2] The US Federal Labor Standards Act exempts youth on small farms, with parental consent, from child labor provisions; there are no specific federal minimum age limits.[19] In Nebraska, the minimum age for driving under a farm husbandry permit is 13 for family members and 14 years if employed.[20] Although voluntary guidelines such as the NAGCAT (North American Guidelines for Children's Agricultural Tasks) have been developed to help parents determine if their child can safely perform various tasks, research suggests that their use is limited.[21,22] A survey indicated that a significant proportion of parents on family farms feel that farm work builds strong work ethic and gives the child confidence, and over one third feel that farm work is not more dangerous than other occupations for children.[23] Hence, some have concluded that legislation may be necessary to ensure child safety.[22]

As farming employs families, we also noted that 21.7% of injuries and 83% of fatalities occurred in individuals aged 65 years or older. In comparison, the two previously mentioned studies also found that 13% of injuries and 30% of fatalities occurred in patients within this age bracket.[9,17] Another study found that 38% of fatalities occurred in patients who were at least 60 years of age.[24] Further investigation and implementation of methods to reduce injury in the elderly is also needed.[13,25,26]

A majority of farm workers are males.[27] Another distinctive characteristic of FMIs is that they predominantly affect males. We found that 95% of the injuries occurred in males; this concurs with findings of other studies.[16,24]

We found that 32% of injuries at our joint system were tractor-related. However, they were responsible for all five fatalities where the specific machine was known. Several North American studies have implicated tractors as a very common cause of FMIs, with a frequency of 23–69%.[3, 9,17,24] They have also been implicated in 81% of fatalities.[12] A leading cause of fatality from tractor accidents is rollovers (overturns).[1,2,14,28] Rollovers can result in crush injury, amputation, evisceration, and limb amputation. A tractor can tip backward to the point of no return in 0.75 seconds; this is insufficient time for evasive maneuvers.[28] Older tractors commonly used on small farms often lack rollover protective structures (ROPS) that provide a protective envelope for the operator in case of an overturn. They also lack seatbelts. Additional important mechanisms of injuries include falls and injuries from mounting/dismounting; these two mechanisms account for one fourth and one third of injuries, respectively.[29] Finally, tractor entanglements can result in amputation and scalping.[13] Of note, small farms are exempt from safety inspections and enforcement of regulations.[13]

Less frequent causes of FMIs include transportation equipment, harvesting equipment, combines, power take-offs (PTOs), and augers.[3,9] According to a five-state study, 20% of injuries occurred while a machine was being

adjusted and 17% during repair.[18] The most common injury mechanism is being caught in machinery (50%).[3] Entanglement results in primarily upper (50%) or lower extremity (29%) injuries, particularly the hands and feet.[30]

We found a preponderance of extremity injuries, consistent with other studies reporting a 50–83% incidence.[3,14,17,30] The types of hand injuries in our study included lacerations, amputations, and crush injuries, similar to findings in a Danish study.[31] A possible reason for the greater preponderance of upper extremity versus lower extremity injuries is that patients may have been trying to manually dislodge jams or repair equipment. However, feet can become entangled with machinery as they are used to kick away and clear obstructions. A key finding of this study is that that the vast majority (82%) of admitted patients required surgical intervention. The majority of these were operations on injured extremities.

Limitations

Available occupational injury data, particularly on nonfatal injuries, are likely underestimated secondary to counting methodology and absence of reporting requirements for small farms and small medical facilities in the United States.[14,15] In this regard, the use of trauma registries is advantageous. They are not dependent on employer reporting and lack incentives for underreporting of injuries.[32] A study of the Illinois Trauma Registry found that in contrast to reports from national occupational injury surveillance programs, the state registry found no significant decline in the incidence of occupational injuries.[32]

However, even our retrospective hospital and state trauma registry admission data likely underestimates the frequency of FMIs in Nebraska and surrounding areas. Many patients are not seen in a hospital, much less at trauma centers. As demonstrated in the 1998 multistate study of 148 patients injured by agricultural machines, excluding tractors, only 5% of injured patients were hospitalized.[18] Furthermore, the first facilities that treated injured patients were a doctor's office or clinic (37.1%), chiropractor's office (19.9%), or emergency room (19.2%).[18] Very low rates of hospitalization were confirmed in a follow-up study (RRIS-II).[29]

Because of expense, 15% of insured farmers and 34% of uninsured farmers reported delaying needed health care in 2007.[33] Although a majority of farm households carry health insurance, this is often because the households has a spouse or other operator who is employed off the farm and therefore employer-sponsored insurance.[34] However, some types of farming have heavy time commitments that preclude off-farm jobs and thereby access to employer-sponsored health insurance, e.g., 36% of dairy households were uninsured in the United States in 2011.[34]

Conclusions and Future Considerations

Machinery is an important source of injury on farms. Although most FMIs do not present to major trauma centers, when they do present, they are resource intensive. The potential for isolated limb trauma as well as multisystem trauma exists. Surgical intervention is frequently required.

To fully understand the magnitude and causes of FMIs, more effective surveillance is needed so that small farms and more medical facilities are included in reports. A particularly alarming aspect of this study is the frequency of injuries to children. Although a difficult economic problem, as children make up a substantial portion of the farm workforce, consideration should be given to better defining and regulating their roles and limitations. To minimize hazards to people of all ages, additional and ongoing education on farm machine safety is needed. Given the preponderance of extremity injuries, perhaps farmers could be equipped with topical hemostatic agents. Some of these agents have been tested in desolate environments.[35,36] Further investigation of the frequency of machinery safety devices disablement and the prevention thereof, via technology and education, is needed. Given that farm machinery accidents occur in rural areas, ready access to cell phones or other inexpensive alarm-system technology by farmers could facilitate quicker response times by EMS. Training EMS providers in rural areas on the unique aspects of farm injury is indicated.

Further development of rural trauma systems would also help.

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