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Patients admitted for treatment of traumatic finger amputations: Characteristics, causes, and prevention

Michael T. Larsen [a], Ian Eldridge-Allegra [a], Jaclyn Wu [b], Sonu A. Jain [a, *]

[a] The Departments of Plastic Surgery and Orthopaedic Surgery, The Ohio State University Wexner Medical Center, Columbus, OH, USA
[b] Ohio State University, USA

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ABSTRACT

Background: The aim of this study was to analyze the epidemiology of patients admitted with finger amputations in the U.S., as well as to evaluate and propose prevention strategies.
Methods: The National Electronic Injury Surveillance System was queried to obtain data on patients that presented to, and were admitted from US emergency departments for treatment of traumatic finger amputations during the period of 2002–2016. The Haddon Matrix, a framework that can be used to analyze the host, agent, and environmental factors of an injury relative to its timing, was then used to evaluate possible contributing factors of amputation events, and thereby explore plausible prevention interventions.
Results: From 2002 to 2016, approximately 348,719 people were admitted from the ED for traumatic amputations. The majority were Caucasian and were male. The mean age was 42.3 years old. This was significantly older than those who were not admitted. The top five products responsible for amputations in admitted patients were power saws (40.9% of cases), doors (10.3%), lawn mowers (7.4%), snow blowers (4.3%), and bicycles (2.4%). This list included a higher proportion of powered tools than those with finger amputations who were discharged from the ED with a finger amputation.
Conclusion: Patients admitted with finger amputations from the ED were older, more likely to be male, and more likely to be victims of powered tools than those that were discharged. Table saws are responsible for a high proportion of the finger amputations that result in hospital admissions. The Haddon Matrix helps us identify factors (host, agent, physical environment, and social environment) to be addressed in prevention strategies. Such approaches might include championing education campaigns, policy measures, and equipment safety features. The effectiveness of such strategies warrants further investigation.

1. Introduction

A finger amputation can have dire psychological and physical repercussions for the patient, not to mention the economic burden it places upon society.[1] Studies have shown that the majority of the costs related to hand injuries are not incurred by the treatment but by the indirect costs, like cost of time off work, lost earnings, transportation to medical appointments, and greater dependence on family.[2–4] Yet, these injuries are often preventable.[5–12]

Of those patients that present to the emergency department with finger amputations, those that are subsequently hospitalized are of the highest acuity and, therefore, represent a high-yield target population for prevention strategies.[4] In this population, the majority of traumatic finger amputations can be attributed to a short list of instruments including circular saws, other power saws, doors, lawn mowers, snow blowers, and most commonly, table saws. Finger amputations account for 10–15% of table saw injuries, which also result in hospitalization more often than other consumer products (7% vs 4%).[13] Based on national data, there has been a 27% increase in non-occupational table saw injuries from 1990 to 2007, making them an important consideration in traumatic amputations.[14]

Additionally, gender and age are strongly correlated with rates and causes of finger amputation. To maximize the effectiveness of prevention strategies, this study aims to analyze the epidemiology of admitted patients and target the most affected groups. To our

* Corresponding author. Hand and Upper Extremity Center, The Ohio State University Wexner Medical Center, 915 Olentangy River Road, Suite 3200, Columbus, OH, 43212, USA.
E-mail address: sonu.jain@osumc.edu (S.A. Jain).

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knowledge, this is the first epidemiological study of traumatic finger amputation trends in all age groups admitted from emergency departments (ED) throughout the United States. We also analyze and propose prevention strategies.

2. Materials and methods

This is a retrospective study using data from The National Electronic Injury Surveillance System (NEISS), which is operated by the US Consumer Product Safety Commission (CPSC). The NEISS is a national probability sample that contains information of patients that present to any of 100 NEISS-associated emergency departments with an injury caused by consumer products. The NEISS database was queried to identify patients who presented to and then were admitted from emergency departments with traumatic finger amputations between 2002 and 2016. The epidemiological data, including age, gender, race, and product involved in the injury, were then analyzed using STATA statistical software.

Qualitative analysis using a Haddon Matrix was then performed for the most common product implicated in finger amputation injuries, table saws, to develop prevention strategies. The Haddon Matrix is the most commonly used framework for injury prevention and has been applied extensively in automotive safety. The matrix typically consists of breaking down an accident into three phases (pre-event, event, and post-event) and then assessing the factors (human factors, equipment factors, physical factors, and social factors) that could be implicated during each of those phases.

3. Results

From 2002 to 2016, 10,554 people presented to NEISS participating Emergency Departments (ED) for traumatic amputations. Using the NEISS weighting system, this translates to a United States national estimate of 348,719 people presenting to the ED for tramautic amputations during this time period (Table 1).

A total of 77.6% were discharged (includes those that were treated then discharged, and those that left without being seen), 21.5% were admitted (includes those that were treated then admitted and those that were transferred to another hospital for admission), and another 0.9% were held for observation. The disposition was unknown for 0.02% of the patients. The incidence of patients admitted for traumatic amputation slowly declined through 2011, then in 2012 rose dramatically (Fig. 1). A vast majority of the patients were male, and among those who were admitted an even higher percentage, 84.9%, were male (Table 2). Of the admitted patients whose race was known, 80.3% were White, 10.0% were Hispanic, 7.1% were Black, 1.4% were Asian, 1.2% were Other. Patients who were admitted were significantly older than those that were discharged, with mean ages of 42.3 years old and 38.9 years old respectively ($p < 0.00001$, Wald test). Fig. 2 compares the incidence of the discharged group to the admitted group. Note that the "admitted" curve has been scaled up in order to compare the proportional incidences with the discharged group per year. It can be seen that the incidences of both the discharged and admitted patients follow the same bimodal curve with incidence peaks in the toddler years and again in the mid-career years between 35–65 years old; however, the mid-career peak is proportionately higher

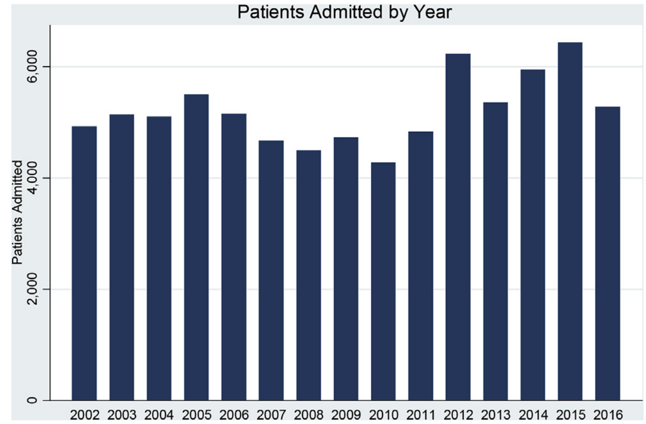

Fig. 1. The Trend of Finger Amputation Hospital Admissions Over 15-year period.

Table 2
Gender and race of patients presenting with finger amputations.

	Discharged (%)	Admitted (%)
Gender		
Male	212,215 (78.4)	66,304 (84.9)
Female	58,279 (21.5)	11,779 (15.1)
Race		
Unknown	74,693	26,748
Known	195,877	51,334
White	153,724 (78.5)	41,223 (80.3)
Hispanic	17,650 (9.7)	3624 (10.0)
Black	19,014 (9.0)	5147 (7.1)
Asian	3207 (1.6)	712 (1.4)
Other	2282 (1.2)	628 (1.2)

Table 1
Disposition of patients who presented to the Emergency Department with traumatic finger amputation.

Year	Discharged	Transferred	Admitted	Disposition Observation	Left AMA	Unknown	Total
2002	16,561	1873	2978	75	–	61	21,548
2003	18,070	2323	2645	171	33	–	23,242
2004	21,115	2567	2207	328	–	6	26,224
2005	18,356	2545	2689	272	134	–	23,995
2006	18,679	2924	1972	256	15	–	23,847
2007	16,809	2017	2564	91	16	–	21,496
2008	18,040	2363	2109	21	–	–	22,533
2009	17,937	1821	2754	154	69	–	22,735
2010	18,857	1732	2383	163	185	–	23,321
2011	19,324	1803	2907	119	62	–	24,215
2012	18,283	1642	4295	301	79	–	24,599
2013	17,346	1980	3039	336	77	–	22,779
2014	15,445	2158	3399	392	163	–	21,557
2015	17,042	2510	3633	297	156	–	23,638
2016	17,622	2285	2801	188	93	–	22,989
Total	269,487	32,543	42,375	3165	1083	67	348,719

AMA = against medical advice.

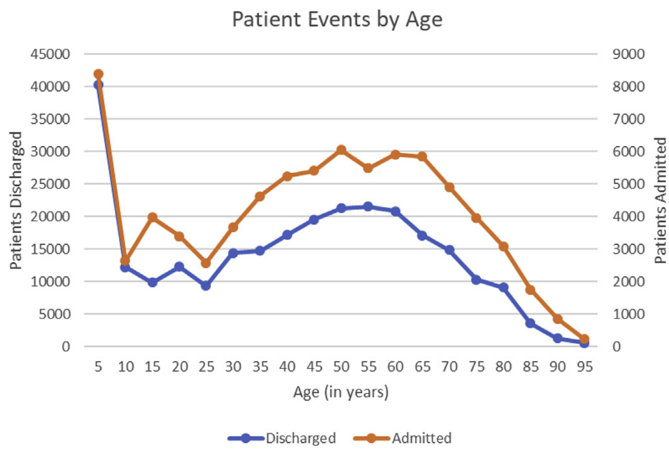

Fig. 2. Patients amputation events by age. Note that the Admitted curve has been scaled up in order to compare the proportional incidences with the discharged group per year. The y-axis for the Admitted curve is on the right side of the graph.

in the admitted group. Hundreds of various products were involved finger amputations. The top eight products are listed in Table 3. The top eight products responsible for amputations in admitted patients were power saws (31,940; 41% of cases), doors (8,080; 10.3%), lawnmowers (5,801; 7.4%), snow blowers (3,340; 4.3%), bicycles (1,900; 2.4%), log splitters (1588; 2.0%), rope/string (1,145; 1.5%); and fireworks (1,069; 1.4%) (see Table 3). This list included a higher proportion of powered tools than those who were discharged from the ED.

Powered saws were found to cause the most hospital admissions for finger amputation. Several strategies can be proposed to reduce the number of high acuity finger amputations by qualitatively analyzing table saw injuries using a Haddon Matrix (Table 4). A summary of possible interventions include the following: a requirement for a training certification in order to use the equipment, age limitation, educational campaigns, required equipment alarms and emergency shutoffs, funding for innovation in safety mechanisms, fully automated or remote operated equipment, lighting standards, workload limits, warning signs, protocols in the event of an injury, and fines for the failure to meet requirements.[15,16] Among these interventions, equipment safety technology, such as SawStop, has been effectively implemented on certain table saw models.[13] However, it can be cost-prohibitive for many users, requires blade replacement with each activation, and cannot be applied when cutting all materials.[13,14]

4. Discussion

In this study, the number of hospital admissions was generally trending downward until 2009, when it began to rise again, with the 15-year high occurring in 2012. The downward trend over the initial 10 years of the study period cannot be elucidated for certain, but could possibly be due to safer products, a greater awareness of the problem of finger amputations when using many devices, as well as an increasing number of interventions over time to curb this problem. However, this decline was quite modest, suggesting minimal implementation or poor traction of new prevention strategies over this time period.

It is more difficult to understand and explain the recent upward trend of finger amputation admissions beginning in 2012. The rise in incidence is unlikely to be due to a reverse in practices from the previous 10 years. Further study is required to determine the causes of these trends. There were large changes in health care that went into effect in 2012 secondary to the institution of The Affordable Care Act; it is possible that admitting practices or criteria changed abruptly. It will be important to perform further research in the future to see if this trend continues or if it is truly an outlier. We found that those admitted to the hospital were more likely to have suffered an injury from a power tool (saw, lawn mower, snow blower) rather than from non-powered devices such as doors or bicycles. Powered devices are also more likely to inflict greater damage, either in the form of complete amputations or of additional lacerations, requiring surgical intervention. Also, these injuries often have a narrower zone of injury and are, therefore, more amenable to replantation, which would require hospitalization. Conversely, non-powered devices are more likely to cause partial amputations and more distal finger injuries that can be treated in the ED and on an outpatient basis. Furthermore, amputations secondary to non-powered devices often have a wide crush or avulsion injury component, which makes these patients poorer candidates for replantation; instead, they are better candidates for revision amputation, which can often simply be done in the ED or as an outpatient.

The patients admitted to the hospital were older than those that were discharged from the emergency department. Others have also

Table 3
List of top products involved in finger amputations.

Rank	Discharged			Admitted		
	Tool	N	%	Tool	N	%
1	Power Saws	67,903	25.1	Power Saws	31,940	41.0
	Bench/Table	40584	15.0	Bench/Table	20875	26.7
	Portable	12033	4.4	Portable	5505	7.1
	Band/Radial	2430	0.9	Band/Radial	932	1.2
	Saws NOS	12788	4.7	Saws NOS	4612	5.9
2	Doors	52,007	19.2	Doors	8,080	10.3
3	Knives, slicers, choppers	25,990	9.6	Lawn Mowers	5,801	7.4
	Knives NOS	16171	6.0			
	Slicers, Choppers	7772	2.9			
	Knives with replacement blades	2047	0.8			
4	Lawn Mowers	20,678	7.6	Snow blowers	3,340	4.3
5	Log Splitters	7,455	2.8	Bicycles	1,900	2.4
6	Bicycles	5,904	2.2	Log Splitters	1588	2.0
7	Snow blowers	5570	2.1	Rope/String	1145	1.5
8	Chairs	4,283	1.6	Fireworks	1069	1.4
	Chairs NOS	2588	1.0			
	Beach/folding	1701	0.6			
	Recliner/rocking	375	0.1			

Table 4
Haddon Matrix applied to table saw-related finger amputation injuries.

Phase	Human Factors	Equipment Factors	Physical and Social Environment
Pre-Event	• Age • Education • Certification • Impairment • Emotional state • Supervision	• Equipment condition • Lighting • fatigue, inexperience • Availability of Safety Gear	• Lighting • Distractions • Warning Signs • Time Constraints and workload
Event	• Area of victim's body affected • Use of safety gear	• Equipment speed • Safety Mechanisms • Quality of Safety Gear	Facility's quality/layout
Post-Event	• Access to healthcare after injury • Victim health status	• Alarms • Emergency Shutoff	• EMS response • Proximity to Hand Surgeon
Possible Interventions	• Certification requirements, Age limits • Educational Campaigns. • Fines	• Requirements for Alarms, Emergency Shutoffs (or taxes for lack thereof) • Funding (Grants) for innovation in safety mechanisms/gear, automated tools	• Lighting Standards. • Workload Limits • Protocols/drills for amputation events • Reminder/Warning Signs • Checklists

shown increasing injury incidence with increasing age.[17] This likely stems from the fact that, as mentioned above, admitted individuals were more likely to suffer from injuries related to power tools, which older individuals are more likely to use (in their vocation or avocations). Younger individuals have limited access to power tools, so their injuries are more likely to be caused by non-powered devices that are fairly ubiquitous (e.g. doors). This trend is manifested in the gender incidences as well. A vast majority of patients admitted are male, which parallels the composition of workers in fields requiring operation of power tools.

Power tool related injuries cause high healthcare resource consumption; therefore, prevention and intervention investments would be the most high-yield in this category of devices. Using a Haddon Matrix, we have proposed numerous interventions to prevent finger injuries from power tools. The Haddon Matrix has long been a powerful tool for evaluating accidents. It represents a systematic approach to enumerating and fully evaluating the many factors in play in the Swiss Cheese model of any accident's causation. With these factors enumerated, thoughtful prevention interventions are then developed. The matrix obviously is not a panacea, for the possible interventions are only as good as the observations and critical thinking of the researcher, and the proposed interventions must still be studied for efficacy and practicality. This can be observed with the SawStop technology, an equipment safety mechanism that was shown to be highly effective in disengaging the blade upon contact with human skin, but has seen poor implementation due to cost and inconvenience.[13] The above-proposed prevention strategies need to be further studied, for more aggressive implementation of these strategies could obviate many finger amputations and reduce the associated economic and social burden.

Several limitations exist in the present study. The NEISS underestimates the true number of finger amputations admitted to the hospital because it does not take into account patients who are directly admitted to the hospital or who are transferred from other hospitals and do not go through the Emergency Department. Furthermore, the full circumstances of the events could not be elucidated from the NEISS. For example, it is impossible to ascertain the reason for admission, the specific digit or number of involved digits, or factors that led to the amputation. Furthermore, the Haddon Matrix does not ensure an exhaustive list of factors or possible interventions, because it relies upon the evaluator's ingenuity and expertise in the field. However, it does represent a thorough and systematic method to assess events. The scope of this study should also be considered when applying prevention strategies. Previous studies have been conducted in specific regions that would be useful for statewide or local prevention plans. The database used in this study suggests national trends, making it more applicable for creating national prevention plans.

5. Conclusion

Patients admitted with finger amputations from the ED were older, more likely to be male, and more likely to be victims of powered tools than those that were discharged. Table saws are responsible for a high proportion of the finger amputations that result in hospital admissions. Although advances in microsurgery have been able to improve physical and psychological outcomes, the best remedy is still prevention. The Haddon Matrix helps us identify factors (host, agent, physical environment, and social environment) to be addressed in prevention strategies. Such approaches might include championing education campaigns, policy measures, and equipment safety features. The effectiveness of such strategies warrant further investigation.

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Disclosures

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