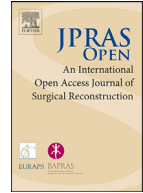




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Original Article

Pediatric Lawnmower Injuries: a 25-year Review[☆]

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ABSTRACT

Background: Despite regulations currently in place, the incidence of lawnmower injuries in children has not decreased for several decades in the United States. In fact, studies in several countries show that the incidence of riding lawnmower injuries are actually on the rise worldwide. Those injuries tend to be devastating and limb-threatening. The purpose of this study was to evaluate a pediatric trauma center's experience with those injuries over the past 25 years.

Methods: All patients who presented to a level I pediatric trauma center with injuries from lawnmowers between 1994 and 2019 were reviewed. Date of birth, gender, date of injury, mechanism of injury, type of lawnmower, and type of injury (including whether an open fracture, soft tissue defect, and/or amputation were present) were recorded.

Results: A total of 142 pediatric patients were treated over the study period. The average age was 7.5 years. The three most common mechanisms of injury were being hit by a riding lawnmower moving forward, falling off a riding lawnmower, and being hit by a riding lawnmower moving backward. Of all patients, 68.3% sustained an open fracture and 38% required an amputation. Riding

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lawnmowers resulted in more operative procedures, longer hospital stays, and more soft tissue defects that require reconstruction than push mowers. Younger patients were at a higher risk to sustain proximal amputations (wrist/ankle or proximal) than older patients.

Conclusion: Lawnmower injuries are devastating and largely avoidable. There are currently recommendations and regulations in the United States, which if followed, would prevent the vast majority of pediatric lawnmower injuries. Unfortunately, the incidence of these injuries has not decreased despite the current regulations. Broader public education is essential to decrease the incidence of serious lawnmower injuries in children.

Level of Evidence: IV

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Introduction

Lawnmowers have become commonly used household tools in society. Unfortunately, there are more than 9,000 lawnmower injuries reported in children every year in the United States.¹ These injuries tend to occur in male children (80%)¹ and have a bimodal age distribution, with peaks at 2–4 and 14–17 years of age.^{1,2,3,4,5} As expected, most of these injuries occur in the spring and summer months.¹ Lawnmowers are much more likely to cause severe injury to bystanders and passengers than to operators.⁶ This explains why children tend to be common victims of lawnmower accidents.

Lawnmower injuries are among the most common causes of traumatic amputations in children.⁷ In a review of pediatric lawnmower injuries in Pennsylvania between 2002 and 2014, Garay *et al.* found that more than 50% of patients required at least one amputation.⁸ Several studies have found that riding lawnmowers are much more likely to cause severe injury and amputation than push lawnmowers.^{9,4,3,8}

Despite the institution of multiple regulations starting in the 1970s, the incidence of lawnmower injuries in children has not decreased over the past few decades.^{10,1} In fact, Laing *et al.* found that the incidence of injuries from riding lawnmowers *increased* between 1998 and 2008.³

The purpose of this study is to evaluate a level I pediatric trauma center's experience with pediatric lawnmower injuries. The aim is for the resulting data to be used for more extensive public education regarding lawnmower safety.

Methods

The records of all pediatric patients who presented to a level I pediatric trauma center with lawnmower-related injuries between May 1994 and August 2019 were reviewed. The date of birth, gender, date of injury, mechanism and circumstances of injury, type of lawnmower, and type of injury (including whether an open fracture, soft tissue defect requiring reconstruction, and/or an amputation were present) were recorded. Amputations were classified as “distal” if distal to the wrist/ankle and “proximal” if at the wrist/ankle or proximal. The number and types of operations, and the date of discharge, were recorded.

Univariate statistical analyses were performed using ANOVA followed by the Tukey-Kramer test for post-hoc analysis. Multivariate statistical analyses were performed using multiple logistic regression. For all analyses, a *p* value smaller than 0.05 was considered statistically significant.

Table 1
Demographics and characteristics of the patients included in the study

	n	%
Number of patients	142	
Gender		
Male	115	81
Female	27	19
Average age (years)	7.5	
Type of lawnmower		
Push	34	23.9
Riding	108	76.1
Mechanism of injury		
Struck by rotating blade		86.6
Fell off mower while riding	29	20.4
Struck by forward-moving mower	45	31.7
Struck by backward-moving mower	24	16.9
Put hand in blades	5	3.5
Slipped under mower	20	14.1
Operating mower on a slope	8	5.6
Struck by projectile	7	4.9
Other (including burn)	4	2.8
Open fracture		
Yes	97	68.3
No	45	31.7
Amputation		
Yes	54	38
No	88	62
Average number of surgeries required per patient	2.2	
Average length of hospital stay (days)	7.4	

Results

Patient and injury description

A total of 142 pediatric patients were treated for lawnmower-related injuries over the 25-year study period (**Table 1**). Males represented 81% and female patients 19%. The average age at the time of injury was 7.5 years.

Riding lawnmowers were the cause of injury in 76.1% of patients, while push mowers accounted for the remainder of patients (23.9%). The most common mechanism of injury was being injured by another person riding a lawnmower forward, which occurred in 31.7% of patients, followed by riding on a lawnmower with another person and jumping or falling off (20.4%), being injured by another person riding a lawnmower backwards (16.9%), slipping under a push or lawnmower while running next to it or operating it (14.1%), being injured in a rollover while operating a mower on a slope (5.6%), being injured by a projectile thrown by a mower blade (4.9%), being injured by running blades while attempting to manually clear blade blockage (3.5%), and other mechanisms (2.8%) (two patients with contact burns, one injured by flash flames and one whose hair was caught in the engine mechanism).

Open fractures occurred in 68.3% of patients, and amputations were required in 38% of patients. The mean number of operative procedures was 2.2 per patient. Patients spent an average of 7.4 days in the hospital. None of the patients died due to their injuries.

Differences between riding and push mowers

When compared with patients injured by push mowers, patients injured by riding lawnmowers were significantly younger (6.3 years vs. 11 years and $p < 0.001$), required significantly more operative procedures (2.5 vs. 1.3 and $p < 0.001$), were more likely to have soft tissue defects requiring reconstruction (56.5% vs. 35.3% and $p = 0.03$), had longer hospital stays (8.9 days vs. 2.7 days and $p < 0.001$), and had a higher average number of digits amputated (2.8 vs. 1.9 and $p = 0.03$) (**Table 2**).

Table 2
Differences in patient characteristics and outcomes between push and riding lawnmowers

	Push lawnmower	Riding lawnmower	p
Patients	34	108	
Age (years)	11	6.3	<0.001
Open fracture	25 (73.5%)	72 (66.7%)	0.5
Amputation	17 (50%)	37 (34.3%)	0.1
Amputation at wrist/ankle or proximal	2 (11.8%)	9 (24.3%)	0.3
Amputation distal to wrist/ankle	15 (88.2%)	28 (75.7%)	0.3
1 digit or portion thereof	9 (60%)	16 (57.1%)	
2 digits	5 (33.3%)	3 (10.7%)	
3 digits	1 (6.7%)	1 (3.6%)	
4 digits	0	6 (21.4%)	
5 digits or entire hand/foot	0	2 (7.1%)	
Average number of digits amputated	1.9	2.8	0.03
Soft tissue defect that required reconstruction	35.3%	56.5%	0.03
Length of hospital stay (days)	2.7	8.9	<0.001
Average number of surgeries required per patient	1.3	2.5	<0.001

In multivariate analysis, the two predictors for increased number of operative procedures were younger age ($p < 0.001$) and injury by a riding lawnmower ($p = 0.02$). The only predictor for sustaining an open fracture was younger age ($p < 0.001$). There were no significant predictors of amputation.

Level of amputation

When only patients who sustained an amputation were analyzed, multivariate regression revealed that the only predictor of a proximal amputation was younger age ($p = 0.03$).

Reconstruction of soft tissue defects

Soft tissue defects that require reconstruction were present in 73 patients. Among patients with a soft tissue defect requiring reconstruction, riding lawnmowers were the cause of injury in 61 patients (83.6%). This is in contrast to patients who did not have a soft tissue defect requiring reconstruction, where riding lawnmowers were the cause of injury in 68.1% ($p = 0.03$).

For patients with a soft tissue defect, reconstruction consisted of undermining and closure in 30 patients, skin graft (with or without a bilayer dermal regeneration template) in 29 patients (Figure 1), a local or regional flap in 10 patients (Figure 2), and a free flap in 4 patients. Of note, riding lawnmowers were the cause of injury in 100% of patients who required a free flap, and in 90% of patients who required a local or regional flap.

Discussion

Lawnmower injuries to children are often devastating, limb-threatening, and preventable. Although the number of children injured by lawnmowers each year is significantly smaller than that of those injured in motor vehicle collisions,¹¹ lawnmower injuries are nevertheless the third leading cause of traumatic amputation in children.¹² In a review of all pediatric amputations documented in the National Trauma Data Bank between 2007 and 2011, Borne *et al* found that 12.1% of all pediatric amputations were due to lawnmowers.¹² The authors also found that children younger than 5 years were six times more likely to require an amputation after a lawnmower injury than children 6 years and older. In a 9-year study of the National Electronic Surveillance system of the United States Consumer Product Safety Commission for children, Bachier *et al* found that, in children who sustained lawnmower injuries, the hands were affected 30.1% of the time, followed by the lower extremities (16.8%), and the face (14%).¹ Children with a lawnmower injury to the lower extremity have been found to require an average of 3–4 operations.^{13,14}



Figure 1. A) After being run over by a riding lawnmower driven backwards, a 3-year-old male sustained a degloving injury of his left medial foot and ankle, without joint penetration or fractures. B) The patient underwent four operative debridements and negative pressure wound therapy, followed by the application of bilayer dermal regeneration template. C) After complete vascularization and granulation of the dermal regeneration template, split-thickness skin grafting was performed. D) and E) The patient healed uneventfully and underwent a period of physical therapy to address ankle stiffness.

Lee *et al* found that the two predictors of longer hospital stay and increased number of procedures were riding lawnmower injuries and younger age.¹⁴ In this current study, riding lawnmowers were more likely than push mowers to cause soft tissue defects requiring reconstruction (particularly local, regional, and distant flaps). Riding lawnmower accidents also resulted in longer hospital stays and increased number of operative procedures. These trends may be explained by the fact that most lawnmower-related injuries are due to one of four mechanisms:

Direct contact with the rotating blade: these tend to be the most common and most severe lawnmower injuries. In the current study, this was by far the most common mechanism of injury, which accounts for 86.6% of all injuries. These injuries were, for the most part, preventable and occurred in five manners:

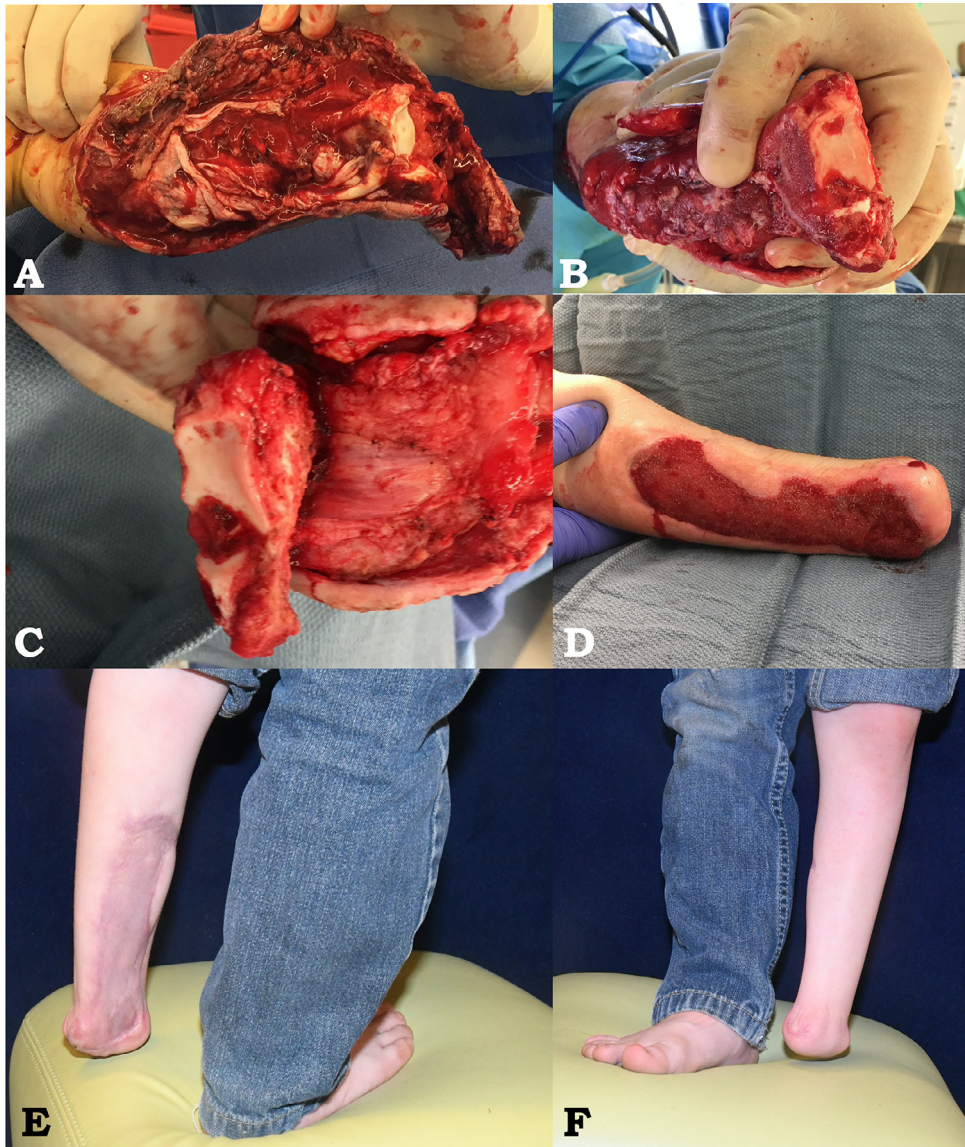


Figure 2. A) A 5-year-old male sustained a traumatic amputation through the talocrural joint, after falling off a moving riding lawn mower that he was sitting on with a family friend. Significant soft tissue injury was evident in the muscles and tendons of the calf. The wound was heavily contaminated.
B) The patient underwent five operative debridements and negative pressure wound therapy. The patient did not have adequate soft tissue coverage over the distal stump (shown).
C) A tibialis anterior myocutaneous flap was elevated and advanced to cover the distal stump with well-padded soft tissue. The flap was myodesesed to the bone through drill holes.
D) After flap coverage of the distal stump, the residual calf defect is covered with a split-thickness skin graft
E) and F) The patient's leg healed fully, and he is able to walk and run with a custom prosthesis

The most common manner of injury was that of an inattentive adult operating a riding lawnmower forward and running over a child. The American Academy of Pediatrics' (AAP) Committee on Injury and Poison Prevention recommends that children should never be in the vicinity when a lawnmower is being operated.¹⁵

The second most common manner of injury was that of a child riding on a lawnmower with an adult, then falling or jumping off in front of the mower. Both the American National Standards Institute and Outdoor Power Equipment standards (ANSI/OPEI B71.1) and the AAP recommend that children should never ride with adults on a lawnmower.^{1,15}

The third most common manner of injury was that of an adult operating a riding lawnmower backward and running over a child. The 2003 update to the ANSI/OPEI B71.1 required that the rotating blades must stop if a lawnmower is backing up.¹ However, many lawnmower manufacturers have *not* fully disabled the ability to engage the blades in reverse.^{16,17}

The fourth most common manner of injury was that of a push lawnmower operator slipping under a running lawnmower blade and sustaining severe foot injuries. One way to avoid this type of incident is to operate a push mower across a slope not down a slope.¹⁸

The fifth most common manner of injury was that of a lawnmower operator using his or her hands to touch mower blades while the blades were running. ANSI/OPEI B71.1 and the AAP both recommend, and federal code 16 CFR 1205.5 requires, that lawnmowers be equipped with a “deadman” mechanism that stops blade rotation within 3 s of the lawnmower handle being released, thereby making such injuries extremely unlikely. However, such injuries still occur, mostly because some consumers tie the “deadman” control to the handle to keep it engaged without having to keep their hands on the handle at all times.¹⁹

Crush injury from the weight of a riding lawnmower: in the current study, this usually consisted of teenagers operating riding lawnmowers on a steep slope, causing the lawnmower to tip over. The 2003 update to the ANSI/OPEI standards recommends that the use of riding lawnmowers on slopes should be avoided.¹ In contrast, the Occupational Safety and Health Administration (OSHA) offers a more nuanced view, recommending that riding lawnmowers should not be used on slopes steeper than 15 degrees.²⁰ It is also recommended that, if a riding lawnmower must be used on a slope, it should be driven up and down the slope, but not sideways.¹⁸ This is in contrast to push lawnmowers, which should be used across a slope, not up and down, as noted above.

Projectiles thrown by the lawnmower:^{21,4} projectiles thrown by the rotating blade may injure the eyes²² or even penetrate vital structures such as the mediastinum.²³ The AAP's Committee on Injury and Poison Prevention recommends removing all debris and rocks from the area before mowing to avoid turning them into dangerous projectiles.¹⁵

Direct contact with lawnmower components: in the current study, this included burns and hair caught in the engine. Lawnmowers are designed such that all hot and moving parts are covered with shields. These accidents should not occur if all shields are intact. Lawnmowers with damaged shields or guards should never be used.¹⁸ The AAP also recommends that lawn mower operators should wear appropriate protective clothing that includes sturdy shoes.¹⁵ Lawnmower operators should also not have loose clothing or hair that can get caught in the mower mechanism.

More than two-thirds of the patients in this study had an open fracture and more than a third required an amputation. The angular momentum at the tip of a rotating lawn mower blade is equivalent to a one pound object traveling at over 230 miles per hour.²⁴ These injuries are analogous to blast injuries,⁸ which often lead to large areas of damage to bone and soft tissue. For these reasons, lawn mower blades have a very high likelihood of causing an open fracture.²⁵ The resultant wounds are often heavily contaminated with debris and multiple organisms.² There is often soft tissue loss, and a large zone of crush injury. When reconstruction is not feasible, amputation is necessary.

Similar to previous studies, this study also found that younger age is a risk factor for longer hospital stay and more operative procedures after lawnmower injury.^{12,14} Younger children are more likely to sustain an amputation at the wrist/ankle or more proximal.

Despite regulations and warnings, the incidence of lawnmower injuries in children has not decreased over the past few decades.^{26,1} This is likely due to two factors: the first is continued high-risk behavior by consumers. Many lawnmower operators still allow children to ride with them on riding lawn mowers, and many still operate riding lawnmowers backwards with the blades engaged and

Table 3

Summary of lawnmower safety recommendations

Summary of lawnmower safety recommendations

Children younger than 16 years should not use a riding lawnmower
Children younger than 12 years should not use a push mower
Make sure no children are around before operating a lawnmower
Operator must remain attentive as children may approach the lawnmower without being noticed or heard
Children should never ride on a lawn mower
Operator must look in all directions while operating mower or changing directions, particularly while backing up
Blades should never be engaged when a riding lawnmower is backing up
Never use a riding lawnmower on a slope steeper than 15 degrees
When using a riding lawnmower on a slope between 0 and 15 degrees, mow up and down the slope rather than across the slope
When using a push mower on a slope, mow across the slope rather than up and down the slope
Before touching the engine or the blades, always make sure the lawnmower is completely off
Never modify the “deadman” mechanism to keep the lawn mower operating with hands off the handle
Remove all debris and rocks from the area before mowing
Do not operate a lawnmower if its shields/guards are damaged or missing
Do not operate a lawnmower with loose hair and clothing
Always wear protective clothing when mowing, which includes sturdy shoes and polycarbonate goggles

without looking behind them before reversing the lawnmower.²⁷ The second factor, as noted above, is that some manufacturers have not followed safety recommendations, such as disabling blade rotation while a riding lawn mower is moving backwards.^{16,17} A summary of the safety recommendations for lawn mowers is shown in **Table 3**.

Even though this study was performed in the United States, and our safety recommendations in **Table 3** are based on regulations from American entities, those recommendations are universal. Numerous studies show that pediatric lawnmower injuries are, unfortunately, a worldwide problem. Nguyen *et al* and Laing *et al* both found increasing incidences of injuries from riding lawn mowers at their institutions in Australia and Ireland, respectively.^{28,29} Klein *et al* found an 87% rate of amputation among French children injured by lawn mowers.³⁰

In addition to the devastating physical injuries that lawnmower accidents can cause, their emotional toll should also be taken into account, particularly given the fact that the lawnmowers that cause the injury are often operated by a family member. Because of the limitations of a retrospective chart review, this study did not evaluate the emotional and psychological effects of these injuries on patients and their families. Future studies on the topic should evaluate these psychological effects as well as quality of life.

Conclusion

Pediatric lawnmower injuries can be devastating, with over one-third resulting in an amputation. These serious injuries are largely avoidable. Unfortunately, the incidence of those injuries is not decreasing. Continued advocacy and education are both needed to encourage manufacturers to fully implement safety recommendations and consumers to practice safe lawn mower use.

Conflicts of Interest and Source of Funding

None of the authors have any relevant financial conflicts of interest. This study was not funded.

Ethical Approval

Ethical approval was obtained through the Institutional Review Board at Nationwide Children's Hospital in Columbus, OH, approval number - STUDY00000420.

Publication of Photographs

Written consent has been obtained.

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