

“TRASH” Lesions of the Pediatric Lower Extremity

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Abstract: TRASH lesions have been coined as a group of pediatric elbow injuries which are underappreciated on radiographs, and which “if treated insufficiently result in chronic long-term consequences.”¹ We describe a series of injuries in the pediatric lower extremity, which are similar to elbow TRASH lesions, in that they are often overlooked or dismissed as inconsequential and may have serious ramifications if managed inappropriately. These injuries include traumatic hip dislocations with subsequent intraarticular pathology, greater trochanteric avulsion fractures, patellar sleeve fractures, minimally displaced proximal tibial metaphyseal fractures, and minimally displaced Salter-Harris III and IV fractures of the medial malleolus. Making the correct diagnosis and implementing appropriate treatment, including adequate follow up, is paramount.

Key Points:

- Traumatic hip dislocations in the pediatric and adolescent hip populations can result in intraarticular pathology, which is not visualized on advanced imaging.
- Greater trochanteric avulsion fractures, while rare, may be complicated by avascular necrosis of the femoral head.
- Patellar sleeve fractures may be easily missed on radiographs, and inadequate management can result in significant sequelae.
- Proximal tibial metaphyseal fractures, even when nondisplaced, may result in posttraumatic genu valgum, and caregivers should be warned of this possibility.
- Non- and minimally displaced Salter-Harris III and IV fractures of the medial malleolus can lead to premature physeal closure, and radiographic follow up of these injuries is warranted.

Introduction

In 2010, Waters et al.¹ published an article describing “TRASH” lesions of the pediatric elbow. TRASH refers to “The Radiographic Appearance Seemed Harmless,” and this term was used by the authors to describe a subset of osteochondral pediatric elbow injuries that may be overlooked on radiographs because of their benign appearance and which, if treated inappropriately, may result in long-term adverse sequelae.

In the spirit of TRASH as it was defined by the authors, we have identified a group of injuries (Table 1) in the pediatric lower extremity which can be similarly classified: injuries which are often overlooked or dismissed due to their unremarkable radiographic appearance but which can lead to significant consequences. This group includes both common injuries with uncommon complications and rare injuries with unusual complications. A closer look at this subset of injuries illustrates the need for providers to maintain a

Table 1. Lower Extremity “TRASH” Injuries

- Traumatic hip dislocation with subsequent intraarticular pathology
- Greater trochanter avulsion fractures
- Proximal tibial minimally displaced fractures followed by Cozen’s phenomenon
- Salter-Harris III/IV minimally displaced medial malleolus fractures which develop growth arrest



Figure 1a. Injury radiograph of 13-year-old male with a dislocated right hip after an ATV accident. The dislocation was reduced in the emergency room under sedation and fluoroscopic imaging. It is always important to reduce these fractures with deep sedation and imaging as iatrogenic physeal injuries have occurred during reduction.

high index of suspicion for these lesions while evaluating patients with lower extremity trauma, and to grasp the pitfalls inherent in the management of these injuries.

Traumatic Hip Dislocations with Subsequent Intraarticular Pathology

The high incidence of intraarticular pathology after traumatic hip dislocations in adults has been well documented,²⁻⁴ and can include labral tears, intraarticular

loose bodies, ligamentum teres injuries, and chondral or osteochondral damage.⁵

Concerningly, these findings can be present in the setting of a radiographically congruent reduction. A similar concern for intraarticular pathology after traumatic dislocation has been observed in pediatric and adolescent populations⁶⁻⁸ (Figures 1 a-e), with an incidence of 44% in 1 series.⁹ All authors recommend post-

reduction plain radiographic imaging in all traumatic hip dislocations; yet more are advocating MRI (over CT) routinely due to the ability of MRI to define non-bony pathology missed on plain radiographs.^{6,10} MRI has a higher likelihood than CT of finding labral tears, intraarticular chondral fragments, chondral defects, and ligamentum teres injuries,⁵ but still may not pick up all lesions.¹¹ MRI is thought to be more reliable than CT for post-reduction imaging in the pediatric and adolescent populations,^{9,12} due in part to the ability of MRI to image the unossified portion of the posterior acetabular wall. In children and adolescents, traumatic hip dislocation has been reported to have a high incidence of injury to the posterior labrum, often with enfolding of the labrum, which then can lead to blocked reduction.^{7,8}

With the increasing use of hip arthroscopy in both the adult and pediatric/adolescent populations in the last two decades, it is becoming clear that some of the intraarticular damage can be missed by both post-reduction computed tomography (CT)^{4,5} and magnetic resonance imaging (MRI).¹¹ Indeed, some authors⁶ have recommended routine arthroscopy after all traumatic hip dislocations in an effort to diagnose and treat any intraarticular pathology.

Another finding which may be specific to the pediatric/adolescent population is the traumatic hip dislocation with spontaneous incomplete reduction, reported by Price.¹⁰ In this series, the authors describe 3

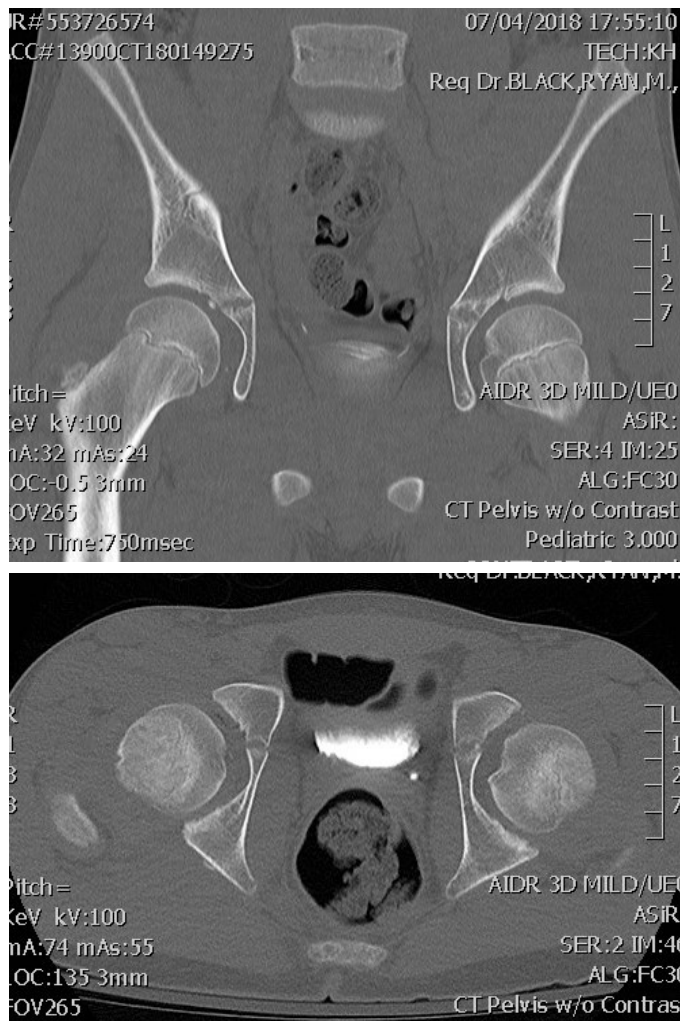


Figure 1b (top) and 1c (bottom). Post-reduction computed tomography (CT) images showing intraarticular fragments.

skeletally immature patients who presented with hip injuries and initial radiographs demonstrating subtle widening of the hip joint which was missed on presentation. All 3 patients were found to have interposed soft tissue in the hip joint at the time of surgical management. The authors recommend that any hip joint asymmetry in the setting of injury, even if there is no documented dislocation, be evaluated with further imaging, and that “magnetic resonance imaging may be the better choice in the pediatric age group since MRI provides better visualization of cartilaginous and ligamentous tissue.”¹⁰

In conclusion, pediatric and adolescent patients have a high incidence of intraarticular pathology following traumatic hip dislocations, and posterior labral injuries appear to be common. MRI is likely a better tool than CT to delineate intraarticular injuries in this population, due to the presence of unossified posterior acetabulum in skeletally immature patients. Arthroscopy may be indicated to treat these pathologies. Finally, dislocation and spontaneous reduction events have been reported in this population, and any hip injury with evidence of joint widening on plain radiographs should be further imaged for intraarticular injury.

Greater Trochanteric Avulsion Fractures and the Risk of Avascular Necrosis of the Femoral Head

Traumatic epiphyseal separation of the greater trochanter was reported by Poland¹³ in 1898 in a series of 12 patients, 10 of whom were diagnosed postmortem. Avulsion fractures of the greater trochanter of the femur are rare injuries in both adults and children, and most subsequent reports of these injuries are small case series and include both children and adults.¹⁴⁻¹⁷ Freitas et al., in a review article from 2016, noted that this injury can often be subtle on plain radiographs, and computed tomography (CT) is indicated when clinical suspicion is high.¹⁸ Injuries to the proximal femoral physis are certainly more common than trochanteric avulsions, with 0.1% incidence of all physeal injuries in a 10-year series from Minnesota.¹⁹ The mechanism of injury of greater trochanteric fractures in adults is thought to generally be a direct impact,¹⁵ often resulting in a partial fracture of the posterior and superior portion of the trochanter. In skeletally immature patients, an additional mechanism has been noted to be an avulsion by the hip abductors, with the entire trochanteric fragment displacing anteriorly.²⁰

There are at least 2 reports in the English literature of avascular necrosis of the femoral head following avulsion of the greater trochanter in pediatric patients,^{20,21} and one in the German literature.²² Several

causes of avascular necrosis after traumatic avulsion of the greater trochanter have been proposed:^{20,21} (1) **traumatic disruption of the blood supply to the femoral head at the time of injury.** The blood supply to the femoral head in the skeletally immature hip has been well described,²³⁻²⁵ and the largest contribution is thought to originate from the lateral ascending cervical artery, which is a branch of the medial femoral circumflex artery at the posterior junction of the greater trochanter and base of the femoral neck.²³ O'Rourke speculates that since the medial femoral circumflex artery is "tethered by the lateral ascending cervical artery and the descending metaphyseal arteries, [it] can be disrupted at its terminal aspect when the hip abductors avulse the greater trochanter";²⁰ (2) **intracapsular hematoma**, with subsequent compression of the veins and increasing pressure leading to decreased head perfusion; (3) **unrecognized proximal femoral injury**, including spontaneous hip dislocation and relocation;²¹ and (4) **intraoperative iatrogenic damage to the blood supply.**²⁰

In summary, fractures of the greater trochanter are rare in both adults and children. This injury can be caused by both a direct blow and by contraction of the abductor muscles. Computed tomography (CT) is recommended in the setting of high clinical suspicion, as the injury can be difficult to detect on plain radiographs (Fig 2 a-b). There are reports of avascular necrosis of the femoral head following greater trochanteric avulsion in the skeletally immature population. Two years of radiographic and clinical follow up is recommended after this injury in skeletally immature patients due to the risk of subsequent avascular necrosis.

Patellar Sleeve Injuries

Patella fractures comprise less than 1% of all fractures in children,²⁶ and patellar sleeve fractures account for more than half of all patellar fractures in skeletally immature patients.²⁷ Patellar sleeve fractures are unique to children due to the central-to-peripheral chondroossification of the patella during growth.²⁸

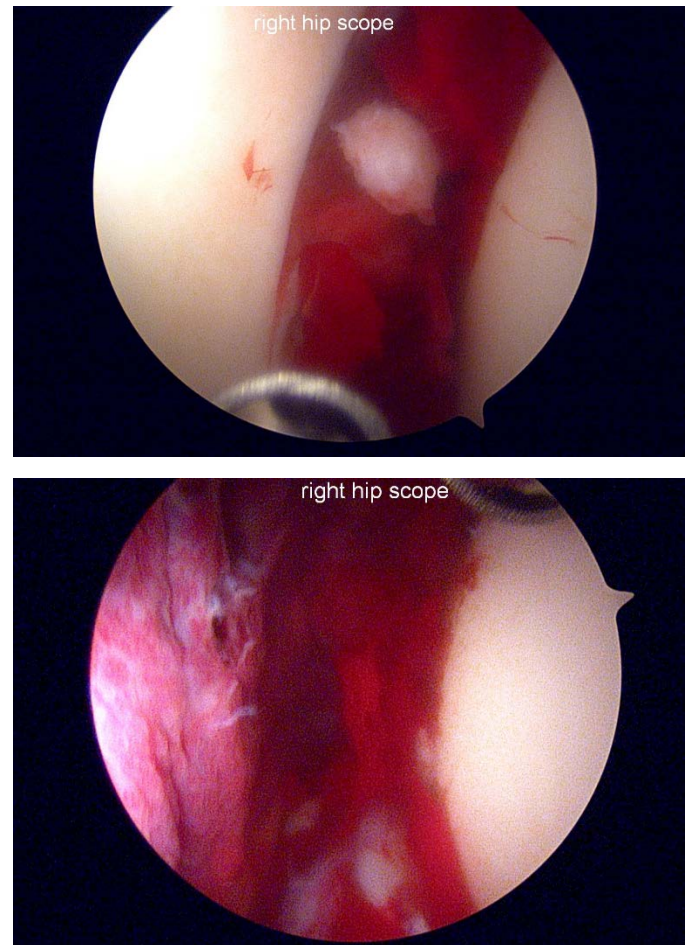


Figure 1d (top) and 1e (bottom). Arthroscopic views showing intraarticular osteochondral fragments.

Sleeve fractures were first described by Houghton in 1979,²⁹ who reported a series of three patients with inferior fractures. Grogan²⁸ collected a series of 47 patients with patellar avulsion fractures, and subclassified them by the direction of displacement of the avulsed fragment: superior, inferior, medial and lateral. It has been noted by other authors²⁷ that only the superior and inferior injuries represent true "sleeve" fractures in that a cuff of articular cartilage and periosteum is pulled off, which can be quite large, and a bony fragment is not always visible with these injuries.²⁹

The mechanism of most patellar sleeve injuries involves vigorous contraction of the quadriceps (soccer, hurdling, high-jumping). Examination is crucial to make the correct diagnosis: findings generally include



Figure 2a. Injury radiograph of 6-year-old male with a right hip injury after a rollover car accident, slight asymmetry in the position of greater trochanter is noted.

hemarthrosis, patella alta or baja, a palpable gap between the patella and the avulsed fragment, and an extensor lag.²⁷⁻²⁹ It has been noted that some patients with this injury can have an intact extensor mechanism due to an intact posterior hinge of cartilage, even with a displaced fracture.^{26,28,30} Sleeve fractures can be easily missed on plain radiographs due to the absence of a visible bony fragment,^{28,29} and when a bony fragment is visible it is often quite small (Fig 3 a-c). Patella alta is generally seen in the setting of inferior injuries, and should be looked for specifically.²⁷ The use of ultrasound has been reported to facilitate the diagnosis.³¹

The consequences of a missed injury can be debilitating and include elongation of the extensor mechanism with extensor lag,²⁸ patella alta,³⁰ malunion, ossification in the tendon,^{28,30} patella magna, and even duplication of the patella.³² Conservative management has led to mixed results as well^{28-30,33} with a risk of decreased motion and patellar deformity. Surgical management, with restoration of the articular cartilage, periosteum, and extensor mechanism is generally recommended in the

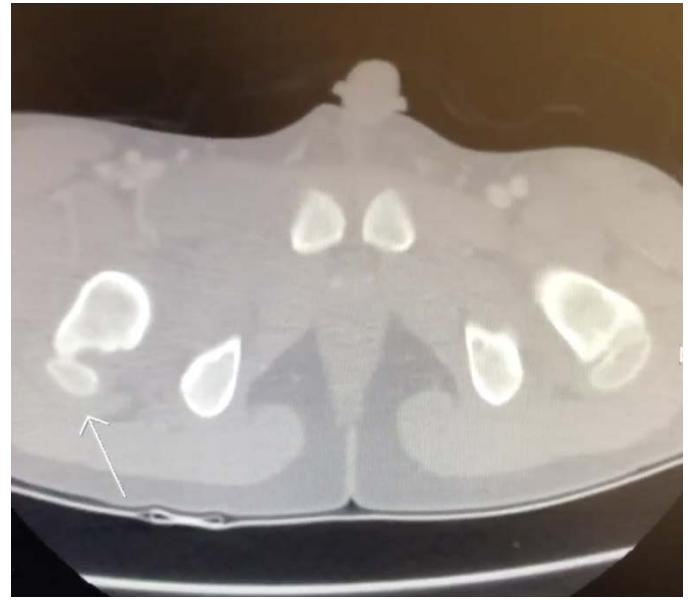


Figure 2b. Computed tomography (CT) image showing posteriorly displaced right greater trochanter.

setting of any patella alta/baja or fragment displacement more than 2 mm.²⁷⁻²⁹

Summarizing here, patellar sleeve fractures are unique to children and skeletally immature athletes. A high index of suspicion is required for patients with an extensor lag, palpable defect in the quadriceps, or patella tendons. These fractures are easy to miss on radiographs, and the examiner must be alert to findings such as patella alta or patella baja with or without a bone fragment. Missed patellar sleeve fractures can have significant sequelae, and thus making a correct, timely diagnosis is paramount.

Minimally Displaced Proximal Tibial Fractures and Posttraumatic Genu Valgum (Cozen's Phenomenon)

In 1953, Cozen³⁴ reported a series of 4 patients who developed valgus deformity after fracture of the proximal tibia between the ages of 3 and 7. The deformity resolved in 2 patients, but the author noted that litigation was threatened in 3 of the 4 injuries and advised that families be warned about the possibility



Figure 3a-b. Injury radiographs of an 8-year-old female with an inferior patellar sleeve fracture, showing patella alta and a small bony fragment.

of valgus deformity after nondisplaced and minimally displaced proximal tibia fractures in children. Following Cozen's report, there have been numerous articles published which detail posttraumatic genu valgum in children following proximal tibia fractures;³⁵⁻⁴⁴ the vast majority of these articles are case series, and most include several different types of proximal tibia fractures (buckle fractures, fractures with a proximal fibula fracture, fractures with a medial gap, and completely displaced fractures). In some series which report Cozen's phenomenon,^{37,38,42-45} the incidence of posttraumatic genu valgum is wide and ranges from 0/7⁴⁵ to 28/31 (90%).⁴⁰ Some authors report the incidence of posttraumatic genu valgum by fracture type,^{37,38,40,44,45} and in general these authors note that the rate of posttraumatic genu valgum is higher in displaced fractures and fractures with a medial gap than in nondisplaced and buckle fractures.

The timing of onset of deformity is variable^{34-36,39,41}; some series have patients with deformity noted at cast removal, which implies malunion after immobilization. It has been recommended by several authors^{34,35,41,43} that families be informed at the outset about the risk of posttraumatic genu valgum in the setting of proximal tibia fractures, even those which are nondisplaced. Yang recommends routine radiographic follow up only in the



Figure 3c. Postoperative lateral radiograph showing healed inferior patellar sleeve fracture, 3 months after repair with nonabsorbable suture through transosseous tunnels.

instance of the fractures which carry the highest risk (fractures with initial valgus greater than 4°, a medial metaphyseal gap, or an ipsilateral fibula fracture).³⁸ When progressive deformity develops, onset has been noticed as early as 5 weeks³⁴ and in general within a year of injury.^{35,36,39,41} Zionts notes that the angulation progresses more quickly during the first year after injury, and then increases more slowly for as long as 17 months.³⁵ Several authors report that the valgus deformity spontaneously resolves in the majority of patients,^{35-38,40} and Zionts notes deformity resolving by an average of 39 months after injury.³⁵

In summary, posttraumatic genu valgum has and may occur even in nondisplaced and buckle fractures. The rate of posttraumatic genu valgum varies widely, but

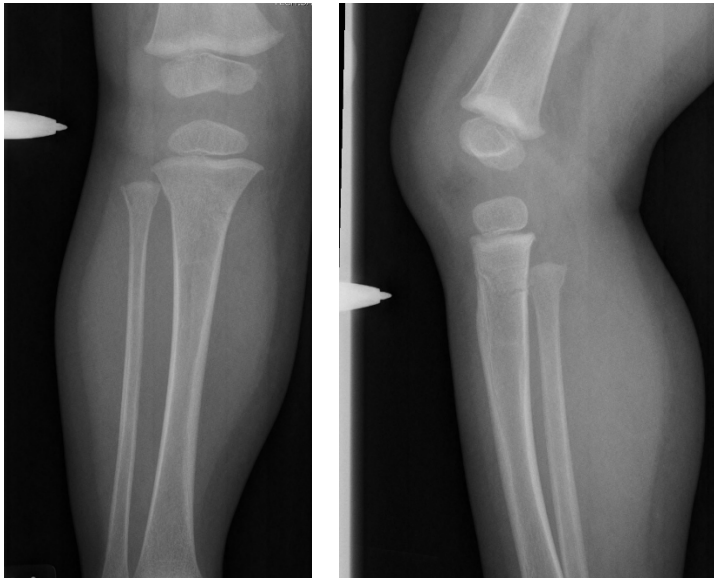


Figure 4 a-b. Injury radiographs of an 18-month-old female who sustained a nondisplaced proximal tibia and fibula fracture on the trampoline. She was treated in a weightbearing cylinder cast for four weeks and healed uneventfully.

appears to be higher in displaced fractures, fractures with a medial gap, and fractures with an ipsilateral fibula fracture. Most deformities spontaneously resolve, and observation is recommended for at least 3 years.

Providers are strongly advised to caution families about the possibility of posttraumatic genu valgum after any type of proximal tibia fracture in children. Due to the high risk of recurrence of valgus deformity,^{39,44} corrective osteotomy during growth is not recommended.^{35,36} Guided growth with temporary hemiepiphyseodesis has been used successfully in the setting of persistent valgus deformity.^{42,46} (4a-d)

Ankle Injuries

Fractures involving the physis of the distal tibia are the second most common type of physeal fractures, representing 11% of all physeal injuries.¹⁹ Distal tibial physeal fractures are a diverse group of injuries, and overall impart a risk of premature physeal closure (PPC) of 2%-39.6% in Salter-Harris type I/II fractures and 7.7%-50% in type III/IV fractures.⁴⁷⁻⁴⁹ One subgroup of distal tibial physeal fractures warrants special consideration—Salter-Harris III and IV medial malleolar

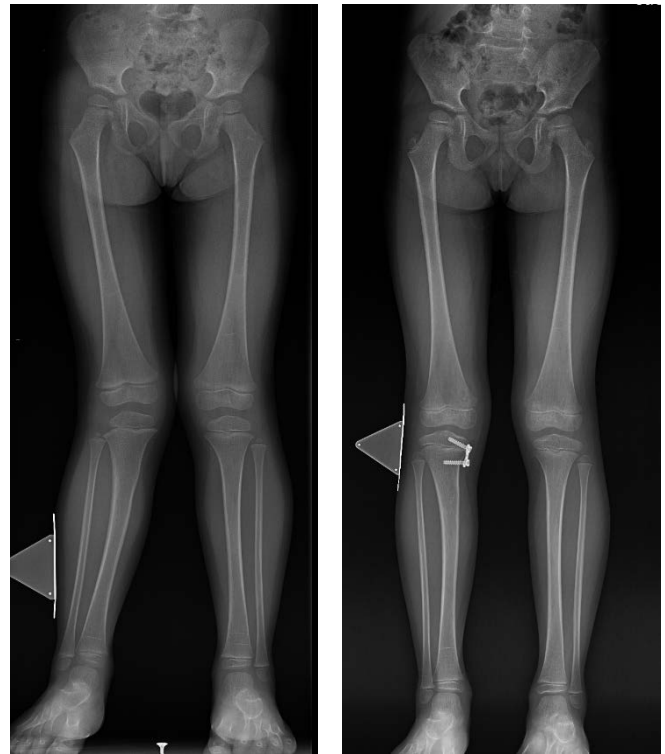


Figure 4c (left). The post-traumatic genu valgum (Cozen Phenomenon) was noted at 8 months after cast removal. This standing anteroposterior radiograph of the patient was taken 2.5 years after injury. **Figure 4d (right).** A standing anteroposterior radiograph of the patient in 12 months after hemiepiphyseodesis. The plate was then removed, and no recurrence has been noted.

fractures—due to their increased risk of premature arthritis from joint incongruity and physeal arrest and potential subsequent deformity.

Prior to the development of the Salter-Harris classification, physeal fractures of the medial malleolus were originally described by McFarland,⁵⁰ He reported a series of patients who sustained adduction-supination ankle injuries while getting their feet caught in a fence and which resulted in growth arrest and varus deformity. Following the widespread use of the Salter-Harris classification after 1963,⁵¹ we now recognize these injuries as Salter-Harris III and IV fractures of the medial malleolus. Patients who sustain these injuries are often younger than patients with other types of distal



Figure 5 a-b. Injury radiographs of an 8-year-old female who sustained a nondisplaced Salter-Harris IV medial malleolus fracture. This fracture was treated closed.

even after anatomical reduction, suggesting that there may be multiple types of physeal damage that may lead to the formation of a physeal bar”. (Figure 5a-f)

In summary: in comparison to other distal tibia fractures, Salter-Harris III and IV fractures of the medial malleolus (McFarland fractures) have a higher risk of premature physeal closure that could lead to clinically significant deformity. When they are displaced 2 mm or more, it is recommended to undergo reduction and operative stabilization of these fractures. Physeal arrest can occur even in nondisplaced

tibial physeal injuries, ranging from 8 to 12.6 years;^{48,52,53,54} and thus have a longer period of growth remaining for a PPC to develop into a deformity. This subgroup has been reported to be 25% of all distal tibial physeal fractures,⁵² and the rate of premature physeal closure following these injuries is 13-50%.^{47,48,53,55}

It is generally accepted that residual displacement of greater than 2 millimeters in this subset of patients leads to an increased risk of PPC^{47,48,52,54} and has prompted most authors to recommend operative reduction and stabilization for fractures with 2 or more millimeters of displacement.^{47,49,52,54,56,57} Subsequent studies that demonstrate a lower rate of PPC in a series of fractures which were reduced and stabilized if displaced.^{47,54,56}

The increased risk of PPC in patients with Salter-Harris III and IV medial malleolar fractures can also be attributed to the mechanism of injury: these fractures are often the result of an adduction-supination injury, which compresses the medial distal tibial physis and may cause a crush injury to the growth plate.^{57,58} Cass⁵³ noted that, following these medial malleolar physeal injuries, “physeal closure can occur



Figure 5 c-d. AP and lateral radiographs 3 years after injury, showing medial premature physeal arrest and varus deformity. She has ankle pain and clinical deformity.



Figure 5 e-f. AP and lateral radiographs 18 months after opening wedge osteotomy. Her pain has resolved.

injuries and is likely due in part to compressive forces sustained during adduction and supination, which is a common mechanism for these injuries. Because patients with these fractures are often younger than patients with other types of distal tibial physeal injuries, follow up for at least 2 years or until physeal closure is warranted^{48,52,53,56,57}.

Conclusion

We present a sampling of lower extremity injuries in the pediatric population, which necessitate vigilance on the part of the treating provider—either because the injury itself is subtle and easily missed or because the consequences of inadequate management of one of these seemingly innocuous injuries can be deleterious. These repercussions may include posttraumatic arthritis,

avascular necrosis, and deformity from growth disturbance. The group of injuries discussed above, while not a comprehensive list of TRASH lesions in the pediatric lower extremity warrant circumspection, and diligence during evaluation and management.

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