



## Missed fractures in paediatric trauma patients

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**Missed fractures and other occult musculoskeletal injuries are common in paediatric trauma patients despite the thorough evaluation with standard trauma protocols. Several factors have been identified that contribute to the risk of failing to identify these injuries during the initial resuscitation and assessment of the paediatric trauma patient. These include patient-related, clinical, technical, and radiological causes. Preventive strategies have been proposed to minimize these overlooked injuries and their potential long-term consequences. A timely review of this problem is appropriate to continually improve the quality of care delivered to paediatric trauma patients.**

**Keywords :** paediatric ; trauma ; missed fractures.

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### INTRODUCTION

A recent annual review of paediatric patient trauma patients from our institution found five patients (1.6%) with missed fractures and other musculoskeletal (MSK) injuries. Several previous studies have noted a high incidence of missed or occult MSK injuries in both paediatric and adult patients with head injuries and/or multiple trauma (8,20, 26,43,48). A timely review of this problem is appropriate to continually improve the quality of care delivered to paediatric trauma patients.

Due to the limited number of studies specifically addressing missed MSK injuries in paediatric poly-trauma patients, studies evaluating adult patients will also be evaluated. Missed or occult MSK inju-

ries remain problematic despite numerous preventive measures taken at most paediatric trauma centers. Heinrich *et al* (20) stated that “the long-term consequences of a missed or delayed diagnosis of a fracture can be devastating.” This review will examine the incidence of missed MSK injuries, specific paediatric occult fractures, factors contributing to diagnostic failures, the consequences of these missed injuries, medical-legal issues, and potential preventive measures.

### LITERATURE REVIEW

Several retrospective studies report the incidence of missed MSK injuries ranging from 2% to 18% (8,10,13,23,48). MSK injuries comprise the majority of occult injuries (14,43). It is human nature to avoid reporting or “airing our dirty laundry,” and prospective studies may provide a more accurate incidence. Enderson *et al* (14) compared a retrospective series to a prospective series at the same

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institution. The authors noted the prevalence to increase from 2% to 9% when documenting missed MSK injuries prospectively.

Born *et al* performed an 18-month prospective study of 1,006 consecutive blunt trauma patients to determine incidence of delayed recognition of skeletal injuries at a Level I trauma center. A delay in diagnosis ranging from 1 to 91 days was noted in 39 fractures involving 26 patients (3% incidence). Delay in diagnosis ranged from 1 to 91 days. One patient in their subset of 54 paediatric patients had an occult atlanto-axial rotary instability injury of the cervical spine (7).

Heinrich *et al* used whole body bone scan imaging in 48 multiple injured/head injury patients to detect prospectively occult injuries in addition to the standard clinical and radiographic examination. Thirty-five of the patients had open growth plates at the time of injury, with an average age of seven years (range : 1-14 years). The bone scans were obtained three days after the injury. Additional imaging using computed tomography (CT) or magnetic resonance imaging (MRI) was also used to delineate injuries around the open physes. Four of the 35 patients (11%) had 8 undiagnosed fractures. Four of the fractures required a change in treatment after they were identified. These included fractures involving the pelvic ring, distal radius, and the distal femur (20).

Sobus *et al* (40) prospectively evaluated 82 patients with either traumatic brain injury (TBI) or spinal cord injury (SCI) using total body bone scans (Tc-99m MDP) to evaluate the incidence of undiagnosed MSK injuries at acute care facilities. Sixteen patients with TBI (27%) had 25 undetected fractures and 19 had evidence of soft tissue trauma. The rehabilitative program was delayed in 12 of these patients. Three fractures (13%) were missed in their SCI patients, but were not clinically significant. Heterotopic ossification (HO) was noted in 14 patients (17%). The authors concluded that total body bone scans help to detect undiagnosed fractures, soft tissue trauma, and HO in children with TBI (40).

Soundappan *et al* (43) prospectively evaluated 76 paediatric patients 15 years of age or less with Injury Severity Scores (ISS) > 9 using an extended tertiary survey. The survey was performed the day

after admission, repeated after extubation in patients on mechanical ventilation, and in head injured patients when they were more cooperative and mobile. Twelve (16%) had missed injuries, with ten of these children having missed fractures on tertiary survey. Pain requiring analgesia, delayed immobilization of the fractures, and prolonged hospital stays resulted from the delay in diagnosing the MSK injuries.

Reid *et al* prospectively evaluated missed spine fractures in 253 consecutive patients over a three-year period. Thirty-eight patients (41 spinal injuries) had a delay in diagnosis. The majority occurred in the cervical spine (85%). Failure to obtain radiographs occurred in 17 patients, and the fracture was missed in 20 patients despite adequate films. Contributing factors included altered level of consciousness, multiple trauma patients, two-level spine fractures in six patients, and head injury in five patients (37).

### Unique characteristics of the paediatric skeleton

Several unique characteristics of the immature skeleton contribute to the risk that fractures or other MSK injuries may not be detected or diagnosed. The increased porosity of a child's bone often results in different fracture patterns compared to adults that can be subtle, such as plastic deformation and torus fractures that may require comparison views to confirm. The child's thick periosteum may prevent displacement, and consequently, detection of complete fractures such as at the pelvis. The presence of growth plate cartilage in the paediatric skeleton also increases the possibility of delayed or missed diagnosis of non-displaced physeal fractures with standard radiographic views (20,36).

The unique features of the paediatric spine may result in different patterns and responses to injury. Incomplete ossification and increased motion of the cervical spine contribute to the variability of radiographic findings, and can easily be mistaken for traumatic injuries. Radiographs alone can miss up to 50% of cervical spine injuries (15). The presence of well-hydrated intervertebral disks within the thoracolumbar spine enables high-energy trauma to be dissipated over several levels, and can result in

Table I. — Common locations of occult paediatric fractures

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| <ul style="list-style-type: none"> <li>• Sternoclavicular joint: physeal fractures</li> <li>• Elbow: Supracondylar distal humerus, lateral condyle fractures, Monteggia fractures</li> <li>• Wrist: distal radius (often associated with supracondylar fractures)</li> <li>• Pelvis: Tri-radiate cartilage, sacroiliac joint</li> <li>• Spine: SCIWORA / CT junction</li> <li>• Knee: nondisplaced distal femoral or proximal tibial physeal fractures</li> </ul> |
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injury to several contiguous and non-contiguous levels. The increased elasticity of the ligamentous complex of the spinal column in response to high-energy trauma may result in traumatic spinal cord injury without radiographic abnormality (SCIWORA) (33,49).

### Specific occult paediatric fractures

Specific anatomic locations of the paediatric patient are more prone to occult injuries due to the anatomic and biomechanical factors previously outlined (Table I). Fractures about the elbow are often quite subtle and can be missed due to presence of cartilage at the articular end of the distal humerus and numerous ossification centers. The identification of a fat pad is often the only radiographic sign of an injury. Ipsilateral extremity fractures, such as distal radius and supracondylar fractures, occur when a child attempts to break his/her fall on an outstretched arm. The clinical examination tends to focus on the more severe of the extremity fractures, diverting attention away from the less obvious ipsilateral fracture.

Pelvic ring fractures in children may often only demonstrate a “single” break in the ring on plain radiographs. The presence of a second break in the ring such as slight widening of the SI joint, is more easily detected by CT scan. CT scan also improves detection of occult acetabular fractures, including triradiate cartilage injuries that may result in premature closure (19). Sternoclavicular physeal fractures are commonly missed on plain radiographs. CT scan is critical in assessing these injuries, the direction of displacement, and the vital structures at risk with posterior physeal fractures (24).

Physeal fractures about the knee, involving either the distal femoral or proximal tibial physis, may appear non-displaced and can mimic knee dislocation. These can result in neurovascular injury and the sequelae of compartment syndrome if not suspected and properly managed. Dickson *et al* (11) prospectively evaluated 25 patients with MRI of the knee after ipsilateral femur fracture. They identified 70% of knees with internal derangement. The authors recommended a thorough intra-operative exam after the femur is stabilized and encourage a low threshold for obtaining an MRI of the knee. Other post-traumatic occult injuries have been described such as osteochondral fractures, stress fractures, and bone bruises. These were the most common and had a high association with anterior cruciate ligament tears (24).

Spinal cord injury without radiographic abnormality (SCIWORA) represents an injury unique to the immature skeleton. It is a consequence of a stretch or distraction injury to the relatively flexible spinal column that exceeds the tensile limits of the underlying spinal cord. These injuries tend to occur at the cervico-thoracic junction, more frequent in children 8 years of age or less, and are more likely to be a complete SCI in these younger patients (33,49). Paediatric fractures without radiographic abnormalities, represent occult long bone injuries not apparent on plain radiographs. Increased intraosseous oedema demonstrated on MRI represents microscopic compression fractures of the trabecular bone. Naranja *et al* (32) reported 25 children who refused to bear weight on a lower extremity following acute traumatic injuries, but with normal plain radiographs. Subsequent MRI of all 25 children showed an occult fracture.

### Factors contributing to diagnostic failures

Previous studies have identified numerous factors in the failure to detect MSK injuries during the initial resuscitation and examination. Soundappan *et al* (43) noted that more than one factor was responsible for missed injury in 30% of patients.

**Patient-Related** : Ward and Nunley (48) identified a group of patients in which an emergent procedure, or inability to communicate due to intubation or paralysis lead to an unreliable musculoskeletal exam and thus missed fractures. Haemodynamic instability, patients presenting in shock, and patients with more severe injuries tend to have other injuries overlooked during the initial resuscitation and secondary survey (16,21,26). Motor vehicle accidents as a mechanism of injury have been identified as a risk factor (26,34). Several studies identified closed head injuries as a significant factor contributing to the risk of missing injuries (8,27,43). In a prospective 2 year review of traumatic brain injury (TBI) patients, Garland *et al* (17) reported an 11% incidence of missed MSK injuries in 254 patients with closed head injuries. These injuries involved 29 patients with undiagnosed fractures or dislocations and 29 previously undiagnosed peripheral nerve injuries (PNI). Common peripheral nerve injuries involved the ulnar, common peroneal, and median nerves. PNIs occur more frequently in the upper extremity than in the lower extremity (22). Patients with any flail muscle groups should increase one's index of suspicion for possible PNI and be evaluated soon after injury, since spasticity ensues early after head trauma and can mask an underlying PNI (17). Kushawa *et al* (22) recommended that a PNI should be suspected in the vicinity of every fracture in patients with TBI. In a prospective study of 50 consecutive patients with TBI, Stone *et al* (44) noted the incidence of undetected PNI to be 34%. All patients suspected of having a PNI were confirmed with EMG studies. The ulnar nerve, brachial plexus, and common peroneal nerve were frequent sites of entrapment, and were commonly found in neurologically impaired extremities with associated spasticity (44).

**Clinical** : the breakdown of clinical routine and inexperience may result in overlooking a less severe injury. Breakdown of clinical routine in a charged

setting such as the trauma bay during the primary or secondary survey of a child with multiple injuries can result in an inadequate evaluation or even complete omission of part of the examination (10). An examiner's inexperience in this setting may lead to misinterpreting clinical information obtained during the secondary survey. The significance and possible consequences of not further evaluating soft tissue injuries such as ecchymosis or abrasions may not be appreciated (10,14,43).

**Technical** : Underlying extremity injuries can often be hidden and not thoroughly examined after the child is initially resuscitated, peripheral IV lines placed, splints applied, and dressings placed. Cervical collars and extremity splints may obscure radiographic images. Failure to take down dressings and explore wounds, remove splints to better assess joint or long bone injury, and examining limbs with previously placed lines may increase the risk of a missed fracture.

**Radiological** : Several radiological errors have been identified as a cause of missing MSK injuries. These include inadequate studies or wrong views, the patient's name plate obscuring the injury, misinterpretation of imaging studies, failure to obtain films, and delay in reading radiographs (7,10,14,43). Born *et al* (7) evaluated the delayed diagnosis in 26 patients after multi-system trauma. In 21 of these patients, no radiographs were taken at time of admission. Nine missed fractures were retrospectively clearly visible on admission films : . Technically inadequate studies were responsible for missing four fractures ; the other five radiographs were adequate films, but the fracture could not be identified on admission radiographs (7).

**Admission to an inappropriate service** : Chan *et al* (10) reported an increased incidence of missed injuries when admitted to a non-orthopaedic ward. In their series of 327 patients, the authors found a 10% chance of being incompletely examined. A significant increased risk of 46% was noted when patients were admitted to non-acute specialist beds (10).

### Long term sequelae of missed paediatric fractures

Several studies have addressed the long term sequelae or consequences of missed injuries.

Albrektsen *et al* (1) performed an autopsy study on 24 blunt trauma patients. Thirty-four percent of these injuries were not diagnosed during initial evaluation. Hidden injury was identified as the sole cause of death in 5% and a contributing factor in 23%. In a retrospective review of 111 multi-trauma patients, Ward and Nunley (48) found that 49% of the orthopaedic injuries identified late necessitated a change in treatment; 19% required surgery, and 30% required cast immobilization. Thirty-five percent of these late fractures may have resulted in a poor functional outcome if they were not treated. Enderson *et al* (13) noted that seven patients out of 41 with missed injuries necessitated operation after identification in their prospective study using a tertiary trauma survey. In patients with closed head injuries and increased survival rates, it is more often the MSK injuries such as HO, PNI, and extremity contractures that result in the patients' long-term morbidity. An aggressive approach to the management and detection of these injuries will hopefully decrease long-term sequelae (22).

### Medical – Legal Issues

Despite the major concerns of malpractice litigation involving missed fractures or MSK injuries in paediatric patients, there is a relative paucity of dedicated orthopaedic reports that could provide to the practicing orthopaedic surgeon strategies to minimize these risks (6,39).

Several studies from other disciplines have used databases to collect information on closed malpractice claims including number of claims, demographics of physicians and claimants, the specific medical error, severity of the health condition, and the indemnity paid (3,6,9,28,39). Studdert *et al* reported that 29% of malpractice claims were related to the category of missed or delayed diagnosis in a closed claims study involving five malpractice insurance companies (45). Selbst *et al* reviewed medical malpractice cases involving paediatric emergency room (ER) physicians. Diagnostic error (39%) was the most common reason for malpractice claims, and delay in treatment comprised 4% of claims. Four of the top ten diagnoses involved in malpractice cases

were extremity fractures (humerus, femur, forearm, and lower leg) (39).

Missed radiographic diagnoses represent the largest category of radiology related lawsuits. In a survey of lawsuits in Cook County, Illinois over a six-year period, missed fractures and dislocations accounted for 38 % of the lawsuits filed (5). Berlin raises the concern that radiologists are at a distinct disadvantage, often lacking clinical information and communication with the treating physician about patients when reading radiographs and other imaging studies. In addition, radiologists are often more vulnerable to retrospective review than other physicians (4).

Previous reports have noted that the majority of patients who incur a medical injury due to negligence do not file a lawsuit (25,45). However, patients often seek compensation for complications resulting from a missed diagnosis of a MSK injury in a child, particularly those that result in permanent disability (18). In a systematic review, Najaf-Zadeh *et al* found the incidence of medical malpractice payments in children was nearly 50% less frequent than in adults (31). Gould *et al* reported that the largest number of paediatric negligent claims occur from complications associated with compartment syndrome and casting, and that closed treatment of femur fractures in the past resulted in the most frequent and expensive malpractice awards (18). The incidence of these claims may change as the pendulum has shifted to open treatment of pediatric femur fractures with intramedullary fixation. In another closed claims study, Bhattacharyya and Vrahas evaluated the medical legal aspects of compartment syndrome; two of claims (11%) involved children with elbow fractures (6).

### Prevention

Several preventive measures have been proposed to reduce the risk of missing fractures in the paediatric patient. The ability to prevent these injuries requires a strict adherence to a protocol that involves multiple examinations and a low threshold to further investigate subtle findings. Soft clinical signs such as ecchymosis, swelling, or abrasions must not be overlooked, and underlying bony injury

should be considered and ruled out with an aggressive radiographic evaluation (7). Primary and secondary surveys are performed during the initial assessment of management (2). Unfortunately, the secondary survey designed to be a complete search for all other injuries the patient may have sustained does not guarantee that all injuries will be detected (14). The tertiary survey is defined as a thorough clinical assessment of the stable trauma patient (13). It has been suggested that an on-going evaluation of the trauma patient, or an extended tertiary survey may also decrease the risk of missed injuries (21,43). The extended tertiary survey is performed the day following admission using a standardized data collection form. Additional radiographs or other imaging studies are obtained when an injury is suspected. The extended tertiary survey is repeated with unconscious patients or patients on mechanical ventilation when they are conscious and more cooperative (43). Ward and Nunley outlined the advantages of a repeat clinical examination (48). These include the ability to perform a more thorough examination at a less hurried pace ; the patient's mental status is often more lucid, areas of apparent swelling more readily seen ; the patient's primary injuries have been stabilized, enabling the patient to identify other sources of pain ; and the emergency splints can be removed for later definitive splinting or casting to further examine the injured extremity (48).

A high index of suspicion requires knowledge of commonly associated injuries. Waddell's triad of injuries following pedestrian versus motor vehicle collisions noted a predictable pattern or grouping of associated injuries in adults. The original report involved adult patients only, but a constellation of injuries (femur, thorax and contralateral skull) occurs in children as well (36,47). Other associated injuries include calcaneus and thoracolumbar spine fractures, hip fractures and dislocations with femur or tibia fractures, and spine fractures with remote or non-contiguous spine fractures. When one pelvic fracture is noted, a second break in the pelvic ring must be looked for. Cervical spine fractures are often associated with facial fractures (30,38,48). Thus, the common saying, "What the mind does not know, the eye will not see" is particularly apropos for missed fractures in children.

Institutions should develop standard radiographic protocols to evaluate major axial skeletal regions such as the spine and pelvis. In a combined series of both adults and children, the spine and pelvis were the sites of the most critical injuries missed (7). Technically adequate films for every paediatric trauma patient should be obtained. Applying the "rule of two's" for each patient may prevent missing many occult injuries (30). The "rule of two's" consists of obtaining two orthogonal views for extremity fractures, imaging two joints above and below each long bone fractures, two limbs if comparison views are needed, and imaging on two occasions if the initial radiographs are negative in the clinical situation with positive clinical findings. Comparative views can help detect subtle fractures in young children such as plastic deformation fractures, impaction, and physeal fractures (46). An example of complementary imaging is the use of internal oblique views of the elbow to diagnose non-displaced or minimally displaced lateral condyle fractures of the distal humerus (42). Other imaging modalities such as bone scan or MRI should be considered if the plain radiographs are negative but a high clinical suspicion of injury exists. This is particularly important in the cervical spine, where plain films can miss up to 50% injuries (15). Additional imaging may be necessary to children whose radiographs are equivocal and whose mechanism of injury and physical findings are highly suspicious for underlying spine or SCI. An uncooperative child or an unconscious, intubated child requiring cervical spine clearance would also warrant additional imaging studies such as CT or MRI (12).

"The only real mistake is the one from which we learn nothing" (35). It is in the fortitude of this quote that trauma centers should continually review on an annual basis their patients with missed injuries within the framework of a quality improvement program. The identification of factors that contributed to the missed injuries help determine means to improve each institution's trauma service (8,41).

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