

# Brachial Artery Injury With a Proximal Humerus Fracture in a 10-Year-Old Girl

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**P**roximal humerus fractures in children are uncommon; their incidence is 1.2 to 4.4 per 1000 per year or fewer than 5% of all pediatric fractures.<sup>1</sup> Nearly all these fractures are treated conservatively because of the potential to heal and remodel without significant residual functional deficits.<sup>2,3</sup> Pediatric orthopedic textbooks describe complications associated with proximal humerus fractures, but none of those reviewed describes a concomitant vascular injury.<sup>1,4</sup> To our knowledge, there have been only 2 published reports of such an injury, and both involved a Salter-Harris type II fracture of the proximal humerus and associated vascular injury.<sup>5,6</sup>

In this article, we describe the presentation, evaluation, and treatment of a 10-year-old girl with an extraphyseal proximal humerus metaphyseal fracture and brachial artery injury—an injury constellation that to our knowledge has not been reported before. A vascular injury associated with a proximal humerus fracture secondary to blunt trauma is uncommon even in adults, and we review the literature on this uncommon injury in both the adult and the pediatric population. The authors have obtained the patient's guardian's written informed consent for print and electronic publication of the case report.

## CASE REPORT

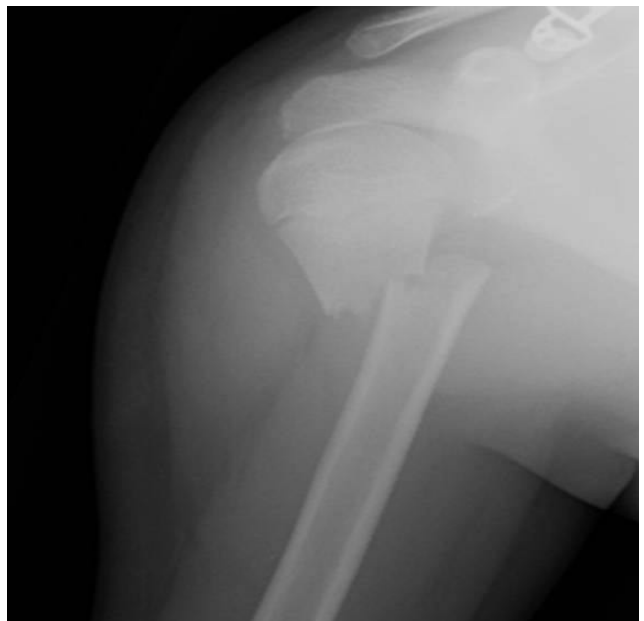
A 10-year-old right-hand-dominant girl was transferred from a rural hospital to our institution after she reportedly fell backward from an all-terrain vehicle and injured her right arm. She was transferred with the preliminary diagnosis of a right proximal humerus fracture and a possible vascular injury.

On arrival in the emergency department, the girl's chief complaint was pain in the upper arm and paresthesias in the arm and hand. Anteroposterior and lateral radiographs of the humerus (Figure 1) showed a signifi-

cantly medially displaced proximal humerus metaphyseal fracture, approximately 2.5 cm below the physis. Clinically, the patient had intact motor and sensory function in the distribution of the median, radial, and ulnar nerves. Distal vascular examination revealed diminished and thready radial and ulnar pulses, but both pulses were audible with Doppler ultrasound. The hand was pink and well-perfused, and oxygen saturation on the right index finger was 95%. After informed consent was obtained, an attempt at a gentle closed reduction was made with the patient under conscious sedation in the emergency department. An essentially anatomical reduction was obtained, and a coaptation splint applied. With the elbow flexed in the splint, both radial and ulnar pulses became nonpalpable, with absent waves on pulse oximetry. The elbow was allowed to extend, and a vascular surgery consultation was requested.

An arteriogram demonstrated a short segment occlusion of the proximal right brachial artery at the level of the fracture (Figure 2). The recommendation from the vascular surgery consultation was to explore and, if necessary, to repair, with fracture stabilization before repair.

A deltopectoral approach was used to expose the fracture and brachial artery. Plate fixation was chosen over pinning because it allowed for more rigid fixation to

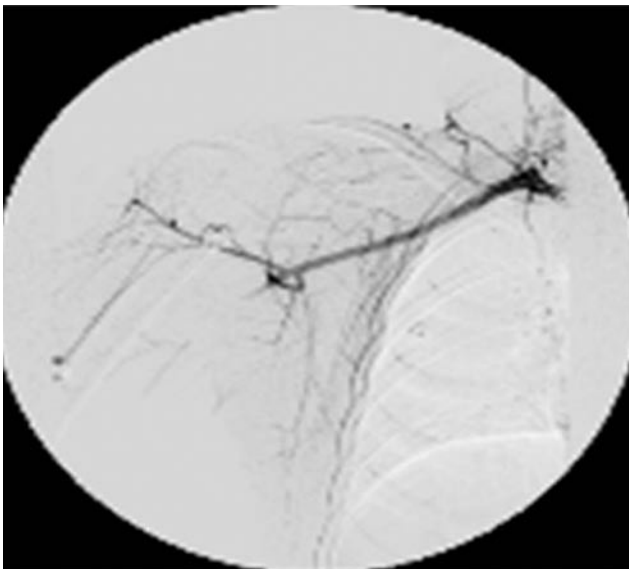


**Figure 1.** Anteroposterior radiograph of right shoulder shows proximal humerus metaphyseal fracture with significant medial displacement of shaft.

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**Figure 2.** Arthrogram shows complete occlusion at level of proximal brachial artery.

facilitate vascular repair and eliminated any violation of the physis in this nonphyseal fracture. A 3.5-mm T-plate was selected. The plate provides 3 holes proximally; however, the bicipital groove was violated by the most anterior hole, and therefore the plate was trimmed. The proximal screws were placed under fluoroscopic guidance to ensure that the physis was not violated (Figure 3).

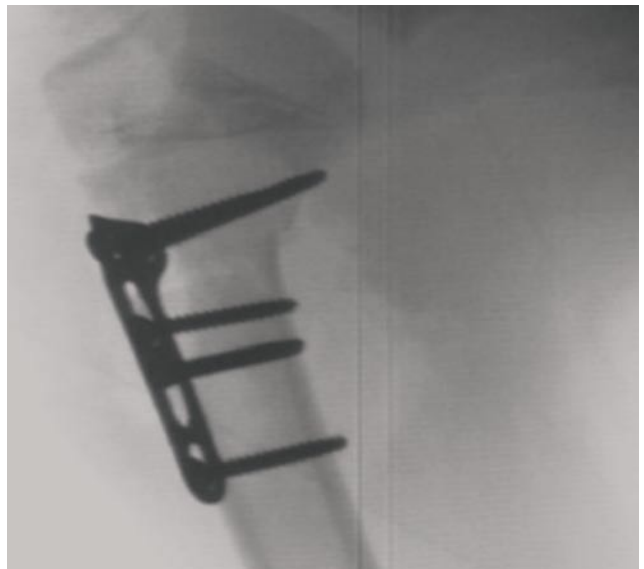
The vascular surgery team then explored the brachial artery. The adventitia was intact with obvious underlying thrombus. An intimal defect in the uppermost portion of the brachial artery adjacent to the fracture site was found. The artery was opened longitudinally 2 cm, and an intemectomy was performed. A large hematoma was found within the artery and removed. A portion of the cephalic vein was harvested and used as a vein patch for closure of the arteriotomy. Blood flow was restored, and the radial artery was now palpable.

After surgery, the patient was admitted to the pediatric intensive care unit for close monitoring of pulses for 24 hours. The radial pulse continued to be palpable. The patient was then transferred to the floor and discharged from the hospital.

The patient followed up in her home state. She was contacted by phone to determine her outcome and obtain consent for this case report. Her fracture had healed radiographically. Her mother reported complete resolution of the paresthesias with full range of motion. The patient had resumed her activities, including athletics, at her previous level.

## DISCUSSION

A vascular injury associated with a proximal humerus fracture secondary to blunt trauma is uncommon even in adults, with a review of the literature yielding a limited number of case reports.<sup>7-28</sup> Such an injury is more common, though still rare, in cases of anterior shoulder dislocation<sup>29,30</sup> and penetrating



**Figure 3.** In treatment of proximal humeral metaphyseal fracture, plate fixation facilitates vascular repair.

trauma.<sup>31,32</sup> It is rarer still in the pediatric population, with no cases reported in several large series of such fractures<sup>2,3,33,34</sup> or in several textbooks on pediatric fractures.<sup>1,4</sup> Only 2 such cases have been described before.

Wera and colleagues<sup>6</sup> reported on a 13-year-old boy who sustained an axillary artery injury with a Neer type 4 fracture (a subclassification of the Salter-Harris type II fracture) that was treated with percutaneous fixation and revascularization. The injury was sustained when a falling television struck the patient on the medial side of the arm just above the elbow. Baxter and Wiley<sup>5</sup> reviewed 57 pediatric proximal humeral fractures and reported on 1 associated vascular injury. An 11-year-old boy fell 6 feet from a fence, sustained a completely displaced Salter-Harris II fracture, and presented with a cool, pulseless extremity. Arteriogram demonstrated “interruption of the brachial artery at the lateral border of the axilla.” The patient was treated with open reduction and Kirschner-wire fixation. Management of the vascular injury was not described.

The patient in our report was a 10-year-old girl with a proximal humerus metaphyseal fracture (not a Salter-Harris fracture) and a brachial artery injury that required surgical exploration, stabilization, and arterial repair. Salter-Harris fractures are more common in the adolescent population, whereas proximal humeral metaphyseal fractures are most common in children 5 to 12 years old.<sup>1</sup> Overall, metaphyseal fractures are more common in the pediatric population than are fractures involving the growth plate by approximately a 2:1 ratio.<sup>2,3</sup> The proximal humerus physis provides 80% of the longitudinal growth of the humerus<sup>35</sup>; therefore, large degrees of initial displacement can be tolerated and treated nonoperatively without adverse effects.<sup>2,3</sup>

In our patient’s case, fixation was required to facilitate vascular repair. Because the physis was not initially involved in the fracture, the preference was to avoid iatrogenic violation of the physis by fracture fixation hardware.

Therefore, plate fixation was selected over pin fixation, as the latter would have necessitated transphyseal fixation.

Arterial injury with proximal humerus fractures, as noted earlier, is uncommon even in adults. In adults, the injury usually involves the third division of the axillary artery.<sup>19</sup> The axillary artery is the continuation of the subclavian artery; it begins at the lateral border of the first rib and extends down to the inferior

border of the teres major, gives off 3 branches—the subscapular artery, the posterior humeral circumflex, and the anterior humeral circumflex arteries.<sup>36</sup>

Milton<sup>37</sup> first proposed that the potential tethering of the third part of the axillary artery by the 3 branches may contribute to vascular injury in cases of blunt trauma. The likelihood of injury at this level may be compounded in the

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border of the teres major. Conventionally, there are 3 divisions in relation to the pectoralis minor tendon. The first division of the artery runs from the first rib to the medial edge of the pectoralis minor and gives off 1 branch, the supreme thoracic artery. The second division gives off 2 branches—the thoracoacromial and the lateral thoracic arteries. The third division of the axillary artery, which starts at the lateral border of the pectoralis

minor and ends at the inferior border of the teres major, gives off 3 branches—the subscapular artery, the posterior humeral circumflex, and the anterior humeral circumflex arteries.<sup>36</sup>

elderly person who has stiff, atherosclerotic vessels, which tend to tear rather than stretch when subjected to significant traction forces.<sup>29</sup> The axillary artery is intimately associated with branches of the brachial plexus, and therefore concomitant neurologic injury is not uncommon.<sup>18,19</sup>

In both our case and the 2 pediatric cases described in the literature, the vascular injury was distal to the trifurca-

### Cases of Axillary Artery Injury in the Literature

A search of the English-language literature yielded 18 reports on a total of 29 cases of acute axillary artery injury associated with a proximal humerus fracture secondary to blunt trauma to the shoulder in adults.<sup>10-17,19-28</sup> Another 5 cases of delayed presentation<sup>7-9,16,19</sup> of vascular injury have been reported, for a total of 34 cases.

Stenning and colleagues<sup>18</sup> reported on 16 patients who sustained an axillary artery injury as a result of low-energy blunt trauma to the shoulder, but the authors did not distinguish between proximal humerus fractures and the more commonly reported<sup>38</sup> vascular injury associated with anterior shoulder dislocation.

Of the 18 reports of an acute injury with associated fracture, 2 reports (on a total of 5 patients) described only the injury and treatment and did not provide further patient details.<sup>17,28</sup> Neer<sup>17</sup> reported on 117 consecutive patients with 3- or 4-part fractures and noted 1 case of axillary artery injury treated with a reverse vein graft, but no further details about the patient were provided. Stableforth<sup>28</sup> in a series of 81 patients with 4-part fractures reported on 4 patients with a vascular injury—1 in whom the humeral head herniated into the pleural cavity, 1 who underwent below-elbow amputation secondary to gangrene, and 2 in whom an “atherosclerotic vessel was ruptured” (one was treated nonoperatively, the other with a vein graft). Detailed information was not given for any of these 4 patients.

Detailed information was available for 24 of the 29 reported cases of a proximal humerus fracture from blunt trauma and an acutely diagnosed axillary artery injury. We analyzed and reviewed the 16 articles involved.

Mean age of this group of patients was 63.8 years (range, 30-91 years), and 75% of their injuries resulted from a simple fall—highlighting the increased risk that an elderly,

osteoporotic patient will sustain this injury complex. Both of the patients who were younger than 40 sustained relatively high energy injuries in motor vehicle accidents and had associated injuries—a femur fracture in one case<sup>16</sup> and multiple rib fractures in the other.<sup>14</sup> Twenty-nine percent of the patients were intoxicated, which highlights the potential contributing factor first described by Zuckerman and colleagues.<sup>25</sup> Sixty-three percent of the patients had significant medial displacement of the shaft, often with complete loss of contact of the shaft with the head.<sup>12,15,16,19,21-24</sup> However, vascular injury has been described even with a minimally displaced surgical neck fracture.<sup>20</sup>

Physical examination was highly predictive of vascular injury, with 92% of the patients having abnormal distal pulses. Six patients (25%) had significant swelling of the anterior shoulder or axillary region, which helped in diagnosing the arterial injury. The overall sensitivity of physical examination for detecting arterial injury was 96%, consistent with the findings of Yagubyan and Panneton<sup>19</sup> in their case series and review of the literature. Neurologic examination, on presentation, was documented in 15 patients, and, of these, 12 (80%) demonstrated an abnormal finding. Five (42%) of these 12 patients had persistent neurologic deficit on follow-up.<sup>13,15,19,25</sup>

Sixteen of the 24 patients underwent an arthrogram. All arthrograms demonstrated occlusion at the level of the third division of the axillary artery. The most common vascular injury (63% of patients) was an intimal tear with a secondary thrombosis.<sup>10,12,14-16,19-21,23</sup> An intimal tear can be sustained when the artery is subjected to a significant traction force, such as being stretched over a displaced segment of bone. The adventitia, which is stronger, usually

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tion of the subscapular and humeral circumflex branches. Our patient had an intimal injury, with an intact adventitia, which was also found in the pediatric case described by Wera and colleagues.<sup>6</sup> This represents the most prevalent type of vascular injury when an extremity undergoes blunt trauma, regardless of patient age.<sup>14,19</sup> Please see the Box for a discussion of the cases of axillary artery injury in adults reported in the English-language literature.

#### Arterial Injury: Clues and Misleading Signals

These injury cases highlight the need for vigilance, as the initial peripheral vascular examination may be unremarkable. Drapanas and colleagues<sup>39</sup> noted that 27% of patients with a significant arterial injury still had palpable distal pulses secondary to collateral flow, and Orcutt and colleagues<sup>31</sup> in their series reported that 40% of patients with an axillary artery injury had a palpable distal pulse. It has been hypothesized that an intimal tear may contribute to delayed presentation of vascular injury, with late occlusion occurring

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remains intact while the weaker intima fails with the resultant intimal flap contributing to thrombus formation.<sup>14</sup> This is exacerbated in the stiff, atherosclerotic vessel, which loses elasticity and tears rather than stretches.<sup>29</sup>

Other arterial injury patterns include direct laceration of the artery by the fractured bone,<sup>15,16</sup> isolated thrombosis,<sup>11,13,23,24,26,27</sup> avulsion of branches of the axillary artery,<sup>8</sup> and trapping of the artery in the fracture site.<sup>15,25</sup> The surgeons used a variety of vascular repairs, including thrombectomy,<sup>11,24,26</sup> intimal excision and repair,<sup>10,12-15,23</sup> reverse saphenous vein graft,<sup>15,16,19,23</sup> and excision with primary repair<sup>15,19-21,23,25</sup> or excision and repair with a Gore-Tex graft.<sup>22</sup> The overall limb salvage rate was 88%. Two patients required below-elbow amputation, and 1 required above-elbow amputation. Of the 3 cases that resulted in amputation, 2 represented a failure of thrombectomy and primary repair,<sup>26,27</sup> and 1 involved prolonged ischemia before presentation.<sup>13</sup>

Yagubyan and Panneton,<sup>19</sup> in their series of 4 patients and review of the literature of an additional 24 cases of axillary artery injury, compiled results on long-term outcomes. They did not separate acute injuries from delayed-presentation injuries. Mean age was 66.6 years. The most common mechanism of injury (80%) was a simple fall. Physical examination was 96% sensitive for diagnosis of arterial injury, and the overall limb salvage rate was 89%. The authors reviewed functional outcome for 18 patients and found an overall neurologic disability in 22% of these patients, including 1 patient with reflex sympathetic dystrophy.

Five cases of delayed presentation of axillary artery injury have been reported.<sup>7-9,16,19</sup> Delay ranged from 4 days after injury to 6 years after injury. Four of the 5 patients had arthrogram-confirmed occlusion of the axillary, and 3 of these 4 demonstrated varying degrees of collateralization. However, even the patients with collateral circulation had significant symptoms of either a vascular or a neurologic nature, often both.

after subintimal dissection has progressed to the degree that thrombus develops.<sup>14</sup>

Although uncommon, especially in the skeletally immature, our patient's injury reinforces how important it is that a complete physical examination be performed and that it include examination of neurovascular status both before and after reduction and splinting of the extremity. The elderly, osteoporotic patient clearly is at increased risk for this injury, even in the setting of a simple fall. Careful physical examination is important, as collateral circulation can mask a significant arterial injury that can later result in significant morbidity. Dopplerable and even palpable distal pulses do not exclude complete transection of the axillary artery.<sup>30,32,39</sup> Significant medial shaft displacement in an elderly, osteoporotic patient is a potential warning sign of an associated vascular injury. Increasing pain and paresthesia, even after closed reduction of the fracture improves alignment, are a concern because of the potential for persistent bleeding, which can compress the brachial plexus and result in neu-

Jensen and colleagues<sup>7</sup> reported on a 75-year-old man who initially presented, after a simple fall, with a medially displaced surgical neck fracture and no signs of neurovascular damage. The patient was treated nonoperatively at first but returned 4 days after injury complaining of increased swelling in the arm, pain, and paresthesias. Physical examination demonstrated ischemic signs and absence of radial and ulnar pulses. The axillary artery was explored, and an intimal tear with subintimal dissection was found and repaired.

Syed and Williams<sup>9</sup> reported on an 80-year-old woman who sustained a medially displaced surgical neck fracture from a simple fall. The neurovascular examination was normal, and the patient was treated nonoperatively. She presented again, 4 months after injury, with frank ischemic changes to the extremity. Arthrogram demonstrated a large pseudoaneurysm of the axillary artery. The patient ultimately required shoulder disarticulation.

Nicholson<sup>8</sup> reported on a 79-year-old man with a proximal humerus nonunion of 6 years' duration. The patient reinjured the shoulder in a simple fall and presented 3 weeks later complaining of an intermittently "painful and white hand." Distal pulses were absent on physical examination. Treatment consisted of a hemiarthroplasty and a reverse saphenous vein graft after an intimal tear and thrombosis of the axillary artery were found.

Two other patients presented after surgical neck fractures, one of 3 months' duration and the other of 2 years' duration.<sup>16,19</sup> Both patients were treated nonoperatively, as arthrograms demonstrated adequate collateral vessels, though a "future attempt to restore continuity" was planned in one of these cases.<sup>16</sup>

Mean age of this group of patients was 73.4 years. Mechanism of injury was described for 4 patients, all of whom had sustained their fractures in a simple fall—again emphasizing the low-energy nature of this injury in the elderly population.



rogenic pain and potential long-term neurologic sequelae.<sup>18</sup> Increasing anterior shoulder swelling, and swelling out of proportion to what usually occurs with a proximal humerus fracture, may be indicative of a vascular injury.

**Loss of Proprioception: Possibly a Causative Factor.** As first noted by Zuckerman and colleagues,<sup>25</sup> it is not uncommon for patients with this injury to be also intoxicated. Since then, several other authors have noted this association.<sup>10,19,20,23,24</sup> Overall, 29% of the cases described in the adult popula-

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tion involved inebriation. The injury has also been found in patients with dementia.<sup>23</sup> The incidence of this injury in these populations suggests that loss of protective proprioception is a potential causative factor in degree of injury.

**Arteriography and Early Surgical Management.** If an arterial injury is suspected, an arteriogram should be performed promptly. An abrupt, sharp complete occlusion of contrast flow without hemorrhage at the fracture site is suspicious for a distally folded intimal flap.<sup>14</sup> Shuck and colleagues<sup>14</sup> described an intimal injury as resulting in a vessel with an intact adventitial wall and a “bruised appearance” from the underlying thrombus. They noted that performing arteriotomy and thrombectomy without addressing the intimal lesion will almost certainly lead to recurrent occlusion. Early surgical management is critical, as devastating complications, including limb loss,<sup>9,13,26-28</sup> have been described with prolonged ischemia.

**Outcomes in Adults.** For adults with this injury pattern, significant long-term morbidity has been reported, including persistent neurologic defect, reflex sympathetic dystrophy, restriction of range of motion, shoulder disarticulation, and both above- and below-elbow amputation.<sup>9,18,19,23,25-28</sup> Nonoperative management of an axillary artery injury is not recommended.

## CONCLUSIONS

Proximal humerus fracture with an associated vascular injury has been typically associated with the adult population. Our case report, to our knowledge, is the third in the pediatric literature and the first to describe vascular injury associated with a proximal humerus metaphyseal fracture in a child. It is possible that the vascular injury associated with these fractures in the pediatric and adult populations is underreported. Accurate diagnosis and prompt treatment are required to minimize potential significant long-term morbidity.

## AUTHORS' DISCLOSURE STATEMENT

The authors report no actual or potential conflict of interest in relation to this article.

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