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O-arm use in the surgical management of pediatric posterior sternoclavicular joint injury: a case report

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Posterior sternoclavicular joint dislocations (SCJDs) or posteriorly displaced physeal fractures of the medial clavicle are injuries that account for 5%-27% of all SCJDs.[11] These injuries can be difficult to diagnose and can be associated with life-threatening complications due to the proximity to mediastinal structures. Damage to adjacent neurovascular structures, closest being the brachiocephalic vein, esophagus, and/or trachea, can lead to significant morbidity and mortality.[9] Associated complications are typically present at the time of injury but have also been reported to present later in cases of chronic or delayed presentations. Kendal et al[4] found that chronic injuries, defined as presentation or diagnosis 48 hours after injury, were more commonly reported (59.2%) than acute injuries.

Given the potential associated injuries and the difficulty in making the diagnosis, a heightened level of clinical suspicion is imperative in assessing these patients. This includes appropriate imaging. There is no current literature that clearly defines parameters for timing of acute vs. subacute vs. chronic presentations. There have been several studies, however, that conclude that the success rate of obtaining a stable closed reduction decreases as the time to diagnosis increases.[6] A meta-analysis of the adolescent population found a success rate of 55.8% when closed reduction is performed within 48 hours compared to a 30.8% success rate when performed outside the 48-hour window.[11]

Regarding diagnosis, axial computed tomography (CT) scan is the most reliable imaging modality to assess these injuries, pre- and postoperatively.[16] This presents a particular difficulty for operative management of these injuries. To assess reduction by imaging a CT scan would either have to be done intraoperatively or postoperatively. In the absence of intraoperative CT scan, accurate radiographic assessment of the reduction may be inadequate.[7]

There have been many different surgical techniques described in the literature; however, there is no widely accepted ideal surgical method.[1-3,5,14,15] A biomechanical cadaveric study done by Spencer and Kuhn[10] demonstrated that a figure-of-eight reconstruction restores superior joint stability compared with other techniques, especially in the posterior direction. Kendal et al[4] performed a systematic review of surgical management of traumatic posterior SCJDs in both adult and adolescent patient populations and found 45 different surgical techniques.

We present a case of a 16-year-old male with delayed presentation of a sternoclavicular joint injury, which was actually a posteriorly displaced Salter-Harris type I physeal fracture of the medial clavicle mimicking a posterior SCJD, which was treated with open reduction and stabilization with use of the intraoperative O-arm surgical imaging system (O-arm; Medtronic, Fridley, MN, USA) and a novel fixation method.

Case report

This is a case of a 16-year-old male who sustained a traumatic injury in which he landed on his left shoulder after being thrown from an all-terrain vehicle, or ATV. He was initially seen at an outside emergency room the day of his injury, at which time initial workup included 3-view radiographs of the left shoulder and a CT scan of his chest, abdomen, and pelvis (Fig. 1). The radiographs were read by the attending radiologist as unremarkable, and the

Institutional review board approval was not required for this case report.

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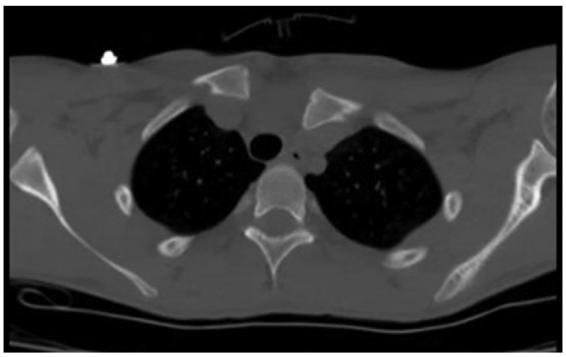

Figure 1 Axial CT scan taken at the time of injury showing left posterior SC joint dislocation. *CT*, computed tomography; *SC*, sternoclavicular.

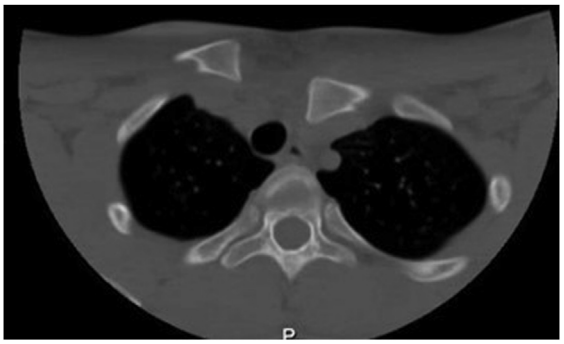

Figure 2 Axial CT scan taken 7 days after injury, again showing left posterior SC joint dislocation. *CT*, computed tomography; *SC*, sternoclavicular.

Figure 3 Three-dimensional reconstruction of the same CT scan demonstrating the left posterior SC joint dislocation. *CT*, computed tomography; *SC*, sternoclavicular.

initial read of the CT scan by the radiologist stated that there was no acute traumatic injury or acute process identified in the chest, abdomen, or pelvis. Two days after being seen in the emergency room, an addendum was made to the CT report by the attending radiologist which stated that "…patient's left [SC] joint appears widened especially on coronal images and the left proximal clavicle appears more posteriorly displaced compared to the right, and the findings are suspicious for left sternoclavicular joint dislocation." He was then referred to our clinic.

He presented to our clinic 7 days after he sustained his injury. A dedicated CT of the bilateral sternoclavicular joints was obtained the same day and confirmed the sustained posterior displacement

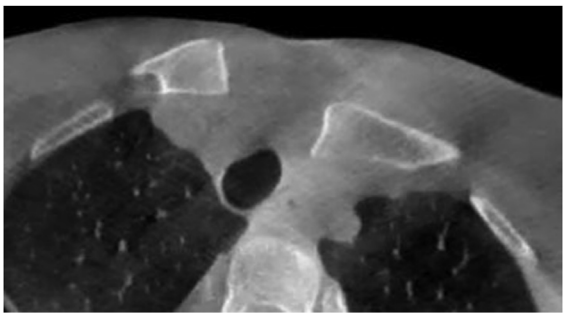

Figure 4 Axial CT scan from O-arm scan after attempted closed reduction, demonstrating unsuccessful closed reduction attempt. *CT*, computed tomography.

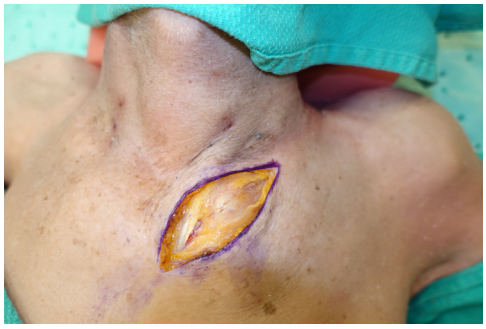

Figure 5 Cadaveric representation of incision over left medial clavicle and manubrium.

of the left clavicle relative to the sternum (Figs. 2 and 3). Furthermore, the medial clavicle was in the mediastinum adjacent to the left common carotid artery.

At presentation, the patient's only complaint was pain over the sternoclavicular joint. He had no numbness, paresthesias, weakness, dysphagia, odynophagia, or dyspnea. On physical examination, there was mild ecchymosis over the left mid-clavicular region and some asymmetry when compared to the contralateral side. The left medial clavicle appeared to be sunken in and not easily palpable when compared to the right. A full examination of range of motion was not performed due to pain, but he was able to actively flex and abduct his shoulder to about 90° in each plane. There were no neurovascular deficits on examination. He had no significant past medical history. After a lengthy discussion with the patient and his parents, he was scheduled for closed reduction vs. possible open reduction and internal fixation of the left SCJD the following day.

Surgical technique

In the operating room, the patient was placed in a supine position, and general anesthesia was obtained. A cardiothoracic surgeon was present for the critical parts of the case. A bolster was placed in the midline below the patient's thoracic spine and then the left upper extremity and chest were prepped and draped in sterile fashion. An O-arm was brought in and we obtained a 3-dimensional reconstruction for baseline assessment. An attempt at a closed reduction was made using a combination of traction and manual manipulation of the medial clavicle. The O-arm was then brought in again after the closed reduction attempt and we obtained an intraoperative scan (Fig. 4) of the sternoclavicular joint which confirmed persistent posterior displacement.

An incision over the medial aspect of the clavicle and sternum was then made (Fig. 5). The subcutaneous tissue was divided and

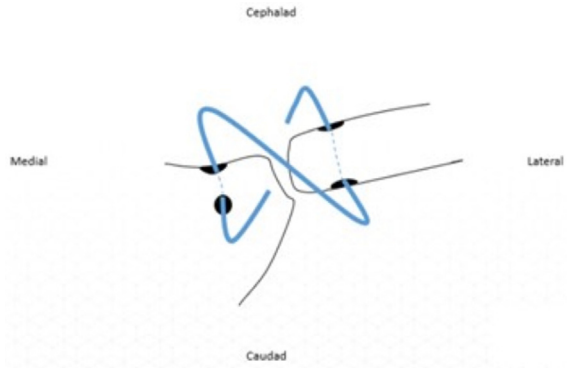

Figure 6 Illustration of the configuration of the bicortical clavicular and 2 unicortical manubrial drill tunnels with figure-of-eight fixation.

Figure 7 Cadaveric representation of clavicular and manubrial drill tunnels, with 26-gauge stainless steel wires demonstrating the trajectory of each tunnel.

Figure 8 Cadaveric representation of Arthrex suture tape (dyed purple) fixation of sternoclavicular joint in figure-of-eight fashion.

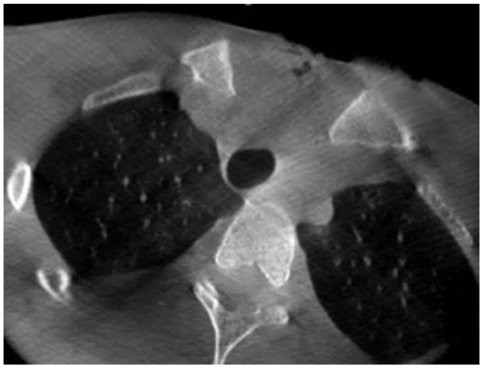

Figure 9 Axial CT scan from final O-arm scan after open reduction and fixation, demonstrating successful reduction. *CT*, computed tomography.

the sternocleidomastoid insertion site into the sternum was identified and protected. The platysma muscle and capsule were divided directly over the periosteum, exposing the sternoclavicular joint. The medial epiphysis of the clavicle was noted to remain in place and the metaphysis was posteriorly displaced. At this point it was confirmed that it was indeed a Salter-Harris type I physeal fracture of the medial clavicle with posterior displacement, mimicking a posterior SCJD. We then used a point-to-point bone reduction clamp over the clavicle for traction and used a periosteal elevator as a shoehorn to carefully elevate the shortened medial clavicular metaphysis back into position. This reduced it back to the epiphysis but, nonetheless, required significant force. Once reduced, the clavicle tended to redisplace posteriorly.

For our fixation, we used a figure-of-eight technique. We began with our clavicular tunnel. We used a 4.0-mm drill bit to make a superior-to-inferior bicortical drill hole through the metaphysis of the medial clavicle. We then turned our attention to the manubrium for the novel portion of our technique. We made a unicortical drill hole in the superior aspect of the manubrial notch (in the superior-to-inferior direction), followed by another unicortical drill hole over the ventral surface of the manubrium (in the anterior-to-posterior direction), taking care to not penetrate the posterior cortex of the manubrium (Figs. 6 and 7). We then connected the 2 manubrial tunnels using a small curette. We used 1.5-mm Arthrex suture tape (Arthrex, Inc., Naples, FL, USA) as our fixation device. This was threaded, using the assistance of a looped 26-gauge stainless steel wire, through both tunnels in a figure-of-eight fashion and tied securely over the anterior surface of the sternoclavicular joint, which gave excellent stability (Fig. 8). We performed another intraoperative O-arm scan, which demonstrated successful reduction (Fig. 9). The sternoclavicular joint was clinically stable with stressing maneuvers. The capsule was then closed with interrupted 0-Vicryl suture (Ethicon, Inc., Sommerville, NJ, USA), the subcutaneous layer was closed with buried interrupted 2-0 Vicryl suture (Ethicon, Inc.), and the skin was closed with 3-0 Monocryl suture (Ethicon, Inc.). A sterile soft dressing was then applied. There were no intraoperative or postoperative complications.

The patient was seen back in the clinic 14 days postoperatively for follow-up. He was doing very well. His surgical incisions were healing, and he had no neurological or vascular deficits. Physical therapy was initiated at 2 weeks postoperatively. The remainder of his recovery was uneventful. By 7.5 months postsurgery, he demonstrated full range of motion of the shoulder with normal motor and sensory function to the hand. Normal clinical appearance was demonstrated, and he had no subjective symptoms. A CT scan performed at 7.5 months postsurgery is shown in Figs. 10-12. Written informed consent for publication of the patient's clinical details and/or clinical images was obtained from the patient's parents. A copy of the consent form is available for review by the Editor of this journal.

Discussion

This report highlights the case of a 16-year-old male with a chronic Salter-Harris type I medial clavicle physeal fracture with posterior displacement—effectively, a posterior SCJD. We report the first documented use of an intraoperative O-arm scan to confirm successful reduction of this type of injury in the literature. Furthermore, we describe a safe technique for manubrial drill

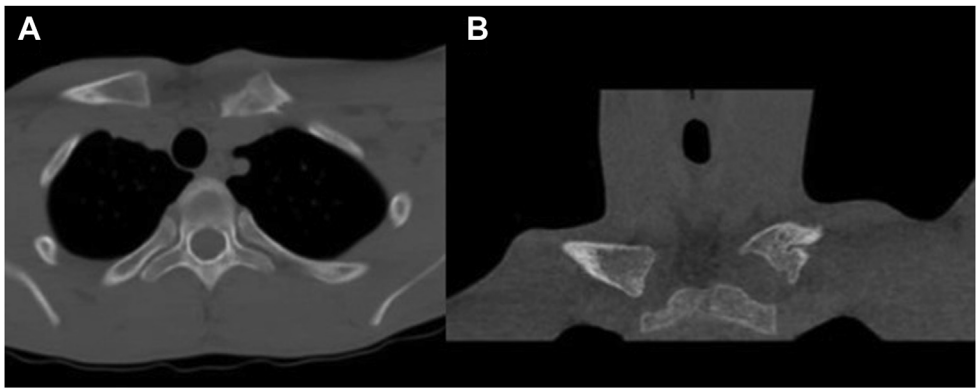

Figure 10 Axial (**A**) and coronal (**B**) CT scan 7.5 months after surgery demonstrating maintained concentric reduction of the left sternoclavicular joint. *CT*, computed tomography.

Figure 11 Three-dimensional reconstruction of CT scan 7.5 months after surgery, again demonstrating maintained reduction of the left sternoclavicular joint. *CT*, computed tomography.

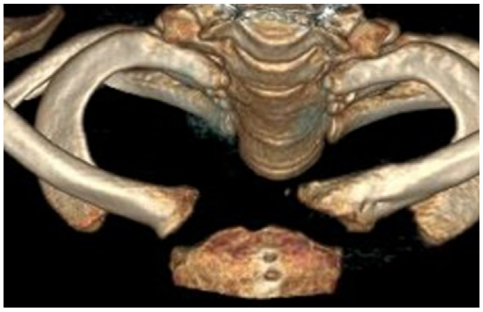

Figure 12 Three-dimensional reconstruction of CT scan 7.5 months after surgery demonstrating the manubrial tunnel drill holes. *CT*, computed tomography.

tunnel placement that avoids bicortical penetration which would otherwise place posterior mediastinal structures at risk.

Missed or delayed diagnoses are often due to infrequency of injury, lack of or benign physical examination findings, and difficulty in obtaining and interpreting imaging. Standard radiographs are unable to capture true orthogonal images of the medial clavicle.[16] Additionally, the medial clavicular physis is the last to ossify and fuse, age 18-20 and 22-25, respectively[12]. Therefore, this could complicate the interpretation of imaging in young patients. A serendipity view, which is a plain radiographic image with beam angle 40° caudad, can be used for evaluation of these injuries. However, a serendipity image may be difficult to interpret.[7] Formal CT scan maintains to be the gold standard for evaluation, but this requires breaking the sterile environment, waking the patient up from anesthesia, and transporting the patient to the imaging department if needed intraoperatively.[16] This puts the patient at potential risk for having to undergo reinduction of general anesthesia and reoperation if the CT scan shows inadequate reduction.

The O-arm is a type of imaging and guidance modality that is used extensively in spine surgery, often to check intraoperative pedicle screw placement. It gives real-time, 3-dimensional imaging at a similar level of quality as a CT scanner.[8] We borrowed this technology in this case to gain accurate intraoperative assessment of this injury. In addition, the O-arm has been shown to deliver lower doses of radiation than a standard CT scan examination.[8]

There is no clear consensus in the current literature on the technique or type of fixation when attempting to stabilize these injuries after open reduction. Kendal et al[4] identified 5 common categories of sternoclavicular joint stabilization: ligament reconstruction using autograft or allograft tendon, local soft tissue repair or augmentation or reconstruction with synthetic materials, open reduction and internal fixation, medial clavicular resection with or without ligament repair, and tendon transfer techniques. From their analysis, they found that most stabilization methods used were in the category of local soft tissue repair or augmentation/reconstruction with synthetic materials. Among these techniques are various ways to wrap and tunnel the graft. Most involve drilling bicortical tunnels from ventral to dorsal through the manubrium and the clavicle, putting the mediastinal structures at risk.[15] We utilized a technique that has been alluded to in the literature but has not been described in detail. For instance, van Diek et al[13] describe their use of "V-shaped drill holes" in the manubrium and clavicle, but do not go into specific detail about the configuration. We describe a detailed technique using 2 unicortical drill holes in the manubrium—one through the superior aspect of the manubrial notch and the other through the ventral cortex of the manubrium which are then connected. This is a safe technique, in that it eliminates the need to place drill holes through the posterior cortex of the manubrium, thus avoiding any potential contact with the mediastinal structures.

Conclusion

Posterior SCJDs in the pediatric population, or Salter-Harris type I medial clavicle physeal fractures with posterior displacement, are rare orthopedic emergencies that can present in a delayed fashion and can be associated with life-threatening complications. This case serves to highlight the importance of accurate diagnosis on initial presentation, to introduce the use of the O-arm to assess adequate intraoperative open or closed reduction, and to describe a safe method of stable fixation. We propose that the combination of

these practices could contribute to improving the quality of care and safety for patients with this type of injury.

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References

1. Adamcik S, Ahler M, Gioutsos K, Schmid RA, Kocher GJ. Repair of sternoclavicular joint dislocations with FiberWire((R)). Arch Orthop Trauma Surg 2017;137:341-5. https://doi.org/10.1007/s00402-017-2632-z.
2. Bonyun M, Nauth A. Techniques for reduction and fixation of the sternoclavicular joint. J Orthop Trauma 2020;34:S1-2. https://doi.org/10.1097/BOT.0000000000001831.
3. Janson JT, Rossouw GJ. A new technique for repair of a dislocated sternoclavicular joint using a sternal tension cable system. Ann Thorac Surg 2013;95:e53-5. https://doi.org/10.1016/j.athoracsur.2012.10.047.
4. Kendal JK, Thomas K, Lo IKY, Bois AJ. Clinical outcomes and complications following surgical management of traumatic posterior sternoclavicular joint dislocations: a systematic review. JBJS Rev 2018;6:e2. https://doi.org/10.2106/JBJS.RVW.17.00157.
5. Kusnezov N, Dunn JC, DeLong JM, Waterman BR. Sternoclavicular reconstruction in the young active patient: risk factor analysis and clinical outcomes at short-term follow-up. J Orthop Trauma 2016;30:e111-7. https://doi.org/10.1097/BOT.0000000000000483.
6. Lee JT, Nasreddine AY, Black EM, Bae DS, Kocher MS. Posterior sternoclavicular joint injuries in skeletally immature patients. J Pediatr Orthop 2014;34:369-75. https://doi.org/10.1097/BPO.0000000000000114.
7. Morell DJ, Thyagarajan DS. Sternoclavicular joint dislocation and its management: a review of the literature. World J Orthop 2016;7:244-50. https://doi.org/10.5312/wjo.v7.i4.244.
8. Pitteloud N, Gamulin A, Barea C, Damet J, Racloz G, Sans-Merce M. Radiation exposure using the O-arm((R)) surgical imaging system. Eur Spine J 2017;26:651-7. https://doi.org/10.1007/s00586-016-4773-0.
9. Ponce BA, Kundukulam JA, Pflugner R, McGwin G, Meyer R, Carroll W, et al. Sternoclavicular joint surgery: how far does danger lurk below? J Shoulder Elbow Surg 2013;22:993-9. https://doi.org/10.1016/j.jse.2012.10.037.
10. Spencer EE Jr, Kuhn JE. Biomechanical analysis of reconstructions for sternoclavicular joint instability. J Bone Joint Surg Am 2004;86:98-105. https://doi.org/10.2106/00004623-200401000-00015.
11. Tepolt F, Carry PM, Heyn PC, Miller NH. Posterior sternoclavicular joint injuries in the adolescent population: a meta-analysis. Am J Sports Med 2014;42:2517-24. https://doi.org/10.1177/0363546514523386.
12. Tepolt F, Carry PM, Taylor M, Hadley-Miller N. Posterior sternoclavicular joint injuries in skeletally immature patients. Orthopedics 2014;37:e174-81. https://doi.org/10.3928/01477447-20140124-22.
13. van Diek FM, Kosse NM, van der Pluijm M, Dorrestijn O. Complications after sternoclavicular surgery. J Shoulder Elbow Surg 2021;30:e392-8. https://doi.org/10.1016/j.jse.2020.09.015.
14. Vitali M, Drossinos A, Pironti P, Pesce E, Salini V. The management of Salter-Harris type II fracture with associated posterior sternoclavicular joint displacement using a locking compression plate: A 14-year-old adolescent's case report. Medicine (Baltimore) 2019;98:e18433. https://doi.org/10.1097/MD.0000000000018433.
15. Wang D, Camp CL, Werner BC, Dines JS, Altchek DW. Figure-of-8 reconstruction technique for chronic posterior sternoclavicular joint dislocation. Arthrosc Tech 2017;6:e1749-53. https://doi.org/10.1016/j.eats.2017.06.046.
16. Waters PM, Bae DS, Kadiyala RK. Short-term outcomes after surgical treatment of traumatic posterior sternoclavicular fracture-dislocations in children and adolescents. J Pediatr Orthop 2003;23:464-9. https://doi.org/10.1097/01241398-200307000-00010.