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Posttraumatic Pseudarthrosis of The Clavicle in Pediatric Patients: Review Article

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Abstract

Posttraumatic clavicle nonunion is very rare, particularly in children. A variety of techniques have been used to treat pediatric clavicle non unions. As the prevalence of pseudarthrosis is really low, orthopedic surgeons need to, not only perform an adequate diagnosis of these fractures, but also an accurate patient follow-up. Failure to either of both may result in an unsatisfactory outcome and pseudarthrosis. We retrospectively reviewed the literature and identified five published articles with a total of five cases of posttraumatic clavicle pseudarthrosis, in patients aged twelve years and younger [1-5].

Introduction

Clavicle is the most commonly fractured bone in the shoulder region, accounting for 10% to 15% of all children's fractures [6-9]. Approximately 90% of the fractures are midshaft fractures, which is the only area without a major muscle or ligament attached to it. Incidence of lateral fractures increase with age [9]. Simple falls or sports events are the main causes of clavicle fractures in children. Fracture mechanism could be either falling on the outstretched hand or direct impact to the clavicle [10]. Children often develop a significant callus, and an operative intervention is seldom indicated. As a result of the surrounding periosteal sleeve of the clavicle in children, most midshaft fractures are either minimally displaced or slightly angulated greenstick fractures [11]. The great periosteal regenerative potential supports the healing of nearly all clavicle fractures in children [10]. Even displaced fractures or fractures of the lateral end of the clavicle appear to unite without any complication [12]. The main reason for this potential of healing and remodeling is the fact that the lateral and medial physics do not close until the age of 19 and 25 years, respectively.

Most clavicular fractures in childhood have excellent remodeling capabilities and therefore can be treated conservatively [13]. In exceptional circumstances, however, operative stabilization may be necessary.

Complications of clavicle fractures in children are uncommon and healing usually occurs within 4–6 weeks [9]. In adults, the incidence of a posttraumatic nonunion of the clavicle is 0.1–5.8% , in adults, but in childhood it is extremely rare [14-15]. The purpose of this review article is to review clavicle pseudarthrosis pathology and compile all cases related to clavicle pseudarthrosis within the pediatric population reported, in order to serve as a collective reference for management and treatment.

Anatomy

The clavicle is large doubly curved long bone. Its shape is very special; it has a rounded medial end and a flattened lateral end. This bone serves as connection between the arm and the trunk of the body. It is easily localized, as it is just above the first rib it acts as a strut to keep the scapula in place so that the arm can hang freely. It can be divided into three parts: medial end, lateral end and shaft.

The clavicle articulates medially with the manubrium of the sternum forming the sternoclavicular joint. At its lateral end it articulates with the acromion, a process of the scapula at the acromioclavicular joint.

Each clavicle curves laterally and anteriorly for roughly half its length. It then forms an even large posterior curve to articulate with the acromion of the scapula. The flat acromial end of the clavicle is wider than the sternal end. The clavicle has rough surfaces for the attachment of muscles and ligaments of the shoulder.

Talking about embryology, the clavicle is the first bone to begin the process of ossification, starting at the fourth to six weeks of gestation. But it is the last one to finish ossification at the age of 19-25 years of age. Its process of ossification depends on which end of the clavicle, as the clavicle has two ossification centers, one medial and another lateral. The medial end is formed by endochondral ossification while the lateral end is formed by intramembranous ossification. The resulting compact bone formed from this to centers is known as the periosteal collar. This periosteal is the reason why many clavicle fractures do not displace.

Fracture Mechanism

If symmetrical specimen of bone is loaded uni axial in tension, then the initial deformations are elastic. Increased loads produce yielding, plastic flow and permanent deformation. In contrast, when strongly compressed longitudinally, bone demonstrates

buckling. Shear failure, along lines, which lie at an angle to the line of application of the force, occurs on the tensile side.

Fractures occur when the stress raises sufficiently form minute imperfections in the material to increase size by using the elastic strain energy induced by deformation

There are three basic mechanisms, apart from uniaxial tension, which can elevate local stress levels in slender bones sufficiently to initiate crack propagation and subsequent fracture. These are bending, torsion and compressive buckling with resultant bowing. The freedom afforded the clavicle by the sternoclavicular joint makes pure bending an unlikely candidate for fracture during clavicular impact loading. Similarly, the available rotation about the longitudinal axis of the clavicle (50 degrees) virtually eliminates torsion as the mechanism of clavicular fracture. The most likely cause of fracture is compressive loading of the clavicle by a force transmitted through the abutment with the acromion process of the scapula.

As the clavicle has a S-shaped curvature and it has geometrical changes (tubular to flat) along the axial length of the clavicle, are likely to accentuate this effect and reduce the critical buckling load.

When impact load in occurs, the force transmitted to the clavicle will only act over the time interval associated with the application of the force. Hence, for clavicular fracture, the critical force will depend on the speed at which the body contacts the ground or other solid object and the time taken for the collision, as well as the weight of the person. Fracture is more likely with a direct blow when the impact energy is absorbed quickly than with a blow in which the impact energy is dissipated more slowly [16].

The usual mechanism of a clavicle fracture is a fall directly on the shoulder with the arm at the side. Rarely, clavicle fractures can occur from a direct blow or from a fall on an outstretched hand in children and young adults, these injuries are typically related to sports participation, especially in contact sports.

When fracture occurs in the middle third, deformation occurs. The proximal end is displaced due to the sternocleidomastoid muscle and medial as consequence of pectorals muscles. The distal end is moved downwards because of the weight of the arm and the deltoid muscle, opposite to what the trapezius muscle does.

Diagnosis

Physical Examination

Pain, swelling, deformity and refusal to be examined are common symptoms in patients with clavicle fractures. These patients usually hold their affected limb adducted close to the body, most of the cases supporting the affected side with the opposite hand. This position is more comfortable as it limits the weight of the arm from pulling on the fractured clavicle.

Physical examination may reveal ecchymosed, edema, focal tenderness, and crepitation on palpation over the clavicle. The defect in the bone may be seen by visual inspection or localized by palpation. Palpation of the affected clavicle may reveal tenting of the skin due to bone fragments or overlapping bone fragments. Inspection often reveals the shoulder slumped infer-medially due to the weight of the shoulder pulling on the fractured clavicle.

It is very important to explore the entire extremity to look for other injuries that may go unnoticed. Also, during the initial assessment, a through neurovascular examination should be performed. We should consider any wound as an open fracture until proven otherwise.

Despite the low incidence of complications, it is important to perform a neurovascular and lung examination, because the subclavian vessels, brachial plexus, and lung apex can be injured in posteriorly displaced fractures.

Imaging Studies

Radiographies should be performed in every patient with a probable clavicle fractures. Initial imagings to diagnose these injuries are a plain anteroposterior view of the clavicle, as well as the cranial and caudal tilt views, if necessary. Most fractures can be diagnosed with these basic radiographic views.

Both, acromioclavicular and sternoclavicular joints should appear in these x-rays. And, what is more important, the entire clavicle should be visualized to rule out segmental fractures and associated injuries.

Apart from the clavicle in newborns and non-collaborative patients imaging the shoulder and humerus are mandatory to discard fractures far from the clavicle. Sometimes, it may be necessary to image both clavicles to compare one to another.

Occasionally, radiographs are inconclusive for minimally displaced clavicle fractures and may need to be repeated in 7–10 days when periosteal reaction or healing callus may be noted.

Additional imaging studies like computed tomography can also be helpful for complex comminuted clavicle fractures, intra-articular fractures and sternoclavicular injuries. Also in these cases MRI studies allow us to visualize neurovascular structures near clavicle.

We should divide pediatric patients into two groups when we are facing a possible clavicle fracture: neonatal patients, and adolescent patients.

Birth Fractures

It is not easy to diagnose a fractured clavicle in a newborn because it is often asymptomatic and more important due to the chance of being diagnoses such as brachial plexus palsy, congenital pseudarthrosis, or congenital muscular torticollis instead of clavicle fracture.

The clavicle is the most frequently injured bone during labor and delivery and accounts for approximately 90% of all obstetrical fractures [17].

It is essential to perform a good diagnosis. The diagnosis is often made when the newborn's parents note a "pseudo

paralysis" or lack of active or spontaneous movement of the affected upper extremity. In addition, newborns with acute clavicular fractures frequently have an asymmetric Moro reflex and may also have localized edema and crepitus. But most of the times, clavicle fracture is only suspected after a callus mass over the affected clavicle. Newborns usually have visible and palpable callus formation only 7–10 days after the clavicle fracture [18]. Neonatal clavicle fractures generally heal rapidly and have an overall excellent prognosis.

Adolescent

In this group, diagnosis is easier to perform, because during physical examination of children and adolescents usually yields point tenderness directly over the fracture site. The child usually holds the involved arm against the body and supports it with the opposite hand, as mentioned before. So, diagnosing clavicle fractures should be easier than in neonatal patients.

Differential Diagnosis

Congenital Pseudarthrosis

Congenital pseudarthrosis is rarely identified at birth. It is normally diagnosed during the first years of life. Diagnosis is made as the family brings the patient complaining about swelling over the middle third of the clavicle with no trauma associated [19].This swelling tends to increase in size as the child grows up.

Range of motion of the shoulder is usually normal and not painful. The most common clinical presentation of this condition is a patient who remains asymptomatic during his or her entire life. A complication that might occur in adulthood is thoracic outlet obstruction, but it is a rare sequela.

Plexus Palsy

Signs and symptoms related to plexus palsy may include a limp or paralyzed arm, lack of muscle control in the arm, hand, or wrist, and lack of feeling or sensation in the arm or hand. This diagnosis could be confused with clavicle fracture, as newborns with this fracture simulate this clinical scenario.

Several mechanisms could cause brachial plexus injuries, but the most common is nerve compression or stretch. Infants may suffer brachial plexus injuries during delivery and these present with typical patterns of weakness, depending on which portion of the brachial plexus is involved. The most severe form of injury is nerve root avulsion, which results in complete weakness in corresponding muscles.

Congenital Muscular Torticollis

Congenital muscular torticollis is a usual condition caused by fibrosis and shortening of the sternocleidomastoid muscle. It is also known as wryneck. This condition is usually discovered during the first few weeks of life. It is characterized by the position of the head, tilt of to one side, with difficulties turning to the opposite side[20].

As well as plexus palsy, this pathology should be discard in newborns. It is easily to do performing a good exploration of the newborn. Congenital torticollis most of the times present a nontender mass attached of the sternocleidomastoid muscle at the side toward the head is tilting can also be noted.

Congenital muscular torticollis and plexus palsy should not be in the differential diagnosis in an adolescent as theses pathologies are typical of newborns. But congenital pseudarthrosis could be asymptomatic and surgeons have always to bear in mind both possibilities when x-rays show pseudarthrosis. By asking the patient about his medical records, posttraumatic clavicle pseudarthrosis could be discard if the patients do not refer clavicle fracture in the past.

Treatment

Midshaft Clavicle Fractures

The most common fracture in the clavicle is the midshaft fracture accounting up to 88% of these fractures[12-21-22].The main cause of midshaft clavicle fractures is sports-related. Mean age of patients is eight years old [18].Non-operative treatment achieves its goal in nearly all cases of midshaft clavicle fractures in children. They usually heal well because of the great periosteal regenerative potential. It is important to tell parents about the callus formation, which is a normal progression of healing. Healing usually occurs within 30 to 45 days[12].

Finally risk factors for nonunion of midshaft clavicle fractures would be[22-27].

- Clavicle Shortening more than 15-20mm
- Female Sex
- Older age
- Extension of initial trauma
- Fracture comminution

Distal Clavicle Fractures

This kind of fracture is very uncommon in children, and when they occur, the mechanism is often a fall on the point of the shoulder. Whereas in adults this mechanism causes AC joint injuries in children causes distal clavicle fractures. The fracture often occurs through the distal physics, with disruption of the thick periosteal sleeve surrounding the clavicle.The coracoclavicular ligaments remain attached to the periosteum while the clavicle herniates through the torn periosteum causing a "pseudo dislocation" [22].

Surgical treatment to this group of clavicle fractures is done, not only, when posterior displacement is present but also when severe superior or inferior displacement is present.

Apart from these cases, non-surgical is the gold standard treatment. Immobilization should last period of four to six weeks.

Proximal Clavicle Fractures

As distal clavicle, proximal third fractures of the clavicle are rare. Most of the times this fractures are non-displaced due to good sternoclavicular joint stability. So, orthopedic treatment

with a sling is the best option as mentioned before in midshaft and distal clavicle fractures.

In this group of fractures is even more important an adequate and accurate initial diagnosis, as posterior displacement of the clavicle could cause neurovascular compromise, and severe complications misdiagnosed.

Another important aspect is dislocation. This must be discard using clinical evaluation and imaging diagnosis (x-ray and CT or MRI). If dislocation is present, acute closed reduction should be performed under anesthesia if possible. If closed reduction fails, open reduction then is performed

Clavicle Pseudarthrosis

Treatment of clavicle pseudarthrosis has been not standardized already (Table 1). Maybe, because there are only five reported papers dealing with this pathology, due to its very low incidence.

Table 1: Literature review of posttraumatic clavicle pseudarthrosis.

Author	Number of patients	Age/Sex	Mechanism of injuty	Type of fracture	Time to surgery	Treatment of Pseudarthrosis	Outcome
Pourtaheri et al	1	10/M	Accidental Fall	Midshaft	8 months	Plate + Bone Graft	Consolidation
Caterini et al	1	7/W	Accidental Fall	Midshaft	14 months	Kirschner wires	Consolidation
Nogi et al	1	12/M	Sports Injury	Midshaft	24 months	Bone resection	Consolidation
Spapens et al	1	8/W	Fall from Bicycle	Midshaft	12 months	Plate + Bone Graft	Consolidation
Wilkins et al	1	7/M	Severe Fall	Midshaft	72 months	Screw + Bone Graft	Consolidation
*Luengo et al	1	7/M	Accidental Fall	Midshaft	38 months	Plate + Bone Graft	Consolidation

* Present case.

Posttraumatic non unions in children below 12 years of age are extremely rare. We only found five reports describing this complication. Wilkins and Johnston5 reviewed their results of operatively treated clavicular non unions. Only one of them was actually a pediatric patient, a 7-year-old boy with a painful hypertrophic nonunion treated with a screw and bone grafts. described the case of a symptomatic clavicular nonunion in a 7-year-old girl [2]. She was treated with a surgical stabilization using a Kirschner wire and cancellous bone grafting. One year after the surgery, the functional and radiological outcomes were excellent. [3] reported another case in a 12-year-old boy treated with no internal fixation, performing a resection of the nonunion site and stabilization was achieved using the coraco-acromial ligament. And finally another two cases in a 10 year-old-boy and 8-year-old girl, treated with opened reduction and internal fixation with a plate [1-4].

In children, persistent clavicular discontinuity can be caused by a posttraumatic nonunion of the clavicle. Other reasons of clavicular discontinuity, such as cleidocranial dysplasia and neurofibromatosis and congenital pseudarthrosis of the clavicle should also be excluded [2].

Outcome

Reviewing literature, and in our experience, every single case of posttraumatic clavicle pseudarthosis treated surgically had an excellent outcome[28]. Pain was assessed using the visual analogue scale (VAS) of 0-10 to describe a minimum and maximum severity of pain, respectively. It is true that a scale 0-100 could be better to analyze results, but children handle better numbers from 0-10 than 0-100.

No matter how long time to surgery was (Table 1), children had a non-complicated postoperative period, and they were back to their previous activities with no limitations. Range of motion was complete, and none of them suffer from pain in their clavicles.

With regards to radiological assessment, there was consolidation in every case with no problem in bone healing

Return to activity depends on surgeon´s opinion. Before returning to their previous activity, they should have full range of motion, normal shoulder strength, clinical and radiographic evidence of bony healing, and no tenderness to palpation. We recommend at least six weeks to start again full daily activity and two to four months before returning to sports. Some surgeons recommend removal of hardware before returning to sports[21,29]. However, plate removal may delay return to sports and other surgeons also advise it against. From our point of view, we recommend not to remove it unless pain related to osteo synthesis is present.

Conclusion

Posttraumatic clavicle pseudarthrosis is exceptional in children. Although most cases of orthopedic treatment achieves good outcome, some of these injuries end up in pseudarthrosis. Sometimes these fractures are undervalued, misdiagnosed, or an adequate follow-up is not performed. The follow up in thesis young patients is essential to achieve a good outcome

Fracture mechanism is like other injuries affecting the upper extremity. A detailed exploration of upper extremity in children is crucial to ensure the best clinical diagnosis, followed by a correct treatment and follow-up after a clavicle fracture.

In case of clavicle fractures, no reduction maneuvers should be done, or anything related other than immobilization to release pain.

Surgical treatment is necessary in symptomatic posttraumatic pseudarthrosis of the clavicle. From our point of view, internal fixation with compression plating and bone grafting is the correct treatment for a symptomatic nonunion clavicle fracture. This treatment has a high rate of union and a low incidence of complications [29]. Operative treatment usually results in an excellent radiological and clinical outcome in these patients.

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Conflicts of interest

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