Contemporary Pediatric and Adolescent Sports Medicine
Series Editor: Lyle J. Micheli

Andrea S. Bauer
Donald S. Bae *Editors*

Upper Extremity Injuries in Young Athletes

Springer

Contemporary Pediatric and Adolescent Sports Medicine

Series Editor
Lyle J. Micheli, Boston, MA, USA

More information about this series at http://www.springer.com/series/11729

Andrea S. Bauer • Donald S. Bae
Editors

Upper Extremity Injuries in Young Athletes

Springer

Editors
Andrea S. Bauer
Department of Orthopedic Surgery
Boston Children's Hospital
Boston, MA
USA

Donald S. Bae
Department of Orthopedic Surgery
Boston Children's Hospital
Boston, MA
USA

ISSN 2198-266X ISSN 2198-2678 (electronic)
Contemporary Pediatric and Adolescent Sports Medicine
ISBN 978-3-319-56650-4 ISBN 978-3-319-56651-1 (eBook)
https://doi.org/10.1007/978-3-319-56651-1

Library of Congress Control Number: 2018958000

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

The Micheli Center for Sports Injury Prevention

The mission of The Micheli Center for Sports Injury Prevention is at the heart of the *Contemporary Pediatric and Adolescent Sports Medicine* series.

The Micheli Center uses the most up-to-date medical and scientific information to develop practical strategies that help young athletes reduce their risk of injury as they prepare for a healthier future. The clinicians, scientists, activists, and technologists at The Micheli Center advance the field of sports medicine by revealing current injury patterns and risk factors while developing new methods, techniques, and technologies for preventing injuries.

The Micheli Center, named after Lyle J. Micheli, one of the world's pioneers in pediatric and adolescent sports medicine, had its official opening in April 2013. Thus far, The Micheli Center has served more than 2800 athletes and has published more than 100 studies. Dr. Micheli is the series editor of *Contemporary Pediatric and Adolescent Sports Medicine*.

Consistent with Dr. Micheli's professional focus over the past 40 years, The Micheli Center conducts world-class medical and scientific research focused on the prevention of sports injuries and the effects of exercise on health and wellness. In addition, The Micheli Center develops innovative methods of promoting exercise in children.

The Micheli Center opens its doors to anyone seeking a healthier lifestyle, including those with medical conditions or illnesses that may have previously limited their abilities. Fellow clinicians, researchers, and educators are invited to collaborate and discover new ways to prevent, assess, and treat sports injuries.

Series Editor Biography

Dr. Lyle J. Micheli is the series editor of *Contemporary Pediatric and Adolescent Sports Medicine*. Dr. Micheli is regarded as one of the pioneers of pediatric and adolescent sports medicine, a field he has been working in since the early 1970s when he co-founded the USA's first sports medicine clinic for young athletes at Boston Children's Hospital.

Dr. Micheli is now director of the Division of Sports Medicine at Boston Children's Hospital and Clinical Professor of Orthopaedic Surgery at Harvard Medical School. He is a past president of the American College of Sports Medicine and is currently the secretary-general for the International Federation of Sports Medicine. Dr. Micheli co-chaired the International Olympic Committee consensus on the health and fitness of young people through physical activity and sport.

In addition to many other honors, Dr. Micheli has served as chairperson of the Massachusetts Governor's Committee on Physical Fitness and Sports, on the Board of Directors of the United States Rugby Football Foundation, as chairman of the

USA Rugby Medical and Risk Management Committee, and on the advisory board of the Bay State Games. He served as attending physician for the Boston Ballet from 1977 to 2016 and is medical consultant to the Boston Ballet School.

Dr. Micheli received his undergraduate degree from Harvard College in 1962 and his medical degree from Harvard Medical School in 1966. As an undergraduate student, Dr. Micheli was an avid athlete, competing in rugby, gridiron football, and boxing. Since graduating, Dr. Micheli has played prop for various rugby clubs, including the Boston Rugby Football Club, the Cleveland Blues Rugby Football Club, the Washington Rugby Football Club, and the Mystic Valley Rugby Club, where he also served as team coach.

Dr. Micheli has authored over 300 scientific articles and reviews related to sports injuries, particularly those sustained by children. His present research activities focus on the prevention of sports injuries in children. Dr. Micheli has edited and authored several major books and textbooks.

Series Editor Foreword

It gives me great pleasure to introduce *Upper Extremity Injuries in Young Athletes*. It is an important new addition to our book series, *Contemporary Pediatric and Adolescent Sports Medicine*, which is being published under the imprimatur of The Micheli Center for Sports Injury Prevention.

The time is certainly right for a new entry in the literature on this topic. Andrea Bauer and Andrea Stracciolini make this clear in Chap. 1, "Early Specialization and the Rise of Upper Extremity Injuries in Young Athletes." As Drs. Bauer and Stracciolini report, sports injuries in young athletes are on the rise due to increased sports participation – and upper extremity injuries make up a considerable portion of these injuries.

Drs. Bauer and Bae are valuable members of our team of orthopedists at the Division of Sports Medicine at Boston Children's Hospital. I am grateful but not surprised they managed to assemble such a first-rate slate of contributors.

I am especially pleased to see overuse injuries being covered so thoroughly in this volume. Acute injuries have always been part of the medical care of children and youth. Overuse injuries are a relatively recent phenomenon that we can trace to the increase in organized sports. Understanding how to diagnose and treat overuse injuries is so very important to us as sports medicine doctors treating young athletes and, of course, so is preventing overuse injuries.

Any project like this is a major undertaking. I know what a full schedule Drs. Bauer and Bae have, and undertaking and completing such a large project is testament to their commitment to the care of young athletes.

Waltham, MA, USA Lyle J. Micheli, MD

Contents

Contributors

Anna M. Acosta, MD Department of Orthopedics and Sports Medicine, Seattle Children's Hospital, Seattle, WA, USA

Donald S. Bae, MD Department of Orthopedic Surgery, Boston Children's Hospital, Boston, MA, USA

Andrea S. Bauer, MD Department of Orthopedic Surgery, Boston Children's Hospital, Boston, MA, USA

Pierre d'Hemecourt, MD Department of Sports Medicine, Boston Children's Hospital, Boston, MA, USA

Katherine C. Faust, MD Private Practice, New Orleans, LA, USA

Felicity G. Fishman, MD Department of Orthopedic Surgery and Rehabilitation, Loyola University Medical Center, Maywood, IL, USA

Elspeth Ashley V. Hart, PA-C, ATC, MS, BS Department of Sports Medicine/Orthopedics, Boston Children's Hospital, Boston, MA, USA

Brian M. Haus, MD Department of Orthopedic Surgery, University of California, Davis Medical Center, Sacramento, CA, USA

Benton E. Heyworth, MD Department of Orthopedic Surgery, Division of Sports Medicine, Boston Children's Hospital, Boston, MA, USA

Sarah S. Jackson, MD, CSCS Department of Orthopedics and Sports Medicine, Boston Children's Hospital, Boston, MA, USA

Dennis E. Kramer, MD Department of Orthopedic Surgery, Boston Children's Hospital, Boston, MA, USA

Kate W. Nellans, MD, MPH Department of Orthopedic Surgery, Northwell Health, Hofstra-Northwell Medical School, Great Neck, NY, USA

Robert L. Parisien, MD Department of Orthopedic Surgery, Boston University Medical Center, Boston, MA, USA

Allan E. Peljovich, MD, MPH Department of Orthopedic Surgery, Children's Healthcare of Atlanta, The Hand and Upper Extremity Center of Georgia, Children's Hospital of Atlanta, Atlanta, GA, USA

Julie Balch Samora, MD, PhD, MPH Department of Orthopedics Surgery, Nationwide Children's Hospital, Columbus, OH, USA

Ameya V. Save, MD Department of Orthopedic Surgery, Yale New Haven Hospital, New Haven, CT, USA

Alton W. Skaggs, BS School of Medicine, University of California, Davis, Sacramento, CA, USA

Suzanne E. Steinman, MD Department of Pediatric Orthopedics and Sports Medicine, Seattle Children's Hospital, Seattle, WA, USA

Andrea Stracciolini, MD, FAAP, FACSM Department of Orthopedics, Boston Children's Hospital, Boston, MA, USA

Timilehin Wusu, BA, MD Department of Orthopedics, Massachusetts General Hospital, Boston, MA, USA

Chapter 1
Introduction: Early Specialization and the Rise of Upper Extremity Injuries in Young Athletes

Andrea S. Bauer and Andrea Stracciolini

Sports play a central role in the lives of youth worldwide. Over 46 million children participate in youth sports in the United States annually, nearly 8 million of these at the high school level [1, 2]. For most children, the social, academic, and health benefits of sports outweigh the risk for injury, including injury to the upper extremity. With increased participation in organized sports, however, comes increased sports-related injuries. In 2013, there were over 1.3 million US emergency room visits by children aged 6–19 years due to sports-related injuries. These accounted for 20% of all injury-related emergency room visits in this age group [3], with an annual cost of nearly 1 billion dollars per year [4].

Upper extremity injuries in the young athlete make up a considerable portion of overall injuries. Andrish et al. reported that 15% of all injuries to skeletally immature athletes occurred in the upper extremity (UE), and, notably, 45% of the UE injuries involved the shoulder [5]. Injuries to the UE occur more often in sports that place increase stress and demand on the UE. For example, in a single season, 35% of baseball pitchers between 9 and 14 years of age report shoulder pain [6]. Furthermore, UE injury patterns vary according sex, sport, and age. For example, in gymnastics, injuries to female participants are sustained primarily to the lower extremity, ankle, and knee, whereas in male participants the most commonly injured body part is the upper extremity, specifically the shoulder and wrist [7–10].

A. S. Bauer (✉)
Department of Orthopedic Surgery, Boston Children's Hospital, Boston, MA, USA
e-mail: andrea.bauer@childrens.harvard.edu

A. Stracciolini
Department of Orthopedics, Boston Children's Hospital, Boston, MA, USA

A. S. Bauer, D. S. Bae (eds.), *Upper Extremity Injuries in Young Athletes*,
Contemporary Pediatric and Adolescent Sports Medicine,
https://doi.org/10.1007/978-3-319-56651-1_1

Specialization Versus Diversification

As youth sports participation continues to increase, there is an emerging concern surrounding early sports specialization and its link to overuse injury and burnout in children [11]. Recently, the association between specialization and overuse injury in young athletes has been defined. In a landmark study on this topic, Jayanthi et al. discovered that youth athletes who train >8 months per year are more likely to be injured. These same authors also found that youth who maintain an organized sport-to-free play ratio greater than 2:1 were more likely to be injured and to develop a serious overuse injury [12].

The American Academy of Pediatrics (AAP) recommends that children play a variety of sports to decrease the chance of injury as well as burnout and that they limit participation to only one team per season. In addition, the AAP recommends one to two rest days per week and 3 months per year (recommended as 1 month at a time, three times per year) completely off from sports for young athletes to recover and recharge [13]. Similarly, the American Orthopaedic Society for Sports Medicine (AOSSM) Consensus Statement in 2016 concluded that there is no evidence to support the benefit of early specialization in the majority of sports but did acknowledge the link between early specialization and overuse injury and athlete burnout [14]. More sport-specific evidence-based guidelines are direly needed at this time.

Formulating generalized youth sports specialization recommendations is not feasible. Athletes who participate at an elite level commonly participate in highly technical individual sports such as gymnastics, dance, swimming, and diving. The argument follows that for the elite gymnast or dancer, in order to obtain *success*, early specialization is *required*. Many coaches and families believe that early specialization in a single sport is the key to achieving *success*, which may be defined to include scholarship money, recognition, and participation on the national or international stage. In tennis, 70% of junior elite tennis players began specializing at a mean age of 10.4 years old, and 95% were specialized by the age of 18 years [15]. In gymnastics, the average age of the 2016 US women's gymnastics team was 19 years, many of whom started participating in gymnastics at the age of 2–3 years and turned *elite* at age 12 years. For other sports, however, delaying specialization may increase the athlete's chance of success in participating at the elite level. For example, of the 322 athletes invited to the 2015 National Football League (NFL) Combine, 87% had played more than one sport during their high school careers [16]. Similarly, a recent study of 102 current professional baseball players found that only 48% specialized in baseball earlier than high school and those players who had specialized early were more likely to have sustained a serious injury during their career [17].

Repetitive Stress Injuries of the Upper Extremity

Repetitive and overuse injuries are a common problem in young athletes. Players with at least one prior injury have two to three times greater risk of sustaining a subsequent injury than those who have never been injured [18]. Overuse injuries have been described as presenting in four stages: (1) pain in a particular area after physical activity; (2) pain during the activity, without restricting performance; (3) pain during the activity that restricts performance; and (4) chronic pain even at rest [19]. This is a useful framework for understanding any overuse injury, regardless of anatomic location. Using this classification, providers can teach young athletes how much pain is too much to "push through" during a season. It is advisable to instruct patients to report to parents and coaches any pain that occurs during activities and to increase rest time if pain after practice persists into the next day. This is particularly important for patients attempting to return to sport after injury.

Overuse injuries are generally believed to be related to overtraining and single-sport specialization, although data is severely limited at this time. A recent systematic review of literature pertaining to injury risk and early single-sport specialization found three relevant studies, which demonstrated associations between sports specialization and overuse injuries [20]. Since that review, a prospective study has been published which focused on lower extremity injury rates in 1544 high school athletes. Athletes were stratified by extent of specialization and followed for several seasons. The authors found that those athletes with moderate to high specialization were more likely to sustain lower extremity injuries than those with low specialization [21].

Many organizations are attempting to combat the ill effects of overtraining and early specialization by providing guidelines to protect young athletes; providers should be aware of existing guidelines, as many families and coaches often lack awareness prior to the onset of injury. For UE athletes, perhaps the best-known guidelines surround limiting pitch counts in youth baseball. Monitoring pitch counts, delaying initiation of "breaking pitches" (such as the curveball), and teaching pitchers to not pitch through arm fatigue and pain can help parents and coaches protect their young athletes from injury [22, 23]. We will discuss baseball injuries and techniques for prevention and treatment more specifically in Chap. 5.

Another good example of overuse to the UE is *gymnast wrist*. This injury occurs from repetitive compressive loading and shearing forces on an extended wrist and represents a disruption to the radial growth plate. As such, it is an injury unique to the growing skeleton [24–26]. We will discuss gymnast wrist and other gymnastics-specific injuries more specifically in Chap. 6.

Summary

There are strong and lasting benefits of participation in youth sports. In addition to the enjoyment and stress relief provided, sports help young children develop gross motor and socialization skills, while older children benefit from learning teamwork and leadership. As organized sports participation increases, however, the risk of sports-related injury also increases. As described, many children now specialize in a single sport at a young age, which may additionally increase the risk of overuse injuries. Pediatric health-care providers should be familiar with the diagnosis and treatment of the most common acute and chronic upper extremity sports-related injuries.

The chapters in this book will describe upper extremity injuries common to the young athlete. Just as we associate ACL tears with downhill skiing, characteristic upper extremity injury patterns exist for many sports. We will highlight these sports-specific injury patterns as well as identify injuries those that are uniquely pediatric, such as physeal injuries. Each chapter will detail specific UE diagnoses in youth sports and address nonoperative and operative treatment. Finally, authors will provide evidence-based recommendations when possible for rehabilitation and return to sport after UE injury. Seemingly benign injuries such as a mild sprain to the elbow, or small fracture of the finger, may be the first sidelining injury for a youth athlete. Providing timely, accurate, and comprehensive care of the young athlete with an UE injury will serve to minimize time loss from play, decrease emotional strife, and promote long-term participation in sport and physical activity.

References

1. National Sporting Goods Association. 2011 vs 2001 Youth Sports Participation NhwnofpvYPwp.
2. National Federation of State High School Association. 2016–2017 High school athletics participation survey. www.nfhs.org/ParticipationStatistics/ParticipationStatistics/. Accessed 5 May 2018.
3. Healy M. 1.35 million youths a year have serious sports injuries. USA Today. 2013. http://www.usatoday.com/story/news/nation/2013/08/06/injuries-athletes-kids-sports/2612429/. Accessed 14 May 2018.
4. Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. Web-based Injury Statistics Query and Reporting System (WISQARS). www.cdc.gov/injury/wisqars. Accessed 27 May 2018.
5. Markiewitz AD, Andrish JT. Hand and wrist injuries in the preadolescent and adolescent athlete. Clin Sports Med. 1992;11(1):203–25.
6. Lyman S, Fleisig GS, Waterbor JW, et al. Longitudinal study of elbow and shoulder pain in youth baseball pitchers. Med Sci Sports Exerc. 2001;33(11):1803–10.
7. Caine DJ, Nassar L. Gymnastics injuries. Med Sport Sci. 2005;48:18–58.
8. Saluan P, Styron J, Ackley JF, Prinzbach A, Billow D. Injury types and incidence rates in precollegiate female gymnasts: a 21-year experience at a single training facility. Orthop J Sports Med. 2015;3(4):2325967115577596.
9. Westermann RW, Giblin M, Vaske A, Grosso K, Wolf BR. Evaluation of men's and women's gymnastics injuries: a 10-year observational study. Sports Health. 2015;7(2):161–5.
10. Kerr ZY, Hayden R, Barr M, Klossner DA, Dompier TP. Epidemiology of national collegiate athletic association women's gymnastics injuries, 2009–2010 through 2013–2014. J Athl Train. 2015;50(8):870–8.
11. Brenner JS. Overuse injuries, overtraining, and burnout in child and adolescent athletes. Pediatrics. 2007;119(6):1242–5.
12. Jayanthi NA, LaBella CR, Fischer D, Pasulka J, Dugas LR. Sports-specialized intensive training and the risk of injury in young athletes: a clinical case-control study. Am J Sports Med. 2015;43(4):794–801.
13. Brenner JS. Sports specialization and intensive training in young athletes. Pediatrics. 2016;138(3):e20162148.
14. LaPrade RF, Agel J, Baker J, et al. AOSSM early sport specialization consensus statement. Orthop J Sports Med. 2016;4(4):2325967116644241.

15. Jayanthi NDA, Durazo R, Dugas L, Luke A. Training and sports specialization risks in junior elite tennis players. J Med Sci Tennis. 2011;16:14–20.
16. TrackingFootball.com. https://twitter.com/trckfootball. Accessed 15 Dec 2017.
17. Wilhelm A, Choi C, Deitch J. Early sport specialization: effectiveness and risk of injury in professional baseball players. Orthop J Sports Med. 2017;5(9):2325967117728922.
18. Kucera KL, Marshall SW, Kirkendall DT, Marchak PM, Garrett WE Jr. Injury history as a risk factor for incident injury in youth soccer. Br J Sports Med. 2005;39(7):462.
19. Mellion MB, Walsh WM, Madden C, Putukian M, Shelton GL. Team physician's handbook. 3rd ed. Philadelphia: Hanley & Belfus; 2002.
20. Fabricant PD, Lakomkin N, Sugimoto D, Tepolt FA, Stracciolini A, Kocher MS. Youth sports specialization and musculoskeletal injury: a systematic review of the literature. Phys Sportsmed. 2016;44(3):257–62.
21. McGuine TA, Post EG, Hetzel SJ, Brooks MA, Trigsted S, Bell DR. A prospective study on the effect of sport specialization on lower extremity injury rates in high school athletes. Am J Sports Med. 2017;45(12):2706–12.
22. Pitchsmart USA Baseball. Guidelines for youth and adolescent pitchers. http://m.mlb.com/pitchsmart/pitching-guidelines/. Accessed 14 May 2018.
23. Olsen SJ 2nd, Fleisig GS, Dun S, Loftice J, Andrews JR. Risk factors for shoulder and elbow injuries in adolescent baseball pitchers. Am J Sports Med. 2006;34(6):905–12.
24. DiFiori JP, Puffer JC, Aish B, Dorey F. Wrist pain in young gymnasts: frequency and effects upon training over 1 year. Clin J Sport Med. 2002;12(6):348–53.
25. DiFiori JP, Puffer JC, Aish B, Dorey F. Wrist pain, distal radial physeal injury, and ulnar variance in young gymnasts: does a relationship exist? Am J Sports Med. 2002;30(6):879–85.
26. DiFiori JP, Caine DJ, Malina RM. Wrist pain, distal radial physeal injury, and ulnar variance in the young gymnast. Am J Sports Med. 2006;34(5):840–9.

Chapter 2
Footballer's Shoulder

Dennis E. Kramer and Timilehin Wusu

Introduction

The clavicle is an important structure involved in support, mobility, and function of the upper extremity. It functions as the structural transition point between the shoulder girdle and the axial skeleton. The medial clavicle takes part in the only bony articulating connection between the upper extremity and the axial skeleton through the sternoclavicular (SC) joint. The lateral clavicle articulates with the acromion of the scapula at the acromioclavicular (AC) joint. Injuries to the clavicle and its articulations follow three main mechanisms of injury. These mechanisms occur during every play in an American football game. The most common mechanism occurs indirectly through a direct forceful impact to the shoulder, such as falling onto the shoulder or collision through the shoulder with another player while blocking or tackling. The second most common mechanism of injury is through direct anterior impact on the clavicle itself. Finally, a fall onto an outstretched arm can also produce indirect injuries to the clavicular structures [1]. Outside of football, the overall most common cause of clavicle injuries is motor vehicle collisions followed by sports-related collisions and falls [1, 2].

D. E. Kramer (✉)
Department of Orthopedic Surgery,
Boston Children's Hospital, Boston, MA, USA
e-mail: dennis.kramer@childrens.harvard.edu

T. Wusu
Department of Orthopedics,
Massachusetts General Hospital, Boston, MA, USA

A. S. Bauer, D. S. Bae (eds.), *Upper Extremity Injuries in Young Athletes*,
Contemporary Pediatric and Adolescent Sports Medicine,
https://doi.org/10.1007/978-3-319-56651-1_2

Adolescent Athlete

There are a number of special considerations for evaluation and management of clavicle-related injuries in the adolescent athlete compared to similar injuries in the mature adult. The most salient is that adolescent athletes in contact sports are more likely to return to a competitive sport that will directly and repeatedly challenge the injured limb through the same or similar mechanism that caused the initial injury. Furthermore, the anatomy of the clavicular structures continues to change until 20–25 years of age. Clavicle joint articulations transition from hyaline to fibrocartilage by age 17 on the acromion and age 24 on the clavicular side of the AC joint [2]. Furthermore, the medial clavicular physis remains open until 25 years of age.

AC Joint Injuries

Introduction

AC joint injuries are commonly referred to "shoulder separations." The AC joint is injured far more frequently than the SC joint, accounting for 9–10% of all shoulder girdle injuries [1, 3]. In the athletic population, AC joint separations account for 40% of shoulder girdle injuries [1]. Though the vast majority of these injuries can be treated non-operatively, surgical intervention may be required for more severe injuries with higher degrees of separation and joint instability. There are two typical mechanisms of injury to the AC joint, direct and indirect. Direct AC joint injuries are caused by a forceful blow to the shoulder, such as with a shoulder tackle or fall directly onto the shoulder. Indirect AC joint injuries occur through a fall onto an outstretched arm where the force is transmitted through the humeral head to abut the overlying acromion. AC joint separations are primarily evaluated with a detailed physical exam followed by plain radiographs. Physical exam should consist of visual inspection of the AC joint region assessing for asymmetry, skin tenting, and swelling over the AC joint with comparison to the non-injured side. The shoulder and clavicle should be palpated for tenderness and deformity. The distal clavicle can be depressed to see if it elevates once the depressive force is released (piano key sign) to get a sense of joint AC stability, once again in comparison to the contralateral side. Neurovascular examination should also be performed. Radiographic imaging may include bilateral Zanca views (upright anteroposterior (AP) radiographic views of the clavicles with the beam pointed 10–15° cephalad) which best demonstrate the AC joint. A glenohumeral axillary view and a Stryker notch view can also be useful for evaluating for Type IV AC separations (in which the clavicle herniates posteriorly) and coracoid fractures, respectively [2].

It can sometimes be difficult to distinguish between distal clavicle physeal fractures and AC joint injuries in skeletally immature patients based on radiographs.

In cases where the injury is mild and radiographs show no clear abnormalities, no further imaging is indicated as the treatment would be the same (nonsurgical) and both injuries should heal without issue over time. Advanced imaging with CT or MRI is indicated in more severe injuries associated with swelling and bruising at the posterior shoulder where posterior dislocation of the clavicle or posteriorly displaced physeal fractures are suspected. The MRI or CT in these cases would better classify the extent of injury and determine if operative intervention is necessary.

Anatomy

The AC joint is a diarthrodial joint with a fibrocartilage meniscal disk between the articular surfaces of the medial acromion and the lateral clavicle. The AC joint is stabilized by both static and dynamic stabilizers. The static stabilizers include the acromioclavicular (AC) and coracoclavicular (CC) ligaments. The AC ligaments surround the AC joint capsule, with the primary function to resist anterior/posterior translation of the clavicle compared to the acromion. The CC ligaments are found medial to the AC joint and anchor the clavicle to the coracoid process just inferior to it. Their primary function is to prevent elevation of the clavicle in relation to the acromion. The dynamic stabilizers of the AC joint include the fibrous attachments of the deltoid and trapezius muscles. As the AC joint progresses through increasing severity of injury and instability, the static stabilizers are disrupted first through the AC ligaments followed by the CC ligaments, followed by the dynamic stabilizers [3]. As a general rule, if the deltotrapezial fascia remains intact, the AC joint separation can likely be treated non-operatively [3].

Classification System

AC joint separations have been classically described using the Rockwood and Green classification system, which evaluates the radiographic appearance of the clavicle in relationship to the acromion [4]. Type I injuries are AC joint "sprains" in which radiographs are negative but physical exam is positive for tenderness over the AC joint. Type II injuries are injuries to the AC joint ligaments, while the CC ligaments remain intact. Radiographs may show slight widening of the AC joint without significant superior elevation of the distal clavicle (less than 30%). Type III injuries represent injury to both the AC and CC ligaments, such that the distal clavicle is elevated relative to the acromion 30–100% on radiographs. Types IV-V-VI injuries are rare. Type IV injuries occur when the distal clavicle herniates through the trapezius posteriorly. These are best seen on axillary radiographic views or cross-sectional imaging. Type V injuries show major elevation (100–300% of the distal clavicle) and occur with detachment of the deltoid and trapezius muscles. Type VI injuries show inferior dislocation of the clavicle.

Treatment

The Rockwood classification [4, 5] also helps to determine the course of treatment. Type I and II AC separations are treated non-operatively with analgesics, cryotherapy, and sling wear for 5–10 days, followed by progressive range of motion and activity as pain and swelling permit. Most athletes return to play in 2–4 weeks as they become asymptomatic, but it can take up to 12 weeks before painless return to play can be achieved [3].

Type IV, V, VI AC joint separations require surgical fixation. There are multiple options for operative fixation:

- Primary fixation across AC joint with pins, screws, rods, or plate + screw
- Fixation between clavicle and coracoid with screw, suture, fiber wire
- Dynamic muscle transfer in which conjoint tendon is transferred to clavicle
- Ligament transfer of coracoacromial ligament (detached from acromion and transferred to distal clavicle)
- Ligamentous reconstruction of CC and AC ligament with allograft

Type III AC joint dislocations are somewhat controversial. Though the majority of Type III injuries can be treated non-operatively, there are specific populations that warrant surgical consideration. Younger active patients, thinner patients with marked prominence of the lateral clavicle, heavy laborers, and overhead-throwing athletes should be evaluated on in individual basis. There is some variation among orthopedic surgeons regarding treatment plans for these cases. We typically do not advocate acute surgical treatment of Type III AC joint injuries. Surgical management of these injuries in our practice is reserved for patients who are persistently symptomatic following a period of rest and rehabilitation. Return to play following operative management of an AC joint injury can vary but involves a period of time to allow the surgical repair to heal followed by physical therapy to regain strength and mobility, and the process can take 3–4 months. Figure 2.1 presents an algorithm for Type III injuries in athletes [2].

SC Joint Injuries

Sternoclavicular (SC) joint injuries are uncommon, accounting for only 1% of all dislocations and 3% of dislocations involving the shoulder girdle [6]. There are two types of SC joint dislocations: anterior and posterior. Anterior dislocations are two to three times more common than posterior dislocations; however, most of the SC joint literature focuses on posterior dislocations because of the risk of serious and potentially life-threatening injuries to the mediastinal structures that lie beneath the SC joint. In the young athletic population, many presumed SC joint dislocations are actually Salter-Harris I or II fractures through the medial clavicle physis, which remains open until 25 years of age. The most common causes of SC joint dislocations occur from motor vehicle collisions, followed by athletic injuries and falls [3].

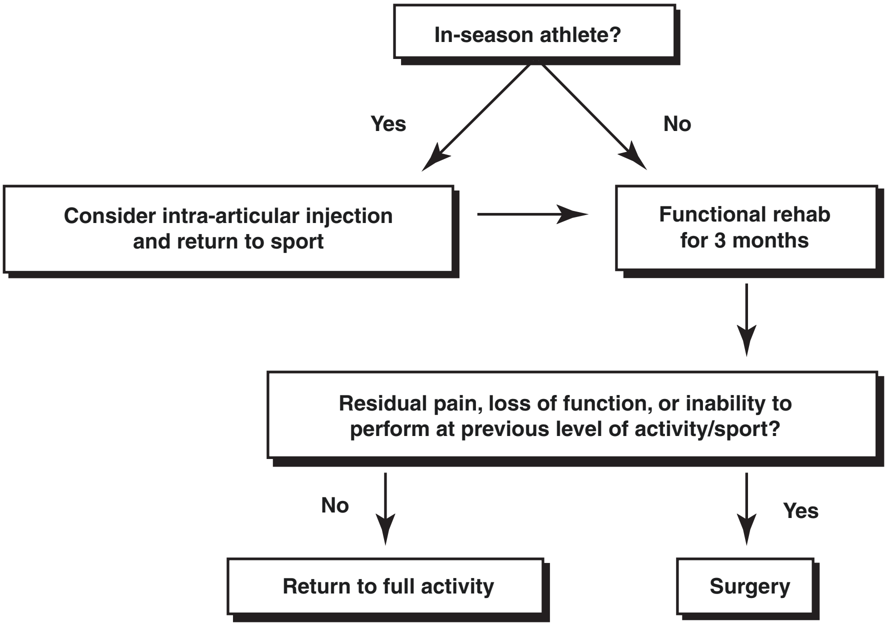

Fig. 2.1 An algorithm that can be used when treating a patient with an acromioclavicular joint injury. (Reproduced from Bontempo and Mazzocca [2], with permission from BMJ Publishing Group Ltd.)

The mechanism of injury involves either a direct blow to the clavicle or, more commonly, an indirect force to the clavicle applied through the shoulder. Anterior SC dislocations occur when an anterolateral force on the shoulder acts to compress the clavicle medially, while the shoulder is pushed backward. Posterior SC dislocations usually occur when a direct force is applied to the anteromedial clavicle. Posterior SC dislocations also occur when a posterolateral force on the shoulder acts to compress the clavicle medially while the shoulder is thrust forward [2, 3]. The position of the arm may also affect the direction of the dislocation when a medially directed force is applied to the shoulder. There is a cantilever effect on the clavicle through the medially positioned costoclavicular ligament. If the arm is abducted, such as when a quarterback is tackled onto their side with their arm outstretched, an anterior dislocation is more likely to occur. If the arm is adducted and flexed, such as under a football "dog pile," a posterior dislocation is more likely to occur [1].

Anatomy

The sternoclavicular (SC) joint is the only bony articulation between the upper limb and the axial skeleton. Yet, the saddle-shaped bony articular surface provides very little intrinsic stability. Instead, the joint capsule, ligaments, and soft tissue connections provide tremendous stability for the joint, making dislocations fairly rare.

Furthermore, the superior and posterior aspects of the SC joint capsule are reinforced and thickened, adding additional protection from posterior dislocations as compared to anterior dislocations. The costoclavicular (rhomboid) ligament provides the greatest stability to the joint [7]. It connects the inferomedial aspect of the clavicle to the superior cartilaginous aspect of the first rib. The costoclavicular ligament also acts as a pivot point for force transmission from the shoulder girdle to the SC joint. This helps to explain why a posteriorly directed force on the shoulder (and associated lateral clavicle) causes an anterior SC joint dislocation, and conversely, an anteriorly directed force on the shoulder causes a posterior SC joint dislocation [3]. The SC joint surfaces of the clavicle and manubrium are lined with fibrocartilage in fully mature adults. A single meniscal disc acts as a cushion from compressive forces transmitted from the shoulder through the clavicle [3].

Just behind the SC joint lies the structures of the superior mediastinum. The structures most frequently encountered just posterior to the SC joint, in descending order, are the left and right brachiocephalic veins, right and left common carotid arteries, aortic arch, trachea, superior vena cava, pleura, left internal mammary artery, and left subclavian vein. Nearly 75% of patients have at least one of these structures within 10 mm of the SC joint [8]. The immediate proximity of these structures has implications when evaluating trauma-related injuries to this area as well as the potential for iatrogenic injuries from surgical intervention.

Evaluation/Imaging

While most SC joint injuries are sprains, anterior and posterior dislocations can occur and must be identified. The patient will complain of medial clavicle pain made worse with any extremity movement. Classically, lying supine will intensify the medial joint pain. On exam, anterior dislocations will demonstrate a prominent medial clavicle. Posterior dislocations have more subtle physical findings, but the examiner may be able to appreciate a recessed medial clavicle, which may be obscured by increased soft tissue swelling in the area. It is important to check for other signs of posterior impingement of underlying structures: tachypnea, dyspnea, dysphagia, and venous congestion. Suspected injuries to the SC joint and proximal 1/3 of the clavicle warrant a serendipity radiographic view of the bilateral clavicles as well as computed topography (CT) imaging of the chest. The serendipity view radiograph is an AP of the clavicles taken with the radiographic beam pointed 40° cephalad [3]. This makes it easier to appreciate anterior to posterior displacement of the clavicle. CT imaging with contrast is used to evaluate mediastinal structural relationships to the displaced clavicle, to assess vascular injuries, and to help differentiate between SC joint dislocation and proximal clavicle fractures [1, 9].

Treatment

Treatment for SC joint injuries depends on the direction of the dislocation and the severity of the joint instability. SC joint injuries can be categorized as Type I (mild), II (moderate), and III (severe). Mild SC joint injuries are essentially sprains with stable joints and maintained ligamentous integrity. Moderate SC joint injuries have joint subluxation due to partial ligamentous disruption, but do not frankly dislocate. Severe SC joint injuries involve anterior or posterior dislocation of the joint with complete ligamentous disruption [2].

The goal of SC joint injury treatment is to manage pain, stabilize the joint, restore functional capacity to the shoulder girdle, address associated injuries, and minimize the potential complications. As previously described, Type I and Type II SC joint injuries maintain a level of stability that lends itself to conservative management. Since there is no frank dislocation, no reduction maneuver is required. Type I (mild sprain) SC injuries can be treated with NSAIDs, cryotherapy, and a sling for 3–4 days. Type II (partial ligamentous tear with subluxation) SC injuries are initially treated with NSAIDs, cryotherapy, and clavicle stabilization using a figure-of-8 brace for 1 week, followed by a simple sling for 4–6 weeks. Unrestricted return to play typically occurs by 3 months. Type III (frank dislocation) SC joint injuries warrant an orthopedic consultation for potential surgical intervention. Posterior dislocations additionally warrant a cardiothoracic surgical consultation [2].

Anterior Type III SC joint dislocations can be initially treated with closed reduction in the emergency department under local anesthetic or conscious sedation or in the operating room under general anesthesia. Although anterior SC joint dislocations have a high rate of redislocation immediately after reduction, it is still recommended that at least one closed reduction be attempted [3]. The technique for reduction includes positioning the patient supine with a rolled towel between the scapulae. The ipsilateral arm is then abducted to 90° and extended posteriorly while traction is applied. A posteriorly directed force is then applied to the medial clavicle to achieve reduction [1, 3]. If the joint remains stable after closed reduction, the clavicle is immobilized with a figure-of-8 brace for 4–6 weeks. Elbow and glenohumeral joint range of motion exercises should be initiated by week 3. If the joint remains unstable after reduction attempts, the deformity is accepted, and the patient can be given a splint for comfort until acute symptoms resolve. Studies have shown that stability of the SC joint is not necessary to ensure normal painless function of the involved shoulder [10]. Operative intervention for chronic anterior SC joint instability is considered for patients that have residual pain and instability after conservative management [3]. The author's preferred technique for these cases involves joint reduction followed by SC joint ligament reconstruction using a figure-of-8 tendon graft reconstruction through drill holes through the medial clavicle and manubrium [11]. If there is significant articular cartilage damage to the medial clavicle, medial clavicular resection can be considered. Following surgical reconstruction, patients are immobilized in a sling and swathe for 4–6 weeks, and contact sports are avoided for 3–6 months postoperatively.

Posterior Type III SC joint dislocations are much less common than anterior dislocations but are a much more serious and potentially life-threatening injury. The close proximity of important nearby mediastinal structures has implications for both urgent evaluation and potential surgical intervention after initial workup. The force required to cause a posterior dislocation can cause abutment of the medial clavicle against at least one or more of the nearby structures, potentially injuring that structure. Accordingly, all posterior SC joint dislocations require a CT of the chest to evaluate associated injuries, and these patients are generally kept in hospital until definitive management [9]. Many posterior SC joint Type III dislocations are actually posteriorly displaced fractures through the medial clavicle epiphysis. These injuries are treated similarly with the exception of the location of surgical repair as discussed below.

In addition to an orthopedic consult, the cardiothoracic team should be contacted and readily available to assist with life-preserving surgical intervention if complications are encountered before or during joint reduction. Closed reduction of the posterior SC joint dislocation or posteriorly displaced medial clavicle physeal fracture has been proposed; however while an initial reduction may be achieved, recurrent instability is very common [12, 13]. We therefore advocate for formal open reduction and suture fixation of acute posterior SC joint fractures and dislocations [13, 14]. The patient is brought to the operating room and, under general anesthesia with appropriate general or thoracic surgery backup, is positioned in the modified beach chair position with a bump between the scapula. The ipsilateral arm is prepped into the sterile field so that it is fully free for intraoperative manipulation. A transverse incision centered over the SC joint is made, and the platysma is divided in line with the incision. Careful subperiosteal dissection of the clavicle is then done in a lateral-to-medial fashion to expose the medial clavicle and SC joint [14]. Inspection is then done to determine if the injury was a medial clavicle physeal fracture with posterior clavicular displacement (more common) or a true posterior SC joint dislocation. If a medial clavicle physeal fracture is encountered, the medial clavicle is carefully manipulated anteriorly to reduce the fracture, and suture fixation with heavy nonabsorbable sutures is accomplished in a figure-of-8 fashion utilizing drill holes in the medial clavicle metaphysis and epiphysis [14]. If a posterior SC joint dislocation is noted, the medial clavicle epiphysis is carefully manipulated anteriorly back to the SC joint (with careful attention to anatomy—the clavicular head is normally only partially seated into clavicular notch of the manubrium), and the repair is accomplished similar to above with a figure-of-8 repair using sutures through drill holes between the medial clavicle epiphysis and sternum [14]. Stability is then assessed intraoperatively with shoulder range of motion. After surgery, patients are immobilized in a sling and swathe for 4–6 weeks. Active assisted range of motion exercises are started at week 6, followed by active motion and strength progression beginning at 12 weeks [3]. Contact sports are avoided for 3–6 months postoperatively [13, 14].

Glenohumeral Instability

Introduction

Shoulder injuries have become more common in young athletes as participation in high-demand contact sports has become more widespread at younger ages. Injury patterns in the adolescent shoulder generally are specific to the sport. One of the most common acute traumatic shoulder injuries in football players is a glenohumeral dislocation [15]. For these injuries, two traumatic instability patterns have