Orthopedics for Physician Assistant and Nurse Practitioner Students

An Introductory Guide

John A. Gracy

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Acknowledgments

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Contents

Introduction

1

The purpose of this book is to serve as an introduction to orthopedics. It is not meant to be inclusive of all conditions, nor to give definitive treatment options but rather to give the advanced practitioner (AP) student a brief overview and insight into what orthopedic surgery can and cannot do, as well as a primer on some of the specialized language and eponyms. To that end I have tried to include the most common conditions as well as those that fall into the category of "don't you dare miss this."

Broadly speaking, orthopedic surgery is the specialty dealing with problems in and of the musculoskeletal system including congenital and developmental defects, degenerative disease, tumors, and trauma to both the skeletal system and the soft tissues such as tendons, nerves, ligaments, and muscles. The treatment options vary from simple reassurance that a particular condition is benign and no intervention is needed to major multistage surgery. Related to orthopedics is the field of rheumatology, and the next to the last chapter will give a brief overview of that field. Trying to learn even the bare basics of orthopedic surgery during the normal 4-week rotation is like drinking from a fire hose. There are an innumerable number of books, journals, and resources online including videos that go into enormous detail about the conditions presented. Most of the references are particular chapters in textbooks or review articles from major journals; the AP student should read those for further detail as needed or as interested. Each of the review articles will have its own set of references that the student can use for even deeper insight.

After the chapter on orthopedic history taking, physical examination, imaging, and other diagnostic studies, there is a chapter on the operating room, followed by nine chapters each addressing a different anatomic area. Each of those chapters is roughly divided into traumatic and non-traumatic conditions (e.g., ankle sprains and clubfoot, respectively). There will be a brief discussion of clinical presentation, any imaging, or other diagnostic studies (if appropriate), the underlying pertinent pathology, and important differential diagnoses, followed by a broad outline of treatment options. Any significant short- or long-term complications of either the condition or the treatment will be mentioned. Exhaustive details about the treatment

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will not be discussed as that is both patient and surgeon dependent. Chapter 13 is a brief overview of rheumatology. Finally, Chap. 14 discusses compartment syndrome.

Several rules of thumb all medical professionals should follow are:

1. Treat the patient, not the radiograph. The treatment of distal radius fracture in an 88-year-old nursing home patient will be different from that of the 22-year-old college athlete.
2. Most clinicians come to a conclusion about diagnosis and treatment in the first 30 seconds, tending to ignore or downplay conflicting information obtained later. Do not be hasty. For the most part, diagnosis in orthopedics is fairly straightforward, but deciding on the best treatment is not always as easy; be sure to involve the patient in the decision-making process. If all the history and physical and diagnostic studies do not "match," figure out why before ignoring or downplaying some of those clues. When a diagnosis is uncertain or if the best method of treatment for that particular patient is in doubt, ask a colleague or your supervising physician.
3. As hard as it is to deal with some of our more long-winded patients, let them tell their story. Not only is it part of the therapeutic process (pain shared is pain divided), many times they will answer your questions and give you clues as to what treatment options to consider. Try to wait at least a minute before interrupting with a question.
4. Ask open-ended questions. Instead of asking "does this cause numbness and tingling?" in the radial aspect of the hand when doing a carpal compression test, ask what kind of symptoms/feelings does this test cause and where.

From here onward, both physician assistants and nurse practitioners will be referred to collectively as advanced practitioners: APs.

Like other specialties and professions, orthopedics is rife with eponyms and abbreviations. As each eponym is introduced, a brief explanation of the associated condition or test will be given. There are various classification schemes for both fractures and non-traumatic conditions. It can be difficult to know which to use or memorize. For example, a literature review in 2018 showed 22 different classification schemes for tibial plateau fractures [1]. The most universal fracture classification system is the one promulgated by the AO/ASIF short for *Association for Osteosynthesis/Association for the Study of Internal Fixation* (or the in the original German *Arbeitsgemeinschaft für Osteosynthesefragen*). It is a cumbersome system mostly for academic use but helpful to be aware of when reading the orthopedic literature. Other abbreviations will be introduced in the appropriate section. Open reduction and internal fixation is ORIF; different types of appropriate ORIFs will be mentioned for each fracture type. Arthroscopy refers to looking into a joint or space with a camera that has the diameter of a pencil and using other specialized instruments of the same size to repair or excise the problem. Arthrodesis means fusing a joint. Arthroplasty refers to replacing the joint which can be with either manufactured material or soft tissue (e.g., total hip arthroplasty or carpometacarpal soft tissue arthroplasty, respectively). Hemiarthroplasty means replacing half the joint and is mostly used when discussing the treatment of femoral neck fractures. It is not

uncommon for these terms to be confusing, and the AP should remember to use plain English, not medicalese, when talking with patients.

A few of the standard orthopedic textbooks are as follows:

Weinstein SL, Flynn JM. Lovell and Winter's Pediatric Orthopedics. 8th ed. Baltimore: Lippincott Williams & Wilkins; 2020.

Herring JA. Tachdjian's Pediatric Orthopedics: from the Texas Scottish Rite Hospital for Children. 6th ed. Philadelphia: Elsevier; 2021.

Tornetta P, Ricci W, Court-Brown CM, McQueen MM, McKee M. Rockwood and Green's Fractures in Adults. 9th ed. Baltimore: Lippincott Williams & Wilkins; 2019.

Waters PM, Skaggs DL, Flynn JM. Rockwood and Wilkins Fractures in Children. 9th ed. Baltimore: Lippincott Williams & Wilkins; 2019.

Wolfe SW, Pederson WC, Kozin SH, Cohen MS. Green's Operative Hand Surgery. 7th ed. Philadelphia: Elsevier; 2017.

Azar FM, Beaty JH, Canale ST. Campbell's Operative Orthopedics. 13th ed. Philadelphia: Elsevier; 2017.

Browner BD, Jupiter JB, Keddrick C, Anderson PA, editors. Skeletal Trauma: Basic Science, Management, and Reconstruction. 5th ed. Philadelphia: Elsevier Saunders; 2015.

And the number of orthopedic journals is over 200. Although each subspecialty in orthopedic surgery has one or more specific journals, the most commonly used and referenced are the following:

Journal of the American Academy of Orthopedic Surgeons. Commonly referred to as the yellow journal, it is published twice per month and has a combination of review, technique, and original research articles some of which are only available only online.

Journal of Bone and Joint Surgery. There is both an American and British version and is widely considered the flagship journal of orthopedic surgery. The American edition is published twice per month.

Journal of the Orthopedic Physician Assistant. Published quarterly by the same company that publishes the *Journal of Bone and Joint Surgery*.

As will be mentioned frequently throughout this book, each surgeon may have different ways of handling various diagnoses, but the above references will give more details on the many different ways of caring for patients with orthopedic problems.

Reference

1. Millar SC, Arnold JB, Thewlis D, Fraysse F, Solomon LB. A systematic literature review of the tibial plateau fractures: what classifications are used and how reliable and useful are they? Injury. 2018;49(3):473–90. Epub 31 Jan 2018.

History, Physical Exam, and Diagnostic Testing

2

2.1 History Taking in Orthopedics

After introducing yourself to the patient and anyone accompanying the patient as well as verifying their relationship, the easiest way to start is to ask how you can help. Then, be quiet and allow the patient to tell his story, interrupting as little as possible. Listen for clues as the patient may answer some of your questions before you ask, as well as listening for items for which you may need more detail.

For acute injuries, the usual where, when, and how are important. Obviously, a fall from the front steps resulting in ankle fracture is very different from a fall off the roof resulting in the same injury. Ask about concurrent injuries, for example, loss of consciousness, and if the injured body part has been injured in the past or has a pre-existing disease. For example, did the patient have a previous fracture that did not heal properly leaving the patient with permanent loss of motion, or have a stroke that has left the patient with weakness or numbness, especially in the injured area.

For chronic or non-traumatic problems, the history of present illness is a little longer. The what, when, and how are still applicable, but the details are important. What is the problem? What are the symptoms, e.g. pain, numbness, loss of motion, and weakness? What makes it better? What makes it worse? Any previous tests? What did they show? When and where were they done? Any previous treatment including physical therapy and surgery, and not just by physicians? For example, many patients will use acupuncture, chiropractic care, herbal medicine, over-the-counter medications, or braces, and many patients are reluctant to mention that they tried nontraditional treatments. Did any of those traditional or nontraditional treatments make a difference?

The past medical history is important as it allows the surgeon and the AP to assess risk if surgery is warranted and will also give the AP an idea of the patient's physiologic age. The obese 35-year-old on three antihypertensives, a H_2 inhibitor, and metformin is probably "older" than the normal weight 45-year-old who needs no medication. Rare childhood illnesses such as polio and rheumatic fever may have some impact on overall adult musculoskeletal health. Adult diseases and

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medications must be elicited by specific questions. Surgical history can give the AP some hints as to how to approach any surgical discussion. Did the patient have problems with pain control or nausea after previous surgery? Past history of addiction may influence perioperative treatment to minimize the risk of narcotic abuse. Allergies are important, but patients may not think of them until asked by the third or fourth healthcare provider. Because reactions to drugs are not necessarily an allergy, the AP should ask what specifically happened when the patient had exposure to the drug or food. This will allow the AP to differentiate a true allergy from sensitivity and other reactions. Specific questions regarding penicillin, NSAIDs, cephalosporins, and latex are helpful.

Social history is not just a way of socializing with the patient. Smoking, vaping, drinking, and illicit drug use impact the patient's health. Occupation and hobbies help determine treatment and treatment goals. With whom the patient lives may be important in determining who will aid with recovery (household chores, personal hygiene, transportation to appointments, including physical or occupational therapy).

In the current age of electronic health records, the review of systems is usually done by check sheets or bubble sheets. Any positives should be followed up to make sure no important diseases were left out of the past medical history. The check mark by shortness of breath may indicate a recent diagnosis of pneumonia, chronic untreated asthma, or as-yet-undiagnosed congestive heart failure.

2.2 Physical Exam

The physical exam starts off with vitals, especially height and weight, followed by calculation of BMI. Temperature should be obtained for all new patients as well as for those patients who might have an infection as well as those in the immediate postoperative period.

During and after taking vital signs be sure to really look at the patient and ask yourself questions such as: How old does the patient appear versus the patient's actual age? How much distress? Does he appear chronically ill? Agitated? Depressed? When the patient entered the room, how did he enter: crutches, wheelchair, or limp? How easily can the patient get from the chair to the exam table? Especially with older patients, can the patient stand up without using the upper limbs to assist in pushing up. For some patients, a timed up and go (TUG) test may be appropriate. To perform the TUG test, have the patient stand from a seated position, walk six meters, turn around, walk back, and sit again. Normal is less than 10 seconds, but pay attention to gait, how the patient turns around, and how the patient both sits and stands.

Then, examine the injured body part or painful area as follows. The general rule of thumb is to examine from the joint above to the joint below. Especially with children, try to examine non-painful areas first (even starting on the opposite side in anxious patients). Check for range of motion (active and passive as well as which parts of the ROM are painful), strength, and when appropriate sensation and reflexes. For the area of concern, inspect first. Look for scars (previously unmentioned injury

or surgery?), abrasions, erythema, ecchymosis, or skin changes. Because of variation in ROM between individuals especially in the hip and shoulder, it is helpful to note side-to-side differences.

Next, palpate the area of concern for tenderness, swelling, and areas of fluctuance. Feeling with the back of the examiner's hand is the most sensitive way to detect excessive warmth. Crepitus, a grinding sensation, on range of motion should be noted, and when present the AP should ask the patient if the crepitus is painful. Strength should be tested with any side-to-side differences or accompanying pain documented. Any give-way weakness or inconsistencies are important to identify. There are a tremendous number of anatomically specific tests for a variety of orthopedic conditions, many with associated eponyms which will be covered in the appropriate chapter. For many, the question to ask is not "does this recreate/reproduce your symptoms," but instead ask what kind of symptoms and where does this test cause them.

For example, when during a carpal compression test (firm pressure over the median nerve at the wrist flexion crease for 30 seconds), do not ask "does this cause your thumb and fingers to go numb," but rather ask "what kind of symptoms, if any, does this cause?" or you can ask, "does this make things better, worse, or the same?" If the answer is worse, "how so?"

There are a dozen or so books available that describe orthopedic examinations, most of which are written by physical therapists including *Ortho Notes: Clinical Examination Pocket Guide* by Gulick [1] and *Orthopedic and Trauma Findings* by Roth [2]. The latter book reminds the examiner what questions to ask when examining each body part in addition to reviewing specific physical tests. In addition, there are innumerable resources in textbooks, in journals [3], and on the Internet if the student is just looking for one exam in particular. Remember the Internet is not always right.

2.3 Testing

Testing includes radiographs, CT, bone scan, MRI, ultrasound, laboratory work for infection and autoimmune diseases, and EMG/NCS.

In these cost-conscious days, it is important to think before blindly ordering tests. Routine ordering foot and ankle films for every patient with a "sprained" ankle that comes through the door is not only costly but exposes the patient to unnecessary radiation. If the history and physical examination indicate both ankle and foot films are necessary, by all means order both. With most tests, the AP should ask the following: Will this test help the patient? Does it confirm a diagnosis? Does it rule out certain diagnoses? Will it change management of the patient? Some patients may be insistent on having certain tests for emotional rather than logical reasons. For example, a patient may insist on having a radiograph to rule out bone cancer because a parent or relative died of bone cancer at the same age. Depending on the anxiety level of the patient, it may be of psychological benefit to obtain the radiograph to reassure the patient.

2.3.1 Imaging Studies

All APs should make it a habit to review all images prior to reading what the radiologist saw so as to read the images without bias. There are two reasons to personally review all diagnostic imaging. First, they may see something that the radiologist missed or misinterpreted. After all, the AP has the benefit of a thorough history and physical examination of the patient. Second, although modern technology and teleradiology provide radiology readings quickly, there will be times and places when and where a radiologist's interpretation is not available in a timely fashion.

2.3.1.1 Radiographs

Radiographs (also referred to as "X-rays," although that term more specifically refers to the ionizing radiation that creates the images) are simply pictures made up of a variety of black, white, and gray overlaid shadows. They come in three forms:

- The traditional way has been exposing a piece of film to the ionizing radiation and then developing it just like a photographic negative. This method is becoming obsolete as most first world facilities have one of the two types of computer-generated images: CR and DR.
- Computed radiography (CR) involves exposing a cassette, which contains a special plate, to ionizing radiation and then placing the cassette into a "reader" which in turn sends the digitized image to a computer screen. It then erases the cassette using bright white light to ready it for the next radiograph.
- Digital radiography (DR) is a slight advance to CR where the image is instantly transmitted via a wired or wireless cassette directly to the computer screen. There is no difference in image quality between CR and DR; however, with digital radiography the radiology technologist will know almost instantaneously if the radiograph taken is adequate.

Because radiographs are shadows and not three dimensional, it is important to take at least two images at right angles (orthogonal) to each other to avoid missing a fracture or dislocation (Fig. 2.1). Interpreting a radiograph is both simple and difficult. All the AP has to do is describe what he sees. When reviewing a radiograph, the first thing is to look at all the views and identify which views are present. For example, there are three views of the left ankle – AP, lateral, and mortise. Then, describe the abnormalities as simply but as accurately as possible. For example, there is a non-displaced oblique fracture through the lateral malleolus, but the ankle mortise and syndesmosis are intact. Fractures should be described in terms of location, comminution (i.e., number of fragments), displacement, direction of the displacement, angulation, and rotation if applicable. Any involvement of the articular surface or growth plates should be mentioned as well.

2.3.1.2 CT Scans

To get more bony detail, a CT scan is an option. Computed tomography (CT) scans are obtained by placing the patient on a gantry and taking a high number of pictures while rotating the source of ionizing radiation and receiver circumferentially around

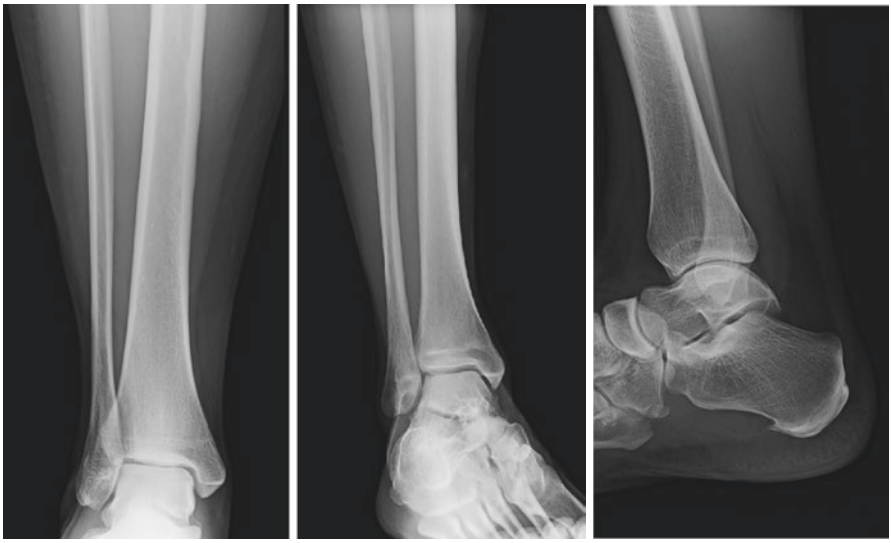

Fig. 2.1 Three views of a normal left ankle. The left radiograph shows an AP view of the ankle with the toes pointed straight up. The middle radiograph shows the mortise view which is taken with the ankle internally rotated 15°. Note the even spacing of the joint along both sides of the talus and the tibiotalar joint. The right radiograph shows a lateral view of the ankle

the patient. The patient is then moved fractionally (in increments as small as 1 mm) and the process repeated until the area of interest has been completely scanned. Marked detail of the bone and soft tissue can be obtained. For tumors and complex fractures, 3D reconstructions can be performed to allow better diagnostic images and surgical planning. With 3D reconstruction, the soft tissue is "subtracted" allowing only the bone to show (Fig. 2.2). Metal implants both prevent transmission of the ionizing radiation and cause deflection of the beam to alternate receptors causing degradation of the image (Fig. 2.3).

2.3.1.3 Nuclear Imaging

In certain instances, knowledge of the activity of the bone is helpful. Bone scans can be done with either labeled WBC scans or technetium scans; the latter is more common. Although rarely used, indium-labeled WBC scans are helpful to diagnose and localize infection. It is done by drawing off a sample of the patient's blood, adding indium 111 (radioactive), and then injecting the cells back into the patient. Images taken by a passive receptor several hours later show where the white cells have accumulated presumably in the area of infection.

Technetium bone scans are done in three phases. After injecting a small amount of radioactive dye (about as much radiation as in one chest radiograph), two sets of pictures are taken almost immediately. The first is the "blood flow" stage, and the second, the "blood pool" stage, both of which are of necessity, are limited to one region of the body. The third phase images are taken several hours later when the technetium has settled in the bone. More technetium settles in the area of bone that is more metabolically active as a result of infection, fracture (old or new), or

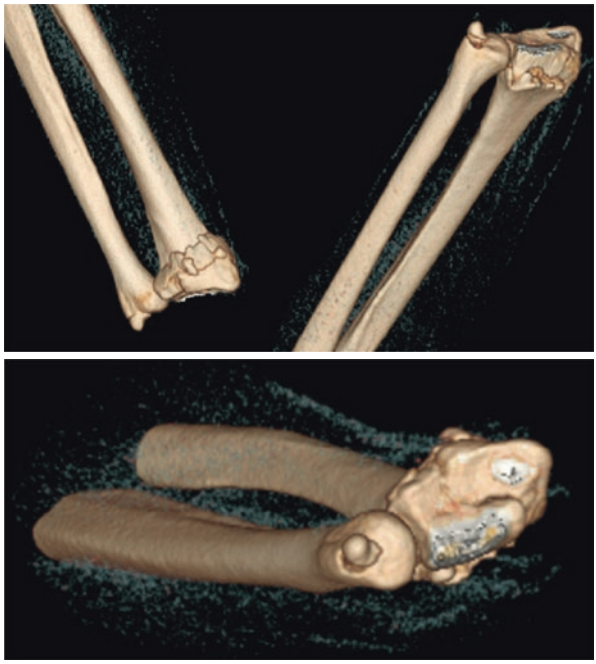

Fig. 2.2 These three images show a 3D reconstruction of a forearm CT showing the details of a complex distal radius fracture with an ulnar styloid fracture. Note that the soft tissues and carpal bones have been "subtracted" allowing detailed visualization of the bone

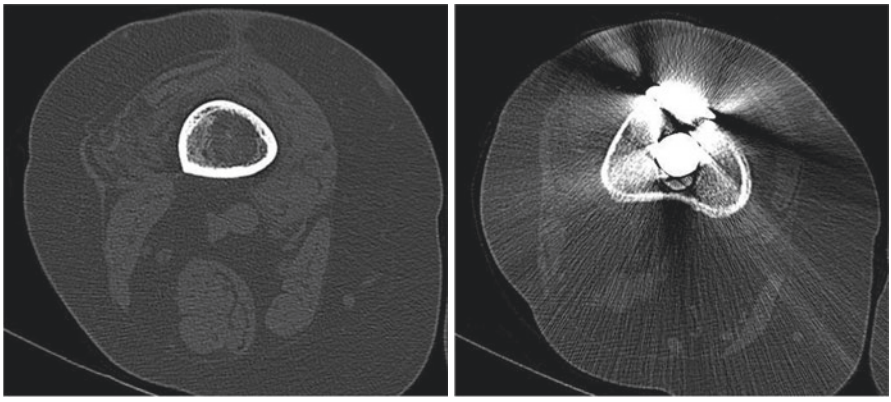

Fig. 2.3 The CT scan on the left shows the midshaft of the femur. Note the bone in the middle as well as the differing soft tissue densities of the muscle and adipose tissue. The CT scan on the right is of the same femur but through a more distal section of the thigh with a metal revision stem from a knee arthroplasty. Note how the metal artifact obscures not only the bone outline but the soft tissue as well

arthritis. The third phase can be done on the whole body if desired but that may need to be specified when ordering the bone scan. Depending on the pattern of uptake in the three different phases, the disease process and extent can be identified, or the differential narrowed (Fig. 2.4).

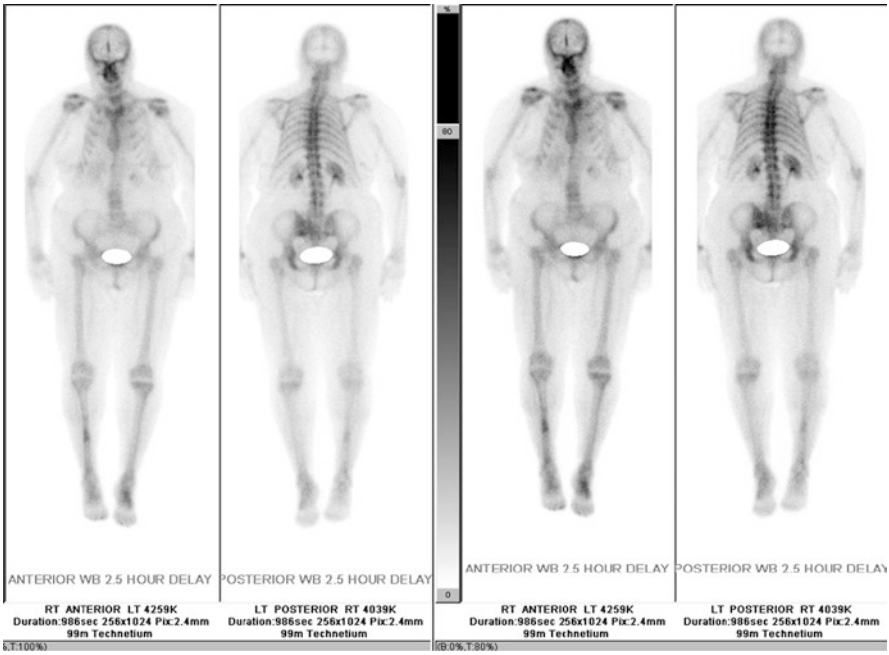

Fig. 2.4 Whole-body technetium bone scan in the third phase. Note the increased uptake in the midshaft of the right tibia consistent with an old fracture and the increased uptake in the left midfoot consistent with arthritis when both are correlated with the patient's history. As the dye is excreted through the kidneys, a shield is placed over the bladder to prevent scatter radiation from obscuring the pelvis

Although not used much except in orthopedic oncology, positron emission tomography (PET) scans use injected fluorodeoxyglucose (FDG). Since cancer cells are more metabolically active, the PET scan will show greater activity in areas of malignancy [4].

2.3.1.4 MRI

Although plain radiographs and CT are excellent at showing bone and bony lesions, they only give hints to soft tissue lesions, primarily swelling and blurring of tissue boundaries on high-quality radiographs. The best way to obtain images of soft tissue is an MRI (magnetic resonance imaging) (Fig. 2.5). Simplifying the actual process, the patient is placed in a high-strength magnetic field and the magnet turned on and off (thus accounting for the loud clicking the patient hears). When the magnet is turned on, the hydrogen ions associated with the water molecules line up in the same direction. When the magnet is turned off, the hydrogen ions go back to their random directions but release a tiny radio signal which is picked up by a receiver and in turn processed by a computer which produces an image. Depending on magnetic field strength, how long the magnet is on, how long the signals are

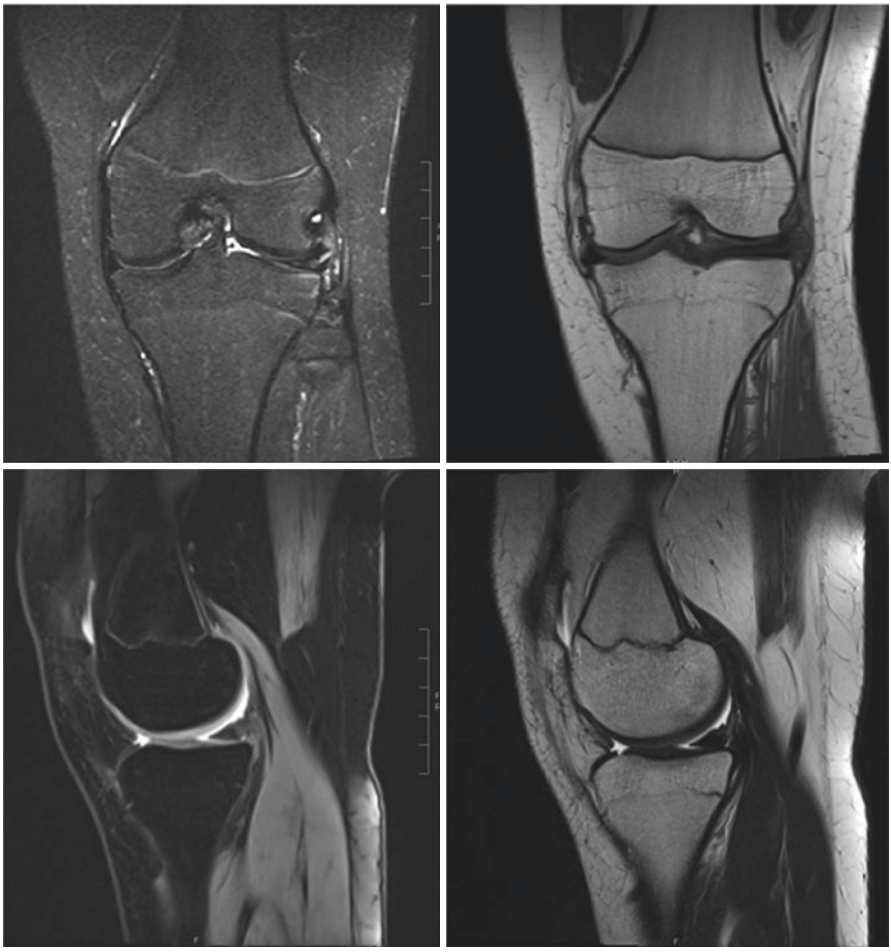

Fig. 2.5 MRI views of the knee. The upper images are coronal or frontal views, while the lower are sagittal views. The images on the right are T1 weighted which highlights the fat. The images on the left are STIR (short tau inversion recovery) based which highlights water as white and suppresses signal from fatty tissue. Note the presence of the distal femoral physeal plate

received, and how the signals are processed all determine the type and quality of images. Resolution can be as small as 1 mm depending on the magnet's strength which is measured in Teslas. The higher the strength, the better the signal to noise ratio with most MRI's currently having 1.5–3.0 T strength [5].

Contrast (typically gadolinium) can outline structure, making interpretation easier. The contrast can be injected intra-articularly, for example, in the shoulder making identification of labral or rotator cuff tears easier; the contrast can also be injected intravenously, for example, to make differentiation between herniated disc material and scar tissue on previously operated spines easier. Because gadolinium can be nephrotoxic in some patients, contrast should only be used when necessary [6].

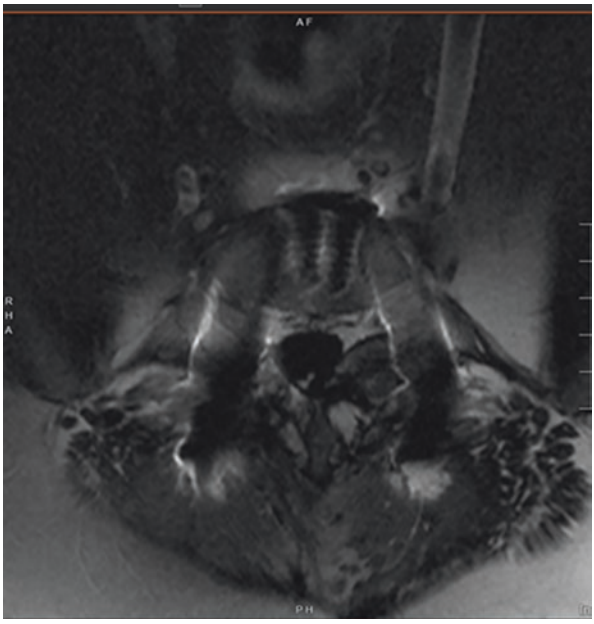

Fig. 2.6 MRI of the spine. This is a transverse image showing the difficulty of visualization in the presence of metal, even with titanium and specialized metal subtraction software

Because it is magnetic, any regional and implanted ferrous metal will make images much more difficult to interpret, although there is software that will "subtract" some of the metal artifact improving the imaging (Fig. 2.6).

2.3.1.5 Ultrasound

MRI machines, however, are expensive (~$500,000), and the clinician may want something quicker or is just looking for a specific soft tissue lesion. In the right circumstances, ultrasound can be useful for diagnostic or therapeutic use. Ultrasound machines for orthopedic use run from $15,000 to $40,000. As described by the name, the transducer bounces an ultrasound wave off the tissue and picks up the echo (much like sonar or radar). Generally, with higher frequencies deeper tissue can be seen, but the image degrades.

Ultrasound interpretation is very user dependent and is best done "live" as opposed to reviewing the static images. The most common use is to diagnose deep venous thrombosis. Other uses include diagnosing rotator cuff pathology (Fig. 2.7), subluxing peroneal tendons, or determining whether an infant's hip is reduced, subluxable, or dislocated (developmental hip dysplasia). From a therapeutic standpoint, it is invaluable in placing intra-articular injections in deeper joints such as the hip as well as placing a scalene block prior to upper limb surgery [7, 8].

2.3.2 Lab Tests

Preoperative laboratory testing should be patient specific and not general. If the AP is prepping an otherwise healthy 22-year-old male for arthroscopy, then no

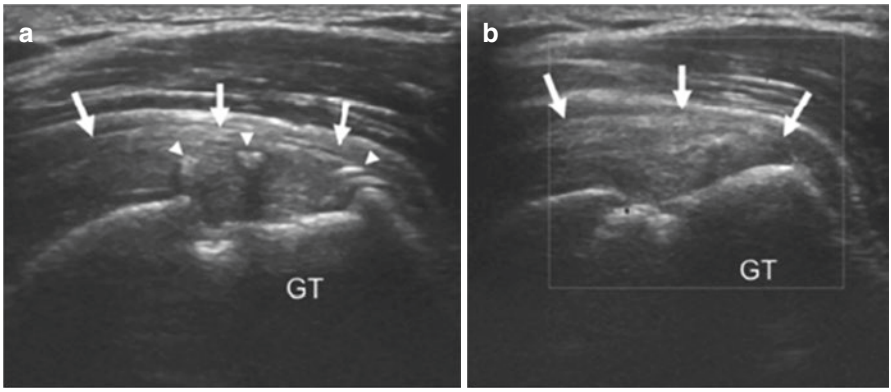

Fig. 2.7 Ultrasound of a repaired rotator cuff tear. GT: greater tuberosity. The arrows in both (**a**) and (**b**) point to the supraspinatus portion of the rotator cuff. The arrow heads in (**a**) mark the sutures placed for the rotator cuff repair (From Susan et al. [12])

laboratory tests are necessary. But if the patient is female, then a serum pregnancy and hematocrit would be indicated. EKGs for older patients and those with heart disease are appropriate. If on a diuretic, then the AP should order a basic metabolic profile. Depending on the patient, other laboratory tests may be necessary prior to surgery such as PT/PTT if on blood thinners or HbA1c to assess long-term diabetic control.

In addition to appropriate preoperative lab tests, there are two sets of labs that are of interest to the orthopedic AP. First there is the set of labs used to help diagnose infection. These typically include a complete blood count with differential (CBC with diff), erythrocyte sedimentation rate (ESR), C-reactive protein (CRP) (not to be confused with a hastily scrawled creatinine), and the most recent addition: alpha-defensin protein (ADP). The ESR is generally thought of as indicating overall inflammation which can result from infection or autoimmune disease, while CRP is much more specific for infection. ADP is a relative newcomer and is likewise very specific for infection; the drawback of ADP is that the test can only be run on synovial fluid. All have a specific range of normal depending on the lab, with false positives and false negatives being possible. They should be reviewed in context of the whole clinical picture. If elevated, they are especially useful to track trends [9]. The second set of labs, less useful for the orthopedist and more useful to a rheumatologist, are those used to aid in diagnosing a variety of autoimmune diseases such as rheumatoid arthritis, systemic lupus erythematosus, psoriatic arthritis, and others. Keep in mind however that many patients will have negative lab tests despite clear evidence that the patient has disease (e.g., seronegative rheumatoid arthritis). These tests include complete blood count with differential, ESR, antinuclear antibody (ANA), anti-citrullinated protein antibody (ACPA), rheumatoid factor (RF), and others. In addition, tracking liver or kidney function may be necessary before starting drug therapy or while taking chronic medications including NSAIDs.

2.3.3 EMG/NCS

Finally, an EMG/NCS test can help evaluate the status of specific muscles and nerves, but like any test there can be false negatives and false positives, and to a certain extent, the interpretation is operator dependent. Nerve conduction studies (NCS) are exactly what the term describes; a specific nerve is stimulated and how fast the impulse travels is measured; the normal velocity is greater than 50 m per second. Various nerves are tested at the usual sites of entrapment or potential compression such as the median nerve at the wrist which may indicate carpal tunnel syndrome or the ulnar nerve at the elbow for cubital tunnel syndrome. Both motor and sensory nerves can be evaluated.

Electromyograms (EMG) are the most painful part of the test. A small-gauge needle is inserted into a specific muscle. How that muscle responds to needle insertion, direct stimulation, and nerve impulses can reveal different pathologies. The EMG/NCS is normally done by a neurologist or physiatrist [10, 11].

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The Operating Room

3

3.1 Infection and Preoperative Evaluation

Orthopedic surgery obviously takes place in the operating room. Like other specialties, one of the biggest concerns is postoperative infections. Unlike other surgical specialties, orthopedics frequently involves large metal implants which makes eliminating postoperative infections extremely difficult. The biofilm (the glycocalyx) that is formed on the metal implant by the bacteria prevents penetration by the body's defense, i.e., the white blood cells, as well as preventing the antibiotics from reaching the bacteria. In addition, because of cortical bones' limited vascularity, bacteria can "hide" in the Haversian canals. After lying quiescent for years, the bacteria can re-emerge when the patient's immune system weakens.

For elective operations many conditions can be corrected preoperatively, thus reducing but not eliminating the chance of infection. This includes optimizing comorbid conditions such as diabetes, hypertension, urinary tract infections, and especially dental caries. Regarding diabetes, the HgBA1c level can give the AP a good idea of the patient's long-term compliance with diet and medication. Glucose levels the morning of surgery of greater than 180–200 portend a higher risk of infection [1]. Other factors can influence the risk of infection including the length of the procedure, emergency/trauma surgery, and even the size of the operating room [2].

Urinary catheters are necessary in some cases to monitor intraoperative hydration as well as easing the patient's ability to void in the immediate postoperative period. Early removal of the Foley either in the postanesthesia care unit (recovery room) or on the floor the evening of or the morning after surgery reduces the risk of urinary tract infection in addition to forcing the patient to move earlier. This in turn reduces the risk of deep venous thrombosis, pulmonary emboli, and pneumonia [3–5].

An excellent review of how to reduce the chance (not prevent) of infection in patients undergoing total knee arthroplasty can be found in "Infection Prevention in Total Knee Arthroplasty" [6].

J. A. Gracy, *Orthopedics for Physician Assistant and Nurse Practitioner Students*, https://doi.org/10.1007/978-3-031-04406-9_3

3.2 Positioning

Unlike other specialties, orthopedic operations often require specific positioning of the patient. This requires planning ahead not only to make sure the appropriate table is available including tables for the morbidly obese but also that all the accessory equipment is working as well.

The simplest position is supine for hand operations and most foot and ankle surgeries. The latter may require a bump under the hip on the affected side allowing easy access to the lateral ankle (Fig. 3.1). Operations on the posterior ankle such as Achilles tendon repair usually require prone positioning.

The lateral decubitus position is extremely common and used for both lateral and posterior approaches to the hip. Either a bean bag (Fig. 3.2) or some type of pelvic positioner (Fig. 3.3) (e.g., a "Montreal" positioner) can be used. The surgical assistant should check, prior to scrubbing, that once the hip is prepped and draped, the full range of motion needed intraoperatively will be available without destabilizing the pelvis. In addition to making sure the downside bony prominences are appropriately padded (greater trochanter, knee, and lateral malleolus), an axillary roll placed under the downside of the upper thorax will ensure blood flow to the downside arm. Checking the radial pulse and using a pulse oximeter on the downside fingers is helpful. For shoulders done in the lateral decubitus position, some type of traction

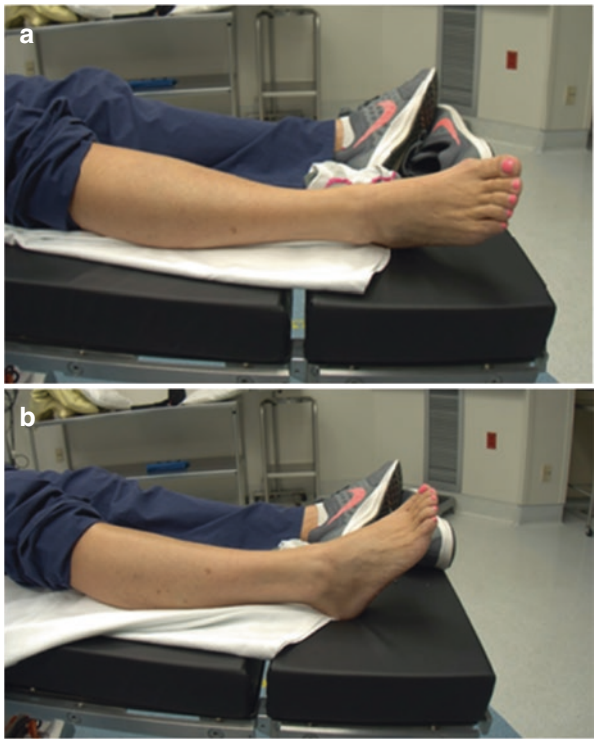

Fig. 3.1 (**a**, **b**) The ankle in (**a**) is without a "bump" under the hip which results in excessive external rotation of the ankle making access to the lateral malleolus more difficult. The same ankle (**b**) shows the much easier access when a "bump" is placed under the ipsilateral buttock. The bump is usually a 5 pound sandbag but can be several towels or even a bag of IV fluid

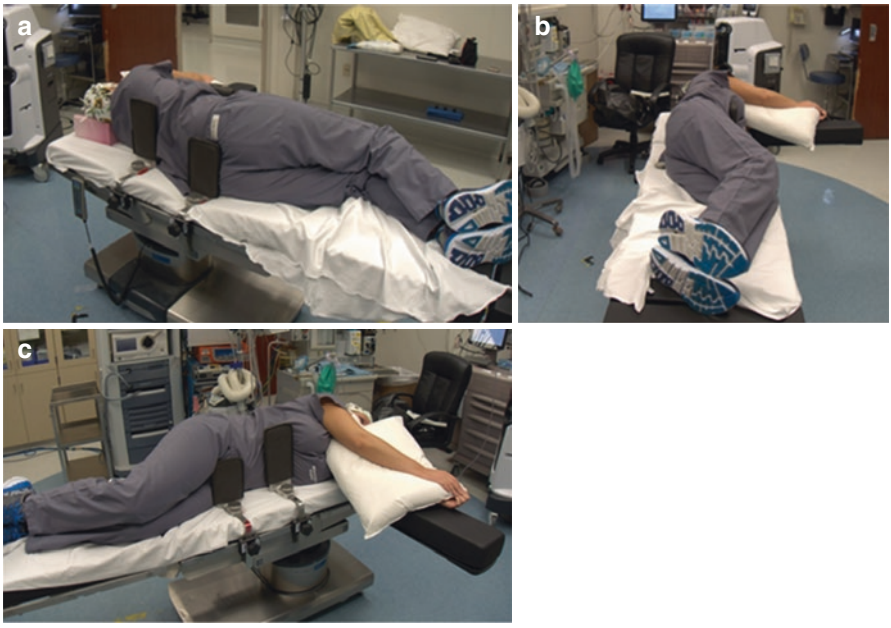

Fig. 3.2 The pelvic positioner stabilizes the pelvis so that appropriate orientation will not be lost when working on the proximal femur or acetabulum. (**a**) shows the two posterior posts to prevent the patient from rolling to the supine position during surgery. (**b**) shows the pelvis perpendicular to the floor and tabl. (**c**) shows the view from the front where the more caudal positioner is short allowing for full flexion of the hip

to distract the glenohumeral joint will be necessary, taking care not to contaminate the operative field in the process. The lateral decubitus position is also used for some elbow and upper arm surgeries (e.g., triceps avulsion, olecranon fractures).

The prone position is almost exclusively used for spine surgeries (Fig. 3.4). Again, appropriate padding for bony prominences such as the anterior-superior iliac crest is necessary, but the AP should also ensure a female's breasts are not pinched, a male's genitals are not pinched, and the abdomen hangs free. If the abdomen has excessive pressure, it makes breathing more difficult and may contribute to the development of deep vein thrombosis. Checking the position of the upper limb is important; a traction nerve palsy can develop quite easily with prolonged abduction or external rotation of the shoulders [7].

The beach chair position (Fig. 3.5) is used for various shoulder operations including clavicle or humeral fracture repair, arthroplasty, and arthroscopy; the operative side can either be draped free or be attached to a mechanical arm to hold the arm in a steady position. This frees up the assistant's hands. In the beach chair position, the position of the cervical spine needs to be as close to neutral as possible to avoid traction injuries to the brachial plexus. The ears should be free of compression with shielding placed over the eyes. In addition some type of bolster under the thighs may be necessary to prevent the patient from sliding down – this may be difficult in

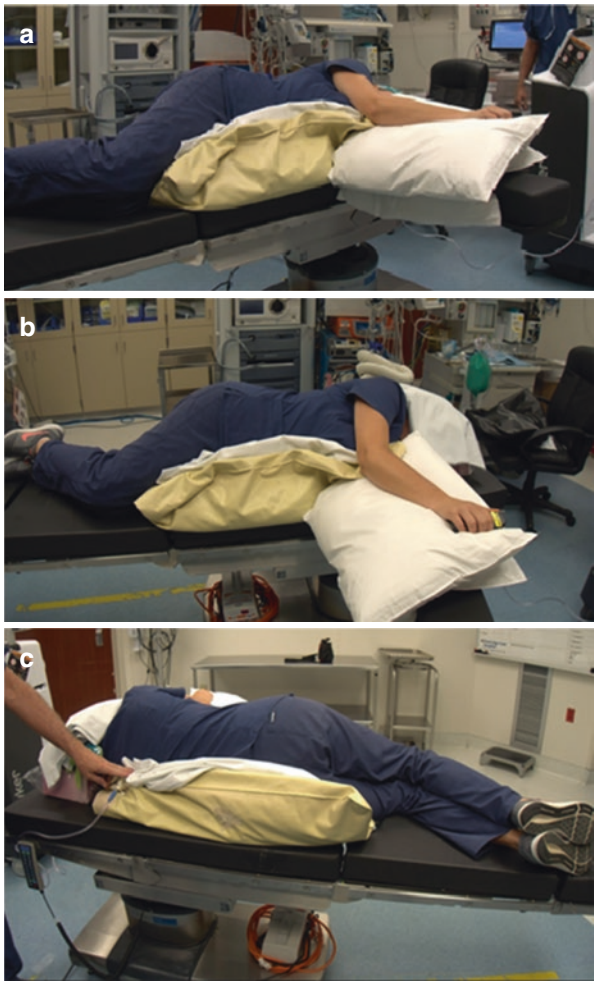

Fig. 3.3 For surgery where the lateral decubitus position is necessary, e.g. posterior approaches to the humerus, a bean bag can be used. Once the patient is positioned suction is applied which results in a stable torso with the pressure symmetrically distributed. It can be used for hip fractures if necessary but the pelvis will not be nearly as stable as with the positioner shown in Fig. 3.2

particularly tall or short patients. Finally beach chair positioners typically have an upper weight limit of 250–300 lbs. (110–140 kg), so heavier patients will require alternate positioning [8, 9].

There are two types of fracture tables used for lower limb fractures including hip and femur fractures. Both allow excellent access to the thigh and allow the C-arm to be utilized in both the AP and lateral planes. The Amsco-type table is the most common (Fig. 3.6). The operative limb is placed in some type of traction, either foot traction or via a transtibial pin. The nonoperative limb must be positioned to allow the C-arm access to all necessary areas of the operative limb in orthogonal planes. Avoidance of excessive traction being placed in the perineal area and ensuring appropriate padding of the fibular head with its associated superficial peroneal nerve on the nonoperative side are all important points to check before draping. The Hana

Fig. 3.4 (**a**, **b**) The Jackson table has multiple padded support positions for the prone position but allows the abdomen to hang free decreasing the risk of deep venous thrombosis and aiding in ease of respiration for long spine cases in addition to allowing access for the C-arm. Note the three isolated pads seen in **a** are for the pelvis, the lower ribs, and the shoulder as seen in **b**

table is similar with the most common use being for anterior hip replacement but can also be used for hip and femur fracture fixation.

Once the patient is positioned on the fracture table, the AP should ensure that the C-arm has access to the operative site in all necessary planes. Care should be taken that the nonoperative limb (right in the photos above) is padded over the peroneal nerve at the knee, that there is not pressure that would compress the popliteal vessels, and that the hip is not excessively flexed [10].

Finally, when it comes to positioning, in addition to making sure the C-arm can acquire appropriate images, the viewing monitors for fluoroscopy and arthroscopy should be where the surgeon and assistant can easily see them without excessive contortions. Some hospitals will have more than one monitor allowing both the surgeon and the assistant to view what is going on without either having to look too far from the operative field.

Preparation of the surgical site after ensuring proper positioning starts with clipping (not shaving) excess hair that may contaminate the operative site as well as hair that may cause pain when the dressing is removed. The most common solutions used to clean the site are povidone-iodine (Betadine scrub and solution) and chlorhexidine gluconate (ChloraPrep) both of which require a short (1–3 minutes)

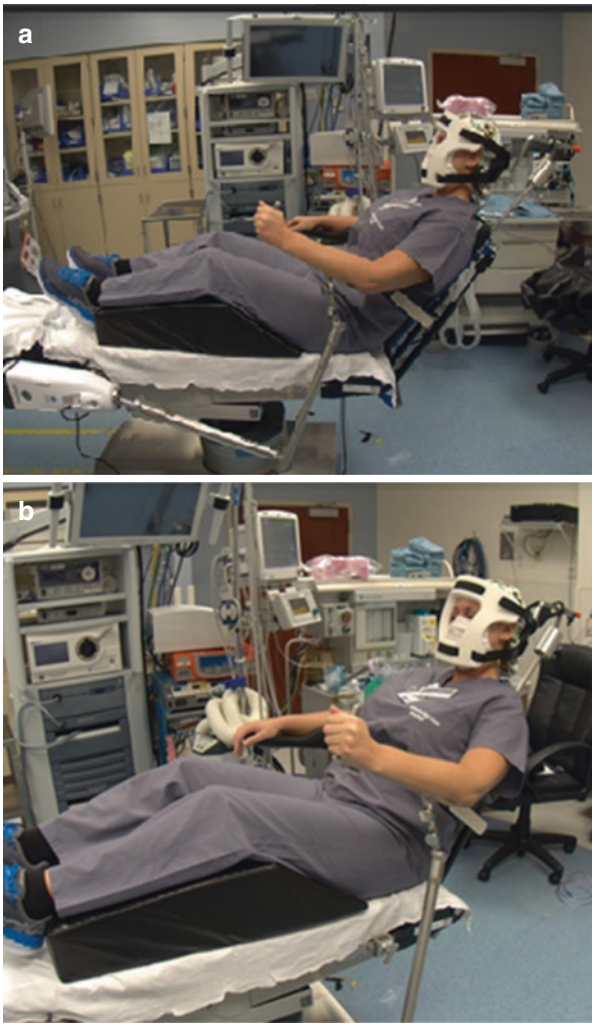

Fig. 3.5 (**a**, **b**) Shows the beach chair position primarily used for operating on the clavicle, proximal humerus, and the soft tissues about the shoulder including open and arthroscopic procedures. Again bony prominences will need to be padded

drying time for maximal effectiveness in killing the skin flora. Some institutions and institutions will "pre-prep" the surgical site with rubbing alcohol.

When draping the operative site, special care must be taken not to cross-contaminate. If there is any question of contamination, say something then re-glove, redrape, or re-prep as appropriate. Normally two layers are used on the patient, and double gloving further reduces the risk of infection for both the patient and the operative team. Always prep and drape a larger field than necessary in case a more extensive exposure is needed.

Although the use of tourniquets has decreased, they continue to be useful to provide a bloodless operating field and possibly reduce overall blood loss. Appropriate padding and making sure the tourniquet does not pinch the skin are part of the

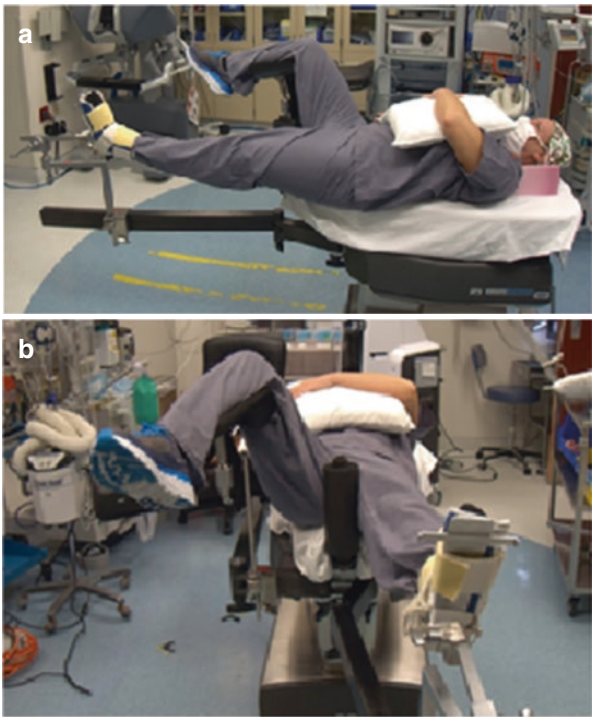

Fig. 3.6 (**a**, **b**) Show one type of fracture table. Note that left operative side has the left arm laid across the torso so that not only will the arm not interfere with the C-arm in obtaining lateral views and the surgeon will be able to insert any necessary guide pins, drills, or fixation devices down the shaft of the femur with minimal bending

immediate pre-op preparation. The tourniquets themselves can be non-sterile and draped out of the operative field, or a sterile tourniquet can be used in the field. For non-sterile tourniquets, a brief inflation before draping to ensure it works is helpful. The tourniquet is normally inflated 100–125 mmHg above the systolic blood pressure and left up for no more than 2 hours. If more time is needed, a good rule of thumb is 5 minutes down for each 30 minutes the tourniquet has been up [11].

Perioperative pain control has been recognized as an important part of the recovery process, not just patient comfort. For some simple operations, like carpal tunnel release, injection of local anesthesia in the operative site before the skin incision is made results in a surprising reduction in both postoperative pain and narcotic use. A variety of regional blocks can do likewise, including scalene blocks for shoulder surgery, femoral nerve at the adductor canal for knee surgery, fascia iliaca blocks for hip fractures, and of course digital blocks for finger or toe surgery. Enhanced Surgical Recovery (ESR) refers to preloading all possible pain receptors in the immediate pre-op holding area which in turn reduce postoperative pain medication requirements for major procedures such as spine surgery and joint arthroplasty. The specifics vary but generally include acetaminophen, an NSAID, a long-acting narcotic like an extended-release formulation of oxycodone (OxyContin), and pregabalin (Lyrica). ESR is primarily for major surgeries such as arthroplasty and spinal fusion. In addition to the medication, a carbohydrate drink imbibed several hours before surgery and a more careful monitoring of intravenous fluid intraoperatively

have been found to be helpful. For more extensive reading on perioperative pain control, see *Perioperative Pain Management* by Azar et al. [12].

Orthopedics is the surgical specialty that uses the widest variety of equipment. Keeping a list of contacts of the various vendors and checking with them several days ahead of any scheduled surgery to make sure all the needed supplies will be available is always helpful.

3.3 Biomaterials

The AP should review the different materials used in joint arthroplasty and fracture fixation to answer questions patients might have and for general knowledge. Ideally the implants used should transfer stress to the surrounding bone perfectly such that there is no loss of cortical nor cancellous bone volume, nor strength. No material yet meets that ideal. Stress shielding refers to the concept of incomplete transfer of forces to the surrounding bone and thus degradation of bone quality or quantity. Another term used to refer to the quantity of stress transferred to bone is modulus of elasticity (Young's modulus). The lower the modulus, the more stress is transferred to bone; this number is affected by both the type of material and the amount (e.g., cross-sectional area). The reader should keep in mind that implant design (shape and size), surgical technique, and patient selection all have an impact on long-term outcomes in addition to the materials used [13].

Early total hip arthroplasties were made of stainless steel, and those stems would occasionally fracture as the result of metal fatigue. Current implants are made of a variety of materials including titanium or cobalt-chrome alloys; the former has a lower modulus of elasticity but is more sensitive to fatigue failure depending on the coating used. The different coatings on arthroplasty implants can be optimized for cement fixation or for "press fit" which will allow bony ingrowth. Coatings may be smooth, beaded, wire mesh, or hydroxyapatite.

One of the more common problems encountered in joint arthroplasty is wear at the bearing surface. Current options in hip replacements are metal on metal, metal head in a polyethylene cup, ceramic head in polyethylene cup, or ceramic head in ceramic cup. The goal is to provide a bearing service that will last (20-plus years) without adversely affecting the patient locally or systemically. At the time of this writing, the majority of knee, ankle, shoulder, and elbow arthroplasties are metal on polyethylene.

For the most part, the metal-on-metal bearing surface for total hip arthroplasty has fallen out of favor due to pseudotumors and elevated systemic levels of metal ions, specifically chromium and cobalt. The most common combination of articulating surfaces and the one with the most historical data is a metal head in a polyethylene cup. The latter is now processed such that polyethylene is highly cross-linked in order to decrease wear and associated polyethylene debris. The problem with polyethylene debris is that if it is of a certain size, it is taken up by the white blood cells which subsequently are stimulated to become osteoclastic; that is, the macrophages "eat" the surrounding bone. This may result in loosening of previously stable implants. Although better, current polyethylene still has a higher rate of wear than

does a ceramic head in a polyethylene cup or ceramic head in a ceramic cup. The problem with ceramic is that it is much more brittle than metal or polyethylene and can "fracture" making subsequent revision difficult. One other complaint the clinician may hear about ceramic-on-ceramic hip arthroplasty is a "squeaking" which can be quite annoying as a hip squeaks with every step. Etiology is unknown but it seems to be more common with certain types and sizes.

Polyethylene comes from a variety of methods of production, shaping, and sterilization all of which can affect its longevity. Newer is not necessarily better as a review of implants used in the past will show [14, 15]. Polyethylene can be "conventional," regular or ultra-high density, cross-linked, or highly cross-linked (via a variety of methods including heat and radiation) all of which have varying advantages. The method of sterilization and shelf time affect oxidation level of the polyethylene which in turn can affect the longevity of the implant [16, 17].

3.3.1 Polymethylmethacrylate

Polymethylmethacrylate, or PMMA, is the cement used to hold total joints in place as an alternative to press fit or bony ingrowth methods of fixation. PMMA can also be used to fill bone defects or augment screw fixation in osteoporotic bone. It is best to think of PMMA as a grout rather than cement or glue as it does not actually stick to the bone or prosthesis but rather acts by filling the interstices and holding the implant by wedging it in place. This of course means that a variety of factors affect the longevity of the PMMA and its ability to stabilize the implant. These factors include eliminating any fluid (blood) between the bone, the PMMA, and the implant; additives such as antibiotics; reducing the porosity of the PMMA; and how the cement is placed such that all gaps and interstices between the bone and implant are filled. Since porosity weakens the cement, both centrifuges and vacuum devices are used to decrease the number and size of air pockets in the cement. In addition, there are several factors that affect how fast the PMMA hardens or cures including brand, viscosity, room temperature, and humidity. Ideally the cement should set slow enough to allow ideal placement of the implant but fast enough that there will not be any motion that creates cracks or instability in the cement. The cement setting is an exothermic reaction, i.e., it becomes quite hot. Before the PMMA hardens, any excess needs to be removed. After the PMMA cures or hardens, the area needs to be thoroughly flushed and examined for any stray pieces of PMMA that may cause third body wear which can lead to early failure of the prosthesis [17].

3.3.2 Hydroxyapatite (HA)

Bone is calcium hydroxyapatite, and some prostheses, especially the femoral and acetabular components of a press-fit total hip, are sprayed with a coat of hydroxyapatite. With proper pore size on the prosthesis, this can encourage bony ingrowth to the prosthesis which results in a longer lifespan of the prosthesis [18, 19].

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The Hand and Wrist

4

4.1 Traumatic

4.1.1 Fractures

4.1.1.1 Scaphoid Fractures

The scaphoid bone (also called the carpal navicular) is the most frequently injured carpal bone, and fractures of the scaphoid most commonly result from a fall on the outstretched hand. Because of its role in linking the proximal and distal rows of carpal bones, proper anatomic healing is crucial. The primary problem with healing of the scaphoid is that the blood supply to the scaphoid enters from the distal aspect which means that displaced fractures of the proximal portion, called the "proximal pole," can result in the proximal pole dying of avascular necrosis with subsequent radiocarpal arthritis.

Traditionally, the physical exam of the scaphoid has been to palpate for tenderness in the anatomic "snuffbox," i.e., the area just distal to the radial styloid between the extensor pollicis longus (EPL) and the combined tendon sheath of the extensor pollicis brevis (EPB) and abductor pollicis longus (APL) (Fig. 4.1).

The practitioner should be sure to examine the distal and proximal aspects of the scaphoid as well by palpating volarly.

Initial radiographs should include a lateral, PA, and scaphoid view. Other views to consider include a clenched fist view which may show scapholunate gap widening and obliques (Fig. 4.2). Because of the twisted bean shape of the scaphoid, the fracture lines may not be seen on any of the above views. If suspicion is high, then a CT scan with 1 mm cuts or an MRI can be ordered depending on the supervising surgeon's preference. CT orders should include requests for reconstruction in the coronal and sagittal planes.

Treatment varies widely depending on the age and activity level of the patient, other injuries (like a scapholunate ligament tear), fracture location, displacement, and angulation. Initial treatment can be a short-arm thumb spica cast or splint until a definite treatment decision can be made. The two primary treatment options are

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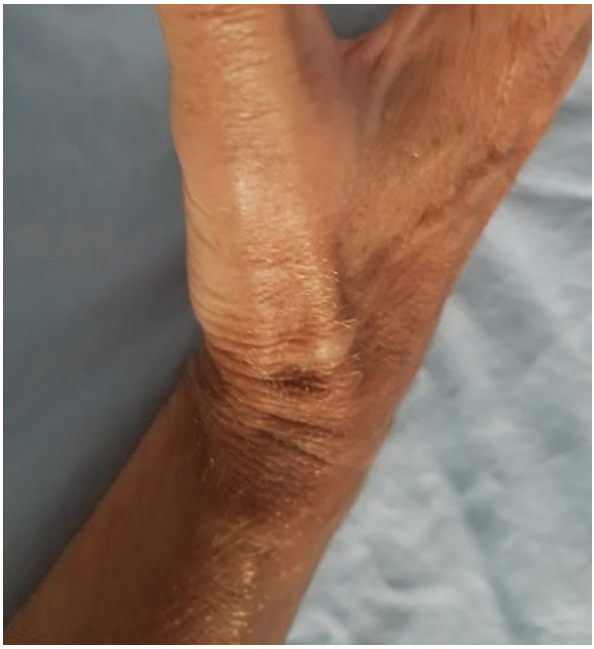

Fig. 4.1 The EPL is the prominent tendon to the right, and the slightly less prominent tendons to the left are the combined EPB and APL tendons. The anatomic "snuffbox" lies between the two just distal to the radial styloid

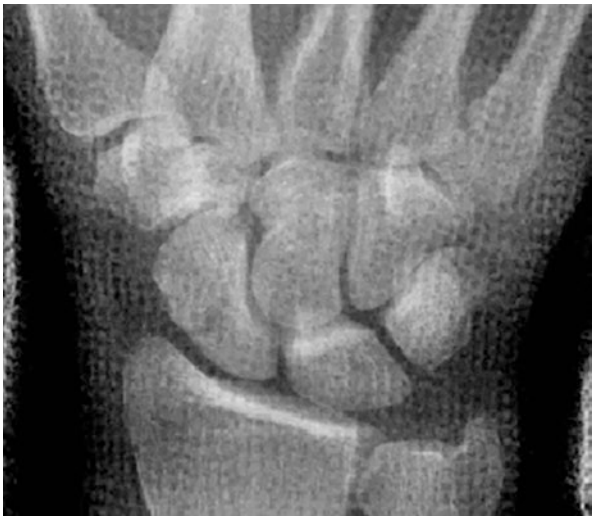

Fig. 4.2 Non-displaced scaphoid fracture seen through a fiberglass cast

casting as described above for 6–8 weeks or open reduction and internal fixation (Fig. 4.3). In the last decade, as anatomical knowledge has increased, and as surgical techniques have become more refined, more surgeons are opting for ORIF. This avoids the cumbersome thumb spica cast, allows earlier return to activity, and appears to result in earlier anatomic healing. Either treatment option may require follow-up CT scan to ensure healing. Nonunions of the scaphoid, which are not

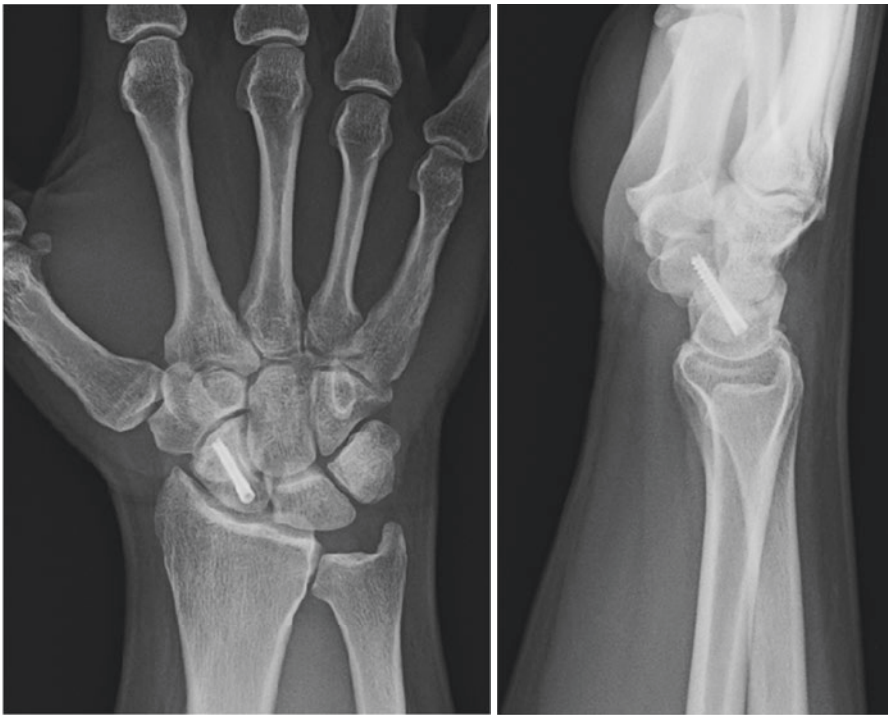

Fig. 4.3 Scaphoid fracture fixed with a screw that has two sets of threads, one at each end and each of which has a different pitch allowing for compression at the fracture site. This also allows the screw to be completely buried within the bone so the "head" of the screw does not impinge on any other tissue

uncommon – the patient "sprained" his wrist 4–6 weeks ago – are beyond the scope of this text [1–3].

4.1.1.2 Phalangeal Fractures

The most common distal phalanx fracture is a "burst" or tuft fracture where the patient has had a sudden compression force applied to the volar or dorsal aspect of the distal phalanx such as from closing a door on a fingertip or hitting it with a hammer. Treatment, for the most part, is reassurance and protective splinting. There is frequently a subungual hematoma that may need to be drained acutely for pain relief. The patient with a subungual hematoma should be warned that the nail may fall off, regrowth will take several months, and the resulting nail may be deformed. Care should be taken not to confuse a distal phalanx fracture that can be treated with protection and time with a bony mallet finger.

Middle and proximal phalanx fractures are less common and result from impact injuries or twisting injuries. The fracture can be open or closed, involve part of the articular surface, and can be oblique, transverse, comminuted, displaced, nondisplaced, stable or unstable, or some combination. Any skin break should be

viewed with suspicion for human bite or intra-articular contamination. A minimum of two orthogonal radiographs, preferably three, should be taken of the involved digits both pre- and post-reduction. As with other injuries, the patient's age, activity level, and other injuries need to be considered in determining treatment.

Treatment can range from buddy taping, splinting, or casting to closed reduction with percutaneous pinning (Fig. 4.4), or open reduction and internal fixation with mini-fragment plates and screws. Post injury or surgery joint stiffness is very common with finger injuries. The ligamentous structures about the MCP and IP joints

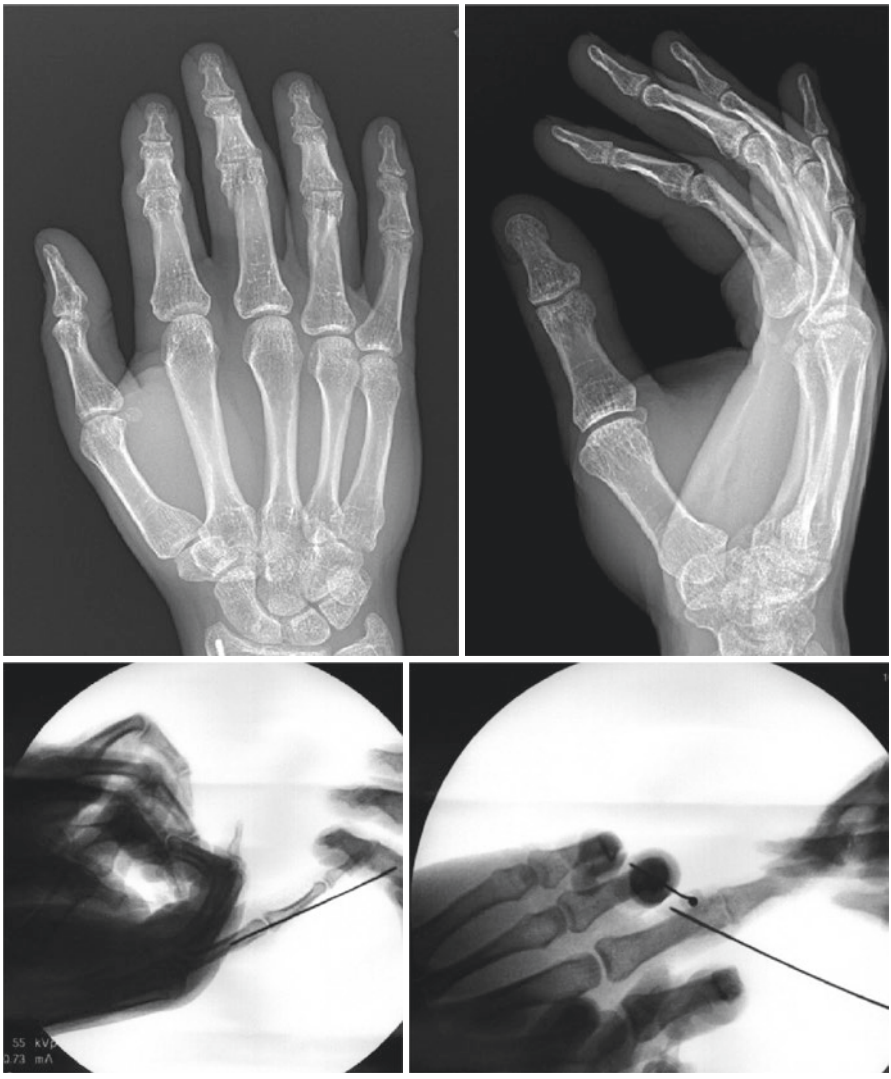

Fig. 4.4 Proximal phalanx fracture of the PIP joint treated with closed reduction and percutaneous pinning. Note that there are fractures of both the ring and middle fingers

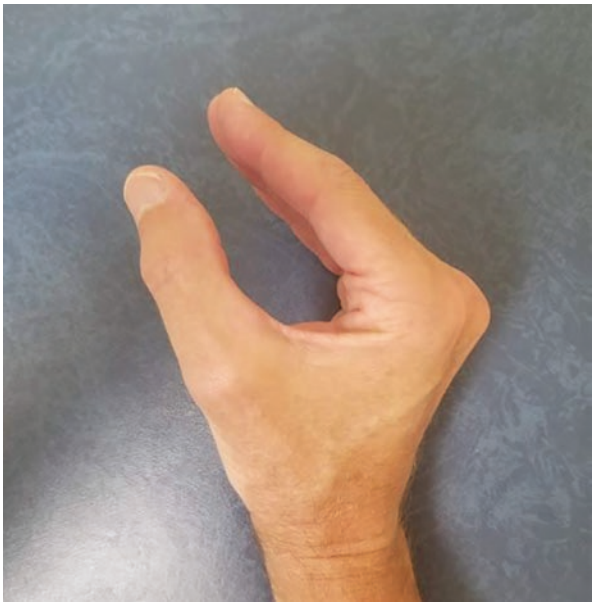

Fig. 4.5 The "safe" position for metacarpal and phalangeal fractures that will minimize the stiffness of the finger joints when the splint or cast is removed. Note that the metacarpophalangeal joints are in flexion and the interphalangeal joints are in extension

are arranged such that the former become stiff if left in extension while the latter become particularly stiff if left in flexion. Therefore, the ideal position for immobilization is one of MCP flexion and IP extension if possible depending on fracture location and type as well as associated soft tissue injuries (Fig. 4.5). Like other joints, mobilization (active or passive) should begin as early as possible.

One of the more common complications of middle and proximal phalangeal fractures is a rotational malunion. When the entire finger is in extension, this may not be obvious, but once the digits are flexed, the overlapping digits make the rotational malunion more apparent [4].

4.1.1.3 Thumb Fractures

Distal and proximal phalanx fractures of the thumb are treated in a similar fashion to those of the fingers. There are two special named categories of fractures at the base of the thumb metacarpal each of which each deserves a paragraph of its own: *Bennett's and Rolando's* (Fig. 4.6).

Bennett Fractures

Bennett fractures are intra-articular fractures at the base of the thumb metacarpal normally with just one fragment. This intra-articular fracture makes the carpometacarpal joint unstable. Most authorities recommend some type of fixation; this can range from open or closed reduction with pinning to the placement of mini-fragment screws after open reduction. Postoperatively the thumb should be splinted in the abducted position to prevent an adduction contracture with pin removal at 4–6 weeks. If only internal fixation is used, early mobilization can be started if the surgeon feels the fixation is stable enough.

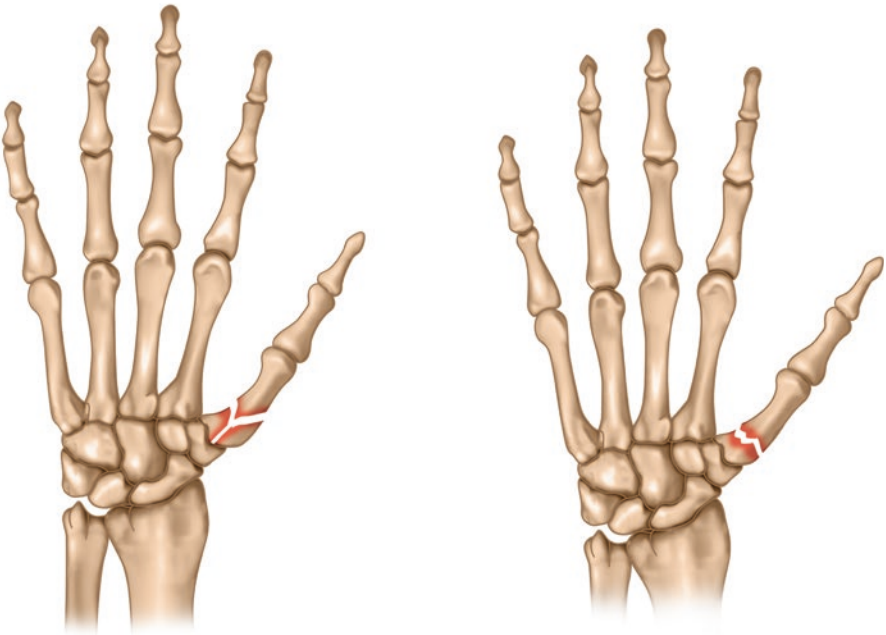

Fig. 4.6 Diagrammatic representation of the difference between a Rolando and Bennet fracture. They should be viewed as a continuum rather than two distinct injuries

Rolando Fractures

Rolando fractures are comminuted (i.e., three or more fragments) fractures at the base of the thumb metacarpal (Fig. 4.7). Occasionally there will be several relatively large pieces that are amenable to pinning or even mini-fragment screws (1.5 mm or 2 mm). For the most part, achieving a smooth articular surface is not possible. Therefore, many surgeons resort to longitudinal traction and either cross pinning to the second metacarpal or using an external fixator, again attached to the second metacarpal to maintain length until the fracture is healed. If the patient develops symptomatic CMC arthritis, the joint can be fused 6–12 months after the fracture heals. Alternatively a soft tissue arthroplasty of the trapezium can be performed.

4.1.1.4 Metacarpal Fracture (Digits 2–5)

The most common metacarpal fracture is that of the neck of the fifth digit (pinky), normally flexed to some degree. As the name implies, a boxer's fracture results from hitting something, so any skin break should be examined for contamination of the metacarpophalangeal joint. In general the following amounts of residual flexion for metacarpal neck fractures are considered compatible with normal function:

5th 45° 4th 30° 3rd 20° 2nd 10°

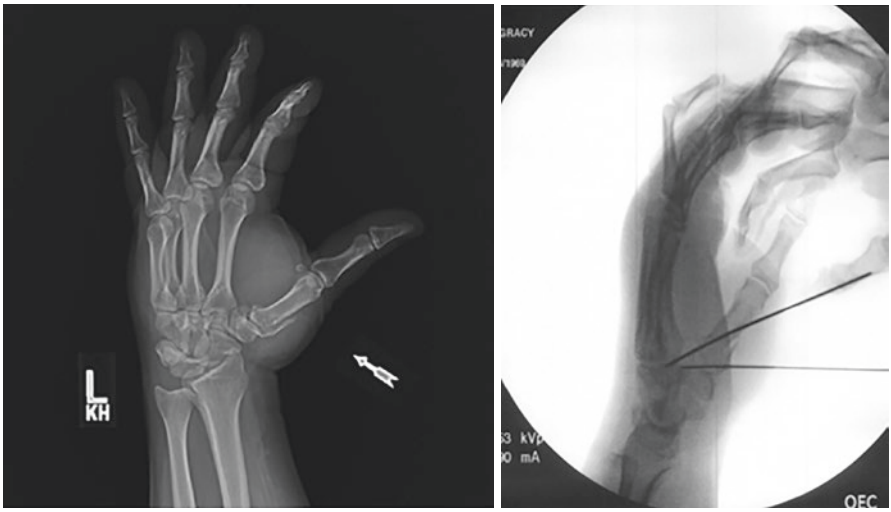

Fig. 4.7 Rolando fracture treated with open reduction and percutaneous pinning. Note the pin that goes through the diaphysis of the first metacarpal into the carpal bones, thus maintaining length while the fracture heals

This is because the ulnar digits have more motion at the CMC joints allowing for compensatory motion. For those patients with residual angulation within acceptable limits, they should be warned of the cosmetic deformity (i.e., a depressed metacarpal head), but that function should be normal [4].

Treatment of metacarpal neck fractures that are angulated enough to warrant reduction can be a challenge due to the difficulty in keeping the fracture reduced solely with external mobilization such as a cast or a splint. This may necessitate treating these fractures with closed reduction and percutaneous pinning.

Metacarpal shaft fractures, like other diaphyseal fractures, have a variety of fracture patterns. Isolated fractures can often be treated with closed reduction followed by immobilization for 4–6 weeks in the previously mentioned safe position. Unstable fractures or fractures involving more than one metacarpal may require pinning, cross pinning, or open reduction and internal fixation. Severe open fractures, with or without bone loss, may require external fixation [4].

4.1.2 Finger Dislocations

Distal interphalangeal dislocations are normally associated with a mallet finger injury (bony or extensor tendon avulsion). Treatment is directed at reducing the joint and then treating the cause of the mallet finger. If the dislocation is not reducible by closed means, surgery will be required to remove whatever is blocking reduction (volar plate being most common).

Proximal interphalangeal joint dislocations are described as to where the middle phalanx is relative to the proximal phalanx: volar, dorsal, or lateral. Dorsal dislocations are the result of a hyperextension injury with varying amounts of axially

directed force. There may or may not be a fracture at the base of the middle phalanx necessitating close examination of both pre- and post-reduction films.

Treatment is reduction. If caught early, e.g., on the sidelines of a football game, reduction can almost always be accomplished without a digital block. If seen in the emergency room, a digital block may be necessary. The most common mistake made when attempting reduction is applying longitudinal traction which creates a negative pressure in the PIP joint which in turn sucks soft tissue into the joint preventing a closed reduction. Proper reduction involves applying axially directed force to the middle phalanx such that the middle phalanx maintains bony contact with the proximal phalanx. Post-reduction, unless unstable, dorsal PIP dislocations are treated with buddy taping to an adjacent digit, and range of motion is encouraged. The patient should be warned that the PIP joint will always have some residual swelling and it may take 6–12 months for the pain to resolve.

Like dorsal dislocations, lateral dislocations are treated with closed reduction, buddy taping, and early motion. Again, careful review of the post-reduction films is necessary to ensure a concentric reduction and that there are no soft tissue or bony fragments.

Volar dislocations, fortunately, are the least common of the PIP dislocations. They are frequently difficult to reduce closed because of interposed soft tissue and there is often an associated rupture of the central slip. The latter can result in a boutonniere deformity if not diagnosed and treated. Once the joint is reduced, the integrity of the central slip will need to be assessed. To test the central slip portion of the extensor mechanism, a digital block will be necessary if not already done to reduce the joint. Elson's test for the central slip is performed by holding the PIP joint in flexion (ideally 90°) and asking the patient to extend the finger. If the central slip is intact, the DIP joint will remain slightly flexed and offer no resistance to passive flexion by the AP despite the patient's best effort. If the test is abnormal, then the DIP joint will extend even against resistance. If the central slip is ruptured, then splinting the PIP joint in extension while leaving the MCP and DIP joints free will allow healing. This may require a custom splint made by a hand therapist [5].

Like PIP dislocations, MCP dislocations are named for the direction of the proximal phalanx relative to the metacarpal head. Dorsal injuries are the norm with volar dislocations being extremely rare. Like dorsal PIP dislocations, MCP dorsal dislocations are the result of a hyperextension force. If the patient presents with the digit extending at a 90° angle from the joint, then like the PIP joint, axially directed pressure, i.e., no traction, and sliding the joint back into place usually works.

If, however, the digit is dislocated and pointed in the same direction as the metacarpal, then closed reduction will usually not work because various soft tissues are entrapped within the joint space. One attempt as described above may succeed, but open reduction is the usual treatment. Surgical reduction can be done through a dorsal or volar approach taking special care regardless of the approach to avoid damaging the digital nerves which will be stretched and not in their usual location.

Postoperatively immobilization in some degree of flexion for several weeks followed by progressive range of motion (with buddy taping) will result in good to

excellent outcomes for most patients but may require up to 6 months for full recovery including resolution of pain to occur.

4.1.3 Tendon Injuries of the Hand

4.1.3.1 Flexor Tendon Lacerations

Flexor tendon lacerations of the hand and wrist can be among the most difficult injuries to treat as the repair is difficult and patient compliance with a good hand therapy program is crucial to optimizing the odds for success. Even with optimal surgery and patient compliance, failure as evidenced by loss of flexor function or a stiff joint is not unusual. To complicate matters, there are often associated nerve and blood vessel injuries not to mention fractures, dislocations, and dirty wounds. This discussion will assume there are no fractures or dislocations.

The history of where, when, and with what the laceration occurred should be obtained as well as assessing the most recent tetanus immunization. Sensation in the distribution of each digital nerve should be tested before any local anesthesia is injected. The latter may be necessary to control the pain in order to adequately examine the status of flexor tendons. Each finger needs to be tested individually as follows. The back of the hand is placed against the examining surface such that the wrist is in the neutral position and the fingers can be fully extended. The flexor digitorum superficialis (FDS) is tested by holding all but one digit in extension at the MP, PIP, and DIP joints and then asking the patient to flex the digit of concern. The process is repeated for each of the four fingers. To test the flexor digitorum profundus (FDP), the MP and PIP joints of the involved finger are held in extension, and the patient is asked to flex the finger while watching for flexion at the DIP joint as the FDP attaches to the distal phalanx. If no local anesthetic has been injected and the patient can flex the digit of concern but there is pain when doing so, there may be a partial tendon laceration; unfortunately, the only way to be sure is formal exploration of the wound in the operating room.

In the emergency room, after the wound is thoroughly cleaned, the skin can be loosely approximated. Definitive repair is urgent but not emergent and should be done within the first 3–7 days, thus allowing time to make sure there is no infection and operating conditions optimal. The goal of surgical repair is to align the ends of the tendon with a strong enough repair that a gap and subsequent failure does not occur as well as providing a smooth surface to maximize the gliding function of the tendon. There are a variety of suture techniques, but it appears that the more sutures that cross the repair site, the stronger the repair is. If the tendon size allows it, 3-0 is better than 4-0. A small circumferential running suture increases the strength of the repair and enhances the gliding of the tendon.

Postoperative rehabilitation varies depending on how many, which, and where the tendons were cut. The principles are similar. The patient is placed in a dorsal splint with varying degrees of flexion at the wrist, MCP, PIP, and DIP joints. This is followed by a supervised passive flexion and active extension program to decrease the chance for adhesions to form between the repaired tendon and the surrounding

tissues including adjacent flexor tendons. At 4–6 weeks after repair, active motion is started, but strengthening is not started until 8–12 weeks. The dorsal splint is removed around 8 weeks postoperatively. All of the timing is dependent on a variety of factors, and the AP should be aware of all the factors that may play into said timing. Frequent consultation with both the supervising surgeon and hand therapist will be invaluable.

The most common complications after repair are the following. The first is total or partial failure of the repair with the latter resulting in stretching at the repair site resulting in limited active flexion and weakness. The second most common complication is adhesions that may prevent excursion of the tendon, thereby limiting motion. The third complication of which to warn patients is joint contractures can occur: most commonly the MP joints in extension and the PIP and DIP joints in flexion.

Finally, the AP should be aware of zones of injury (Fig. 4.8). The most critical and difficult zone of injury is zone II, also called "no man's land" because of the marked difficulty in obtaining good results from repair of either or both of the flexor tendons in that area. Zone II extends from where the two heads of the FDS inserts on the middle phalanx, leaving only the FDP distally, to the proximal end of the A1 pulley. Because of the close proximity of the FDS to the FDP and the split heads of the FDS, repairs in this area are particularly prone to adhesions necessitating particular attention to surgical technique and the rehabilitation process [6, 7].

Fig. 4.8 Flexor tendon zones: Zone I – tip of finger to the middle of the middle phalanx (insertion of FDS); Zone II – No Man's Land, where the FDS splits to form a tunnel for the FDP; Zone III – Lumbrical origin; Zone IV – Over the carpal tunnel; Zone V – Musculotendinous junction, distal forearm. All have the potential to scar limiting motion but Zone II is the most problematic

4.1.3.2 Extensor Tendon Injuries

Lacerations of the extensor tendons to the fingers and the distal portion of the wrist extensors are both easier and harder to repair. Because the neurovascular structures are on the palmar side, the injury is usually limited to just the tendon. In addition, the skin, especially over the dorsum of the hand, is more mobile allowing for better access. The repair is made more difficult by the fact that as the tendons leave the wrist, they become both flatter and thinner making suturing techniques that are helpful for the flexor tendons (four- and eight-strand techniques) less feasible or impossible.

Once the tendon is repaired (and the technique varies depending on the zone of injury as well as tendon site and quality of the tissue), the postoperative immobilization and rehab are just as important as with flexor tendon injuries. The difficulty is that as the MP joint is held in full extension, the MP joint collateral ligaments will tighten making flexion of the MP joint limited or impossible by the time the tendon has healed. Subsequently, the wrist is placed in extension along with the PIP and DIP joints with the MP joint in 30–40° of flexion. Early motion with limited active flexion and passive extension will decrease the chance of adhesions. The expectation is the patient will regain 70–80% of pre-injury motion (with loss of flexion being the more common) and only about 80% of grip strength compared to the contralateral side.

The most common complication is the adhesions alluded to above causing a loss of flexion. Any laceration on the dorsum of the hand can be the result of a bite (e.g., a punch to the mouth); thus, care should be taken to rule out penetrating injuries to the underlying joints that may produce an infection if not properly treated with irrigation, debridement, and appropriate antibiotic. [8]

4.1.3.3 Closed Tendon Injuries of the Hand

Jersey finger (aka rugby jersey finger) is an avulsion of the flexor digitorum profundus, usually of the ring finger, sustained as a result of forced extension of the finger while the patient is maximally flexing his fingers (e.g., while clutching a "jersey" of the opposing player who is running away) (Fig. 4.9). The patient will be unable to actively flex the DIP joint of the involved finger although passive flexion is possible (Fig. 4.10).

Treatment depends on the length of time since injury, any bony involvement, and the degree of retraction. Either direct repair or indirect repair with tendon grafts is an option. As with other flexion tendon injuries, careful but early mobilization will minimize the chance for scarring and maximize the return of motion [9].

4.1.3.4 Sagittal Band Injuries

The sagittal band is the portion of the extensor tendon that wraps around the proximal portion of the proximal phalanx from the extensor mechanism, thus allowing extension of the metacarpophalangeal joint. When the sagittal band is injured, either from direct trauma, resisted extension, or rheumatologic disease, the extensor tendon is no longer centered over the MP joint in flexion but rather slips to one side of the MP joint (usually ulnar as the radial sagittal band fails more often), thus losing its lever arm to pull the MP joint into extension.

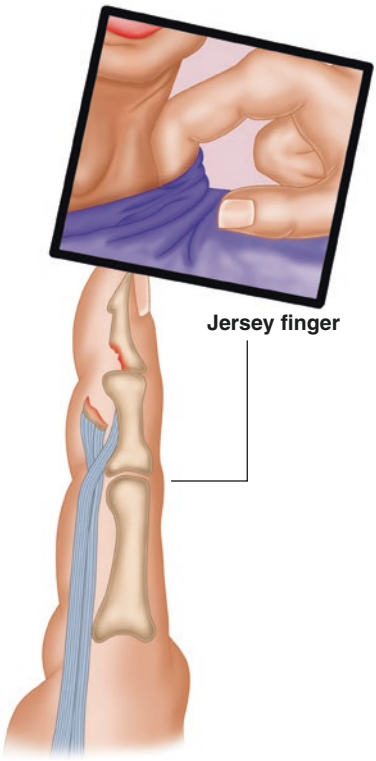

Fig. 4.9 Mechanism of injury causing an avulsion of the FDP most commonly to the ring finger

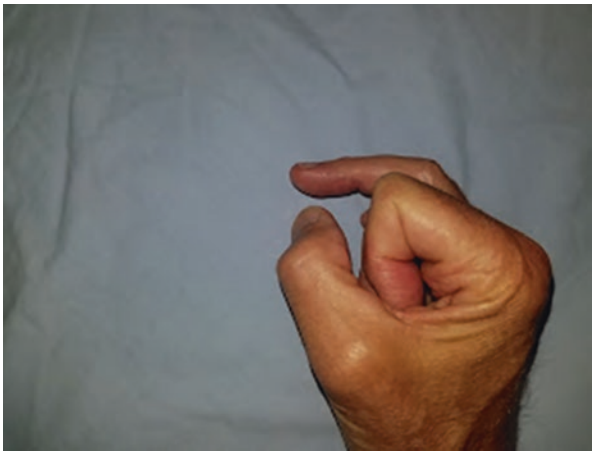

Fig. 4.10 Clinical appearance of a jersey finger. Passive flexion of the DIP joint is possible but active flexion is not

Patients with traumatic sagittal band injuries most often present with the inability to actively extend the middle finger at the MP joint. Patients with rheumatic disease will have difficulty most often with the two ulnar digits. In either the traumatic or the rheumatoid patient, once the joint is passively brought to full extension, the

patient can hold it there. Radiographs, unless there is an underlying rheumatologic disease, are normal.

If caught very early (i.e., the first 1–3 weeks), splinting the joint in extension may allow for healing, but if not, surgical repair or reconstruction will be necessary for those sufficiently symptomatic patients. Like other tendinous injuries of the hand, the rehabilitation time for both operative and nonoperative treatments is 8–12 weeks, and there may be some discomfort for up to 1 year. Differential diagnosis includes trigger finger as the subluxing tendon frequently pops as the MP joint is flexed or extended [10].

4.1.3.5 Mallet Finger

Patients with mallet finger present with loss of active extension of the DIP joint of the index, middle, ring, or pinky fingers after a traumatic injury such as hitting it with a hammer or not quite catching a baseball. Diagnosis is straightforward based on history and physical exam. Physical exam reveals that passive extension to neutral is easily obtained, but the patient cannot actively extend the DIP joint of the involved finger (Fig. 4.11). Two to three radiographs of the involved finger are necessary to identify any associated fractures.

The underlying cause is a disruption of the extensor tendon to the dorsal aspect of the distal phalanx. This can be a soft tissue tear, or an avulsion of the extensor

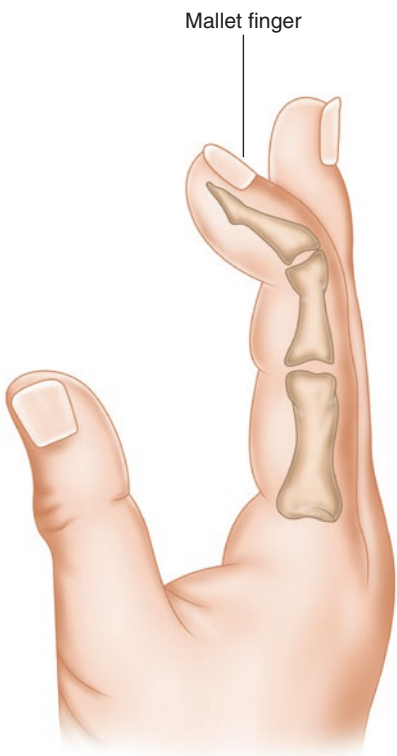

Fig. 4.11 The much more common injury to the tendons of the DIP joint is the mallet finger. Opposite of the jersey finger, passive extension of the DIP joint is possible but active extension is not

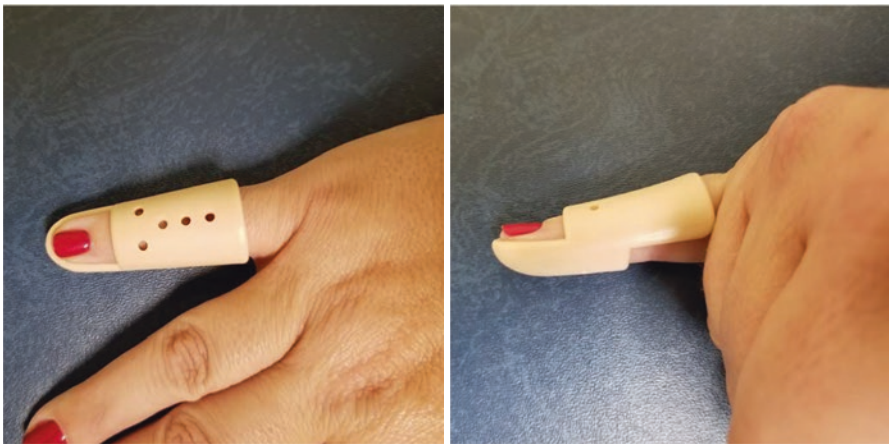

Fig. 4.12 Typical splint used to treat a mallet finger; tape is normally applied around the middle phalanx allowing full motion of the PIP and MCP joints while keeping the DIP joint in extension

tendon with or without a bony fragment off the proximal end of the dorsal portion of the distal phalanx.

Treatment involves splinting the DIP joint in extension while leaving the PIP and MCP joints free to move. There are several commercial splints available for doing so (Fig. 4.12). The only dilemma is trying to get the patients to understand that the DIP joint must stay in extension all the time (24 hours per day, 7 days per week) for 6–8 weeks, followed by some type of weaning schedule for another 4–8 weeks. If the patient allows the finger to droop, especially in the first few weeks, the "clock" or more properly "calendar" starts over.

Surgery is reserved for those patients with large intra-articular fractures or irreducible mallet fingers. Late reconstruction is possible, but the consequence is some degree of loss of flexion [11].

4.1.4 Nail Bed Injuries

Two types of nail bed injuries will be discussed: subungual hematomas and lacerations. The former is the result of a crush or impact injury such as hitting the top of the finger with a hammer. Clinically there is a hematoma trapped under the fingernail, and the patient complains of severe throbbing pain. Radiographs are performed to rule out fracture. If the pain is severe enough, the hematoma can be drained; the finger is prepped, and a hole placed in the nail centered over the hematoma. This can be done with a large-bore needle or small electrocautery unit. It should be done slowly to avoid further injury to the nail bed, and the hole should be big enough to allow the hematoma to continue to ooze. Removal and repair of the underlying nail bed is not usually necessary. The patient should be warned that

it will be 3–6 months before the discoloration disappears and there may be a resultant nail deformity.

The second type of injury is a laceration with part or all of the nail avulsed or missing. If the laceration is simple, then repair can be performed with small (6-0, 7-0) chromic suture under loupe magnification. To protect the repair and prevent scarring of the eponychium to the nail bed, the injured nail should be replaced, or, if not possible, silicone film or nonadherent gauze should be gently inserted under the eponychium. Protective splinting will be necessary for several weeks [12].

4.2 Non-traumatic

4.2.1 Diseases

4.2.1.1 Trigger Fingers

Patients with a trigger finger (often multiple) are usually 40–60 years old and present with the affected finger(s) catching or locking in flexion. It may be present for several weeks, months, or years before the patient seeks medical attention. The finger can be actively or passively extended from that position with a palpable, sometimes audible pop. Radiographs of the hand to rule out accompanying arthritis are appropriate.

The most common accompanying systemic disease is diabetes, while the most common accompanying local disease is carpal tunnel syndrome. Trigger thumbs occur as well.

The underlying pathology has to do with the pulleys that keep the flexor tendon (flexor digitorum superficialis, flexor digitorum profundus) close to the underlying bone providing a lever arm to maximize strength. There are five annular pulleys and three cruciate pulleys for each of the four fingers; two annular pulleys; and an oblique pulley for the thumb.

The A1 pulley of the fingers overlies the metacarpal head, and it becomes tight and fibrotic resulting in the finger locking in flexion. Alternatively there may be some swelling and inflammation of the underlying flexor tendons. If there are multiple fixed contractures, the diagnosis may be different, e.g., late sequelae of compartment syndrome or stroke.

Treatment options are multiple. First, it does not cause flexor tendon rupture, and for some patients, once reassured, they will not want any intervention. Steroid injection into the tendon sheath at the level of the A1 pulley has a success rate varying from 50% to 80%. The patient should be informed prior to injection that the accompanying anesthetic may cause a few hours of finger numbness due to the proximity of the digital nerves; for diabetic patients the steroid may cause a temporary elevation in blood sugar. If steroid injections fail to relieve the symptoms, then surgery with longitudinal transection of the A1 pulley, usually under local anesthesia, is appropriate. The most common complication is damage to the digital nerves especially in the thumb as in the thumb the digital nerves follow a slightly oblique course adjacent to the flexor mechanism compared to the parallel course in the

fingers. Early motion post-op is necessary, but postoperative therapy or narcotics are not. Recurrence is rare [13–15].

4.2.1.2 Dupuytren's Contracture Disease

The patient with Dupuytren's contracture is usually an older white male who presents with varying degrees of skin tightness, subcutaneous longitudinal chords, and contractures of the palmar fascia affecting the two ulnar digits more commonly than the radial. As the disease progresses (and progression can be extremely varied from not at all to severe), the patient will develop chords in the palmar fascia with subsequent contractures of the metacarpophalangeal and proximal interphalangeal joints.

There are a variety of classification symptoms, none of which are widely used making comparisons of disease stage and treatment outcomes difficult. The underlying pathology is a change in the fibroblasts in and around the palmar fascia resulting in subsequent banding, nodules, and chords. This shows up clinically as skin dimpling (Fig. 4.13) and changes the fascia into shortened longitudinal bands that in turn cause the contractures that typify the disease.

Treatment options include doing nothing but periodic observation, percutaneous needle fasciotomy, injection with collagenase (derived from clostridium), or open surgery excising the diseased fascia without damaging the digital nerves that are often displaced. Treatment in the future may change to some type of medicinal treatment as tamoxifen seems to decrease recurrence [16–18].

4.2.1.3 Swan Neck

The swan neck deformity is a hyperextension deformity of the PIP joint with a flexion deformity of the DIP joint of the fingers (Fig. 4.14). It can be the result of a hyperextension injury to the PIP joint, the consequence of cerebral palsy, traumatic brain injury, or rheumatoid arthritis.

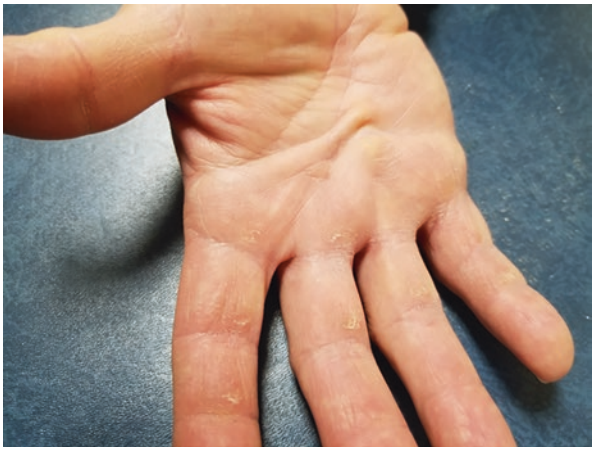

Fig. 4.13 Right hand of a 45-year-old man with a mild Dupuytren's disease. Note the dimpling of the skin in the distal palmar crease in line with the ring finger

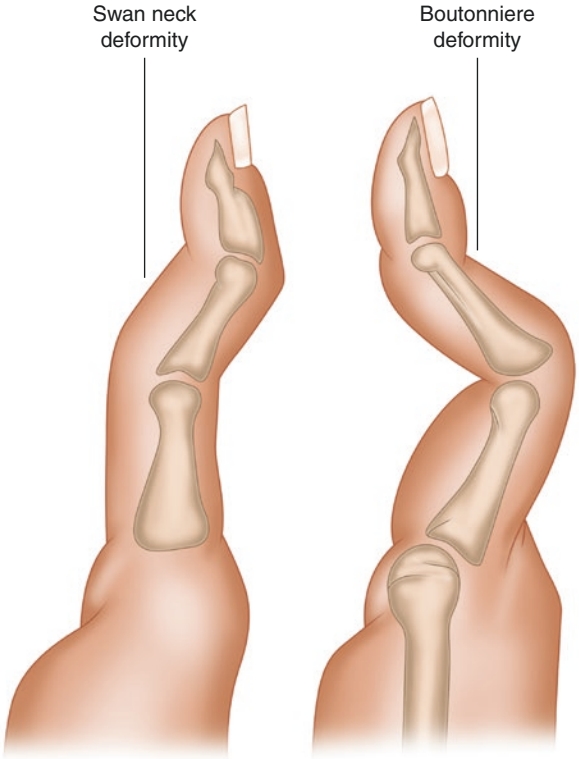

Fig. 4.14 Two common deformities of the finger that are opposites. Swan neck deformity is flexion of the DIP joint with extension of the PIP joint, while a boutonniere deformity is extension of the DIP joint and flexion of the PIP joint

Treatment takes into consideration the underlying disease, patient dysfunction, and expected level of recovery given the underlying disease. Options include doing nothing, splinting, and various surgical repairs. The latter includes tendon lengthening, tendon transfers, tendon releases, ligament repair and reconstruction, or arthrodesis of either the PIP or DIP joints or both [19, 20].

4.2.1.4 Boutonniere Deformity

Boutonniere deformity of the finger is hyperflexion of the PIP joint with extension or hyperextension of the DIP joint (Fig. 4.14). It is normally isolated to one finger after a traumatic injury to the central slip. Diagnosis is straightforward in patients who present late, but early diagnosis of central slip ruptures may require special examination. Performance of Elson's test is done by holding the PIP joint in 90° of flexion (a digital block may be necessary in acute injuries) and asking the patient to extend his DIP joint. Ability to do so indicates a positive test, and rupture of the central slip which when left untreated will lead to a chronic boutonniere deformity. Radiographs of the involved finger are appropriate.

The underlying pathology has to do with the way the extensor mechanism to the finger is constructed. While passing over the proximal phalanx, the extensor tendon divides into thirds with the central slip terminating on the dorsum of the middle

phalanx. The other two thirds – lateral bands – pass to the radial and ulnar aspects of the PIP joint and merge back together to attach to distal phalanx (see mallet finger). When the central slip is disrupted, the lateral bands slip volar to the axis of rotation of the PIP joint causing a flexion of the PIP joint when active extension is attempted.

Like the mallet finger, treatment is straightforward and nonoperative when diagnosed early. A splint that holds the PIP joint in extension while allowing free motion of both the MCP and DIP joints will work. Although there are prefabricated splints that work, the AP should not be surprised if a custom splint made by a hand therapist is necessary. Splinting time is 6–8 weeks. Late surgical repair is possible but usually results in some degree of loss of motion [19].

4.2.1.5 Gamekeeper's Thumb/Skier's Thumb

Stability of the thumb's metacarpophalangeal joint depends in large part on the ulnar collateral ligament. Both eponyms refer to injury to the UCL of the metacarpophalangeal joint, and both are the result of an abduction force to the MCP joint of the thumb. The difference is the "gamekeeper's" thumb is a repetitive stress injury that results in attenuation of the UCL over a long period of time, whereas the "skier's" thumb is a result of a onetime forceful injury.

For an acute injury, a clinical exam will show tenderness over the ulnar aspect of the MCP joint of the thumb with varying amounts of swelling and bruising. Stress testing will show a side-to-side difference with grade I and II injuries having some laxity but a solid end point. Grade III injuries have a "soft" end point. The best position to assess stability is with the MCP joint flexed to 30–40 degrees. A small amount of local anesthesia may be necessary for pain relief to allow adequate testing.

Radiographs may reveal an avulsion fracture of varying size at the ulnar base of the proximal phalanx which may or may not be displaced.

Grade I and II lesions can be treated with splinting, whereas grade III lesions generally need operative repair to ensure long-term stability. The repair may involve soft tissue repair only, fixation of the avulsed bony fragment, or some type of drill holes or suture anchor fixation to repair avulsed soft tissue. A term the AP may hear with regard to an acute injury to the UCL of the thumb is a Stener lesion. This refers to a complete avulsion of the UCL's attachment to the proximal phalanx that has displaced such that the adductor pollicis's aponeurosis is interposed between the UCL and bone. This obviously prevents proper healing even with immobilization and thus the need for surgical repair.

Postoperative immobilization typically lasts 4–8 weeks, but the patient should be warned the repair may be sore for up to 1 year.

Since gamekeepers' thumbs are chronic injuries with attenuation and atrophy of the UCL, direct repair of the ligament may not be possible. This will mean some type of tendon graft is necessary. Again, postoperative immobilization of the MCP joint for 6–10 weeks may be necessary. If the joint has been unstable long enough to develop osteoarthritis, then arthrodesis should be considered [21].

4.2.1.6 Carpal Tunnel Syndrome (CTS)

Patients with carpal tunnel syndrome are typically middle-aged and present with a variety of symptoms including hand numbness in the median nerve distribution; dropping things, especially in the morning; increased symptomatology with prolonged driving; and waking at night with hand numbness or paresthesias. The latter is often relieved by shaking the hand or washing it. The patient may think it is work-related, but except for occupations with high vibrational activity and prolonged extreme wrist flexion, the relationship of occupational exposure and development of carpal tunnel syndrome is controversial. Patients who have diabetes or hypothyroidism, are obese, or are pregnant all have a higher incidence of carpal tunnel syndrome (as well as other compression neuropathies). Physical exam includes various sensory testing from light touch, vibration, and two-point discrimination. The latter worsens in more advanced cases. Semmes-Weinstein filaments are also used. Thenar atrophy is a sign of advanced CTS. Tinel's sign (tapping on the nerve at or just proximal to the site of compression) is useful if it reproduces tingling in the area of median nerve distribution. Likewise, a Phalen's test or a reverse Phalen's test (90° of wrist flexion or extension, respectively) held for 1 minute that reproduces the symptoms is considered positive for CTS. Unfortunately, no clinical test is 100% specific and sensitive.

Radiographs and other imaging are not necessary unless there is suspicion of additional pathology such as CMC arthritis of the thumb. The most frequently ordered tests are electromyograms (EMG) and nerve conduction studies (NCS). The former measures the activity of the muscle, while the latter measures nerve function and speed. The diagnosis should be made in the context of both the clinical picture and the EMG/NCS. Patients can have CTS yet have a normal EMG and NCS. The converse is also true; a patient can have positive electrical testing for CTS with no clinical signs or symptoms.

The underlying pathology of carpal tunnel syndrome is the compression of the median nerve in the carpal tunnel which also allows passage of the four flexor tendons of the flexor digitorum profundus, the four flexor tendons of the flexor digitorum superficialis, and the flexor pollicis longus. The exact cause of increased compression is unclear but may be related to subtle changes in the cross-sectional area of the carpal tunnel or alteration of blood flow.

Treatment options are limited. Splinting the wrist in the neutral position helps some patients, but because the functional position of the wrist is in extension, splinting is usually only tolerated at night. For early cases, steroid injection may help, but the risk of injury to the median nerve from an intraneural injection is high enough that most surgeons opt for surgical treatment. Surgery can be done open through a 2–4 cm curvilinear incision at the base of the palm or endoscopically through a 1–2 cm transverse incision just proximal to the wrist, depending on surgeon preference. Early (2–7 days) postoperative mobilization is encouraged with gentle massage on either side of the incision to reduce the incidence of pillar pain. Once the stitches are removed, massage of the scar is allowed. Possible complications include nerve damage, pillar pain, scar sensitivity, and loss of grip strength. Pillar pain is

pain in either the hypothenar or thenar eminence or both that is normally self-limited albeit annoying. In advanced cases there may not be full return of motor or sensory function or both [22–25].

4.2.1.7 Cubital Tunnel

Cubital tunnel syndrome is the second most common compression neuropathy and presents as numbness in the ulnar two digits and weak grip strength. In late cases there may be atrophy of the ulnarly innervated intrinsic muscles of the hand; this is most obvious in the adductor pollicis. Patients may complain of worsening of the symptoms when talking on the phone while holding their elbow flexed. The symptoms may be recreated or worsened on physical examination with prolonged elbow flexion (i.e., elbow flexion test). Tinel's testing at the elbow may cause tingling in the ulnar two digits. Radiographs are not usually necessary unless there is loss of motion. EMG/NCS are helpful in definitive diagnosis as well as ruling out compression of the ulnar nerve at the wrist or a C8 radiculopathy. There is a high incidence of normal electrical testing even in clinically obvious cases of cubital tunnel syndrome.

The underlying pathology is compression of the ulnar nerve as it passes around the posteromedial aspect of the elbow. There are several possible sites of compression including the arcade of Struthers above the elbow, the cubital tunnel itself, and the fascia overlying the two heads of the flexor carpi ulnaris (Fig. 4.15).

Initial treatment is aimed at avoiding tension and compression of the ulnar nerve. The former is done by extension splinting of the elbow, usually at night, for 6–12 weeks. The latter is done by use of elbow pads and avoidance of resting the medial elbow on armchairs, etc. If this proves unsuccessful, operative treatment is indicated. This consists of releasing the ulnar nerve from compression at the above-mentioned sites. Transfer of the nerve anterior to the medial epicondyle can be done submuscularly, subfascially, or subcutaneously if the nerve is unstable after release. No one method has proven superior to date. Some surgeons opt to transfer the nerve

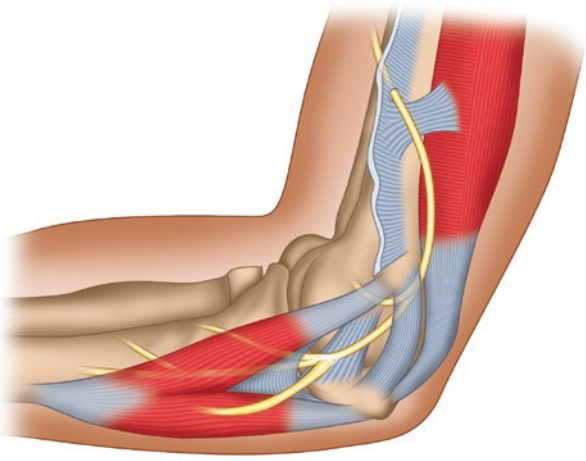

Fig. 4.15 Various possible sites of compression of the ulnar nerve as it passes around the posteromedial aspect of the elbow. These include from proximal to distal the arcade of Struthers, the cubital tunnel itself, and the fascia between the two heads of the flexor carpi ulnaris

regardless of stability thinking that it reduces the tension when the elbow is flexed. Postoperative immobilization is from several days to several weeks, depending on the specifics of the operation and surgeon preference [26].

4.2.1.8 De Quervain's Disease (Tenosynovitis)

The typical patient with De Quervain's disease is a middle-aged woman (40–60 years old) who presents with radial wrist pain exacerbated by grasping. Physical exam shows tenderness along the first dorsal compartment of the wrist which contains the extensor pollicis brevis and the abductor pollicis longus. In addition, the Finkelstein's test is positive: the thumb is placed inside the fingers and then the patient makes a fist; the wrist is then passively ulnarly deviated. Recreation of the symptoms is a positive test.

Radiographs are necessary to rule out other causes of radial wrist pain such as carpometacarpal arthritis of the thumb and old scaphoid injuries. Other imaging is not usually necessary.

The underlying pathology may be the same as that of trigger fingers. The fibro-osseous sheath through which the tendons pass becomes "tight" causing pain when the thumb moves.

Treatment includes splinting, injections, and surgical release. For the most part, splinting (thumb spica splint) has a high failure rate, but for acute cases and patients who do not want an injection nor surgery, it is an option. Injection is a combination of steroid and local anesthetic injected into the tendon sheath. Because of the thin skin and superficial aspect of the tendon sheath, depigmentation and local skin reactions are not unusual.

Surgical release can be done under local or regional anesthesia with an incision over the first dorsal compartment of the wrist. After retracting the superficial branches of the radial nerve (sensory), the fibrous tissue around the tendons is incised. Care is taken to make sure each slip of each tendon is released as there can be multiple "tunnels" and multiple slips of tendon (up to four or five) in the first dorsal compartment.

Postoperatively a soft dressing is applied, and the patient is instructed to use the thumb as tolerated. The two most common complications are incomplete release (often due to incomplete visualization of all the slips) and damage to the radial nerve (transection, traction, or getting caught in the suture used to close the wound) [27, 28].

4.2.2 Hand Infections

Although cases of cellulitis are treated with either intravenous or oral antibiotics, many hand infections will require some type of surgical drainage, either under digital block, a local field block, or general anesthesia. Particular points to obtain in the history include when and where any skin penetration occurred (e.g., cat bite or did the patient cut his hand when punching someone in the mouth). Underlying diseases that may interfere with resolution of the infection such as diabetes, smoking, and

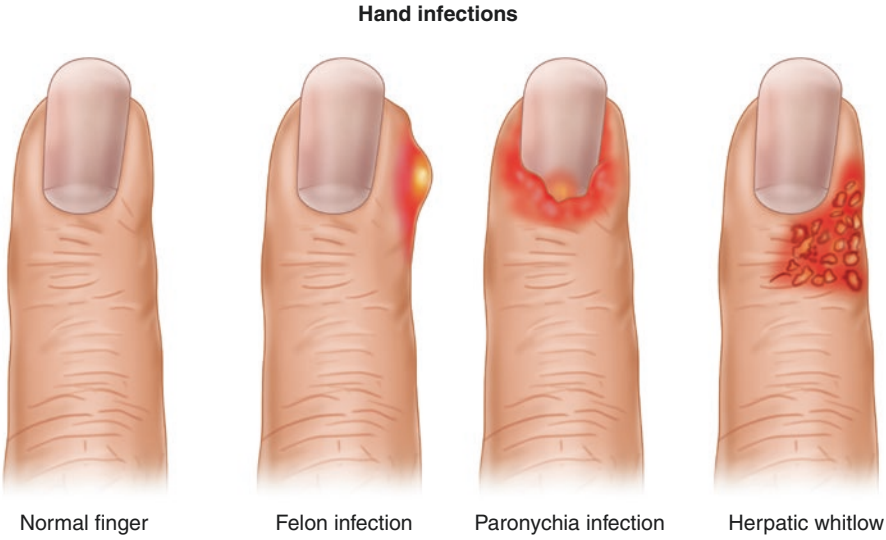

Fig. 4.16 Various fingertip infections. Both the paronychia and felon almost always require some type of drainage, whereas surgical treatment of herpetic whitlow should be avoided

autoimmune problems should be inquired about as well as status of tetanus immunization. Specific reactions to any antibiotics given in the past should be elicited (Fig. 4.16).

4.2.2.1 Felons

A felon is an infection of the pulp of the distal phalanx frequently after a puncture wound (Fig. 4.16). After ensuring the patient's tetanus is up to date, a digital block is performed. A 1 cm stab incision is made laterally. The ulnar side of the fingers and radial side of the thumb are preferred to decrease scar sensitivity. The soft tissue is spread using a hemostat. A drain is placed, appropriate antibiotics are given, and the drain is removed 24–48 hours later. Care should be taken to differentiate felons from flexor tenosynovitis. Care should also be taken when draining a felon not to contaminate the flexor sheath.

4.2.2.2 Paronychia

A paronychia is an infection of the skin at the base of the nail bed (Fig. 4.16). There may be no precipitating event or only trivial trauma such as nail biting or a manicure.

If it extends along the lateral border of the nail, it is known as an eponychia. When caught early, warm soaks and antibiotics will often resolve the infection. If treated late or if it does not respond to nonoperative treatment, then surgical drainage will be required. This is done under a digital block, and the infected skin at the edges of the nail is elevated or incised as necessary. If the infection extends below the nail into the nail bed, then the nail may have to be removed. Postoperatively the drain is removed at 2–3 days, and antibiotics are given for 7–10 days. The most

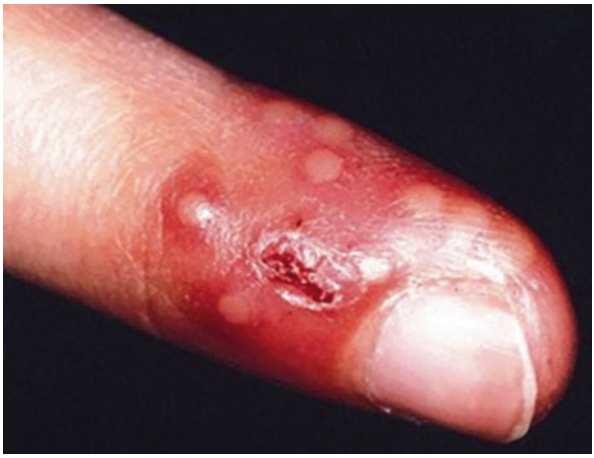

Fig. 4.17 Patient with herpetic whitlow from https://link.springer.com/article/10.1007/s15010-014-0667-4

common short-term complication is failure of the infection to resolve due to inadequate drainage or inappropriate antibiotics. Chronic osteomyelitis of the distal phalanx is possible but rare. The most common long-term complication is nail bed deformity [29].

4.2.2.3 Herpetic Whitlow

Herpetic whitlow is the result of infection of the skin, or the fingers as a result of herpes simplex virus (type 1 or 2) (Fig. 4.17). It is frequently mistaken for a felon or paronychia.

It was common in the dental profession prior to universal gloving. Treatment is nonsurgical with support and reassurance. The clinician should ensure that the patient does not spread the disease. Surgery should be avoided as it may make the infection worse. Finally, the recurrence rate is as high as 20% in immunocompromised patients.

4.2.2.4 Metacarpophalangeal Joint Infections

Any laceration over the dorsum of the metacarpophalangeal joint should be assumed to have resulted in bacterial inoculation of the underlying joint. Because of the mobility of the skin over the dorsum of the hand, the laceration may appear remote from the MCP joint. Like other infections, if caught early, antibiotics alone may suffice. However, these patients usually present late necessitating surgical drainage in the operating room. Another cause of a benign-appearing skin injury with underlying MCP, PIP, or DIP infection is a cat bite. Again, surgical drainage and coverage with appropriate antibiotics (especially against *Pasteurella multocida*) will be necessary.

4.2.2.5 Flexor Tenosynovitis Infection

Patients with flexor tenosynovitis of the hand or fingers present 1–3 days after a penetrating injury to the flexor sheath with pain in the affected finger, and some

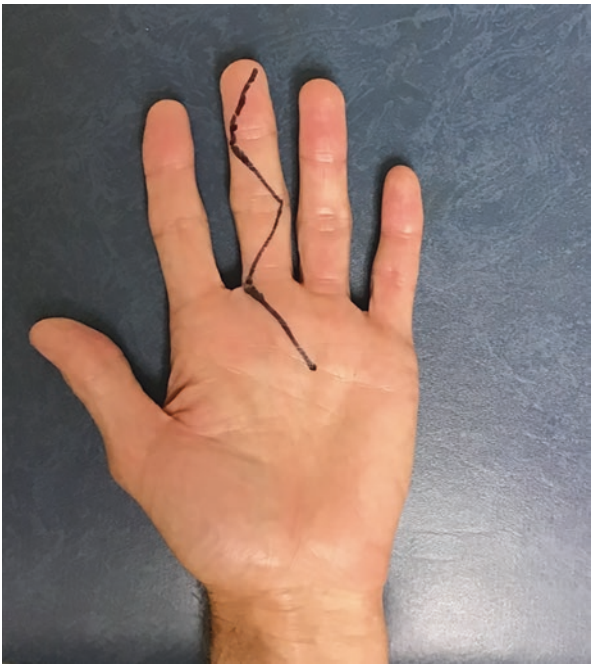

Fig. 4.18 One surgical approach for irrigation and debridement of a flexor sheath infection or high-pressure injection injury. If caught early some flexor sheath infections can be treated with smaller incisions and irrigating with a small catheter

combination of Kanavel's signs listed in the table below. Unless caught extremely early, surgical drainage will be required which can be done by wide surgical incision (Fig. 4.18) or done with several smaller incisions and a small catheter inserted through the flexor sheath. The method depends on surgeon preference, infectious organism, as well as the extent and severity of the infection. Frequently a second or third trip to the operating room will be required.

Four signs of infected flexor tendon sheath of the hand are:

1. Holding the finger mildly flexed.
2. Swelling of the involved digits.
3. Tenderness along the course of the flexor tendon.
4. Marked pain on passive stretch into extension.

Postoperatively the patient should expect it to take 6–12 months to obtain full motion and for the swelling to completely resolve [30–32].

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The Elbow and Forearm

5

5.1 Elbow Fractures and Dislocations

Most elbow trauma results from either a fall directly on the elbow or a fall on an outstretched hand with the forearm in various degrees of pronation or supination, and the elbow in various degrees of flexion. Most patients will not remember the exact position but will describe what they were doing when they fell. Certain fractures and fracture/dislocations have a predilection for age groups, and there are a number of eponyms associated with elbow injuries. With all these injuries, it is important to document the neurovascular status before and after reducing them, operating on them, or just applying a splint.

5.1.1 Supracondylar Fractures in Children

Like most upper limb fractures, supracondylar distal humerus fractures of the elbow result from a fall on an outstretched limb. The child, usually less than 8 years old, presents after a fall with pain and, depending on the severity, some degree of deformity of the elbow. A careful neuromuscular exam (see below) and examination for other injuries is followed by radiographs of the elbow (Figs. 5.1 and 5.2). Good orthogonal views may be difficult to obtain due to pain and anxiety such that definitive films for displaced fractures may have to wait until the patient is in the operating room under general anesthesia. Supracondylar fracture can be difficult to diagnose especially in younger children before all the epiphyses have ossified. If in doubt contralateral elbow films, taken at the same angle, can be helpful as can a CT scan although the latter is rarely needed.

Most (>95%) of supracondylar elbow fractures are the result of a hyperextension injury to the elbow or a forced extension of the distal humerus from the coronoid process and radial head impacting on the distal humerus.

J. A. Gracy, *Orthopedics for Physician Assistant and Nurse Practitioner Students*, https://doi.org/10.1007/978-3-031-04406-9_5

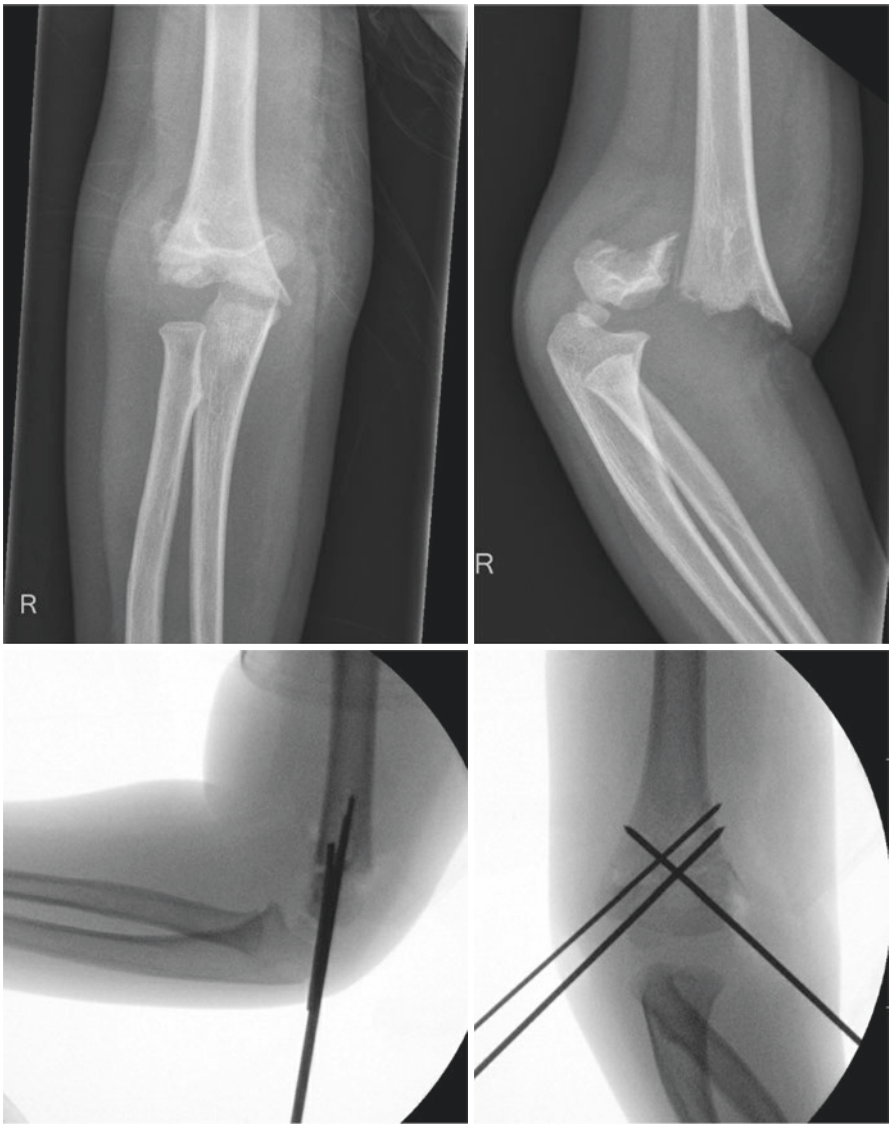

Fig. 5.1 Markedly displaced supracondylar elbow fracture in a child. The medial pin was added because of the marked instability of the fracture despite the risk to the nearby ulnar nerve. (Courtesy of Medical College of Georgia, Department of Orthopedics)

There are four significant complications to make sure the patient does not have nor develop. The first is damage to the radial or median nerve, especially the anterior interosseous branch which is a branch of the median nerve that innervates the flexor pollicis longus and the flexor digitorum profundus to the index finger. The second is vascular compromise which is often relieved after reduction; nonetheless,

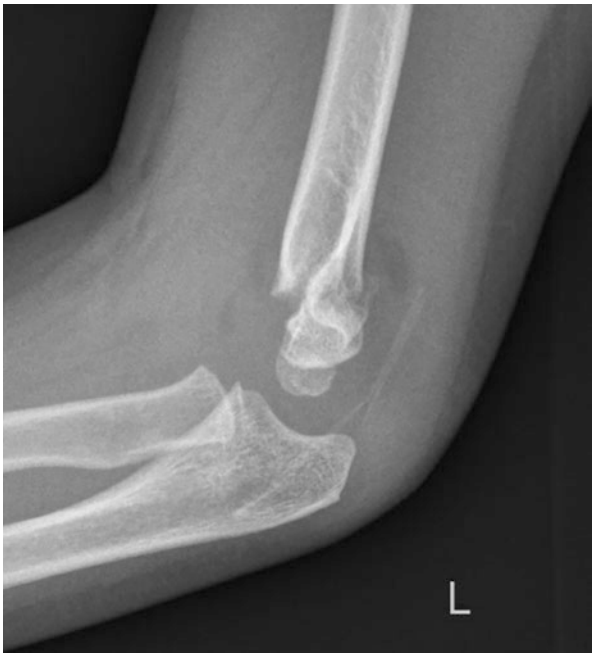

Fig. 5.2 Another supracondylar fracture. Note that on this lateral view, the anterior cortex of the humeral shaft does not intersect the capitellum. It should, so this patient was taken to the operating room for reduction and pinning. (Courtesy of Medical College of Georgia, Department of Orthopedics)

the clinician should be prepared for exploration of the brachial artery which can be trapped in the fracture site. The third is compartment syndrome which was more common when the elbow was immobilized in hyperflexion. It is less common now as the elbow is usually immobilized in 60–80° of flexion. Fourth and finally, malunion with a resulting cubitus varus deformity can occur (Fig. 5.3). This can be a result of poor reduction or damage to the medial column of the growth plate. In contrast a lateral condyle fracture can result in a cubitus valgus deformity which may result in a delayed-onset ulnar nerve palsy.

Treatment depends on the degree of displacement or angulation. For nondisplaced or minimally angulated fractures, a long-arm splint or long-arm cast for 3–4 weeks is appropriate with early (2–4 days) repeat radiographs to ensure the amount of displacement does not worsen. For fractures that are displaced, closed reduction followed by percutaneous pinning is the treatment of choice. For the displaced but neurovascular intact fracture, urgent (e.g., next morning) surgery is appropriate. Most supracondylar elbow fractures in children can be treated with closed reduction and percutaneous pinning under fluoroscopic control. The current thinking is to use two diverging pins placed laterally. Sometimes crossed pins are necessary, but a medial pin puts the ulnar nerve at risk. Postoperatively a long-arm splint or cast in 60–80° of flexion is placed for 3–4 weeks, and then the pins are removed in the office. Pulseless forearms are a surgical emergency and should be reduced promptly under general anesthesia with preparation made to explore the antecubital fossa if the pulse does not return after a closed reduction [1–4].

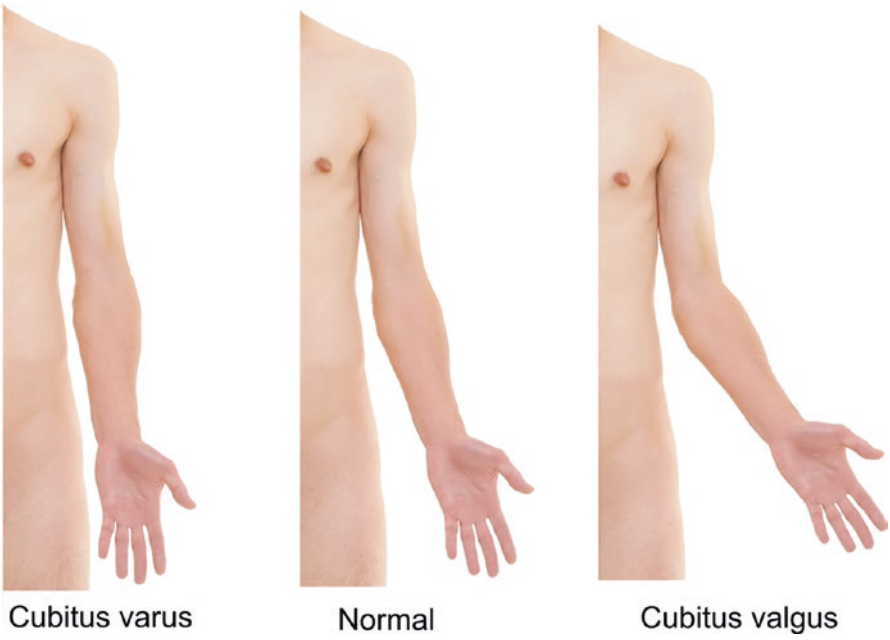

Fig. 5.3 The two elbow deformities that can result from malunion of a distal humerus fracture. (By Mikael Häggström. When using this image in external works, it may be cited as Häggström [33]. ISSN 2002-4436. Public Domain or By Mikael Häggström, used with permission. Own work, using File:Anterior view of human male, retouched.jpg, CC0, https://commons.wikimedia.org/w/index.php?curid=20760698)

5.1.2 Supracondylar Elbow Fractures in Adults

Like other adult fractures, supracondylar humerus fractures present in two distinct groups; one is the high-energy injury in the young adult, while the other is the low-energy fragility fracture in the elderly. In addition to searching for other injuries in the young patient and comorbidities in the elderly, a careful neurovascular exam is important to document especially of the ulnar and radial nerve. Unlike children's supracondylar fractures, in adults it can be difficult to determine the fracture pattern as they are often T-shaped and markedly displaced. Traction may need to be applied under anesthesia with radiographs at that time showing the fracture pattern. Some fractures may require a preoperative CT scan, but that is not usually the case.

Except for minimally displaced fractures, which can be treated with casting, most supracondylar fractures in adults will require open reduction and internal fixation (Fig. 5.4). Percutaneous pinning may provide temporary stability while other more serious injuries are addressed, but mere pins will not provide sufficient stability in adults to allow the fracture to heal. Positioning for surgery is prone or lateral decubitus while ensuring the C-arm has access. The approach is posterior with a triceps splitting, triceps peel, or an olecranon osteotomy being necessary to obtain

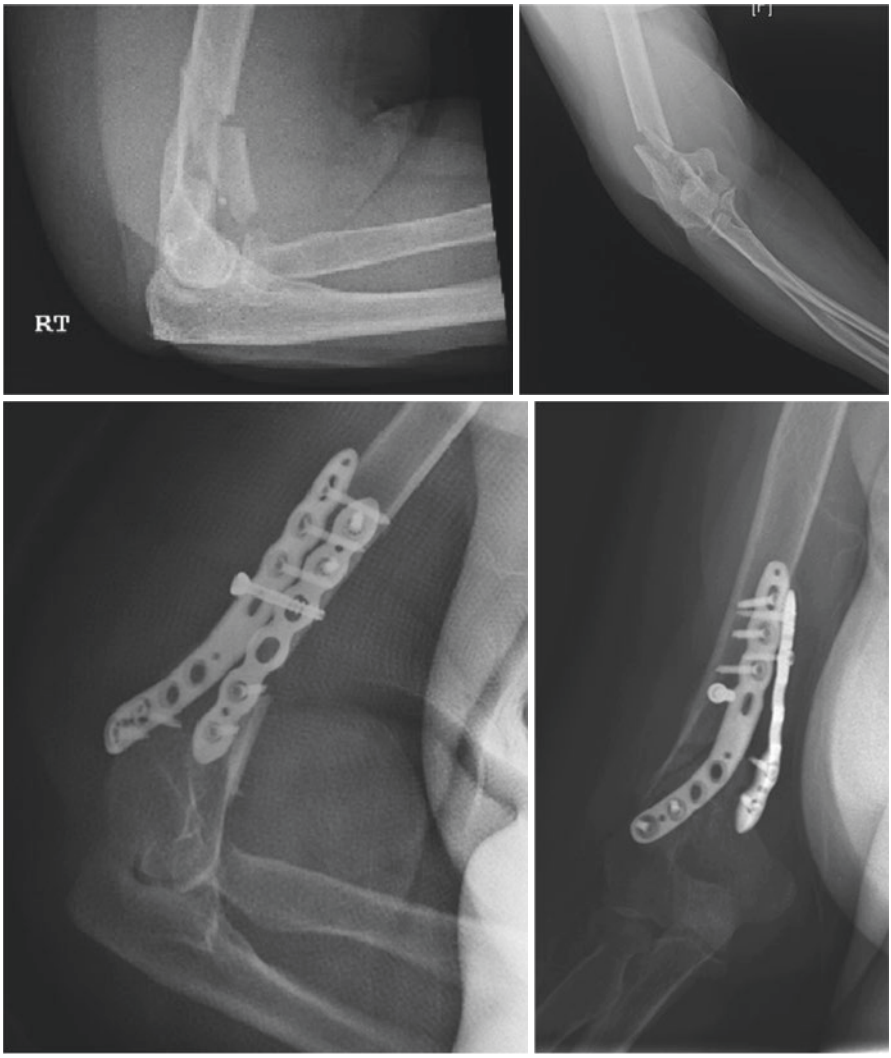

Fig. 5.4 Pre- and postoperative films of a supracondylar fracture in a 55-year-old female who fell in the parking lot

access to the fracture. These fractures require a wide variety of implants with K-wires used for provisional fixation, variously sized isolated screws for smaller fragments, and plates and screws for the larger. Rarely, in elderly, low-demand patients in which the fracture is not "fixable," a total elbow arthroplasty may be necessary. Depending on the fracture pattern, an ulnar nerve transposition is often performed.

Postoperatively, if fracture stability allows, early passive range of motion is started with active extension timing being dependent on the surgical approach. The

patient should strive for full motion, but the expectation is that the range of motion will be about 20–120°. There is also a loss of strength in both flexion and extension of about 20%. Complications include damage to the ulnar or radial nerves, nonunion (with subsequent fixation failure) and the stiffness mentioned above [5, 6].

5.1.3 Monteggia Fracture/Dislocation

A subcategory of an olecranon or proximal ulnar shaft fracture is when there is an associated radial head dislocation (Fig. 5.5). This can occur in both children and adults. The easiest way to verify that this injury is not missed is to ensure that on all views of the forearm or elbow, the radial head and neck are pointed at the capitellum of the distal humerus.

Once noted, treatment is open reduction and internal fixation of the ulna fracture which allows reduction of the radial head dislocation. It may be necessary to hold the forearm in supination or pronation (depending on the direction of the radial dislocation) for 4–6 weeks to allow soft tissue healing and subsequent stability of the elbow. Treatment of a Monteggia fracture/dislocation diagnosed late (i.e., nonunion or malunion of the ulna fracture with soft tissue contractures) is beyond the scope of this book [7, 8].

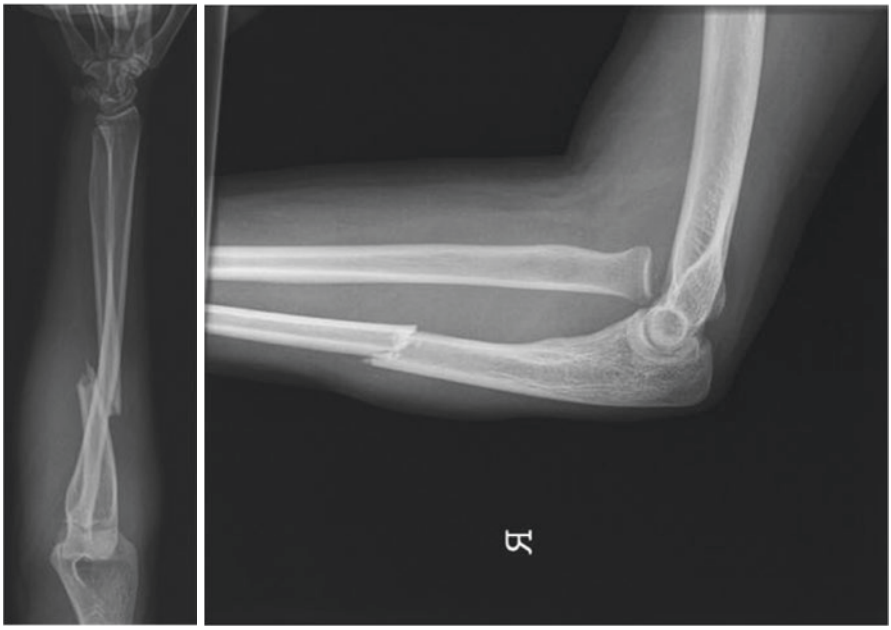

Fig. 5.5 Radiograph of a fracture/dislocation known as Monteggia lesion. The ulnar fracture can be either in the proximal shaft of the ulna or be an intra-articular fracture of the olecranon. The associated radial head dislocation can be anterior or posterior to the distal humerus from https://link.springer.com/chapter/10.1007/978-3-319-66857-4_20

5.1.4 Olecranon Fractures

Olecranon fractures are the result of direct trauma or occasionally an eccentric contraction of the elbow in patients with osteoporotic bone.

For non-displaced fractures casting or splinting in mild extension will work for most patients, but careful follow-up is necessary to ensure displacement with subsequent loss of active extension of the elbow does not occur. Most olecranon fractures will require ORIF with careful attention paid to restoring joint congruity. The most common method is a longitudinal screw with or without a tension band wire (Figs. 5.6 and 5.7). For osteoporotic bone a washer to decrease contact pressure and reduce the chance of metal cutout may be necessary. Some fractures may require a plate and screws to ensure anatomic reduction and stability [9, 10].

5.1.5 Essex-Lopresti Lesions

Another named fracture/dislocation is the Essex-Lopresti fracture/dislocation. In this case it involves a fracture of the radial head or neck with a dislocation of the distal radioulnar joint (Fig. 5.8). This injury is often missed because of the pain at the radial head or neck fracture. The proximal migration of the radius (due to disruption of the interosseous membrane) causes the distal ulna to impinge on the carpus resulting in loss of rotation of the forearm. Like the Monteggia fracture/dislocation, early identification of the complete injury makes treatment much easier. This is accomplished by forearm films to include the wrist and distal radioulnar

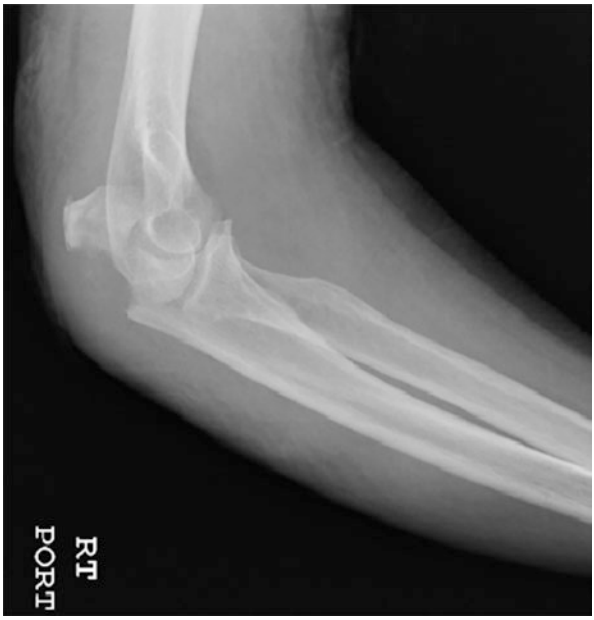

Fig. 5.6 Note that this is just an olecranon fracture, not a Monteggia fracture/dislocation. The radial head and neck are pointed directly at the capitellum as they should be no matter the angle of the radiograph

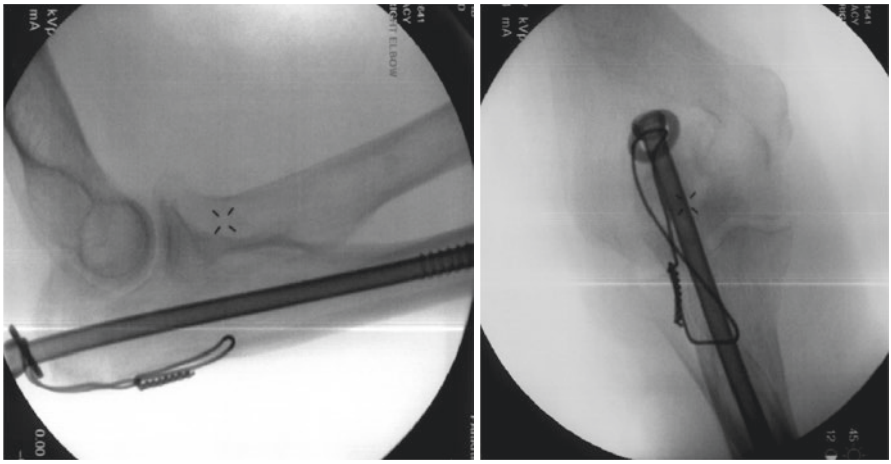

Fig. 5.7 Longitudinal screw placement with tension band wire fixing the olecranon fracture. The washer is present to spread out the pressure of the screw head as the bone was osteoporotic

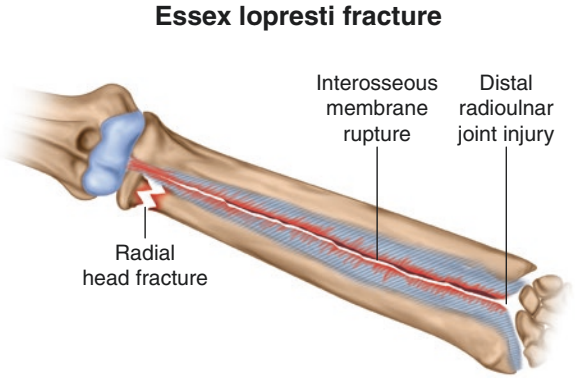

Fig. 5.8 With any radial head or neck fracture, the AP should at a minimum examine the wrist, and if there is any suspicion of a Essex-Lopresti lesion, then wrist or forearm radiographs should be made to rule out a distal radioulnar joint subluxation or dislocation, often evident by the ulnar head impacting the carpal bones

joint as well as physical exam to ensure stability of the distal radioulnar joint. The AP should keep in mind that this particular injury is a result of relative shortening of the radius after a radial head or neck fracture, so consideration should be given to placing a radial head prosthesis if any radial head or neck fracture is excised due to excessive comminution [11].

5.1.6 Radial Head and Neck Fractures

Radial head and neck fractures most often result, like other wrist, forearm, and elbow injuries, from a fall on an outstretched hand. For the radial head fracture, if there is minimal displacement, then sling and early motion are the appropriate

treatments. For displaced fractures (usually defined as greater than 2 mm of articular discontinuity) and if 1/3–1/2 of the joint surface is involved, ORIF with a mini-fragment set may be optimal in the right patient. For comminuted fractures nonoperative treatment and radial head replacement are both options depending on the patient's age and activity level. Care should be taken not to miss the Essex-Lopresti lesion mentioned above [12, 13].

5.1.7 Elbow Dislocations

Most elbow dislocations are the result of a fall on an outstretched arm and present to the emergency room acutely with obvious deformity. The olecranon is usually located straight posterior to the distal humerus, but the dislocation can be posterolateral or posteromedial (Fig. 5.9). Dislocations posteromedially are rare.

After checking the neurovascular status (especially the ulnar nerve), closed reduction under IV sedation with longitudinal traction and flexion is preferred. Biplanar radiographs after reduction are necessary to ensure there is no residual medial or lateral subluxation as well as to check for previously undetected fractures. Immobilization for a period of no more than 10 days is appropriate. Longer periods of immobilization can lead to a marked loss of motion. Long-term sequelae of elbow dislocation include loss of terminal extension, valgus instability, and pain when throwing.

Not all elbow dislocations however are stable after reduction. Those with coronoid fractures of the ulna or radial head fractures should be viewed with suspicion for the "terrible triad" of instability which includes the aforementioned structures as well as the lateral collateral ligament. To provide a stable elbow, surgical repair of the involved structures may be necessary. Preoperative CT scan to evaluate the extent of the coronoid fracture can be helpful, and fluoroscopy in the operating room to assess stability as the repair progresses is mandatory.

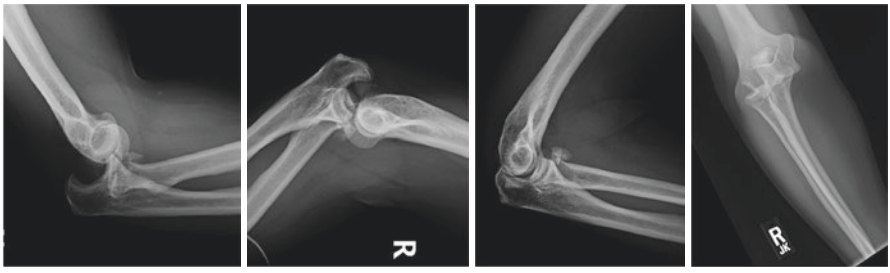

Fig. 5.9 Posterior elbow dislocation as well as post-reduction films. In the first three images, there is the fracture fragment visible just above the radial head that may be off the coronoid process indicating possible instability

5.1.8 Radial Head Subluxation "Nursemaid Elbow"

The typical patient with radial head subluxation is 2–3 years old, and the injury is a result of either snatching a child up by the hand with subsequent unexpected extension of the elbow or swinging a child around too forcefully while holding on to one or both hands. The child presents the elbow flexed about 30° and with the forearm pronated and will not actively move the elbow. The child is typically in mild distress but not as severe as one would expect if there was a fracture.

Treatment is often inadvertently accomplished by the radiology technologist when positioning the elbow for radiographs. To reduce the subluxation, the arm (distal humerus) is held still, the forearm supinated, and the elbow flexed. Frequently a click is felt or heard in the elbow with immediate relief of the child's distress. If there has been a prolonged period before treatment, relief may not be as obvious. Rarely, overnight splinting of the elbow in supination and 90 degrees of flexion is necessary. The parents can remove the splint the next day. No significant follow-up is necessary.

5.2 Forearm Fractures

This section will deal only with fractures of the shaft of either the radius, ulna, or both but will not discuss injuries with associated dislocations.

5.2.1 Radial Shaft Fractures

Isolated radial shaft fractures may be tempting to treat closed, and indeed a few nondisplaced, non-angulated radial shaft fractures can be treated with cast immobilization. The anatomy of the radial shaft is not a straight line; rather the radius has a gentle curve that allows full pronation and supination of the forearm (Fig. 5.10). This necessitates open and internal fixation which can be done through a volar or dorsal approach depending on fracture location and surgeon preference (Fig. 5.11). A few fractures may be amenable to intramedullary rodding. Intraoperative fluoroscopy is helpful.

Postoperative immobilization may or may not be appropriate depending on fixation stability and patient cooperation.

5.2.2 Ulnar Shaft Fractures

Isolated ulnar shaft fractures, as the eponym of nightstick fractures suggests, frequently result from raising the forearm to protect from an overhead blow. When the fracture is minimally displaced in the distal 2/3 of the shaft, it can usually be treated with immobilization. In the proximal third, open reduction and internal fixation is more frequently needed. As with any ulnar shaft fracture, the distal radioulnar joint

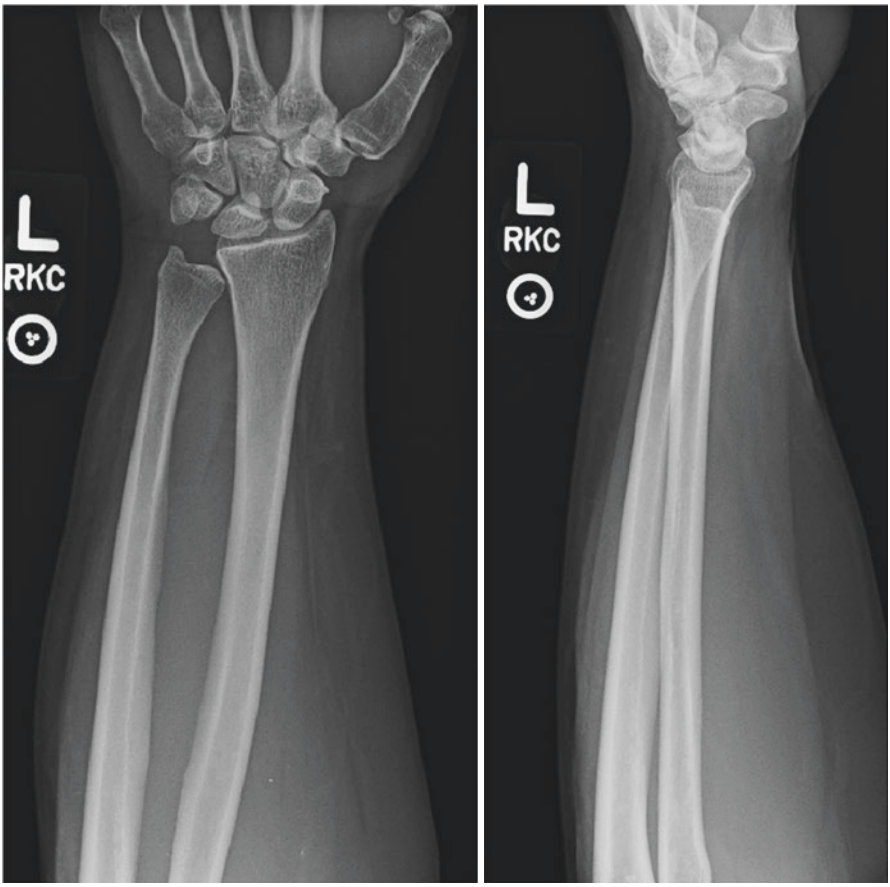

Fig. 5.10 Normal forearm with an AP and lateral view. Note the radius has a gentle curve allowing for the normal supination/pronation of the forearm. Also note that the complete forearm is not visualized; i.e., one cannot see the radial head nor olecranon

must be examined carefully as should the radiohumeral joint (Fig. 5.12). Normal pronation/supination is usually regained without difficulty.

5.2.3 Two-Bone Forearm Fractures

When both the radial and ulnar shafts are fractured, open reduction and internal fixation is almost always required in order to restore the proper anatomy and regain maximal motion. Two incisions are normally required, one for each bone. The usual approach is to expose both fractures and then reduce both fractures before applying the plates and screws (Fig. 5.13). Again, early motion is permitted depending on fixation stability and patient reliability. Despite anatomic healing of the fracture, there may be some loss of forearm rotation due to scarring of the soft tissues.

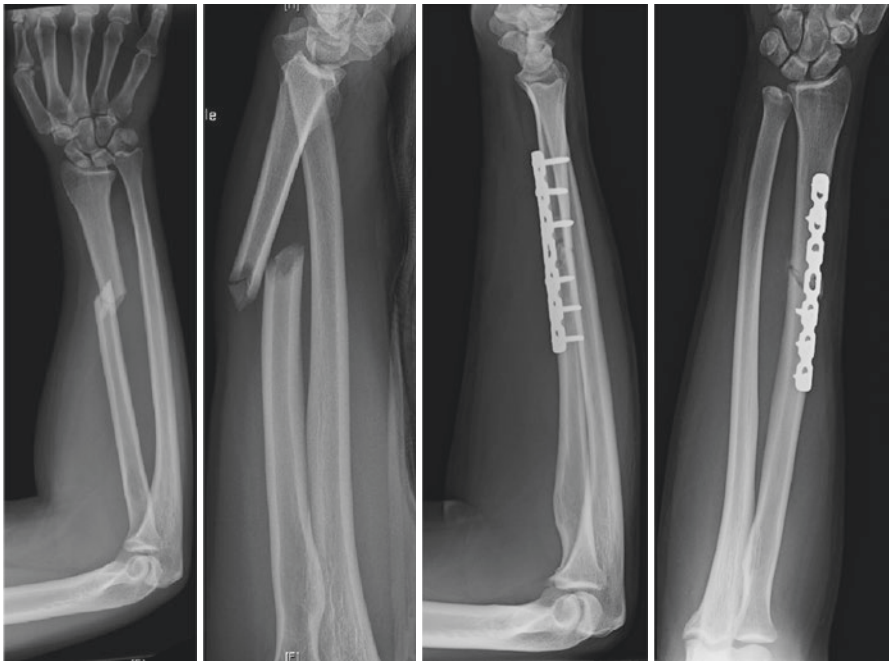

Fig. 5.11 Radial shaft fracture before and after open reduction and internal fixation

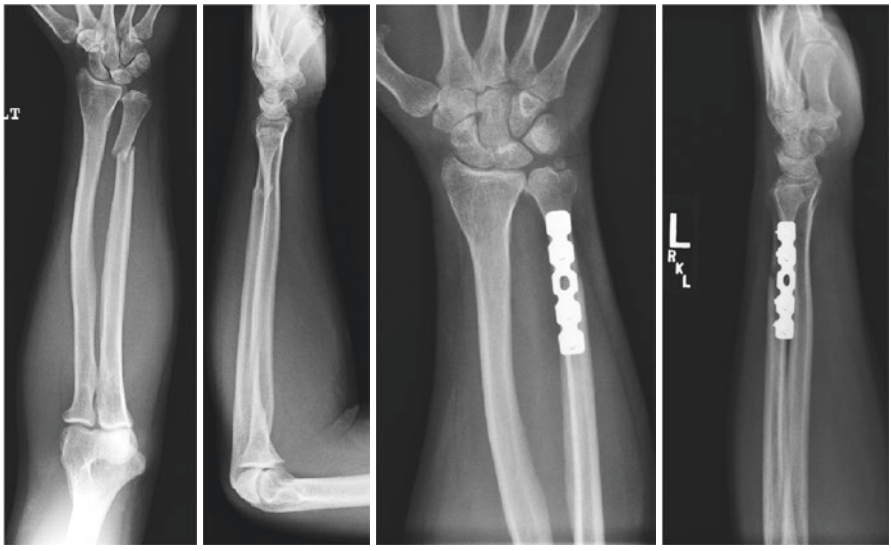

Fig. 5.12 Distal ulnar shaft fracture before and after open reduction and internal fixation. It was treated with ORIF rather than casting because of the instability of the distal radioulnar-carpal joint

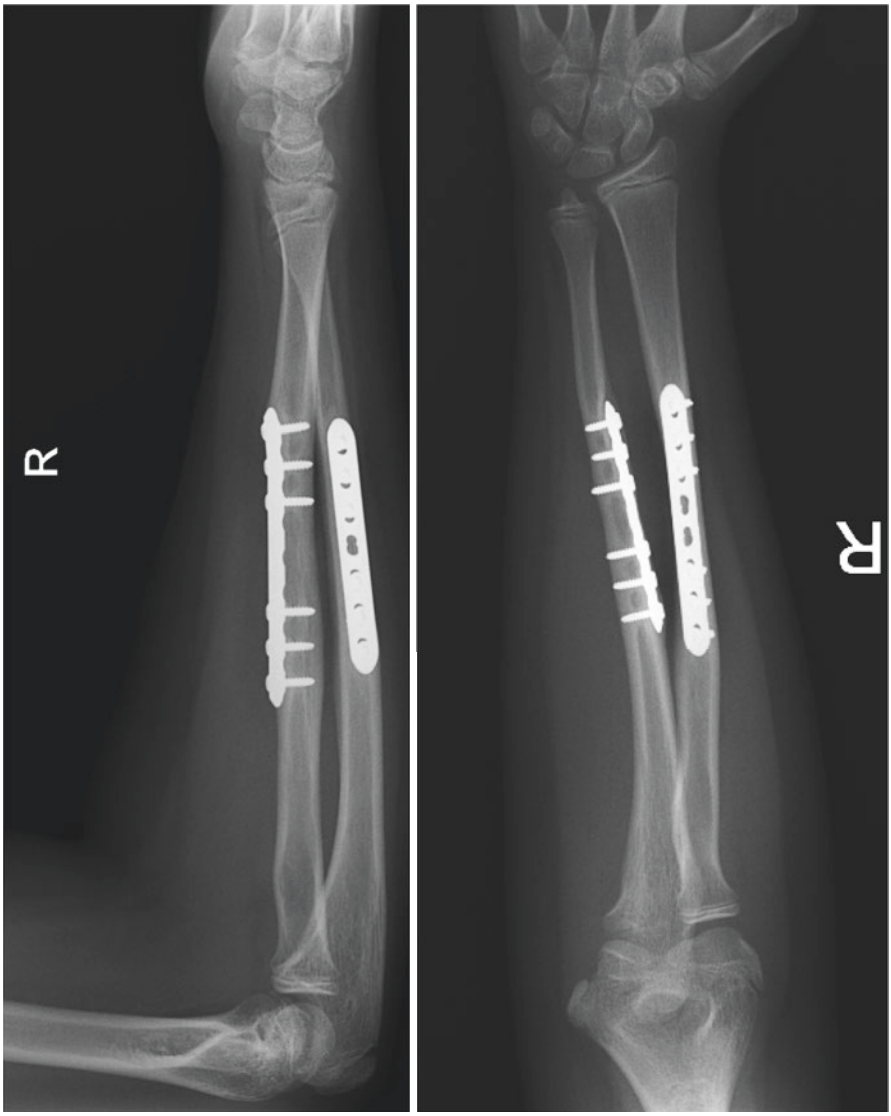

Fig. 5.13 Two-bone forearm fracture after ORIF in an adolescent male nearing skeletal maturity. Note the open physis at the distal end of the forearm as well as the restoration of the gentle curve of the radial shaft. Intraoperatively, after fixation, the forearm should be tested to make sure full pronation and supination is possible

The exception to ORIF of two-bone forearm fractures is in pediatric patients because of the marked remodeling ability of children (Fig. 5.14). Adults on the other hand almost always require fixation of two-bone forearm fractures [14].

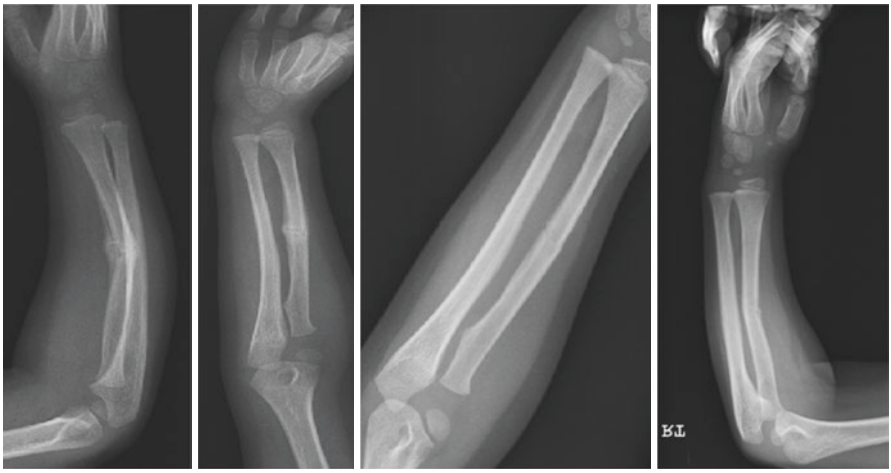

Fig. 5.14 Forearm films in a child with a radial shaft fracture at 6 weeks and 6 months post injury. Note the marked callus at 6 weeks and the remodeling at 6 months. By 1–2 years the healed fracture will be undetectable

5.2.4 Complications of Forearm Fractures

In common with all fractures, compartment syndrome will result in a devastating outcome if not caught early and treated. Nonunion is rare (less than 5%) as is synostosis. A synostosis is a fusion of the two bones with callus that bridges the interosseous membrane making forearm rotation extremely limited if present at all. Treatment is difficult and involves excising the bridging bone, but recurrence is common – up to 10% [15–17].

5.3 Distal Radius Fractures

Distal radius fractures are the result of a fall on the outstretched hand with the amount of supination, pronation, angle of impact, force of impact, and underlying muscle and bone pathology and growth (e.g., osteoporosis or open growth plates) determining the injury pattern which in turn influences the treatment decisions. Most of these fractures occur in the young (less than 30 years) male population or in the elderly (over 65 years), the latter usually from low-energy injuries.

Physical examination may or may not show some deformity of the wrist, the most classic deformity being the “silver fork” or “dinner fork” deformity present in an elderly patient with a distal radius fracture; this is the classic Colles fracture (Fig. 5.15).

Neurovascular exam especially of median nerve is important as the latter is often stretched or contused in the injury process (Fig. 5.16). If the patient has signs or symptoms of carpal tunnel syndrome at the time of surgery, consideration should be

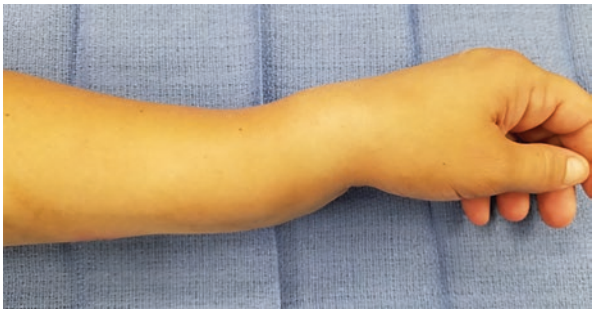

Fig. 5.15 Distal radius fracture, Colles, with the typical dinner fork deformity

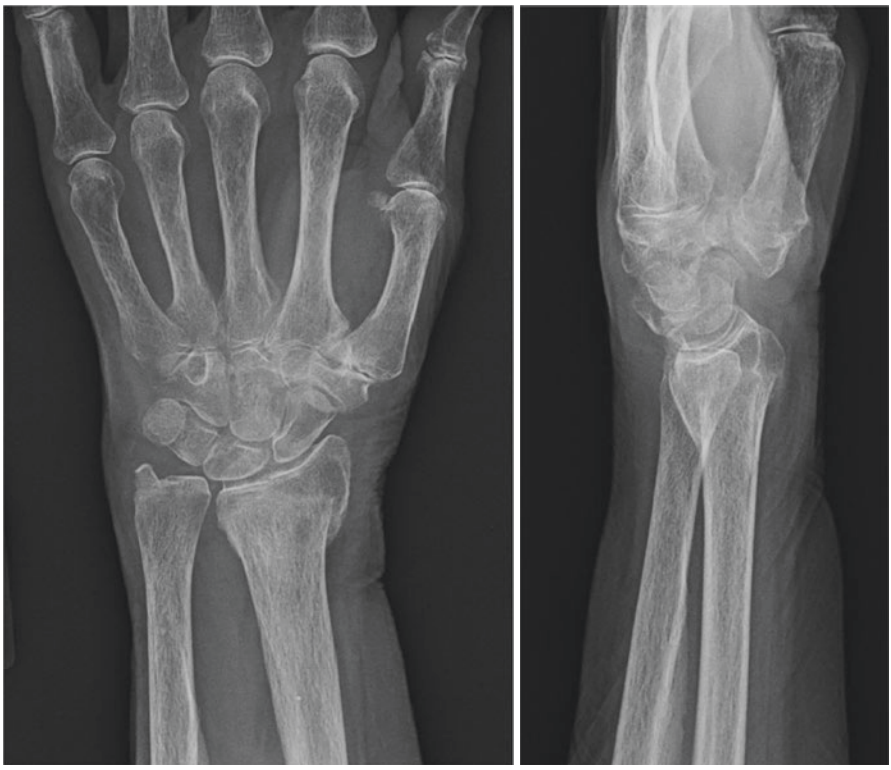

Fig. 5.16 Healed distal radius fracture with malunion. Note the longer ulna impacting the carpal bones on the left and the dorsal tilt (instead of the normal volar tilt) of the distal radial articular surface on the right. The patient's only complaint, however, was of carpal tunnel syndrome

given to doing a contemporaneous carpal tunnel release. Skin breaks should be noted as should tenderness on the ulnar side of the wrist.

Radiographic evaluation begins with high-quality PA and lateral films. After evaluating displacement, angulation should be carefully measured. The first of the two most common measurements is the radial inclination – the angle between a line

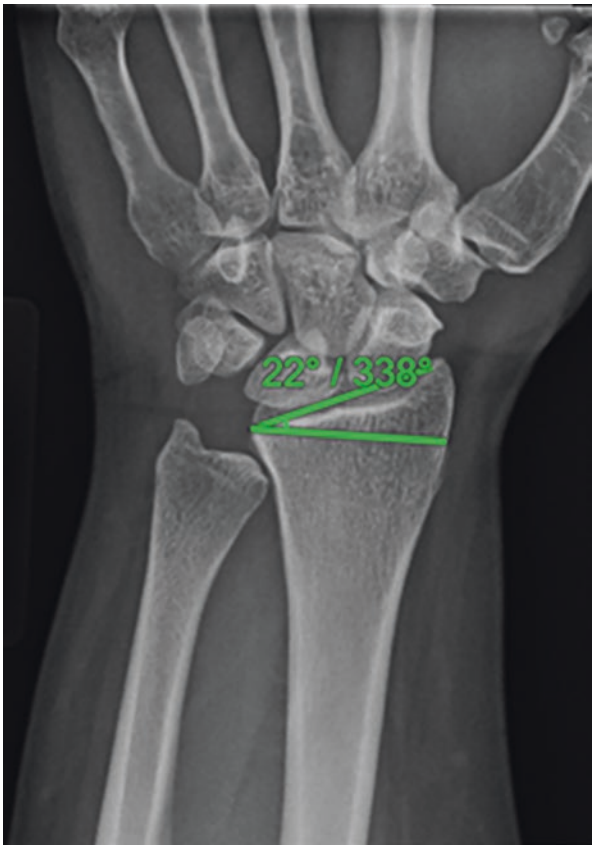

Fig. 5.17 Radial inclination measurement is the acute angle between a perpendicular line to the radial shaft and a line from the radial styloid to the ulnar lip of the distal radius

drawn on the PA radiograph along the joint surface of the distal radius and a line drawn perpendicular to the long access of the radius. Normal is 23° (Fig. 5.17).

The second line is drawn on the lateral radiograph commonly called the palmar or volar tilt; it is the angle between a line drawn from the dorsal lip to the volar lip of the distal radius and a line perpendicular to the long axis of the radius. Normal is 10–12° (Fig. 5.18).

Finally, one way to measure the length of the radius is to look at ulnar variance, that is, where is the distal ulna (assuming it is not broken) in relation to the ulnar side of the distal radius. Although there is some variation, the ulna is normally 1–2 mm shorter which is considered a negative variance. Complicated distal radius fractures, i.e., marked comminution, may require a CT scan to fully appreciate the details of the fracture pattern and make the appropriate treatment plan.

More than any other fracture location eponyms are used to describe various fracture patterns of the distal radius (Fig. 5.19). Ideally, they should be described, and are in modern literature, on some type of anatomic basis. However, since the eponyms are so ubiquitous, the most common will be listed here.

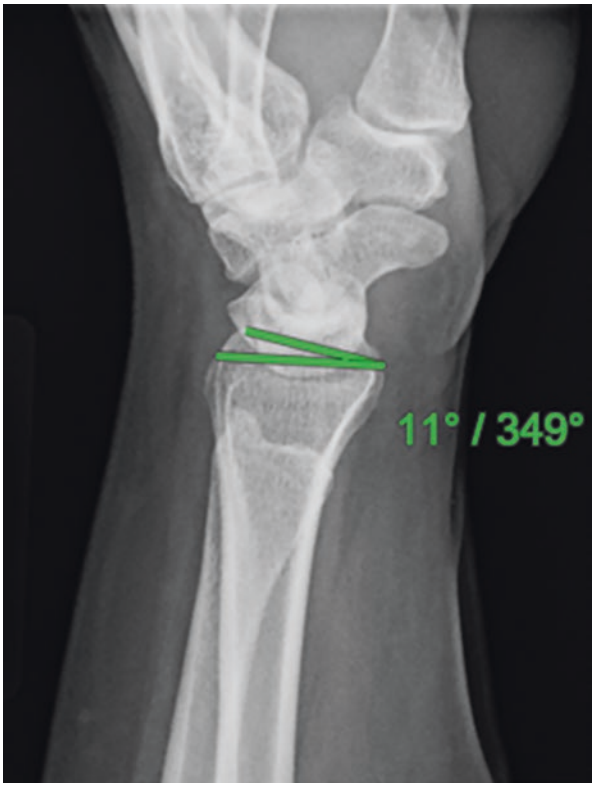

Fig. 5.18 The volar tilt angle is the acute angle between a line perpendicular to the shaft of the radius and the line from the dorsal lip to the volar lip of the distal radius

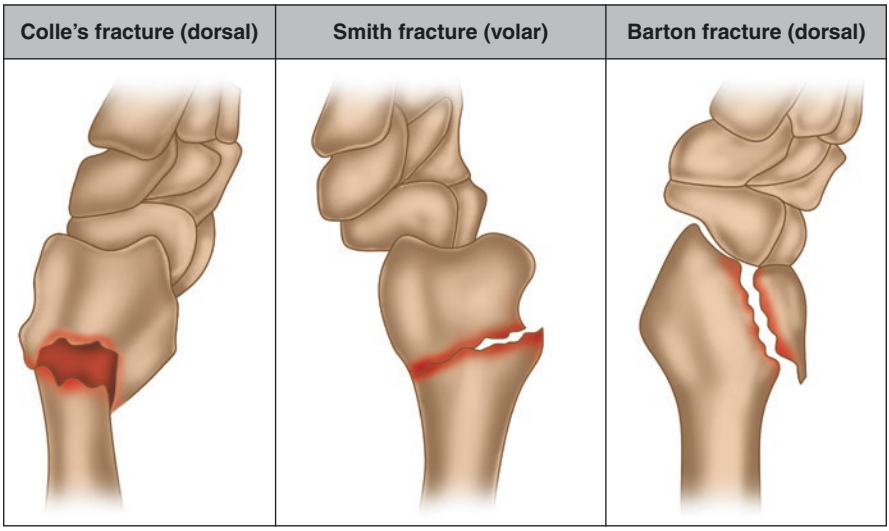

Fig. 5.19 Of the three, the most common is the Colles fracture with distal fragment being dorsal and the angulation volar. Smith's fractures are the opposite

5.3.1 Colles Fracture

Colles fracture involves a distal fragment that is displaced dorsally with varying degrees of dorsal comminution and angulation.

5.3.2 Smith Fracture

A Smith fracture is essentially the opposite of a Colles fracture with volar displacement and angulation of the distal fragment.

5.3.3 Barton Fracture

Whereas the classical Colles fracture and Smith fracture are extra-articular, Barton fracture is a dorsal displacement of an intra-articular distal radius fracture with the primary fracture line in the coronal plane. A volar Barton, also called a Smith type II, is just the opposite.

5.3.4 Chauffeur's Fracture

Chauffeur's fracture is a displaced fracture of the radial styloid. The name comes from cars in the early 1900s when the motor had to be started by a hand crank. When the motor started, if the chauffeur did not let go of the crank fast enough and remove his hand, the crank would whip around and hit the wrist causing a radial styloid fracture.

Finally, with any distal radius fracture, the radiographs should be examined closely for a "die punch" fragment resulting from the lunate "punching" a hole in the ulnar aspect of the distal radius creating an intra-articular fracture. This fragment will need to be addressed operatively by elevating it and possibly using some type of graft material in addition to fixation to allow it to heal in the proper position.

Treatment options are probably more variable for this fracture than any other. This includes simple casting, closed reduction and casting, closed reduction, and percutaneous pinning followed by casting, external fixation, open reduction, and internal fixation with either a volar or dorsal approach, utilization of arthroscopy, utilization of autograph, allograft, or bone substitutes or some combination of any of the above. Because of wide variations in populations studied, methods used, and lack of large, well-controlled studies, it can be difficult to determine the "right" approach for a particular fracture.

The method will depend on the patient, fracture pattern, and surgeon preference (Figs. 5.20 and 5.21). However, the AP should ensure that at least one of the backup options are available including allograft or bone substitute. Intraoperative fluoroscopy with a full-size or mini C-arm will be necessary if operative treatment is method of treatment.

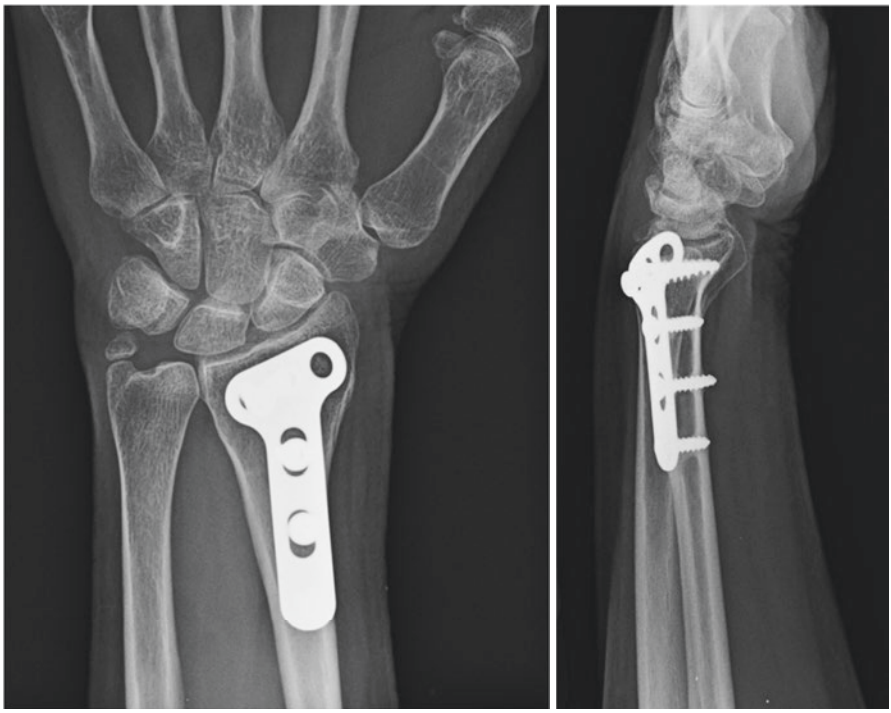

Fig. 5.20 Distal radius fracture after fixation with dorsal plate

After reduction or surgery, the patient should be encouraged to move the fingers through a full range of motion with more frequent checks for patients who seem to be having trouble regaining motion. For those who are having excessive pain or stiffness, the diagnosis of complex regional pain syndrome should be considered and appropriate treatment given. Supination exercises should be instituted, as that is harder to regain than pronation and the former correlates well with patient satisfaction. Although the goal is full range of motion, at the conclusion of treatment, slight loss of wrist extension and mild loss of wrist flexion are normal.

Complications of which the patient should be warned, in addition to complex regional syndrome, include tendon rupture, most commonly the extensor pollicis longus but the flexor tendons are not immune. The rupture can accompany the injury but more often is an attrition rupture caused by bony spicules or irritation from one of the various fixation devices. Despite appropriate reduction and fixation, malunion still occurs, and functional impairment should be the primary driver of whether to correct the deformity with an osteotomy, not just cosmetic appearance [18–22].

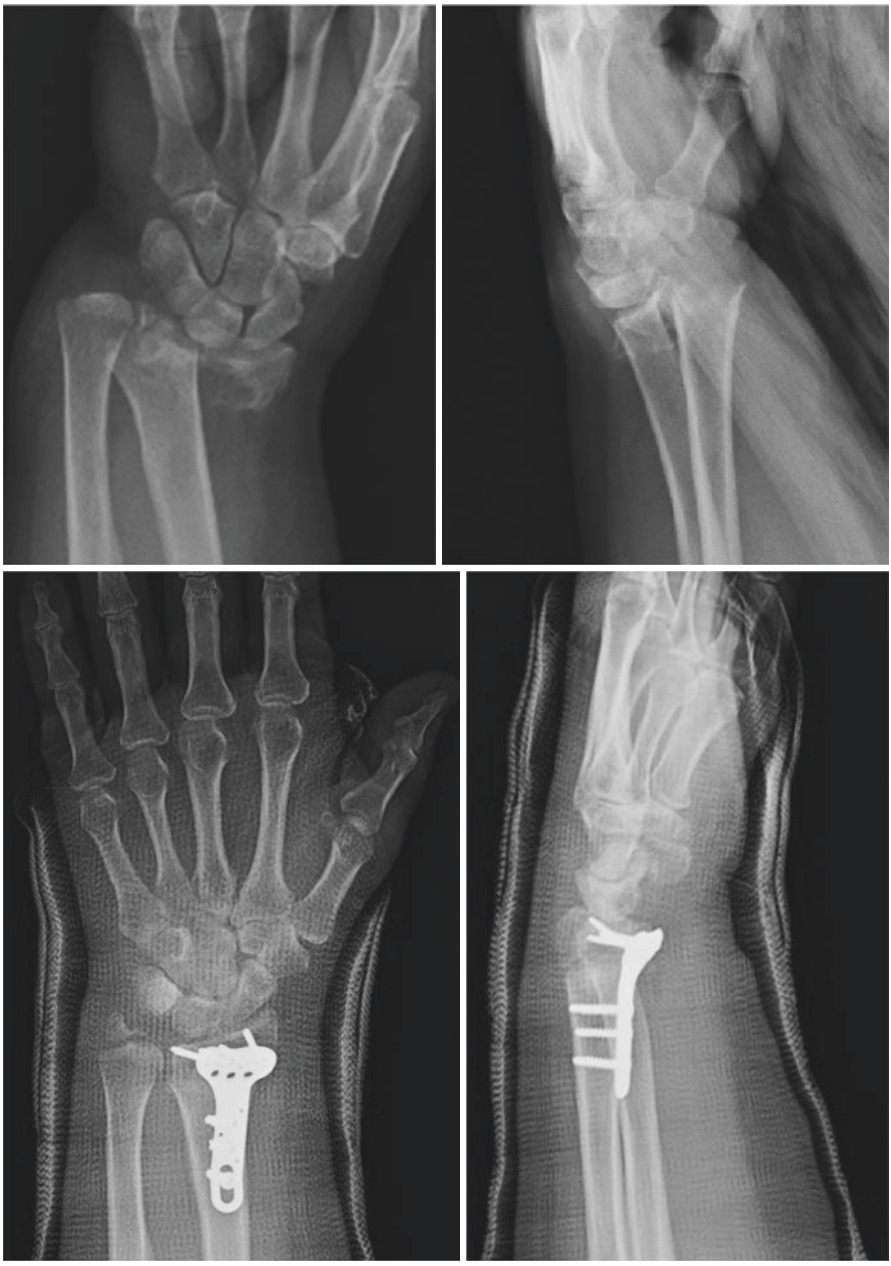

Fig. 5.21 Completely displaced distal radius fracture in a 38-year-old after falling from a stool treated with a volar plate. The ulnar styloid nonunion after the radius healed was asymptomatic

5.3.5 Galeazzi Fracture/Dislocations

The definition of a Galeazzi fracture/dislocation is a fracture of the distal two-thirds of the radial shaft and an associated distal radioulnar dislocation, with the ulna usually being dorsal to the radius (Fig. 5.22). Treatment is straightforward, the radial fracture needs to be anatomically reduced, and plate fixation needs to be applied to the volar side. Once this is accomplished, the distal radioulnar joint usually reduces itself. If the reduction is unstable, the forearm can be immobilized in a long-arm cast in supination for several weeks or even temporarily pinned. If felt necessary, the ulnar styloid (if fractured) and the triangular fibrocartilage complex can be repaired to restore stability.

The trouble with Galeazzi fracture/dislocations is that the more subtle ones are not always recognized. These are usually the result of a non-displaced but mildly angulated fracture at the meta-diaphyseal junction of the distal radius with subluxation rather than a complete dislocation of the distal radioulnar joint. The temptation is to treat these with a closed reduction – "just push on it a little." Because of the distal radioulnar subluxation, the reduction fails, and the joint remains subluxed or dislocated with subsequent loss of forearm rotation. Like other fractures, late treatment is always more difficult. If treatment is delayed long enough, then an osteotomy of the radial fracture site may be necessary to reduce the distal radioulnar joint [23].

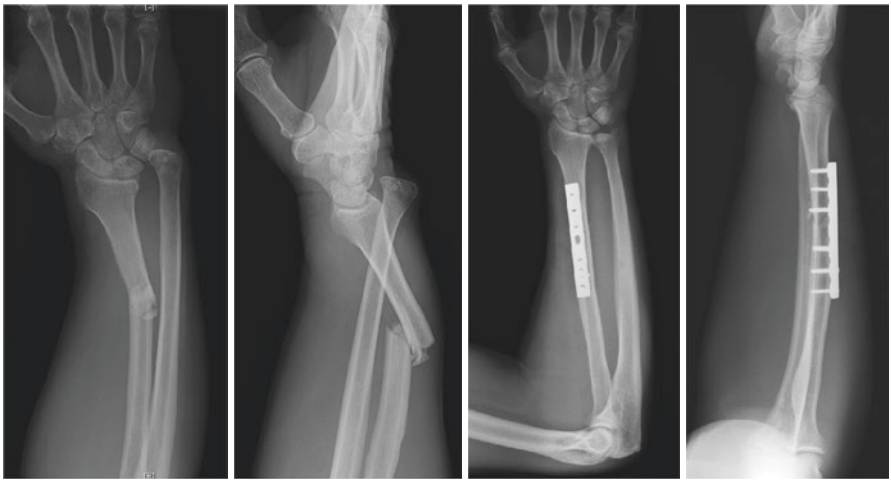

Fig. 5.22 Galeazzi fracture/dislocation with radial shaft fracture and distal radioulnar joint dislocation. In this patient, after fixation of the radius, the distal radioulnar joint was stable enough to be managed with cast immobilization. The dislocation at the distal radioulnar joint is not always so obvious

5.3.6 Ulnar Styloid Fractures

Isolated ulnar styloid fractures are rare, and unless there is associated instability or dislocation of the distal radioulnar joint, no treatment is necessary. They can be associated with tears of the triangular fibrocartilage complex.

Most ulnar styloid fractures are associated with a fracture of the distal radius and indicate that there may be some degree of instability of the distal radioulnar joint. Once the radial fracture is reduced, and fixed if necessary, the distal radioulnar joint should be examined clinically and radiographically for signs of subluxation or dislocation. Because of the wide variation between patients, the non-injured side should be examined to obtain an idea of what that particular patient's normal is. If instability is present, the ulnar styloid may need to be fixed. The method of fixation depends on the size of the fragment and surgeon preference, but includes suture anchors, suture (nonabsorbable or small-gauge wire), or even mini-fragment screws.

5.4 Biceps and Triceps Rupture: Distal

Biceps tendon ruptures at the elbow are typically the result of a sudden excessive eccentric load while the elbow is partially flexed such as trying to catch a load of sheetrock that is toppling over. It is predominantly a male injury between the ages of 40 and 60.

Diagnosis is usually straightforward as the patient comes in complaining of hearing or feeling a pop in the elbow with a history of injury as above. The patient may or may not complain of weakness. Physical exam shows a palpable defect in the antecubital fossa with a positive hook test (Fig. 5.23), and there may be some ecchymosis. As the brachialis is the dominant elbow flexor, there is often minimal weakness on resisted flexion although resisted flexion may make the defect more obvious. There is, however, marked weakness of supination with the elbow at 90° of flexion. Radiographs may show an avulsed bony fragment, but usually not. With incomplete ruptures ultrasound (by an experienced musculoskeletal ultrasonographer) or an MRI can lead to a clear diagnosis.

Treatment is surgical. As always, treat the patient and not the diagnosis. There are a few patients that will not require surgery because of physiologic age or lifestyle. Ideally, surgery should be done in the first 2 weeks for complete ruptures; after that time period, the tendon is retracted making direct repair difficult or impossible such that an autograft or allograft may be necessary. Results with allograft or autograft are worse than with a primary repair.

Repair is done through an antecubital incision. There are three ways to repair the tendon. One is with a single anterior incision using some type of suture anchor (usually two) to secure the tendon to the radial tuberosity. The second is through an antecubital incision with a unicortical hole drilled in the radius. The biceps tendon is then secured inside the bone with an interference screw. The third is a two-incision technique – one incision anterior and one posterior. Parallel drill holes are placed in the bone and suture that has been woven through the tendon passed through the

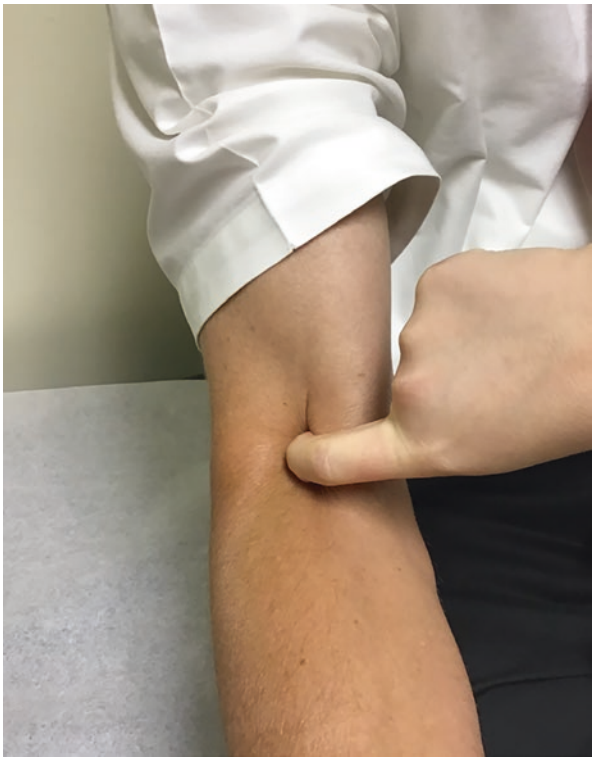

Fig. 5.23 Biceps hook test showing the biceps tendon is intact. For partial rupture the test may show the tendon is intact but the pressure exerted may cause pain. In addition, with partial rupture resisted supination is painful, weak, or both

holes and tied posteriorly. Careful surgical technique is necessary to avoid damaging the lateral antebrachial cutaneous nerve anteriorly and the radial nerve posteriorly. In addition, care must be taken to ensure the forearm is in the appropriate position (supination) while the tendon is being attached.

Rehabilitation has traditionally been 6 weeks of splint or cast immobilization followed by another 6 weeks of progressive range of motion and a hinged elbow brace. The trend over the last few years, with better fixation, has been for earlier mobilization preventing muscle atrophy. Again, timing depends on the patient's health, compliance, tendon quality, repair quality, and surgeon preference. Depending on the aforementioned factors, limited range of motion in an elbow brace is permitted with passive flexion and active extension after a short period of immobilization. This is followed by a period of limited use (nothing heavy, nothing fast, nothing eccentric) with full activity allowed at 6 months. The length of time in immobilization varies from 2 to 6 weeks and bracing from 6 to 10 weeks depending on a variety of factors as listed above. Re-rupture rates are 3–5%.

Triceps ruptures are not nearly as common as biceps but follow a similar pattern. Triceps tendons can also be ruptured or avulsed in whole or in part from the olecranon, and like the biceps is the result of a sudden, heavier than expected, eccentric contraction.

Diagnosis is straightforward in patients with a complete rupture; there may or may not be pain upon resisted elbow extension. There is a palpable defect in complete ruptures but not always with partial ruptures. The defect may be obscured by hematoma or an intact superficial fascia. Some patients may require MRI for definitive diagnosis. Radiographs are helpful to rule out olecranon fractures and triceps avulsion fractures.

Surgery is the treatment of choice. Because the triceps tendon inserts broadly on the olecranon, several suture anchors or drill holes through which suture can be passed are the methods of repair. Placing the patient in the lateral decubitus position makes the posterior surgical approach easier in addition to applying the postoperative splint or cast. The splint or cast will need to be applied with the elbow slightly flexed (10–20°) to prevent it from sliding off. Like the biceps the length of absolute immobilization varies depending on the extent of the rupture (complete or partial), security of repair, surgeon preference, and patient compliance. Immobilization is followed by a period of hinged bracing limiting the amount of flexion. Full activity can be resumed at 6 months post-surgery. Like the biceps, re-rupture rates are in the 3–5% range [24–26].

5.5 Elbow and Forearm: Non-traumatic

5.5.1 Lateral Epicondylitis

Lateral epicondylitis, often called tennis elbow, presents in the 30–50-year-olds as lateral elbow pain with no specific trauma, although there is often a history of repetitive use, especially forceful forearm supination or wrist extension. The pain may radiate down the forearm and may be worse when grasping something (like shaking hands), or picking something up with the forearm in the pronated position.

Physical exam shows point tenderness over the lateral epicondyle with increased pain on resisted extension of the wrist. The main differential diagnosis is radial tunnel syndrome where the tenderness is in the proximal forearm rather than the epicondyle; radial tunnel syndrome is frequently associated with weakness of the wrist and finger extensors. Unless there is loss of motion or a definitive history of trauma, radiographs are not necessary acutely. If the problem persists, radiographs may be taken.

The underlying pathology is a partial avulsion of the extensor carpi radialis brevis (ECRB) tendon from the lateral epicondyle. Abnormal scar tissue (angiofibroblastic) fills in the gap between the ECRB and the bone. The natural history is one of gradual improvement over a period of 6–9 months. This assumes the inciting event, usually repetitive trauma, is avoided or reduced in volume or intensity.

Treatment is difficult as there is no clearly superior treatment that shortens the natural history; for many patients all that is needed is reassurance of the benign natural history. First-line treatment consists of a tennis elbow strap to decrease the tension at the lateral epicondyle (Fig. 5.24) and an exercise program to strengthen and stretch the forearm musculature. Other orthopedic surgeons may use a wrist

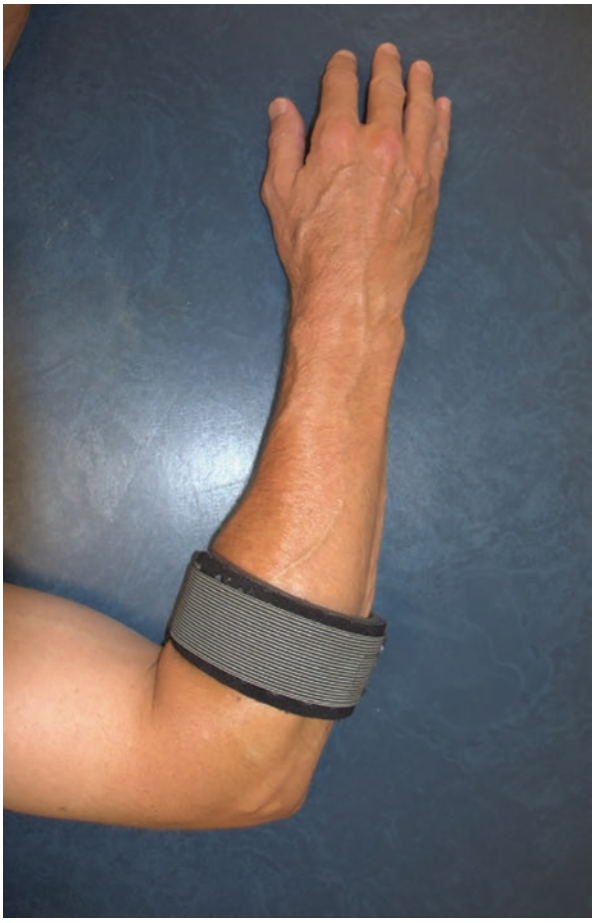

Fig. 5.24 Tennis elbow strap in place. The pad of the strap should be just distal to the lateral epicondyle with the strap snug enough to take some of the tension off the ECRB insertion

immobilizer again to reduce the tension exerted by the ERCB on the lateral epicondyle.

Other treatments include injections of corticosteroids, platelet-rich plasma, or botulinum toxin. Surgical options include release of the ECRB, open or percutaneous, with or without debridement of the angioblastic tissue; release, debridement, and reattachment of the ECRB, or debridement via elbow arthroscopy. None have shown clear superiority [27, 28].

5.5.2 Medial Epicondylitis

Much less common (9:1 ratio) than lateral epicondylitis is medial epicondylitis, also called golfer's elbow. Again, the typical patient is a 30–50-year-old with or without a history of repetitive trauma. There may be some radiating pain down the medial forearm and occasionally an accompanying diagnosis of cubital tunnel syndrome.

Physical exam will show point tenderness over the medial epicondyle of the distal humerus with increased pain on resisted flexion of the wrist. Without a history of trauma and with normal motion, radiographs are not indicated acutely but may be appropriate in chronic cases.

Like lateral epicondylitis, the underlying pathology is tendinopathy but of the pronator teres (PT) or flexor carpi radialis (FCR) where they attach to the medial epicondyle of the distal humerus. Again, like lateral epicondylitis the natural history is one of gradual resolution over 6–9 months, if the offending repetitive trauma can be avoided or reduced. The precipitating trauma (usually cumulative) is a repetitive pronation or wrist flexion force.

Treatment is symptomatic including reducing or eliminating the causative motions. Wearing a tennis elbow strap on the proximal forearm in reverse just distal to the medial epicondyle takes tension off the tendon insertion allowing healing to take place. Care must be taken not to wear the strap too tight causing compression of the ulnar nerve. Persistent cases may respond to local steroid injection. If injected, the patient should be warned that if the local anesthetic reaches the adjacent ulnar nerve, then there will be a period of numbness in the ulnar digits. Once the symptoms subside, forearm stretching and strengthening help prevent recurrence. Surgery is rarely indicated and consists of retracting the FCR and PT, debriding the offending tissue while taking care not to destabilize the elbow by cutting the anterior bundle of the ulnar collateral ligament. If there is an associated cubital tunnel, ulnar nerve compression should be addressed contemporaneously. With the latter one must be careful not to destabilize the ulnar nerve [29].

5.5.3 Olecranon Bursitis

Olecranon bursitis is one of the more common bursitides and appears in three forms. The most common is a relatively painless swelling of the olecranon bursa after the patient has allowed the posterior elbow to rest on a hard surface, often with some vibration or movement (picture a truck driver resting his elbow on the center console or grandma knitting while resting her elbows on a rocking chair). There may, however, be no precipitating event.

Physical examination will show a normothermic, non-erythematous, minimally or non-tender fluid-filled sac of fluid over the olecranon. Radiographs may or may not show a spur.

Treatments are avoidance of pressure on the area and reassurance. Needle drainage does not usually work and runs the risk of infection. Open or arthroscopic drainage can be entertained but has a high rate of infection [30].

Infected olecranon bursae are obviously different. They are red, hot, and tender and there may be an associated cellulitis. If caught very early, aspiration and antibiotics may work, but surgical drainage is the normal treatment. Wound healing can be problematic, and immobilization in a cast or long-arm splint with a window over the incision for wound inspection and dressing changes can be helpful. Like other orthopedic infections, a second trip to the operating room is not unusual. For

persistent or recurrent cases, evaluation with MRI or bone scan to rule out osteomyelitis may be necessary.

Finally, patients with rheumatoid arthritis can develop olecranon bursitis or nodules in the olecranon bursa. Unless it becomes secondarily infected, treatment is directed at the underlying rheumatologic disease. If infected, treatment can be complicated by any immunosuppressive drugs the patient is taking [30–32].

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The Shoulder and Humerus

6

6.1 Traumatic

6.1.1 Clavicle Fractures

6.1.1.1 Midshaft Clavicle Fractures

Like other upper limb fractures, clavicle fractures are most often the result of a fall on the affected limb but can also be the result of a direct blow. Diagnosis is straightforward with tenderness, ecchymosis, and deformity being apparent on physical exam with radiographs showing the fracture. Like other injuries, neurovascular exam of the involved limb is appropriate, but do not neglect a survey of the rest of the musculoskeletal system to rule out other injuries. Radiographs should include an AP of the entire clavicle and a second AP angled cephalad to examine for displacement and comminution.

Treatment of open fractures and those with neurovascular compromise is operative generally with plate and screws although there is a place (and surgeon preference) for intramedullary rods. Pins are contraindicated as pin migration even into the chest cavity can be a problem.

There is some controversy whether closed clavicle fractures should be treated operatively and if so which ones. Fractures that are significantly displaced, which is defined as shortening greater than 2.5 cm or separation of the fragments by greater than 1–2 diameters of the shaft of the clavicle, are generally treated operatively (Fig. 6.1). In multi-trauma patients, early fixation helps early mobilization and pain control. Like many other fractures, treat the patient, not the radiograph. For example, the otherwise healthy desk worker in his mid-40s may be best treated nonoperatively, but the active 25-year-old manual laborer may be better served with open reduction and internal fixation. Regardless of operative or nonoperative treatment, there may be some loss of strength in internal rotation (pectoralis major); it is uncertain if this is due to the injury, treatment choice, or inadequate rehab. Average healing time for either operative or nonoperative treatment is 8–9 weeks [1, 2].

J. A. Gracy, *Orthopedics for Physician Assistant and Nurse Practitioner Students*, https://doi.org/10.1007/978-3-031-04406-9_6

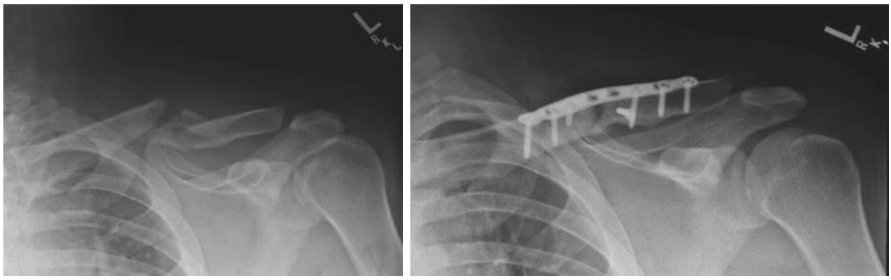

Fig. 6.1 Midshaft fracture of the clavicle treated with ORIF. Many patients will require metal removal after the fracture heals

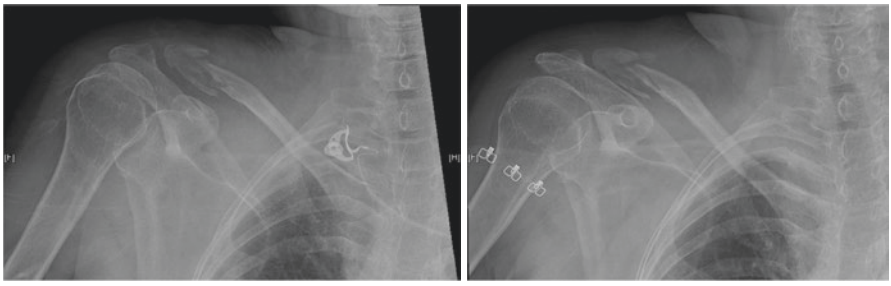

Fig. 6.2 Comminuted distal clavicle fracture but with the coracoclavicular ligaments intact; it was treated nonoperatively

6.1.1.2 Fractures of the Distal Third of the Clavicle

Like clavicular shaft fractures, fractures of the distal third of the clavicle can result from indirect trauma (fall on outstretched arm) but are more common with direct trauma (falling on point of the shoulder). These fractures are not easily categorized because of the multiple possible configurations, depending on comminution, fracture location – medial or lateral to the coracoclavicular ligaments – possible intra-articular involvement of the acromioclavicular joint, as well as associated acromioclavicular dislocations (Fig. 6.2).

Like other injuries around the shoulder, careful evaluation with appropriate radiographs is necessary to rule out other injuries including other fractures and damage to the neurovascular structures, e.g., the brachial plexus.

Treatment is widely variable from sling and swathe to ORIF, with or without ligament reconstruction, as well as excision of the distal clavicle. The AP is referred to a variety of articles, fracture books, and consultation with the supervising orthopedic surgeon for more specifics [3].

6.1.2 Scapular Fractures

Fractures to the body of the scapula are the result of high-energy injuries except for the extraordinarily rare pathologic fracture. Consequently, a careful search for

associated injuries is crucial, especially rib fractures, flail chest, and hemo- or pneumothorax. Once these are ruled out or treated, most scapular fractures are treated with a sling and time. The exception is if there is a fracture of both the glenoid neck and the clavicle which results in an unstable shoulder. In that case, one or the other or both fractures will need to be surgically stabilized [4].

6.1.3 Humerus Fractures

6.1.3.1 Proximal Humerus Fracture

Like many other injuries, there is a bimodal age incidence of proximal humerus fractures with a peak in the 20s secondary to high-energy injuries and a much larger peak in the elderly population as a result of a low-energy fall. After checking for other injuries and a neurovascular exam, the next step is radiographs. It can be difficult to get orthogonal views given the reluctance of the patient to move his shoulder. Axillary views are normally not possible, so initial screening may be an AP with the shoulder in internal rotation and a Y-view. If the patient is not in too much pain, an AP in external rotation may be possible. Depending on the body habitus, associated injuries, and the skill of the radiographer, this may not suffice in which case a CT scan will prove helpful for delineation of the fracture pattern and to ensure there is not an associated glenohumeral dislocation.

The most common classification scheme is that originally described by Dr. Neer (Fig. 6.3). He described the proximal humerus as having four parts:

- Lesser tuberosity (to which the subscapularis is attached).
- Greater tuberosity (to which the supraspinatus and infraspinatus are attached).
- Humeral head.
- Humeral shaft.

He described the fractures as being two-part, three-part, or four-part. For instance, a two-part fracture could be just the lesser tuberosity fractured or just the greater tuberosity. Each "part" can be displaced or non-displaced.

Treatment is variable depending on fracture type, displacement, bone quality, physiologic age, and associated injuries. The majority of proximal humerus fractures are treated nonoperatively, i.e., a sling or sling and swathe. The expectation is that the fracture will heal in 6–10 weeks, and the patient will obtain a functional but not full range of motion. Other treatment options are:

- ORIF, especially in physiologically young patients.
- Shoulder hemiarthroplasty, total shoulder arthroplasty (Fig. 6.4), or reverse shoulder arthroplasty in older patients with displaced three- or four-part fractures.

The difficulty with the hemiarthroplasty is getting the tuberosities to heal in order to restore rotator cuff function. A reverse shoulder arthroplasty (RSA), on the other hand, will of necessity lose some cuff function that will be taken over by the deltoid. External rotation strength can be an issue with RSA's [5].

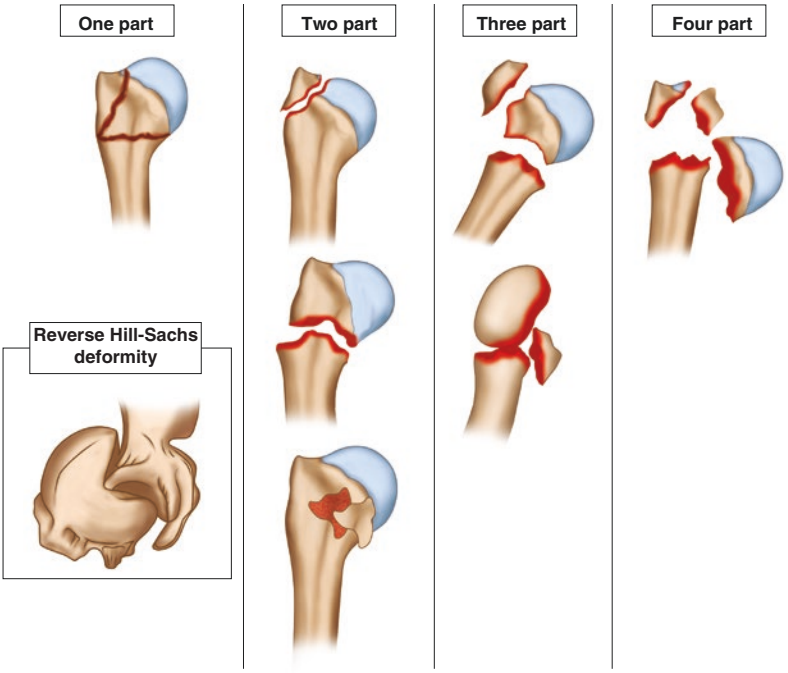

Fig. 6.3 Neer fracture types. It is important to not only mention the number of parts but the amount of displacement and if there is any associated dislocation. The inset shows a posteriorly dislocated humeral wedged on the glenoid rim causing the wedge-shaped impaction fracture known as a reverse Hill-Sachs lesion; when on the humeral head dislocates anteriorly a similar wedge fracture occurs - the Hill-Sachs lesion

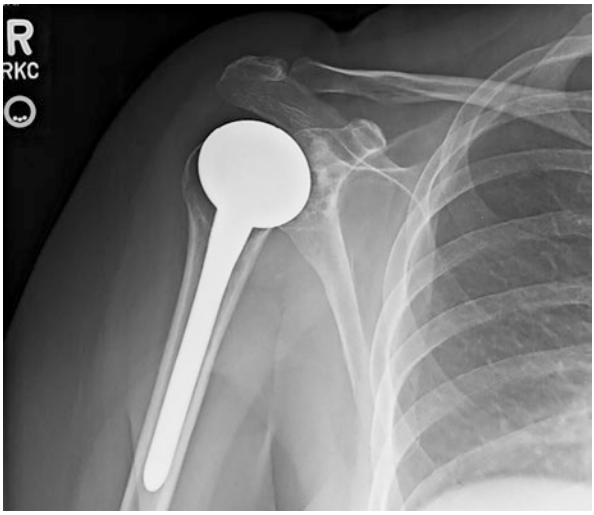

Fig. 6.4 Total shoulder arthroplasty. The outline of the scant amount of cement holding the glenoid component can be seen on careful examination

6.1.3.2 Humeral Shaft Fractures

Humeral shaft fractures occur primarily in younger patients usually as the result of a fall or direct blow. Initial evaluation includes ruling out other injuries including ipsilateral fractures (i.e., of the hand, wrist, forearm, supracondylar humerus, and proximal humerus). As with other fractures, a careful check of the neurovascular status is important. The most common associated injury is to the radial nerve manifested as a wrist drop (loss of active wrist extensor) and/or loss of metacarpophalangeal extension. The AP should be sure to document the status of the radial nerve both before and after any intervention so that if there is a change, appropriate measures can be taken. Possible remedies include removal of splint or cast, surgical exploration, and a period of observation. The last is controversial.

The only imaging studies normally required are orthogonal views of the humeral shaft and either a Y-view of the shoulder or an axillary view to ensure there is no associated glenohumeral dislocation. Like proximal humerus fractures, obtaining adequate views of the glenohumeral joint to ensure there is no associated dislocation may be difficult due to pain. If there is any question of a glenohumeral dislocation, the AP should not hesitate to get a CT scan.

Treatment strategies vary depending on fracture pattern (oblique, transverse, or spiral), the degree of comminution, amount of displacement, age, and associated injuries. Options include bracing which works best for distal 2/3 shaft fractures; intramedullary nailing, which can be antegrade through the humeral head or retrograde through the posterior distal humerus (Fig. 6.5); and open reduction and

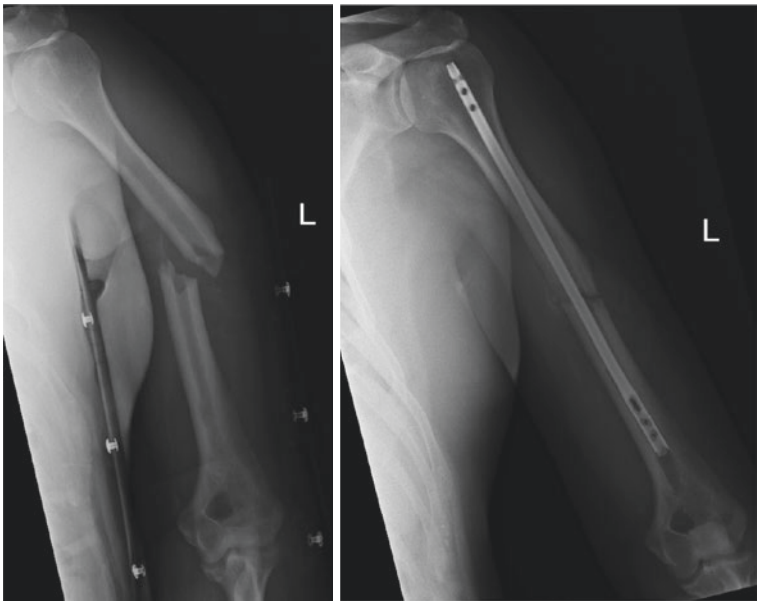

Fig. 6.5 Humeral shaft fracture after ORIF with a retrograde nail. Internal fixation is used more often in multi-trauma patients to allow earlier mobilization, in widely displaced fractures, and in those fractures with associated neurovascular damage. Careful documentation of the radial nerve function before and after surgery is critical

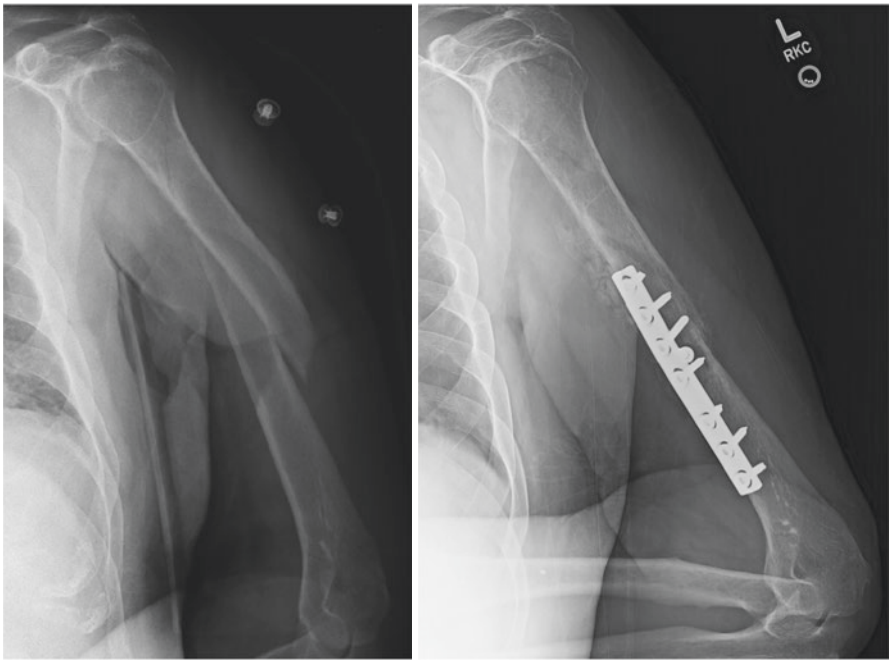

Fig. 6.6 Preoperative and postoperative films of humeral shaft fracture and delayed union, treated with open reduction and internal fixation

internal fixation with plate and screws (Fig. 6.6). For brace or cast treatment, up to 20° of varus/valgus angulation and 15° of anterior/posterior angulation is generally considered acceptable (Fig. 6.7). In general, slightly more angulation can be accepted with more proximal shaft fractures and slightly less with more distal shaft fractures. Union time is about 8 weeks, but if it does not heal by 12–16 weeks, consideration should be given to additional treatment. Options include ORIF, bone grafting, and external bone growth stimulators (which can be either an electromagnetic or an ultrasound device). If the fracture has already been surgically stabilized, it may be necessary to repeat the ORIF in addition to using the aforementioned options [6].

6.1.4 Dislocations

6.1.4.1 Sternoclavicular Dislocation

Like most upper limb fracture/dislocations, sternoclavicular dislocations are the result of a fall on an outstretched limb. The injury can be either an anterior or posterior dislocation referring to the clavicle's position relative to the sternum. On physical exam there is usually an anterior prominence or sunken appearance of the medial clavicle depending on the direction of dislocation. It is difficult to get quality

Fig. 6.7 Humeral fracture brace for a humeral shaft fracture. It may be more difficult to fit on obese patients

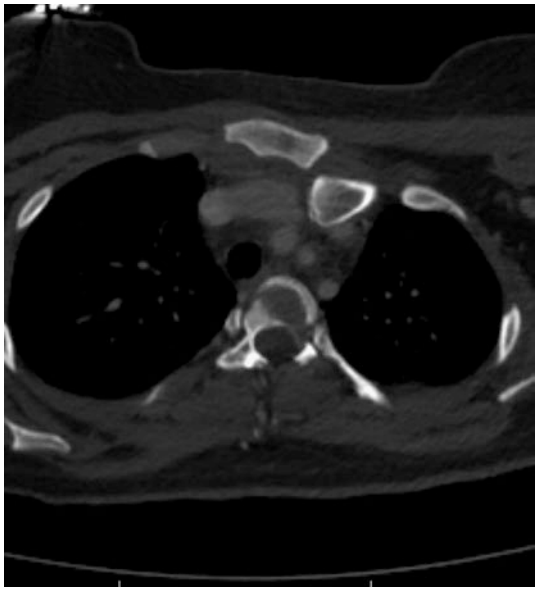

Fig. 6.8 CT scan of a left posterior SC dislocation. Note the accompanying hematoma and remember that CT scans are viewed from the foot; thus, the left SC dislocation is on the right in this CT. (Courtesy Medical College of Georgia, Department of Orthopedics)

diagnostic radiographs of the sternoclavicular joint because of its midline location, the surrounding ribs, and the thoracic spine. Therefore, a CT is the most useful diagnostic imaging modality (Fig. 6.8).

Treatment varies depending on whether it is anterior or posterior. For anterior dislocation the treatment is a sling for several days followed by activity as tolerated. Attempts to reduce are almost invariably followed by repeat dislocation or subluxation. Other than a slightly prominent medial clavicle, there does not appear to be any long-term consequences including arthritis.

Posterior dislocations are a different matter. Because of impingement on the retrosternal structures (trachea, esophagus, and subclavian vessels), reduction is relatively urgent but not emergent unless there is obvious vascular compromise or hemodynamic problems. Reduction is usually straightforward but done under general anesthesia. Immediate (i.e., in the operating room at the same time) availability of a vascular or cardiothoracic surgeon is mandatory as reduction may cause a tear in the vascular structures. Various methods of maintaining the reduction are available including plate fixation or a tendon weave using autograft or allograft material. Posterior SC dislocations are high-energy injuries, so a search for other injuries including pneumothorax is necessary [7, 8].

6.1.4.2 Acromioclavicular Dislocations

Again, like many shoulder injuries, acromioclavicular dislocations are the result of a direct blow to the shoulder, but with most or all of the force directed onto the acromion causing varying degrees of injury according to the amount of force and direction. For example, it is a common injury in American football when the patient lands directly on the shoulder. Physical examination will show marked tenderness of the AC joint with varying degrees of prominence of the distal clavicle. There may or may not be associated ecchymosis or abrasions. Because traction injuries to the brachial plexus are possible, a careful neurologic exam is appropriate. Radiographs show varying degrees of separation of the distal clavicle from the acromion (Fig. 6.9). To better assess the degree of injury to the associated ligaments, some physicians will order weighted films. Two important points to remember about weighted films. First, weighted vs unweighted films should be compared to each other as well as compared to the uninjured side. Second, the weights should be suspended or attached to the wrist. If the patient grasps the weights, he will involuntarily also contract his deltoid muscle giving a faulty evaluation of the degree of ligamentous injury.

Generally speaking, the dislocations are classified as follows (Fig. 6.10).

Class I has tenderness at the AC joint but normal radiographs. Class II has tenderness at the AC joint with the radiographs showing slight superior displacement of the clavicle relative to the acromion. Patients with class III injuries have obvious deformity with radiographs showing complete loss of contact of the clavicle with the acromion (complete or near-complete disruption of the coracoclavicular ligaments). Class IV AC joint disruptions have the distal clavicle disrupting additional soft tissues and the distal clavicle protruding posteriorly, frequently into the trapezius. Class V injuries are just more severe versions of class III.

Treatment as always is patient, not radiograph specific. Class I and II injuries are always treated nonoperatively, i.e., sling for comfort and reassurance with return to activities as tolerated. There continues to be significant controversy with regard to

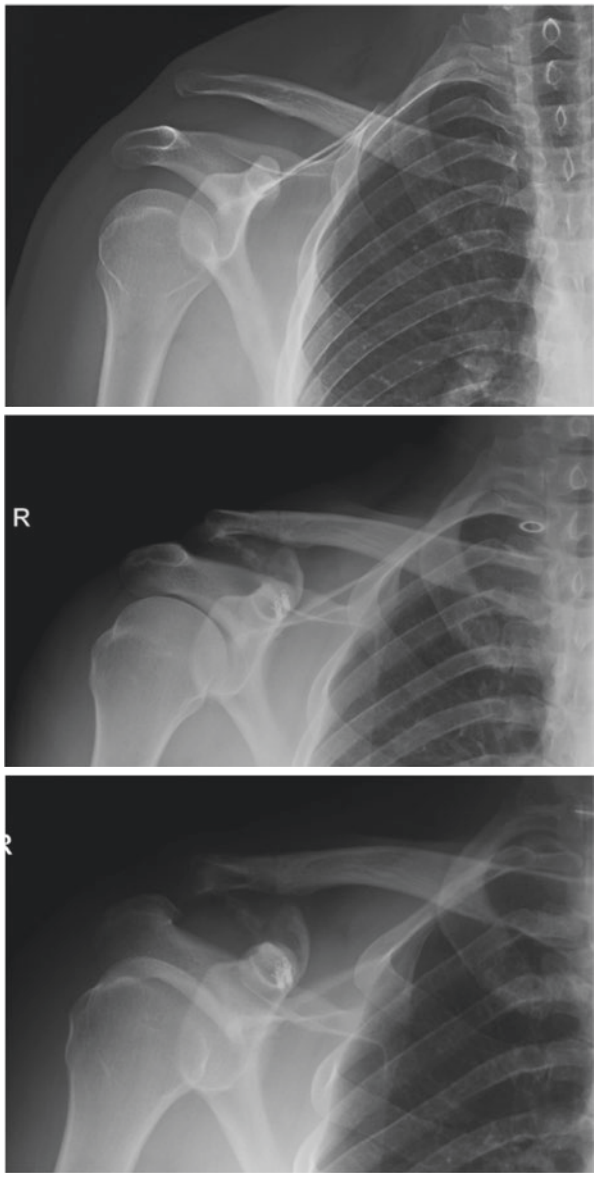

Fig. 6.9 Grade III–IV AC separation pre-op and post-op. Note the drill hole in the clavicle for passing of the suture and the subsequent calcification of the coracoclavicular ligaments in the postoperative films. The Zanca view is one taken with the beam aimed ~15° cephalad enabling a better view of the AC joint not obscured by the upper body of the scapula

class III and IV injuries. Most studies show equivalent outcomes in both pain and function with operative vs nonoperative treatment for class III injuries at 1 year; still there are some patients who opt for surgical treatment (including for cosmetic reasons). Many surgeons treat class IV injuries operatively, but long-term outcomes compared to nonoperative treatment are not clear as the few randomized controlled studies done comparing operative vs nonoperative treatment tend to lump together class III and IV injuries. Class V injuries are generally treated operatively.

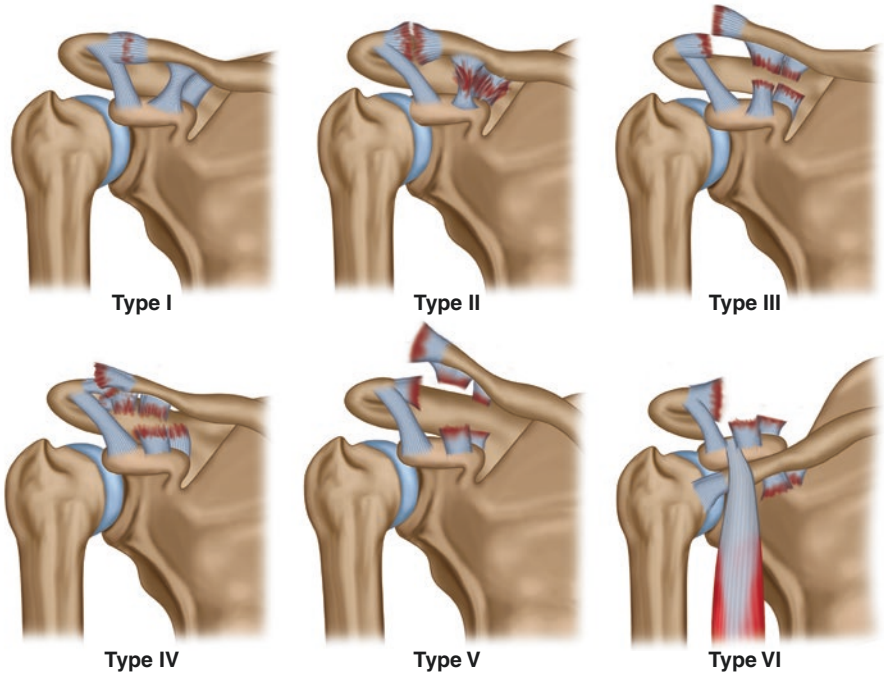

Fig. 6.10 The six types of AC separation; see text for details

As with any injury, do not stop looking once the AC joint dislocation is identified. Common additional injuries are brachial plexopathies and clavicle fractures.

Surgical treatment, if appropriate for the injury and the patient, is generally a combination of suture and suture tape (Fig. 6.11) to protect the repair or reconstruction of the coracoclavicular ligaments, although some surgeons will use a hook plate. Drill holes through which to pass suture as well as suture anchors can be used [9, 10].

6.1.4.3 Glenohumeral Dislocations

Ninety percent of glenohumeral dislocations are in the 15–25-year-old age group and are anterior, i.e., the humeral head is anterior to the glenoid. However, the dislocation can also occur in those over the age of 50, can be posterior (Fig. 6.12), and can be associated with a proximal humerus fracture. There can be an associated fracture of the humeral neck as well as one or both of the tuberosities. Presentation is typically to the ER soon after either direct trauma or a fall on an extended, abducted shoulder. For most patients, the deformity of an anteriorly protruding humeral head and defect on the posterior shoulder is obvious, but in larger patients it may not be so. Detailed neurologic exam is necessary as up to 25% of patients may have a neurologic deficit (especially of the axillary or radial nerve) although some of these deficits are only detectable electromyographically. Imaging evaluation is primarily plain films. All shoulder radiography for trauma should include an AP and either a Y-view or axillary view as just obtaining AP views in internal and

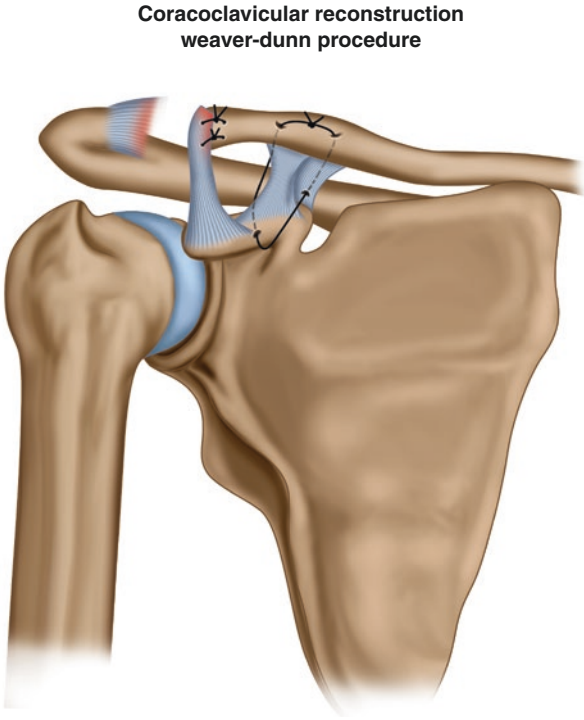

Fig. 6.11 Diagram of one way of repairing an AC dislocation

external rotation can miss the dislocation or misdiagnose the direction (anterior or posterior). If for some reason (patient size, pain, or inability of the radiology technologist) a Y-view or axillary view is not obtainable, then a CT scan should be obtained.

Treatment of shoulder dislocations is usually straightforward: closed reduction. There are a variety of methods of reduction, as well as various methods of pain control. Some patients can tolerate the pain, and with vocal encouragement the dislocation can be reduced. Others will require either narcotics for pain control or benzodiazepines for anxiety control before reduction can be accomplished. Rarely general anesthesia will be necessary, and this is usually with patients who present 1–3 days after sustaining the dislocation. If the reduction is attempted early before muscle spasm has set in, then it is generally quite easy. The important part to remember is gentle sustained traction. Do not try to jerk the shoulder into place. Most of the time, the practitioner will feel or hear a "clunk" as the shoulder is reduced.

Post-reduction treatment includes a sling or sling and swathe as well as orthogonal radiographs (see above) to ensure a good reduction and to make sure there are no previously undetected fractures. The length of immobilization is highly variable depending on a wide variety of factors including surgeon preference. Generally, for first-time dislocations, the length of immobilization is longer. For older patients the length is shorter (to avoid stiffness) [11–15].

Two long-term problems result from shoulder dislocations. First and foremost is recurrent dislocation. There is a direct correlation between age and chance of

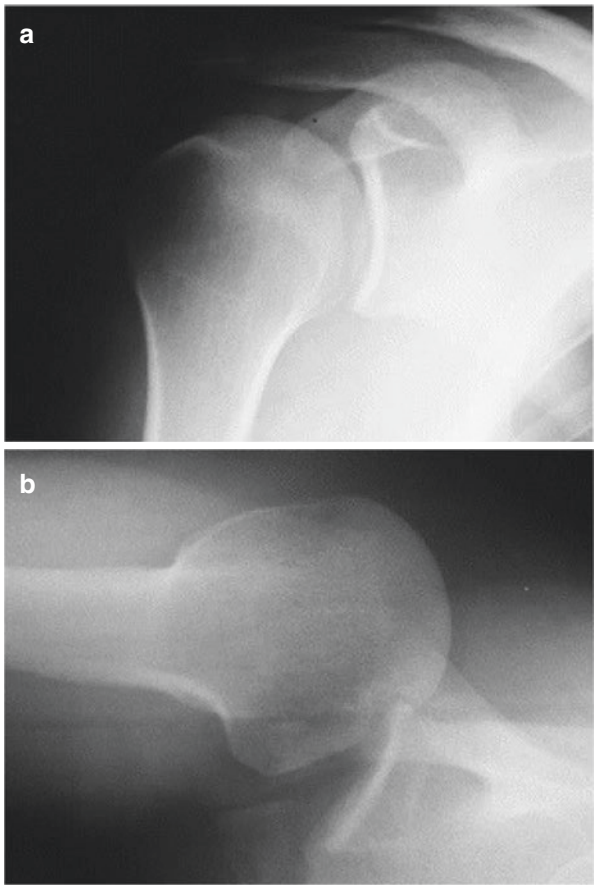

Fig. 6.12 Radiograph of a posterior glenohumeral dislocation which most commonly results from trauma but the AP should be aware that seizures are also a common cause (including those from epilepsy, hypoglycemia, and alcohol or drug withdrawal). Note the AP radiograph (**a**) looks deceptively normal, but the axillary view seen in (**b**) clearly shows the posterior dislocation. (From the Mouzopoulos sign, a radiographic sign of posterior shoulder dislocation: https://link.springer.com/article/10.1007/s10140-010-0862-2)

recurrence such that if an 18-year-old dislocates his shoulder, there is a 95% chance it will dislocate again. The more often it dislocates, the more likely it will continue to do so. Associated defects that can cause recurrence are discussed in the following section. The second problem associated with shoulder dislocations is in the population of those over forty years of age. These patients frequently have a rotator cuff tear as a result of the dislocation. Again, treatment depends on the patient. For the 55-year-old construction worker, repair is appropriate, but for the 75-year-old sedentary grandmother it may not be. Nonetheless, not repairing it may lead to recurrent dislocations, shoulder weakness, or rotator cuff arthropathy.

6.1.5 Complications of Dislocations

6.1.5.1 Hill-Sachs Lesion

A Hill-Sachs lesion is a wedge-shaped defect in the posterolateral humeral head caused by the anterior glenoid rim when the shoulder dislocates anteriorly. The

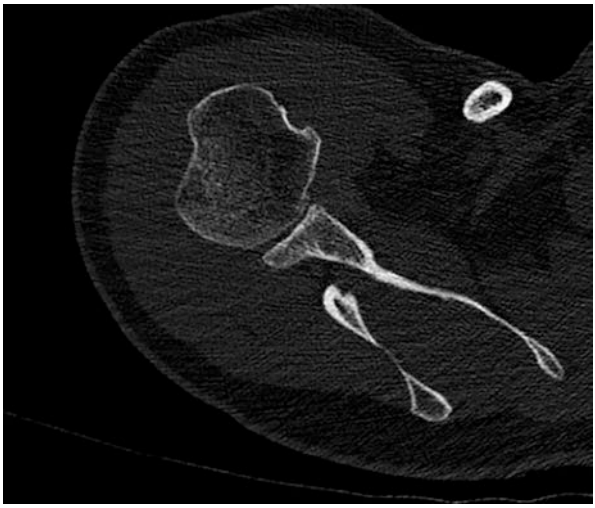

Fig. 6.13 CT scan of a Hill-Sachs lesion that can result from an anterior glenohumeral dislocation. The lesion can vary in size according to the energy of the original injury and the quality of the bone. The small indentation on the front of the humeral head is the bicipital groove. The larger indentation laterally is the Hill-Sachs lesion. A reverse Hill-Sachs is the same lesion on the anterior aspect of the humeral head after the much rarer posterior dislocation. (Courtesy Medical College of Georgia, Department of Orthopedics)

larger the Hill-Sachs lesion, the more likely it will allow dislocation upon external rotation of the shoulder, thus increasing the size of the defect (Fig. 6.13) [16].

6.1.5.2 Bankart Lesion

The Bankart lesion is a tear of the anterior labrum (Fig. 6.14). This results in a lessening of the concavity of the glenoid socket allowing anterior dislocation or subluxation. These lesions are not always apparent on MRI, and on arthroscopic examination the labrum can scar to the anterior neck of the glenoid giving the inexperienced arthroscopist a false sense of anatomic normality and stability.

The anterior or inferior capsule or both can also be stretched or torn resulting in varying degrees of laxity. In addition, with multiple dislocations there can be significant anterior glenoid bone loss.

Treatment of recurrent dislocation is, as always, based on the patient including age, activity level, and the underlying anatomical pathology. If nonoperative treatment (i.e., PT and activity modification) does not resolve the problem, then surgery is appropriate but must address the underlying pathology. Whether this is done through an open procedure or arthroscopically is dependent on the underlying pathology, equipment availability, and the surgeon's skill and experience.

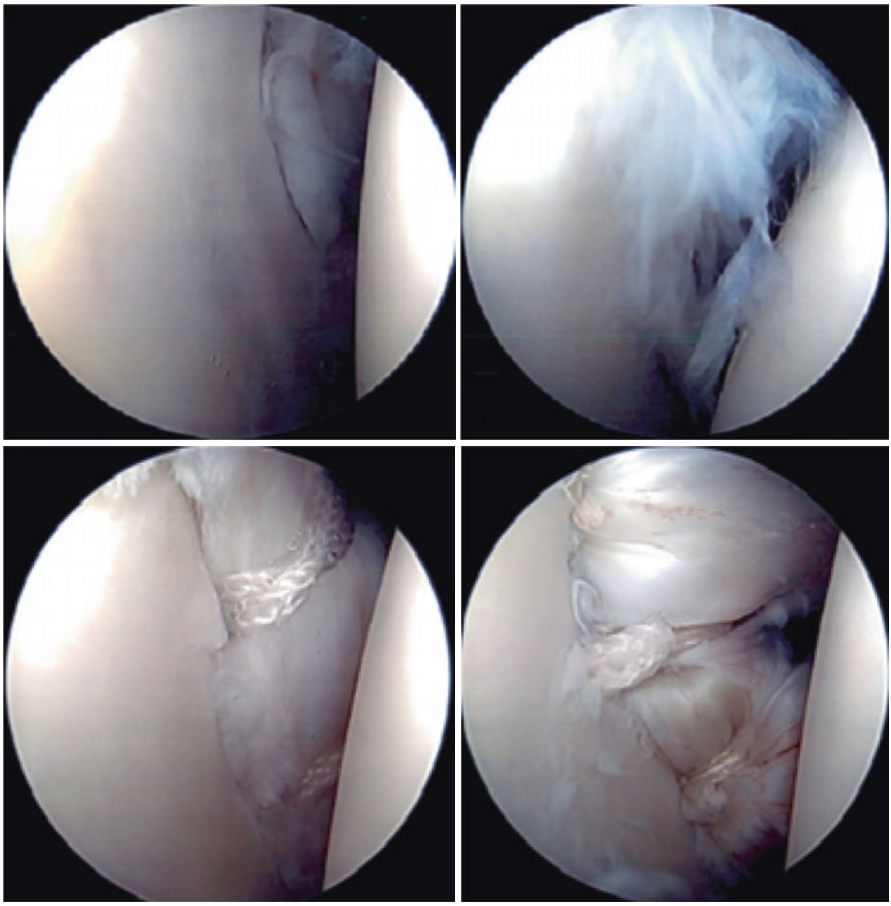

Fig. 6.14 Arthroscopic view of the right shoulder from the posterior portal of a Bankart lesion before and after repair. Note that the buttress of the labrum is restored in the bottom two photographs

6.1.6 Other Common Shoulder Pathology

6.1.6.1 Labral Tears and Long Head Biceps

Labral tears are not always associated with shoulder instability. The patient may present with vague shoulder pain or may have complaints of painful clicking with the following tests being positive: the crank test and O'Brien's. The crank test is performed in either the standing or supine position with the shoulder abducted to 90° in the plane of the body. With the patient relaxed, the shoulder is compressed and gently internally and externally rotated with clicking and pain being considered positive for a labral tear. O'Brien's test is performed by having the patient sit or stand and flex the shoulder to 90°, adduct 10°, and, with the elbow straight, internally rotate the shoulder and pronate the forearm (thumb down) and then attempt to

flex the shoulder further against resistance. Pain is suggestive, but again not definitive of a labral tear.

Imaging consists of radiographs to rule out other pathology, including osteoarthritis of the glenohumeral joint. For the diagnosis of labral tears, an MRI without contrast is not nearly as helpful as an MRI with intra-articular contrast. Although a positive MRI is generally accurate, the false-negative rate (i.e., a labral tear is present but not seen on the MRI) can be as high as 50%.

Arthroscopy is currently the gold standard for diagnosis. Treatment consists of repair or debridement dependent on the patient, location and degree of the tear.

The biceps tendon attaches distally to the proximal radius and functions primarily as a forearm supinator and secondarily as an elbow flexor. The short head originates from the coracoid process with the long head going over the top of the humeral head between the lesser and greater tuberosities to attach to the superior aspect of the glenoid via the labrum, thus acting as a humeral head depressor.

The typical patient with long head biceps pathology is usually male in the 40–60 age range and presents with one of the two pathologies.

The first is easily diagnosed clinically as the patient complains of a pop (sometimes painful, sometimes not) in the shoulder and subsequent deformity of the biceps muscle belly. This is frequently called a "Popeye deformity" (referring to the spinach eating sailor of the comic first printed in 1929 and televised beginning in 1957). If there is no associated cuff tear, most surgeons treat this injury nonoperatively as forearm supination strength loss is only 10–15%.

The second is more difficult to diagnose: tendinitis of the long head of the biceps tendon, especially as it passes between the tuberosities (Fig. 6.15). The patient

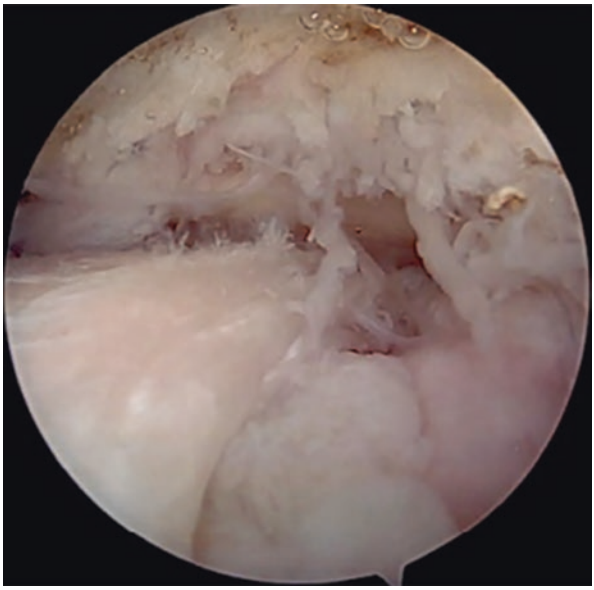

Fig. 6.15 Arthroscopic view of a degenerative, symptomatic biceps, long head, tendon. The tendon runs from the 7:30 position to the middle of the picture where it dives into the intertubercular groove

presents with anterior shoulder pain with tenderness in the intertubercular groove and sometimes pain in the anterior shoulder on resisted supination of the forearm.

Like labral tears, diagnosis of long head biceps pathology via MRI is not nearly as accurate as for rotator cuff tears. Some patients will have noticeable fraying on the MRI but no pain (i.e., false-positive MRI), while others will have a normal MRI but have pain and an obviously degenerative tendon on arthroscopic exam.

If NSAIDs and physical therapy do not relieve the symptoms, treatment is either tenodesis or tenotomy. A few patients will accept the latter – i.e., cut the long head of the biceps at its origin on the labrum and which will either cause a "Popeye" deformity or it may get caught and scar spontaneously in the intertubercular groove. Many patients and surgeons, however, opt for a tenodesis. The long head is cut at its attachment to the labrum and either secured in the superior end of the groove, in the intertubercular groove, or where it emerges just below the pectoral tendon. Postoperative care consists of sling and limited use for a period of 3 weeks to 3 months depending on patient activity level and strength of the tenodesis. Several studies have shown no long-term difference in patient satisfaction or function between tenodesis and tenotomy.

6.2 Non-traumatic

6.2.1 Glenohumeral Arthritis

Arthritis of the glenohumeral joint is a degenerative process affecting patients over 55 years old. There may or may not be a history of injury of repetitive use. Like adhesive capsulitis, the patient complains of a gradual onset of pain and stiffness with pain being the more predominant symptom.

Physical exam differs from that of adhesive capsulitis in that in addition to loss of motion, there may be crepitus and pain within the range of motion that the patient has been able to maintain. Strength testing is difficult due to pain but is usually normal.

Plain radiographs include an AP in both internal and external rotation as well as an axillary view. Some surgeons will use a Grashey view which is an AP view taken perpendicular to the plane of the scapula rather than perpendicular to the torso. If there is uncertainty about the status of the rotator cuff, an MRI may be appropriate.

Like other joints affected by arthritis, the initial treatments include activity modification, anti-inflammatories, and physical therapy. If that does not relieve the symptoms, then shoulder arthroplasty is an option. The patient needs to understand that unlike knee and hip arthroplasty, the amount of cooperation and time required to completely recover from a shoulder arthroplasty is much more extensive. This is primarily because there must be time for the subscapularis (which is taken down to allow for replacement of a humeral head and resurfacing of the glenoid) to heal before active strengthening and a full range of motion can begin (Figs. 6.16 and 6.17).

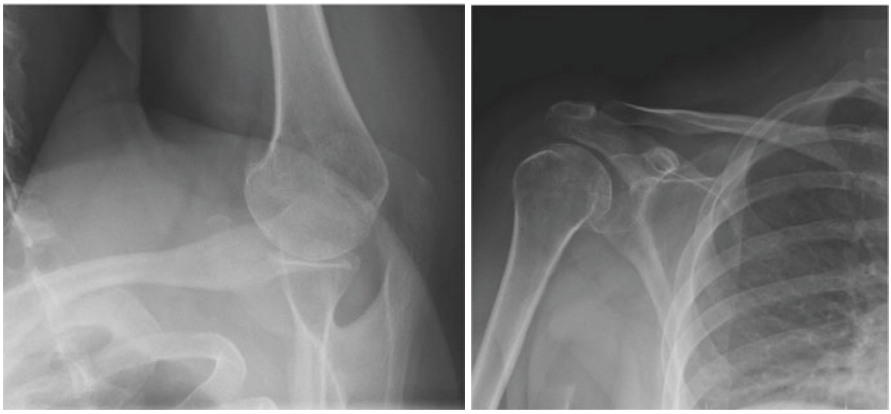

Fig. 6.16 Pre-op films of a patient who underwent an anatomic total shoulder arthroplasty. The lack of joint space seen on the axillary view is not readily apparent on the AP view. See Fig. 6.4 for the post-op film

Fig. 6.17 Zimmer anatomic total shoulder arthroplasty components. There is ongoing discussion about metal pegs (for bony ingrowth) vs all polyethylene pegs fixed with cement. (Image courtesy Zimmer Biomet)

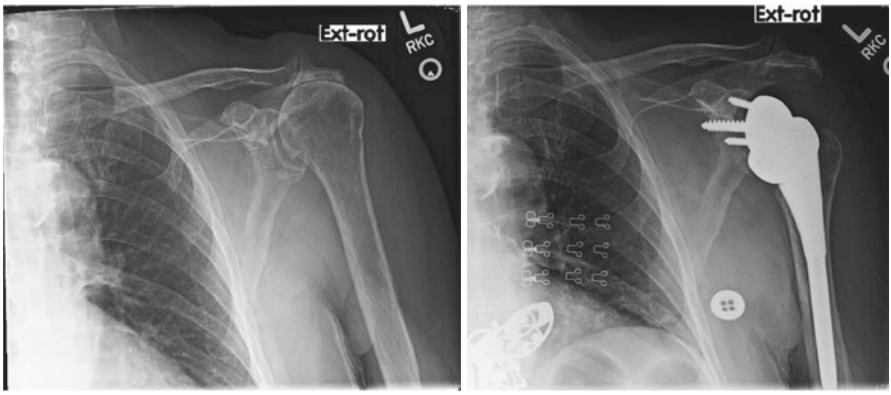

Fig. 6.18 Pre- and post-op pictures of a patient with rotator cuff arthropathy. Because there was no rotator cuff tissue, a reverse shoulder arthroplasty was performed. In the figure on the left, the humeral head is articulating with the underside of the acromion

A special case of shoulder arthritis is that which results from a large, chronic rotator cuff tear. Because the rotator cuff is not functional and not repairable, a reverse shoulder arthroplasty can be performed. An RSA changes the center of rotation of the shoulder allowing the deltoid to partially take over cuff function and to allow both better flexion and abduction (Figs. 6.18 and 6.19). External rotation strength, however, will depend on the integrity, or lack thereof, regarding the posterior cuff muscles.

6.2.2 Acromioclavicular Arthritis

Acromioclavicular arthritis is a common accompaniment to rotator cuff disease but can develop independently. Patients will present without a history of trauma; some patients will have a long history of heavy weight lifting. Physical examination shows normal motion and strength with prominence and tenderness of the acromioclavicular joint. The cross-arm adduction test may be positive for recreation of the pain. The best radiograph for seeing arthritis of the acromioclavicular joint is the Zanca view (Fig. 6.20).

Treatment includes assurance, activity modification (mostly avoiding overhead use and heavy lifting such as bench press), and corticosteroid injection. Corticosteroid injections can be difficult because of both localization with osteophytic overgrowth and overpenetration of the needle into the subacromial space.

If these measures do not work, then excision of the distal 5–10 mm of the clavicle (either open or arthroscopic) is an option if the amount of pain justifies surgical intervention.

If the patient has no tenderness of the AC joint and a negative cross-arm adduction test, then the AP should look for other causes of shoulder pain despite the positive imaging findings. Treat the patient, not the radiograph.

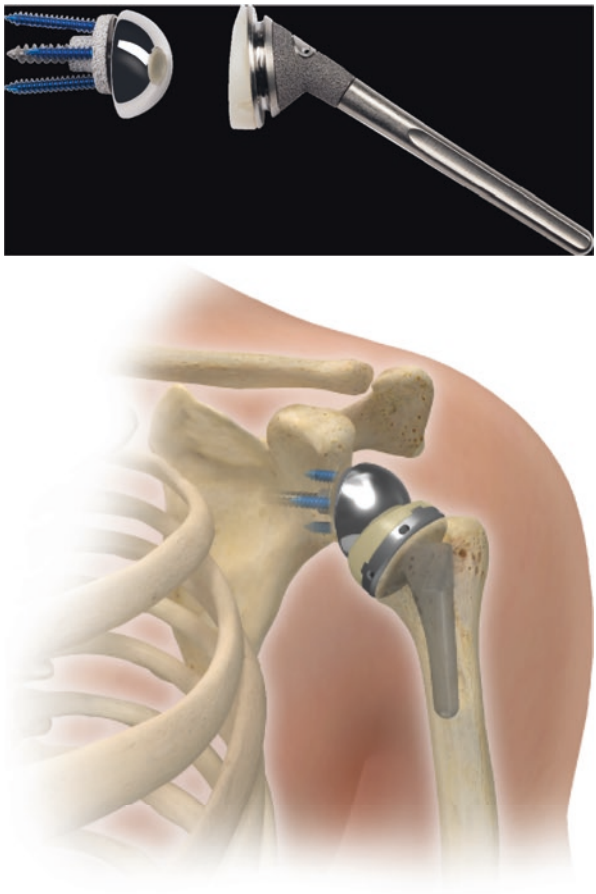

Fig. 6.19 Zimmer Biomet reverse shoulder arthroplasty components with schematic of component positioning. (Courtesy Zimmer Biomet)

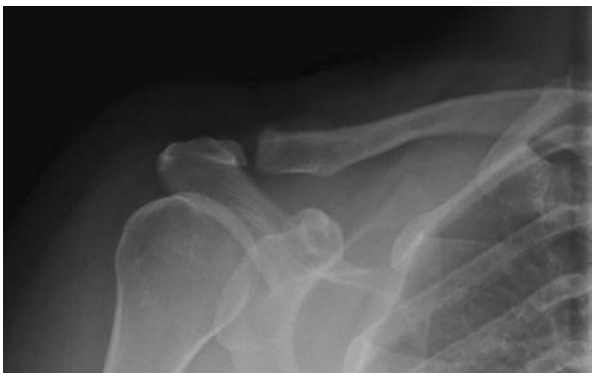

Fig. 6.20 Zanca (or cephalad view) of a normal AC joint. Angling the X-ray beam slightly upward allows better visualization of the AC joint so that it is not obscured by the upper portion of the scapula

6.2.3 Rotator Cuff Disease

Rotator cuff disease covers a wide spectrum of problems from a minor tendonitis to a full-blown four-tendon retracted tear. As a reminder, the rotator cuff is made up of the subscapularis anteriorly, the supraspinatus superiorly, and the infraspinatus and teres minor posteriorly. Oversimplifying, the primary purpose of the rotator cuff is to stabilize the glenohumeral joint while the deltoid does the "heavy work" of abduction and flexion. Unfortunately, several terms are used interchangeably when referring to rotator cuff disease including impingement syndrome, subacromial bursitis, subdeltoid bursitis, and rotator cuff tendinitis. They are all related and refer to different stages of rotator cuff problems, but there is not necessarily a progression from one to the next. The bursitis and tendinitis are self-explanatory, while impingement refers to the greater tuberosity pinching the cuff tendons against the acromion when the shoulder is flexed or abducted. Impingement can cause tendinitis or be caused by tendinitis.

Most patients present with shoulder pain of several months' duration. The typical patient is 45–60 years old. Other complaints include more pain with overhead or outstretched use, loss of active motion, waking at night, and the occasional loss of motion. There may or may not be a precipitating injury.

Physical exam includes checking distal neurovascular status (including grip strength), checking for biceps deficits (proximally and distally), as well as range of motion of the neck. Elucidating whether there is an actual tear of the rotator cuff clinically can be difficult as partial tears or tendinitis can appear to be a complete tear and some patients can compensate such that a complete tear can appear to be just tendinitis. The following tests are helpful, but none are definitive for a cuff tear.

For the subscapularis the belly-press test and the lift-off test are helpful. The belly-press test checks primarily the upper half of the subscapularis, the lift-off test primarily the lower half. For the belly-press test, the patient places both hands on the abdomen and pushes the elbows forward against resistance. The lift-off test is performed by having the patient put the back of his hand against his lower back and using the shoulder to "lift" off his hand straight posteriorly. Be sure the patient is not using his triceps to "beat" the test.

The empty can test is for the supraspinatus and is performed just like it sounds. The arm is held at 90° abduction at 45° away from midline with the thumb pointed down. The patient attempts to continue abduction against resistance and any weakness noted.

External rotation strength testing is performed both with the elbow by the side and with the shoulder abducted to 90°. The former tests the infraspinatus and the latter the teres minor. All of these tests should be performed on both sides looking for asymmetries.

Two passive ranges of motion tests are done to look for tendinitis. The first is the Hawkins test done with the shoulder flexed to 90° straight ahead and internally rotating the shoulder. If pain is elicited, the test is considered positive. The examiner must make sure, however, that the patient does not rotate the torso away from the affected side preventing the greater tuberosity from impinging against the acromion.

The second passive test is the Neer impingement sign. It is done twice, first slow and then fast. If the first elicits pain, it is considered positive and the faster test is not necessary. The test is performed by the examiner bringing the arm/shoulder in straightforward flexion to the vertical position. Pain on forward flexion is a positive test indicating possible cuff tendinitis.

Diagnostic imaging begins with radiographs of the shoulder. Different surgeons have different preferences, but views that can be obtained include anterior-posterior in both internal and external rotation, axillary, Grashey, Y-view, and Zanca (to isolate the acromioclavicular joint). The AP should look for arthritis, loss of the subacromial space (normal distance from inferior acromion to superior humeral head is 8–10 mm; anything less than 6 mm is almost surely consistent with a rotator cuff tear), and the upper lung looking for a Pancoast tumor.

Depending on the patient (age, duration, severity of symptoms, and findings on physical examination), further imaging can be done. An MRI is almost always definitive if a tear is present, especially if intra-articular contrast is used. In addition, the MRI can identify other pathologies including tear size, associated atrophy, arthritis of the AC and glenohumeral joint, labral tears, and long head biceps pathology. Ultrasound is also an option although it is not nearly as good as an MRI at identifying deeper pathology and is both operator and equipment dependent.

Treatment is again patient dependent. For tendinitis/bursitis temporary activity restriction (no overhead or outstretched arm use) and a course of physical therapy usually suffice. Some patients may require a subacromial steroid injection through a lateral approach, with or without ultrasound guidance.

Symptomatic full-thickness tears in the physiologically young patients are best treated with surgical repair as the natural history is one of progression of the tear and subsequent loss of function and increasing pain. This can be done arthroscopically or through a larger incision. Either way the patient needs to understand the results are in large part dependent on following the postoperative restrictions and therapy instructions. The early post-op period (first 6 weeks) consists of a sling with an abduction pillow to take tension off the repair. The pillow is removed at 2–6 weeks depending on tear size, tissue quality, and repair stability. There is ongoing debate about if and how long the sling should be worn postoperatively. Pendulum exercises and limited passive range of motion exercises are to start at the discretion of the surgeon dependent on tear size, tissue quality, and stability of the repair. Full motion and active-assisted range of motion started at 6–8 weeks, and finally active motion and strengthening at 8 weeks. The patient should expect recovery to take 5–9 months. Anatomic failure of repair occurs in 5–10% of patients, but surprisingly some of the patients with anatomic failures remain asymptomatic. Patients with partial thickness tears that fail nonoperative treatment have several options. Obviously, no treatment is an option. The tear can be completed and then repaired, the tear can be repaired without completing the tear (so-called PASTA – partial articular supraspinatus tendon avulsion – repair), or the tear can be reinforced with autograft (typically taken from the tensor fascia latae (TFL)) or allograft (typically processed acellular dermis). This subject is controversial as to the best method and depends on surgeon preference, experience, as well as the patient's specific pathology [17–19].

Some tears are markedly retracted and irreparable. There are no perfect answers for this problem. Some patients are best treated nonoperatively with activity modification and a short course of physical therapy. The following is a list of possible surgical treatments, but all are considered salvage operations, i.e., making a bad problem not so bad:

- Reverse shoulder arthroplasty for patients greater than 60 years old.
- Tendon transfer such as the latissimus dorsi can restore some function.
- An interposition graft (either a piece of the patient's own TFL or an allograft).
- Superior capsular reconstruction (SCR).

The SCR is where either an autograft (typically a doubled over piece of the TFL) or a thicker dermal allograft is attached to the superior glenoid rim on one side and to the humeral tuberosity on the other. This prevents superior migration of the humeral head decreasing pain and allowing better but not normal function [20–22].

6.2.4 Adhesive Capsulitis

The patient with adhesive capsulitis (also known as frozen shoulder) is typically 40–60 years old and presents with a 3–6-month history of shoulder pain or stiffness. Most of the time, the patient does not remember any specific trauma. On physical examination there is a loss of motion, the most common being loss of internal and external rotation. The patient may complain of inability to insert his belt through the loops on the back of his pants or fasten her bra. Strength is normal, but testing for strength or impingement may be difficult due to loss of motion.

The only imaging normally used is plain films to rule out arthritis or rotator cuff arthropathy. MRIs are not usually ordered but will show an intact rotator cuff, and if intra-articular contrast is used, the radiologist may note decreased volume.

The underlying pathophysiology is that the joint capsule starts to contract and develop scar tissue; consequently, the patient uses the shoulder less which results in progressive tightening of the joint capsule. The natural history is one of resolution in 6–18 months. Patients present when it interferes with activities in which they normally engage.

Treatment is initially reassurance that the disease is self-limited. The first line of treatment is a home stretching program; if that does not relieve symptoms, then a course of physical therapy may be helpful. Finally, for persistent, recalcitrant cases where stiffness is not resolving after a sufficient period of time, surgery is an option. Manipulation under anesthesia and arthroscopy to cut part of the capsule intra-articularly can be helpful. Cutting the inferior portion of the capsule puts the axillary nerve at risk. The AP should emphasize that the best results from surgery occur if the patient immediately (same day or next day) follows up with aggressive home stretching and physical therapy. An indwelling scalene block (regional anesthesia affecting the brachial plexus) can help control the pain allowing for adequate stretching and physical therapy [23].

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The Foot and Ankle

7

7.1 Introduction to Ankle Fractures

Ankle fractures occur at all ages and in a variety of situations from simple tripping to high-speed motor vehicle accidents. Occasionally patients can tell exactly how the injury occurred, but most cannot other than that they fell and the ankle hurts. After inquiring if there are other injuries, a careful physical exam can tell the examiner if radiographs of the foot are necessary in addition to those of the ankle.

Unfortunately, the standard protocol for most hospital ERs is AP, lateral, and oblique views of the ankle, when AP, lateral, and mortise views are more helpful. The mortise view is especially important as this gives some idea as to the necessity of closed vs open treatment. On the mortise view, there should be even spacing between the talus and medial malleolus, talus and distal tibia, and talus and lateral malleolus. In addition, there is a shallow concavity in the dome of the talus that should line up with the shallow convexity in the distal tibia (Fig. 7.1).

Radiographically, there are two major systems to classify ankle fractures in addition to the AO system. The Weber system is easiest (A, B, C).

The Weber (full name is Danis-Weber) system primarily describes where the lateral malleolar fracture is in relation to the tibiotalar joint. The Weber classification is supplemented by describing any medial or posterior malleolus fractures and displacement of said fractures. Weber A fractures have the lateral malleolus fracture line below the level of the mortise (tibiotalar joint line), Weber B at the joint line, and Weber C above (Fig. 7.2). The original articles describing this classification method are not in English [1, 2].

The other system is generally too complicated to remember, but it is useful for reduction methods and research. The Lauge-Hansen system is based on the position of the foot (pronation/supination), the direction of the deforming force (e.g., varus/valgus), and the number of structures injured [3–5].

When operative management of any foot or ankle fracture or injury is being considered, the AP needs to remember that swelling from the injury may make skin closure difficult. Generally, surgery is done in the first 8–10 hours before the

J. A. Gracy, *Orthopedics for Physician Assistant and Nurse Practitioner Students*, https://doi.org/10.1007/978-3-031-04406-9_7

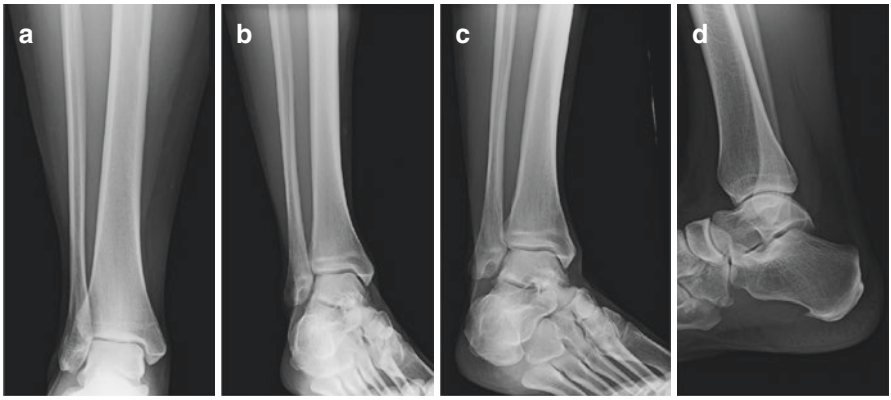

Fig. 7.1 (**a**) AP radiograph with no rotation of right ankle in flexed position. (**b**) Mortise view of right ankle, rotated medially 15–20° showing the even spacing around the talus. (**c**) Oblique view of right ankle, rotated laterally to 45°. (**d**) Right ankle lateral view

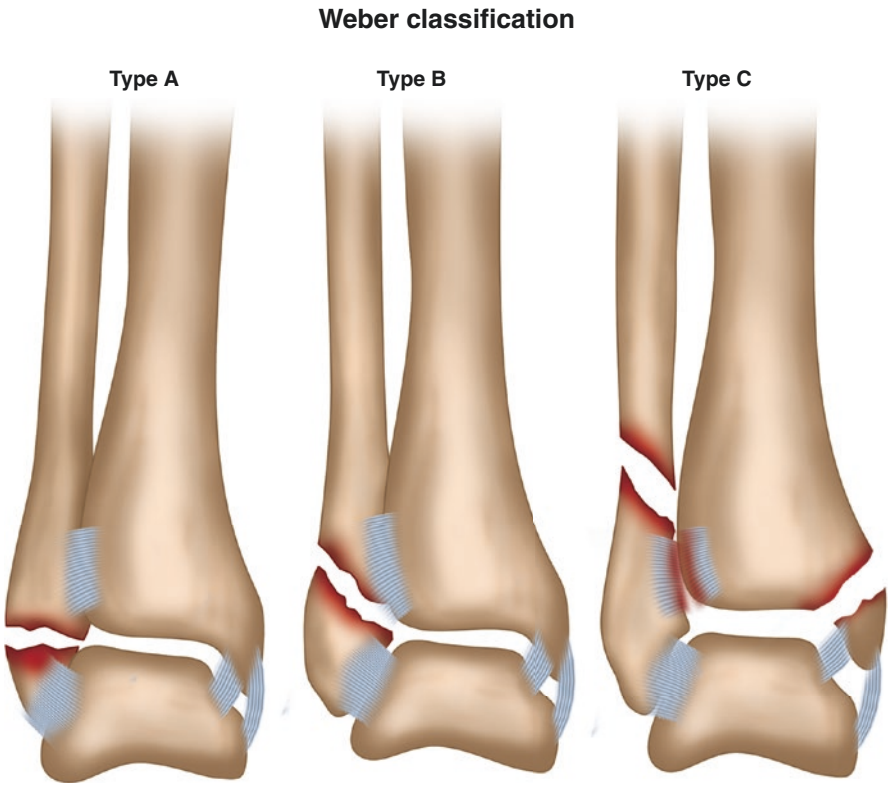

Fig. 7.2 Weber classification

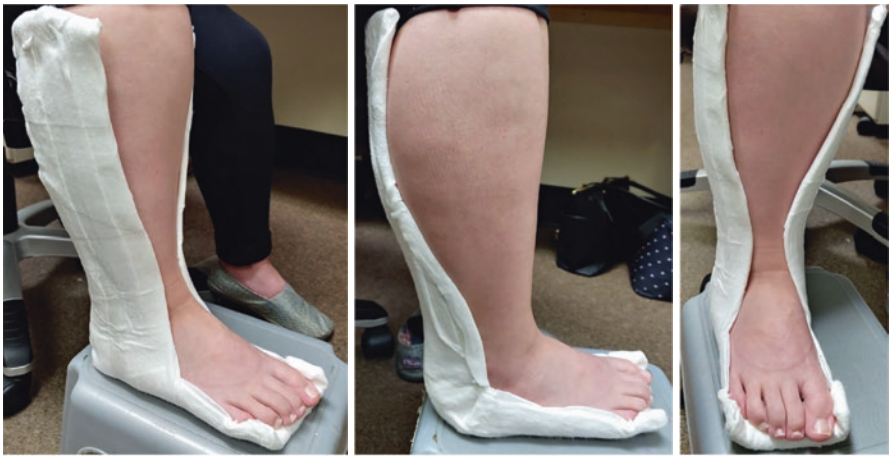

Fig. 7.3 A posterior splint, as seen in the middle, is easier to apply but typically breaks at the heel rendering it nonfunctional for the purposes of immobilization. The posterior and horseshoe (or stirrup) splint, as seen on the left and right, provides much better stability, but care must be taken to leave a gap anteriorly to allow for swelling. Also be careful not to pinch the toes when applying the posterior portion of the splint

swelling has become severe or after 3–5 days when the swelling has subsided. For the latter time frame, splinting in a reasonably reduced position as well as ice and elevation will promote swelling reduction. In the operating room, a bump is placed under the ipsilateral hip allowing access to the lateral malleolus while intraoperative fluoroscopy ensures fracture reduction, metal placement, and stability of the syndesmosis. Patients with a posterior malleolar fracture may need to be treated in the prone position.

Many ankle and foot fractures will initially be treated with a splint before operative treatment or casting. It is important to splint using both a posterior and "horseshoe" splint. Using a posterior splint only is weak and ineffective at immobilization because it will break at the heel rendering the splint useless (Fig. 7.3).

7.2 Traumatic

7.2.1 Specific Foot and Ankle Fractures

7.2.1.1 Triplane and juvenile Tillaux

Triplane ankle fractures are most common in 12–14-year-old males and are the most common Salter-Harris type IV fracture. The fracture typically occurs just as the growth plates slightly widen before closure. Diagnosis is made with plain radiographs that show a fracture extending up the posterior tibial metaphysis in the coronal plane, across the physeal plate in the transverse plane and through the epiphysis into the joint in the sagittal plane. The mechanism of injury is an external rotation force.

Because the amount of displacement is not always easy to determine, CT scans are frequently necessary. If the articular surface is displaced greater than 2 mm or there is a step off, then closed (possible open) reduction is appropriate, followed by two percutaneous screws placed under fluoroscopic control. One screw is placed medial to lateral through the epiphysis across the sagittal fracture. A second screw is placed from anterior to posterior through the metaphysis. Some fractures may require two screws in the aforementioned locations. Many orthopedic surgeons use a cannulated screw to ensure the most accurate placement and minimize damage to the physis and the articular surface [6, 7].

A second special type of ankle fracture is the juvenile Tillaux which occurs slightly later in the growth spurt of the adolescent. The mechanism of injury is the same as the triplane, but because the medial portion of the distal physis is closed, this is a Salter-Harris type III with the anterolateral portion of the distal tibial epiphysis being fractured. Treatment is closed reduction followed by percutaneous screw fixation. Because the growth plate is nearly closed, avoidance of injury to the physis with any metal placement is not nearly as critical as it is in the triplane fracture, but anatomic reduction of the articular surface is still critical. Obtaining a CT scan to assess articular surface gap and step off is not unusual.

Although in an ideal world the patient would be non-weight bearing for 3–6 weeks postoperatively, to allow the growth plate time to recover, these are teenagers who will probably start weight bearing as soon as tolerated pain wise. Six to eight weeks of cast time is normal. Metal removal is rarely necessary. The long-term consequence of both the triplane and the juvenile Tillaux fractures, even with an anatomic reduction, is possible ankle arthritis due to the cartilage damage suffered at the time of injury or inadequate reduction.

7.2.1.2 Calcaneus Fractures

The most common cause of calcaneal fractures is a fall from height. The patient cannot bear any weight on the affected heel, and there is marked swelling and ecchymosis. Associated compartment syndrome is rare, but associated fractures of the knee, hip, and pelvis as well as compression fractures of the thoracolumbar spine are not uncommon. Careful physical exam and radiographs, where indicated, are crucial to avoid missing additional injuries.

There are a wide variety of radiographs that can be taken to assess the severity of calcaneal fracture and disruption of the subtalar joint. On a plain lateral film of the foot, two angles are important: Böhler's angle which measures from the superior aspect of the posterior calcaneus to the "peak" and then to the superior distal end of the calcaneus. Normal is 25–40° (Fig. 7.4); the second angle is the critical angle of Gissane: an angular measurement made directly inferior to the lateral process of the talus. It is formed by the downward and upward slopes of the calcaneal superior surface. Its normal value is usually between 120° and 145° (Fig. 7.4).

Böhler's angle helps to measure the proper height of the calcaneus, while the angle of Gissane angle helps determine the proper relationship of the three facets of the superior aspect of the calcaneus to the talus.

If operative intervention is being considered, a CT scan is very helpful in delineating fracture lines as well as determining operative approach.

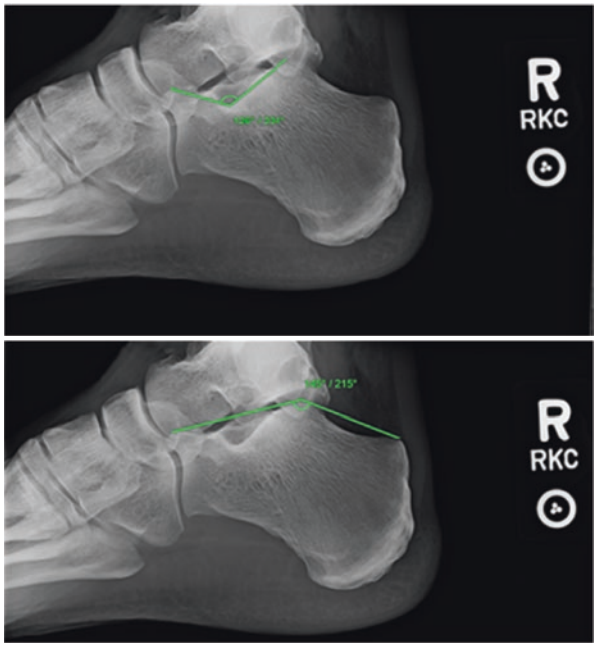

Fig. 7.4 Normal calcaneus. The upper picture shows the angle of Gissane (normal is 120–145°), while the lower picture shows how to measure Böhler's angle which is subtracted from 180 to arrive at a normal of 20–40°

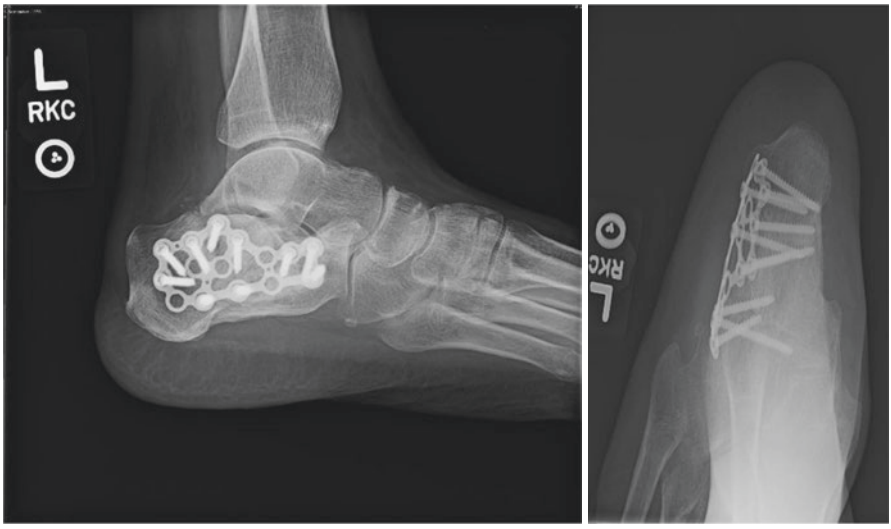

Fig. 7.5 Lateral and axial view after ORIF of calcaneus. The axial view can show if there is over-penetration of the screws that may interfere with the posterior tibial tendon, nerve, and vessels. In addition the heel can be widened as a result of the calcaneus fracture, so the axial view ensures the heel width has been restored

Treatment is based on physiologic age, activity level, severity of injury, associated medical conditions, and skill of the surgeon. Some studies clearly show better outcomes for surgically treated calcaneal fractures (Fig. 7.5), while other studies

show equivocal outcomes. Whether treated operatively or not, the typical non-weight bearing time is 8 weeks with up to 2 years being necessary before improvement plateaus. In either case, the patient should be warned that there will be a partial permanent loss of hindfoot inversion/eversion [8].

From a practical standpoint, there are two important questions. Is the fracture significantly displaced (i.e., does it need reduction; if so, how urgently)? If it is reduced, is it stable? Treatment by casting or open reduction and internal fixation is determined by answers to the two above questions. For cases where the best method to use is uncertain, a past medical history of severe diabetes or peripheral vascular disease may tilt the treatment toward casting.

7.2.1.3 Tibial Pilon

Tibial pilon or plafond fractures are in a category all by themselves. They are most commonly the result of a fall from a height or direct high-energy blunt force trauma. Rather than shattering the calcaneus, the distal articular surface of the tibia is shattered. After ensuring there are no other injuries, careful evaluation of the neurovascular status including serial monitoring for compartment syndrome is appropriate. CT scan is almost always necessary to get a better idea of the fracture lines and extent of injury.

Surgical treatment is almost always necessary with a wide variety of options including external fixators which may be only temporary until definitive internal fixation is applied or may be left in place until the fracture is healed (completely or partially). The external fixator may be a simple uniplanar construct or may be a ring/circular fixator. Internal fixation may be multiple screws or a plate and screws (Fig. 7.6). If there is an associated fibular fracture, it is usually fixed first to identify and restore appropriate length. The healing process is long (3–12 months) and often complicated by infection or tissue breakdown because of the lack of muscular coverage and/or tenuous wound closure. The patient should be reminded that a second or third trip to the OR is not unusual.

The most common long-term complication is post-traumatic arthritis which can be treated with an offloading brace, arthrodesis, or arthroplasty depending on patient age, activity level, and the state of the bone and soft tissues [9, 10].

7.2.1.4 Syndesmosis Injury

Syndesmosis injuries usually indicate a more severe injury and are the result of a significant external rotation force with disruption of ligaments connecting the distal fibula to the distal tibia. The more severe injuries are easy to diagnose, but the less severe may only be detected with stress films (external rotation) under general anesthesia.

In the past treatment had been closed reduction and placing a screw across the four cortices of the fibula and tibia with persistent controversy as to how long to ask the patient to limit weight bearing and timing on screw removal (if at all). The latter is important because motion of the fibula relative to the tibia will eventually cause screw breakage.

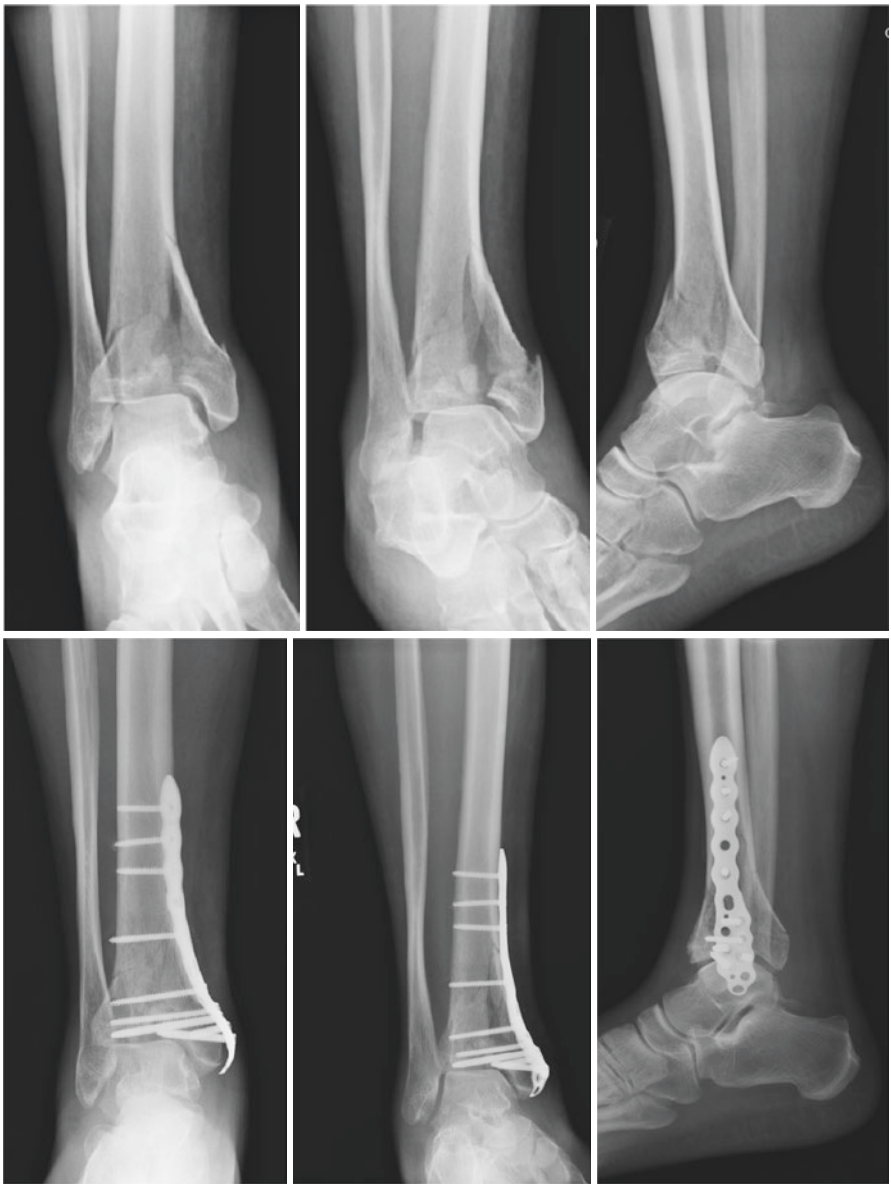

Fig. 7.6 Pre- and post-op pictures of a tibial plafond or pilon fracture. If the fibula is fractured, it is normally fixed first to restore length

The trend over the last few years has been to a more dynamic fixation system (Arthrex) in which the dislocation is reduced, and two metal buttons placed: one on the lateral aspect of the fibula and one on the medial aspect of the tibia. Stout

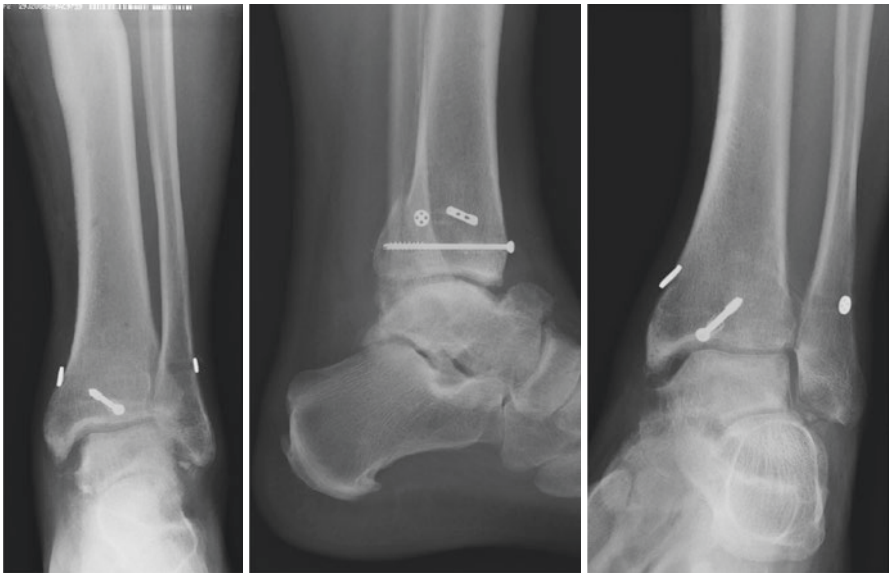

Fig. 7.7 Radiograph of the Arthrex TightRope used to fix a syndesmosis injury. The single screw from anterior to posterior was used to fix an associated posterior malleolar fracture

nonabsorbable sutures connecting the two buttons are tightened, thus finalizing and holding the reduction while the syndesmosis injury heals (Fig. 7.7) [11, 12].

7.2.1.5 Phalangeal Fractures and Dislocations

Most lesser toe fractures and dislocations come from kicking something on purpose or by accident. Many are self-reduced. Once reduced and in reasonable alignment, treatment is buddy taping to an adjacent toe and wearing a stiff open toed shoe or cast shoe. Return to activity and regular shoes is up to the patient with regard to activity type and pain tolerance. If seen acutely, there may be a subungual hematoma (i.e., blood under the nail bed), and the patient should be offered the option of drainage (trephination with an 18 gauge needle) if the hematoma is too painful (Fig. 7.8).

Open fractures of the lesser toes are uncommon except during the mowing season. Because of the high energy and dirty nature of the wound, these injuries should be taken to the operating room for thorough irrigation and debridement, followed by several days of antibiotics to cover both gram-positive and gram-negative bacteria. Verification of tetanus coverage should be obtained. Because of the usual severe contamination, the patient should be warned of the possible need for a second trip to the operating room and the possibility of the loss of a portion of the foot.

Great toe fractures are treated similarly to lesser toe fractures with the exception of intra-articular fractures where consideration should be given to closed reduction and percutaneous pinning or even open reduction with internal fixation using a mini-fragment screw set.

Loss of one or two of the lesser toes does not usually alter gait, but loss of the great toe will cause a mild limp.

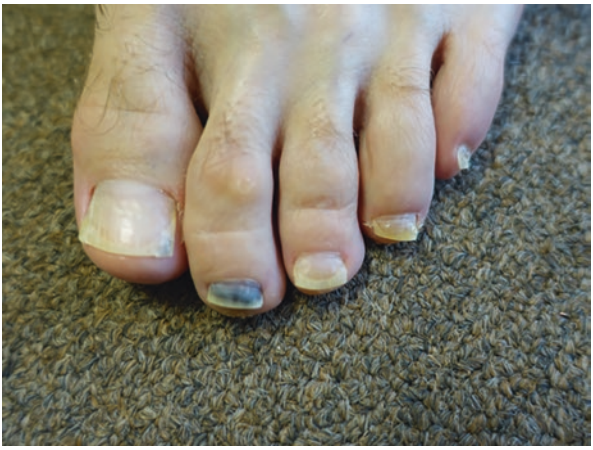

Fig. 7.8 Typical appearance of subungual hematoma. This happens to be in a distance runner, is chronic and non-painful. A change in shoe size may alleviate the problem

7.2.1.6 Metatarsal Fractures

Metatarsal fractures require more energy than phalangeal fractures and often are the result of a fall from a height, dropping a weight, heavy contact sports like American football, or motor vehicle accidents. With higher-energy injuries, it is important to be aware of the possibility of compartment syndrome as missing this diagnosis can result in long-term foot pain and dysfunction [13]. Three special types of metatarsal fractures will be discussed below.

The important thing to remember about metatarsal fractures is that a significant amount of angulation can be accepted in the medial-lateral direction (coronal plane), especially of the middle three metatarsals. What is not tolerated well is significant deviation in the dorsal or plantar direction. If there is excessive dorsiflexion of one metatarsal, then the other metatarsals will have to bear more weight than designed resulting in painful plantar callosities. If there is excessive plantar flexion, then the head of the fractured metatarsal may develop a painful plantar callosity. If not corrected acutely (with either closed reduction and percutaneous pinning or open reduction and internal fixation), treatment options are a custom orthotic with a channel cut out under the offending metatarsal head(s) or a corrective osteotomy. How much displacement is acceptable is unknown.

7.2.1.7 Avulsion Fractures

Fractures at the base of the fifth metatarsal are most often the result of a "near-fall" or misstep with acute pain at the point of injury. Diagnosis is straightforward based on history, physical exam, and plain films of the foot. Because of its location, it is important to examine the ankle to rule out an ankle fracture or sprain. Whether or not to get ankle radiographs in addition to the foot is dependent on the results of both the history and physical examination. One should avoid getting routine radiographs of both the foot and ankle just because one or the other is injured (Fig. 7.9).

Treatment is symptomatic allowing the patient to weight bear as tolerated. Some patients may only require stiff soled shoes, while others may need more aggressive immobilization such as a fracture boot or even a short-leg walking cast depending on pain tolerance and activity level [14].

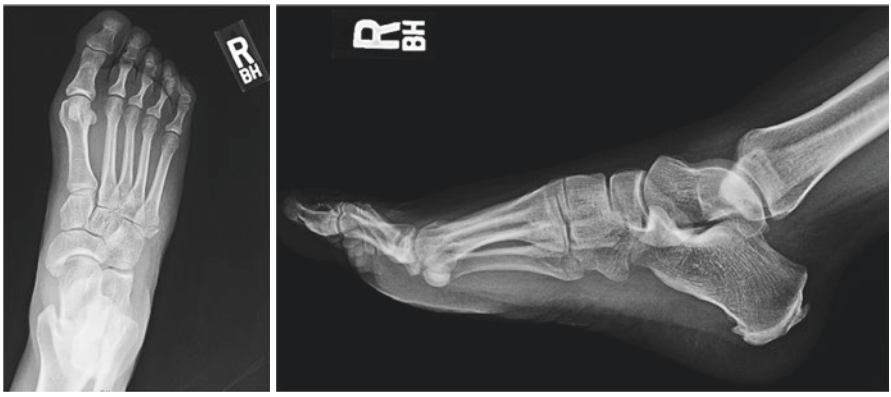

Fig. 7.9 Avulsion fracture at the base of the fifth metatarsal. Symptomatic treatment is usually all that is necessary. It should be differentiated from the much less common Jones fracture which occurs at the proximal meta-diaphyseal junction

7.2.1.8 "Jones" Fractures

Although anatomically close to the avulsion fracture at the base of the fifth metatarsal, the Jones fracture is a very different injury. The patient presents either with very limited weight bearing or completely non-weight bearing after a higher-energy injury than normally associated with an avulsion fracture of the fifth metatarsal. Physical exam shows tenderness along the lateral border of the foot, especially the fifth metatarsal, while radiographs show a transverse fracture at the proximal meta-diaphyseal junction of the fifth metatarsal shaft.

This can be a difficult fracture to treat because the blood supply to this area of the fifth metatarsal is poor and nonunion is common.

Careful history may reveal some aching in the foot in the several weeks or months prior to injury, and close examination of the radiographs may even reveal early callus in what is supposed to be an acute injury. Either one of these findings indicates the injury is the end stage of a stress reaction and has a higher chance to result in a nonunion. If this is the case, serious consideration should be given to early operative intervention, especially in athletes to minimize downtime. For truly acute injuries, a short-leg cast with 6–8 weeks non-weight bearing will result in healing. For fractures that are the consequence of a stress reaction or nonunion of an acute fracture, surgery consists of an intramedullary screw inserted from proximal to distal with or without autogenous iliac crest bone grafting or bone marrow aspirate [15].

7.2.1.9 Tarsometatarsal Dislocations and Midfoot Fractures

The final category of special metatarsal fractures is the *Lisfranc fracture/dislocation*. The sine qua non of this injury is a fracture at the base of the second metatarsal with associated dislocation/subluxation or fractures of some or all of the remaining tarsometatarsal joints. Like many other fractures, there is a bimodal demographic with high-energy injuries in the younger population and low-energy injuries in the

elderly. Typical injury patterns in the younger population are hyperdorsiflexion injuries to the midfoot in American football or simultaneously hitting the brake when the vehicle hits an immovable object. In the elderly, low-energy injury can result from a hyperdorsiflexion injury to the midfoot when excessive force is used such as when stepping on a curb with the forefoot.

Physical exam shows more swelling than expected with a forefoot or midfoot sprain. Before assigning the diagnosis of a mid- or forefoot sprain, it is incumbent on the AP to rule out a Lisfranc injury. Pronation/supination of the forefoot while stabilizing the hindfoot is unusually painful in those patients with a Lisfranc injury.

If non-displaced, the fracture and associated dislocation/subluxation may be difficult to see on initial plain films especially if the initial films are non-weight bearing (Fig. 7.10). Consequently weight-bearing films (when and if the patient can tolerate) or a CT scan may be necessary to identify a Lisfranc injury. On plain films, any fleck of bone around the base of the second metatarsal, especially plantar, should raise suspicion of a Lisfranc injury. Because of the location, the dorsalis pedis artery may be injured; ultrasound may be necessary to ensure its integrity.

Truly non-displaced Lisfranc injuries are rare and may be treated with casting and strict non-weight bearing. Displaced fracture/dislocations will require anatomic reduction, closed or open, with fixation, either percutaneous pins, screws, plates, or a combination thereof (Fig. 7.11). Prolonged casting and non-weight bearing is required in the postoperative period. The patient should be warned that like calcaneal fractures, recovery may not plateau for 2 years. The earliest complication is compartment syndrome; the late complication is midfoot arthrosis [16, 17].

Fractures of the cuboid and cuneiform bones are uncommon and can usually be treated with immobilization and limited weight bearing, unless significantly displaced usually in compression. If significantly displaced, open reduction and internal fixation, perhaps with autogenous or artificial bone graft, will be necessary especially in younger or more active patients [18].

7.2.2 Stress Fractures

Most stress fractures occur in athletes or people starting an aggressive exercise program, so history is important. Questions to ask include recent changes (6–12 weeks) in activity level at home, work, or play; change in running surfaces or shoes; recent weight gain or loss; and when does the pain bother them and how much. Is the pain only present after the activity, is the pain present during but not interfering with activity, or is the pain interfering with the activity? Physical exams will often show point tenderness, and the base of a vibratory tuning fork placed on the affected bone will elicit pain. Range of motion is normal, and depending on severity there may or may not be an associated limp. For some the limp is only detected while running.

Radiographs are often normal or only show changes late in the process: typically a periosteal reaction showing new bone formation or the fracture edges may have resorbed showing a clear fracture line. Bone scans are not used much for stress

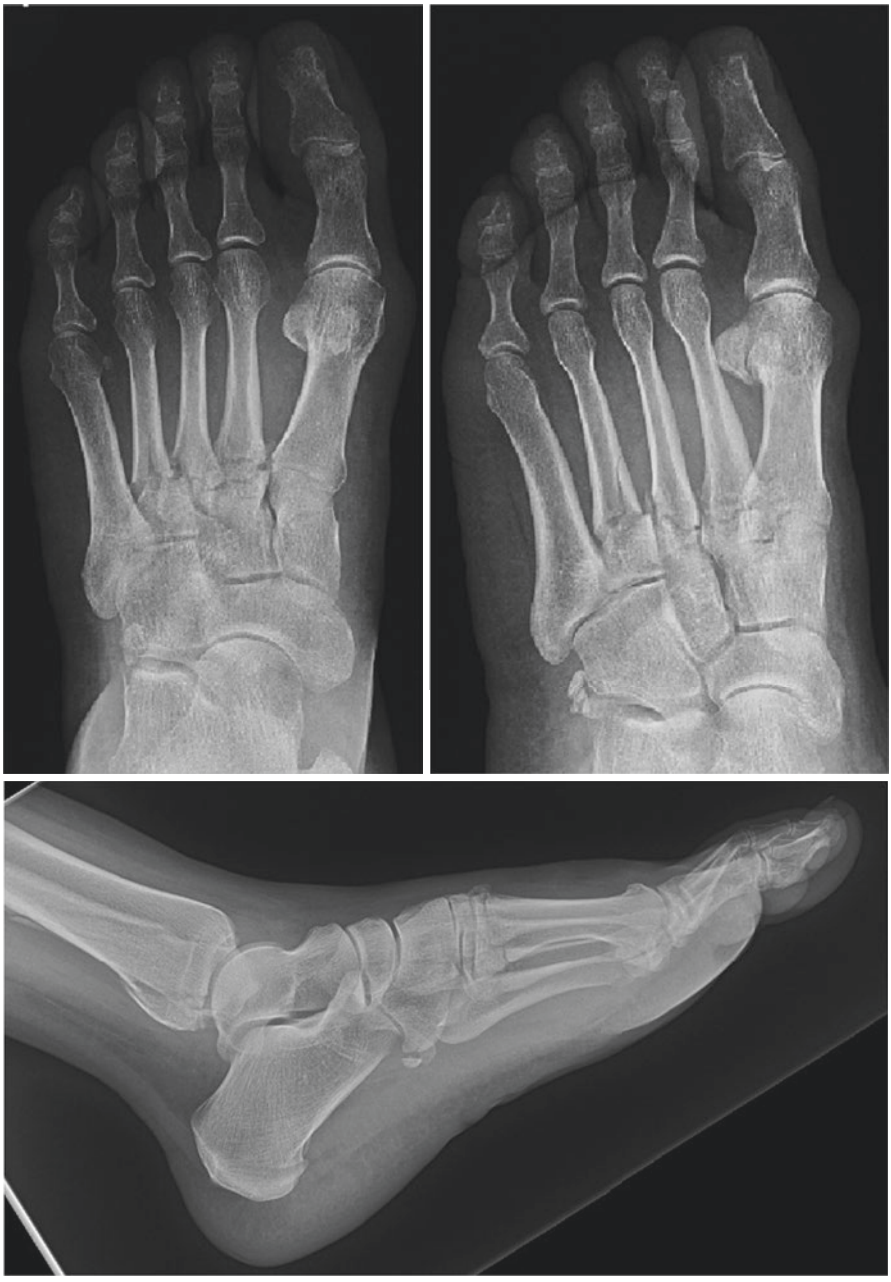

Fig. 7.10 Preoperative films of Lisfranc fracture/dislocation. Note the fractures at the bases of both the third and fourth metatarsals in addition to the sine non qua of the fracture at the base of the second metatarsal. The first tarsometatarsal joint is stable

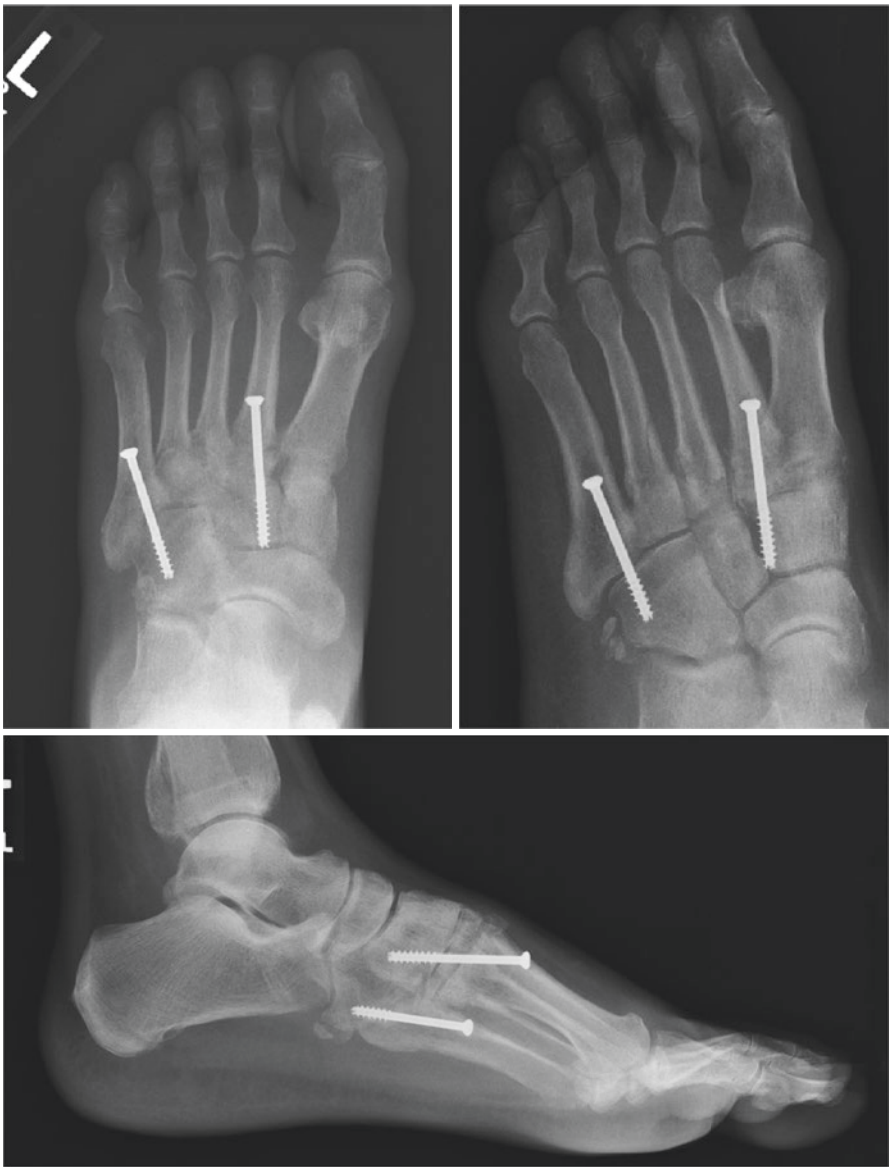

Fig. 7.11 Post-op radiographs of a Lisfranc fracture/dislocation. Once the second metatarsal fracture was stabilized, a second screw was placed through the fifth metatarsal into the cuboid which stabilized the rest of the TMT joint. Healing was uneventful

fracture diagnosis as MRI has become the imaging modality of choice if the plain films are nondiagnostic.

Like muscle, bone when subjected to stress gets stronger. The process by which this occurs is when stress is applied, the old bone is partially taken down (osteoclast

activity) followed by new thicker, stronger bone being laid down (osteoblastic activity). Stress fractures arise when the external stress continues to be applied during the temporary weak phase, i.e., when the bone is being rebuilt.

Although it can occur in any bone, the most common locations for stress fractures are fifth metatarsal (aka March fracture – the name taken from the frequent occurrence in military recruits), medial tibial plateau, femoral neck, and distal tibial metaphysis.

Treatment varies. Convincing most athletes to stop is an exercise in frustration for both the patient and the AP. In addition complete rest (except extreme cases) prevents any stimulation necessary to continue the healing response. Treatment consists of three parts. First, any underlying muscle weakness or imbalance needs to be addressed, ideally by a physical therapist who specializes in athletes. Second, technique, equipment, and training issues need to be addressed by a qualified coach. Third, the athlete needs to cut back but not stop training. This can include either volume or intensity or both with the amount of decrease dependent on the severity of the stress fracture or stress reaction [19].

Differential diagnoses include a variety of bursitides and tendinitis depending on the body part involved.

A special case that needs to be briefly discussed is the female athlete triad of anorexia, amenorrhea, and stress fractures. As part of the history, routine questioning of female athletes should include recent weight change and regularity of menstrual periods. Many female athletes, especially dancers and distance runners, put themselves at risk for long-term health issues by eating less than what is required to maintain a positive energy balance. In addition to amenorrhea, they can also develop osteoporosis even as a teenager. Although not seen often, an energy deficit causing osteoporosis and stress fractures can occur in male athletes such as distance runners or wrestlers trying to make weight. As most healthcare providers now know, treatment of eating disorders such as anorexia and bulimia is not a simple "just eat more" but are symptoms of underlying psychological distress that needs to be addressed by mental health practitioners [20].

7.2.3 Ankle Sprains

Ankle sprains are endemic in almost all sports that require movement on the feet from running to basketball to gymnastics to ice hockey. They occur at all ages but are most common from 15 to 40 years of age. The history is of an inversion injury, either the result of a misstep, uneven ground, or landing on another player's foot. With minor sprains the patient may be able to continue playing, albeit at a reduced level, but most are unable to do so. Many ankle sprains are never seen by a medical professional as the patient "walks it off" or modifies his activities until the symptoms go away. Some patients may not see a medical practitioner until they have a sprain from which they are unable to recover despite having self-treated previous sprains.

On a physical exam, there is tenderness over the lateral collateral ligaments of the ankle with variable amounts of swelling and ecchymosis. Weight-bearing ability

varies depending on the degree of injury. Many patients will walk with the lower limb externally rotated to decrease the stress on the lateral ligaments. Careful palpation will reveal if there is any additional injury. The following should be palpated: the peroneal tendons, the base of the fifth metatarsal, the Achilles tendon, the posterior tibial tendon, and the anterior aspect of the distal tibiofibular joint. The degree of instability resulting from an ankle sprain is determined by talar tilt and anterior drawer. Because of the wide variation in ligamentous laxity in each patient, it is important to examine the normal, uninjured side first. Due to swelling in the acute injury, it may be difficult to determine if there is significant laxity with the talar tilt and anterior drawer tests. Talar tilt is performed by grasping the posterior ankle with the left hand for a right ankle and grasping the midfoot with the right hand with the thumb over the anterolateral aspect of the talus and placing the hindfoot in inversion and feeling for the amount of gapping of the lateral tibiotalar joint. The anterior drawer test is done by placing the right hand on the anterior left distal tibia, grasping the posterior calcaneus with the left hand, and pulling forward and observing the amount of subluxation of the talus. If the patient has a syndesmotic injury, the so-called "high" ankle sprain, recovery may be longer than average.

Two additional tests may help to diagnose a syndesmotic injury; the external rotation test is performed with the knee flexed, and applying an external rotation force to the forefoot looking for an increase in pain. The second is the squeeze test where again while the knee is flexed, firm pressure is applied at the midportion of the leg squeezing the tibia and fibula together. An increase in pain is a positive test.

Radiographs are helpful to rule out associated fractures and periodically a small fleck of bone associated with either the anterior talofibular or calcaneofibular ligament can be seen. Additional imaging is rarely needed for most ankle sprains. In children and adolescents with open growth plates, non-displaced Salter I fractures of the distal fibula are much more common than true ankle sprains. Careful palpation in these patients shows tenderness over the growth plate rather than the collateral ligaments of the ankle.

The Ottawa ankle rules were developed by Dr. Ian Stiell [21] in an effort to decrease the number of radiographs for ankle sprains. According to the Ottawa rules, radiographs are needed only if:

- There is tenderness of the tip or posterior half, distal 6 cm, of the fibula.
- If there is tenderness of the tip or posterior half of the medial malleolus.
- Bony tenderness at the base of the fifth metatarsal.
- Bony tenderness over the tarsal navicular.
- Inability to bear weight for four steps after injury and inability to bear weight for four steps in the emergency room.

Several exclusions apply, including intoxication, severe swelling, and other injuries. In addition, one cannot neglect the "therapeutic" value of the patient knowing it is "just a sprain" and nothing is "broken." Ultimately history, physical, and clinical judgment should prevail in ordering any diagnostic test including ankle radiographs for ankle injuries.

The underlying pathology of course is a tear, stretch, or avulsion of one, two, or all three lateral ankle ligaments (anterior talofibular (ATF), calcaneofibular (CF), and posterior talofibular (PTF)) with the most common and important being the anterior talofibular ligament. Grading of ankle sprain can be done by determining the number of ligaments injured, the degree of injury to the ligament (sprain, stretched, or torn), or the amount of clinical laxity. Again, comparison to the uninjured side is helpful.

Treatment for most ankle sprains is nonoperative. For severe sprains an upright fixed walking brace is appropriate. Other patients may only need some type of ankle-stabilizing orthosis.

The initial treatment for ankle sprains, like other strains and sprains, is RICE: rest, ice, compression, and elevation. Tylenol or OTC NSAIDs should suffice for pain control in all but the most severe injuries. The ice is primarily for pain control and should be limited to no more than 15–20 minutes at time (to avoid frostbite) and should not be used after the first 48 hours. This is followed by a course of either physical therapy or a home exercise program depending on the severity of injury and level of activity to which the patient wishes to return. Recovery can be anywhere from 2 to 12 weeks, again depending on the severity of the injury and desired activity level.

A few ankle sprains do not respond to treatment and will need operative intervention. There are two types of repair. One involves taking all or part of a peroneal tendon and weaving it through the fibula and talus, occasionally the calcaneus, in various patterns to restore stability with the Chrisman-Snook, Watson-Jones, and Evans being the most common. The second is direct repair of the ligaments sometimes reinforced by the inferior retinaculum (Broström repair). A recent addition to the direct repair is an internal brace made of synthetic material to protect the repair as it matures. Both types of procedures are followed by a period of immobilization and therapy which vary depending on the repair type and stability as well as the surgeon's preference [22].

Differential diagnoses include fracture, bone bruising, and peroneal tendon tears [23] or subluxation.

7.2.4 Achilles Tendon Ruptures

Achilles tendon ruptures are the result of abrupt excessive load, either while starting a sprint (e.g., running for first base) or an unexpected excessive eccentric contraction (e.g., landing after going for a rebound in basketball). The injury occurs in the 40–60-year-old age range and is much more common in males than females. Some patients describe it as feeling like they have been hit or shot in the calf; others simply describe a pop and inability to walk or run.

Physical exam, especially early, is remarkable for loss of continuity of the Achilles tendon. There is an inability to stand on one foot (affected side). If examined after the hematoma forms, the hematoma may conceal the defect making

diagnosis more difficult. Weakness of plantar flexion can be hidden by the long toe flexor, the posterior tibial, and peroneal tendons. The Thompson test is especially helpful and should be done in any suspected cases of Achilles tendon rupture. The test is performed by having the patient lie in the prone position with a knee flexed to 90°. Squeezing the upper calf muscle normally results in plantar motion of the foot and ankle. If there is little or no motion, the test is considered positive with the presumptive diagnosis of Achilles tendon rupture. Radiographs are useful to rule out concomitant injuries such as avulsion of the calcaneal tuberosity as well as looking for signs of chronic Achilles tendinopathy, such as calcification and posterior calcaneal spurring. If the diagnosis is in doubt, MRI or ultrasound can be used but are rarely necessary.

The underlying pathology is rupture of the Achilles tendon, typically one to two centimeters proximal to the calcaneus. As stated above it is normally the result of greater than expected eccentric loading and occurs in a portion of the tendon that has less than an optimal blood supply.

Treatment varies according to the patient and surgeons' preferences. The first surgical option is open surgical treatment with repair of the torn ends, which frequently look like mop ends, followed by casting in plantar flexion, gradually bringing the foot into the neutral position over a period of 6–8 weeks. The second surgical option is the repair of the tendon percutaneously followed by a similar period of casting (Fig. 7.12). The disadvantage of the first method is that there can be difficulty getting the skin closed with open surgery; however, the second percutaneous method is technically more difficult.

The third option is to treat the tendon rupture solely by casting the ankle in plantar flexion. The primary advantage is the avoidance of surgical complications such as infection and wound dehiscence. The primary disadvantages are a longer time in cast and a slightly higher re-rupture rate [24, 25].

7.2.5 Puncture Wounds

Most puncture wounds are benign. After making sure the patient's tetanus vaccine is up to date, no further treatment is usually necessary. Radiographs can ascertain if any radiopaque foreign body is retained with follow-up in 2–5 days or if the patient develops symptoms such as worsening pain, fever, and cellulitis. In that case additional imaging such as CT or MRI looking for an abscess is appropriate. Whether or not antibiotics are necessary is controversial. The patient's health and the type of puncture wound should be considered. For instance, an otherwise healthy 20-year-old stepping on a thumb tack in the living room is a very different situation than a 60-year-old with poorly controlled diabetes stepping on a rusty nail in the barnyard. If the puncture wound is intra-articular, surgical debridement may be necessary. Common organisms, if an infection develops, are *Staphylococcus*, *Streptococcus*, and surprisingly *Pseudomonas* [26].

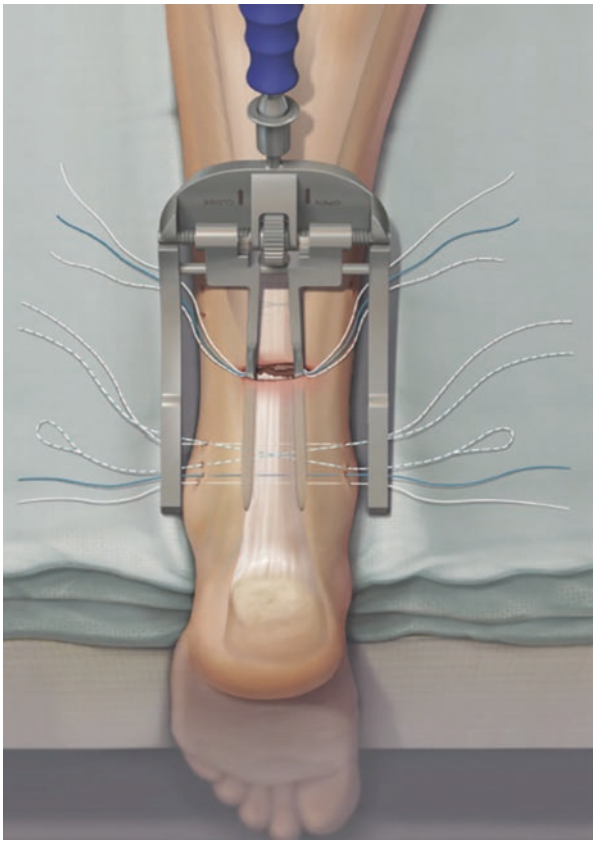

Fig. 7.12 Picture of percutaneous Achilles tendon repair. https://link.springer.com/chapter/10.1007/978-3-662-58704-1_34

7.3 Non-traumatic Foot and Ankle Conditions

7.3.1 Ankle Arthritis

Ankle arthritis (specifically of the tibiotalar joint) may present in both ankles or be unilateral. The most common causes are osteoarthritis, rheumatoid disease, and post-traumatic arthritis; gout and pseudogout must also be considered. Most patients present with a gradual onset of ankle pain and stiffness that is worse with prolonged weight bearing. Examination shows tenderness over the anterior talotibial joint as well as decreased flexion-extension. Physical examination should include vascular status and examination of the posterior tibial tendon function.

Imaging is normally limited to weight-bearing radiographs of the foot and ankle. Other diagnostic testing may include labs (to rule out infection or autoimmune

disease), bone scans, or MRI to rule out chronic infection (especially after ORIF of a previous fracture).

Initial treatments are bracing and physical therapy. The length of time to try bracing and physical therapy varies according to the patient and surgeon, but a minimum of 6–12 weeks is the norm. NSAIDs are of limited benefit; intra-articular corticosteroid injections give relief, but do not last. There is some evidence that the steroid or accompanying anesthetic (e.g., bupivacaine) may cause additional cartilage deterioration, thus accelerating the arthritis. Surgical treatment has traditionally been arthrodesis of the tibiotalar joint which can be done open or arthroscopically. Ankle arthroplasty has become more common over the last few years with early to mid-term results show equivalent outcomes compared to arthrodesis [27–29].

7.3.2 Plantar Fasciitis

Plantar fasciitis is the most common diagnosis made when a patient comes in complaining of plantar heel pain, but other diagnoses are possible (see below). Patients with plantar fasciitis present with medial plantar heel pain that is worse when getting up in the morning or after sitting for a period of time. After walking for 5–15 minutes, the pain subsides but returns as an ache toward the end of the day.

The majority of the time there is no known precipitating cause, but many patients will have a history of recent weight gain or of beginning an aggressive exercise program.

Physical exam is remarkable for tenderness on the medial plantar aspect of the heel. Inspection, sensory, motor, and stability exams are normal, although some patients may have decreased ankle dorsiflexion.

Imaging consists of lateral and axial radiographs of the heel and is usually normal. Some patients will have an inferior calcaneal spur, but the significance is unclear as many patients without plantar fasciitis have an inferior calcaneal spur as well (Fig. 7.13).

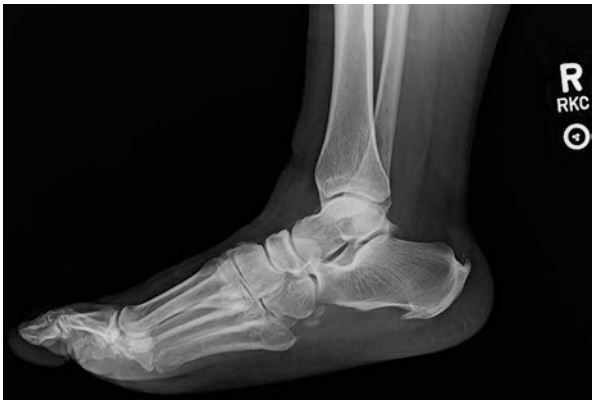

Fig. 7.13 Lateral of a foot and ankle showing both a posterior and inferior calcaneal spur. The former frequently accompanies Achilles tendinitis but a significant portion of the population has one or the other with no accompanying symptoms

Advanced imaging is not necessary unless the pain is persistent or exam atypical; then, an MRI may rule out other pathologies.

Etiology is still debated but may be related to tight heel cords or microtears of the plantar fascia where it attaches to the inferior calcaneus.

Treatment for most patients is nonoperative. This consists of some combination of heel-cord stretching, plantar fascial massage, night splints (to keep the ankle dorsiflexed), and NSAIDs. Other patients may respond to off-the-shelf or custom orthotics. More invasive treatment includes extracorporeal shockwave therapy (similar to lithotripsy), a localized steroid injection, PRP injection, or rarely surgical intervention. Importantly, before trying the more invasive or expensive treatments, a wide variety of alternate diagnoses should be considered including peroneal or posterior tibial tendonitis, tarsal tunnel syndrome, Achilles tendinitis, retrocalcaneal bursitis, and stress fractures [30, 31].

7.3.3 Deformities of the Midfoot

There are three "varieties" of a flatfoot: physiologic (flexible) flatfoot, tarsal coalition, and acquired flatfoot from posterior tibial tendon dysfunction.

7.3.3.1 Flexible Flatfoot

Patients with physiologic flatfeet usually present, if at all, with "sore" feet after prolonged walking or running. They are otherwise asymptomatic. The easiest way to assess whether or not the flat feet are physiologic is to look for symmetry, and a normal arch appears when non-weight bearing.

The underlying problem is mild ligamentous laxity, usually isolated to the midfoot, and there is often an association with obesity.

Treatment is symptomatic with weight loss for obese patients, activity modification, and arch supports [32].

7.3.3.2 Tarsal Coalition

Tarsal coalition presents in adolescents as a unilateral flatfoot which can be fairly rigid. The pain varies from mild discomfort to pain that interferes with athletic pursuits. Physical exam may show tenderness over the coalition (calcaneo-navicular, talonavicular, or talocalcaneal) with painful lack of motion on pronation/supination of the forefoot in those with talonavicular coalition. There will be a lack of inversion/eversion in those with talocalcaneal coalition. Those with calcaneo-navicular coalition tend to lack subtalar motion and have some hindfoot valgus.

More than the usual AP, lateral, and oblique radiographs (Fig. 7.14) may be necessary to identify the coalition which can be fibrous, cartilaginous, or bony. In fact, CT or MRI (Fig. 7.15) may be necessary to fully delineate the nature and extent of the coalition.

Etiology is unclear, but there seems to be a strong genetic component.

Treatment varies per coalition type. Many patients of all types respond to temporary activity reduction or intermittent casting (which of course reduces their activity

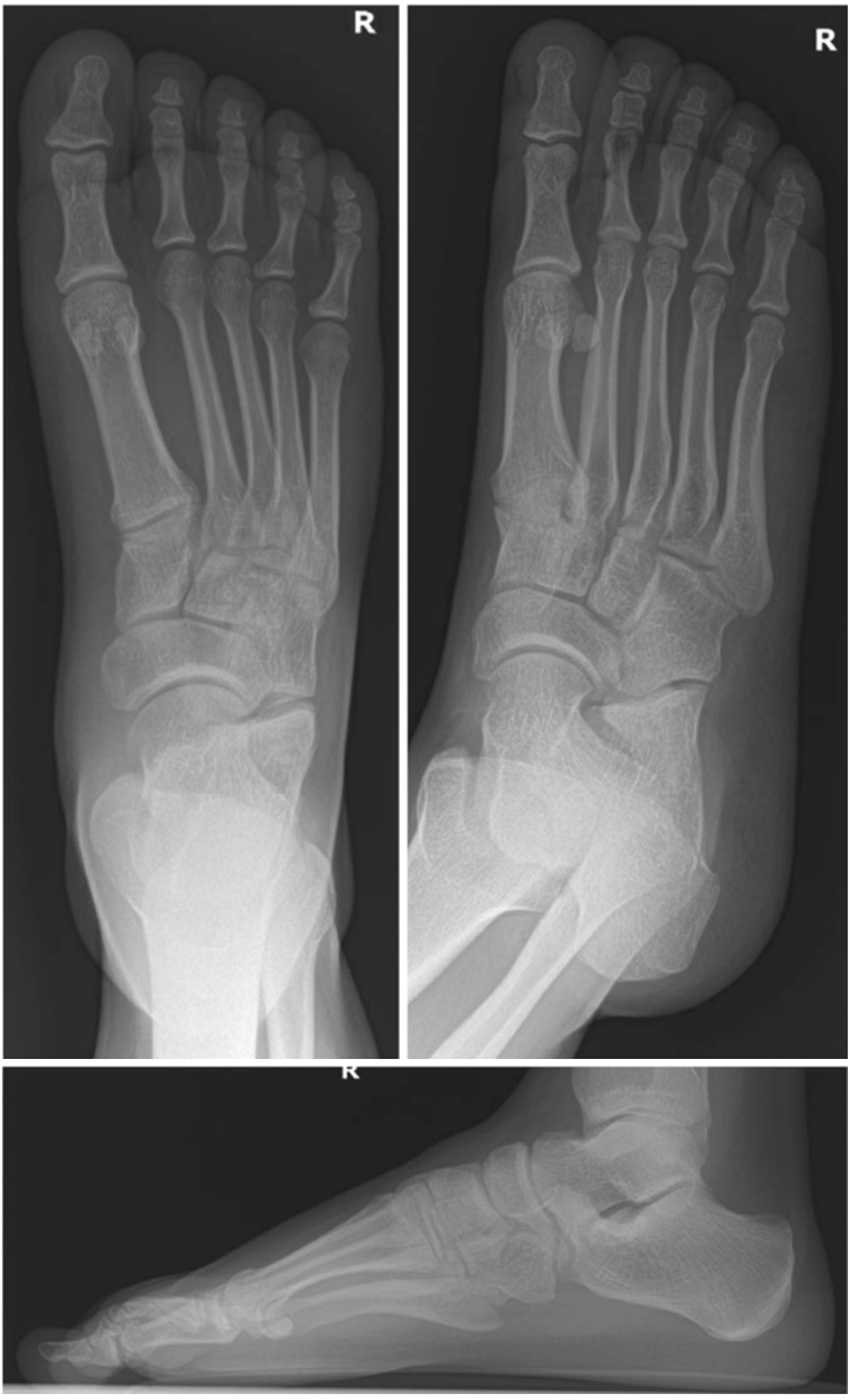

Fig. 7.14 Three views of the foot with a tarsal coalition. Note the subtle peaking between the calcaneus and navicular. The MRI is in Fig. 7.15

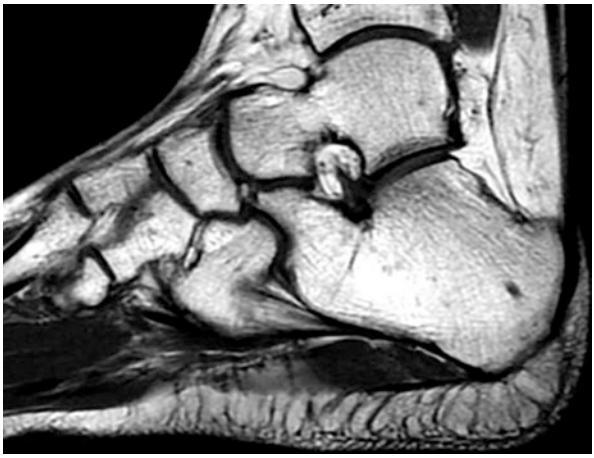

Fig. 7.15 MRI scan of a tarsal coalition between the navicular and calcaneus. Courtesy Medical College of Georgia, Department of Orthopedics

level). If this fails, surgical resection accompanied by some type of soft tissue interposition (e.g., autologous fat or extensor digiti minimi muscle belly) is the normal treatment. Postoperatively there will be a period of casting and limited weight bearing followed by range of motion exercises. Surgery in adults with tarsal coalition is not as successful as when the surgery is performed in adolescence. For adults, subtalar or triple arthrodesis (subtalar, talonavicular, calcaneocuboid joints) may be a better option. For both adults and adolescents using the resection option, the AP needs to make sure the patient and family understand that motion will be improved but not normal [33].

7.3.3.3 Acquired Flatfoot

Posterior tibial dysfunction appears in middle-aged or older adults and has several presentations. Stage I is vague medial ankle pain with worsening on prolonged walking or standing. On physical exam there is tenderness along the course of the posterior tibial tendon with either a painful single-heel raise or inability to do so in addition to painful, weak resisted inversion from an everted position. The AP should remember that testing inversion strength from the inverted position can be deceptive as the anterior tibial tendon can maintain inversion strength from that position.

Stage II symptoms are generally worse. The patient will have a flatfoot while weight bearing and difficulty or inability to perform a single-limb heel raise. When viewed from behind, there will be a "too many toes" sign (Fig. 7.16). Foot flexibility remains normal.

Stage III exhibits the same as stage II except flexibility is decreased, and the patient is always unable to do a single-heel raise.

Because of loss of medial support, patients in stage II, III, or IV of posterior tibial dysfunction may have lateral ankle pain from impingement of the lateral malleolus.

Stage IV is a rigid collapse of the hindfoot into valgus with subtalar arthritis.

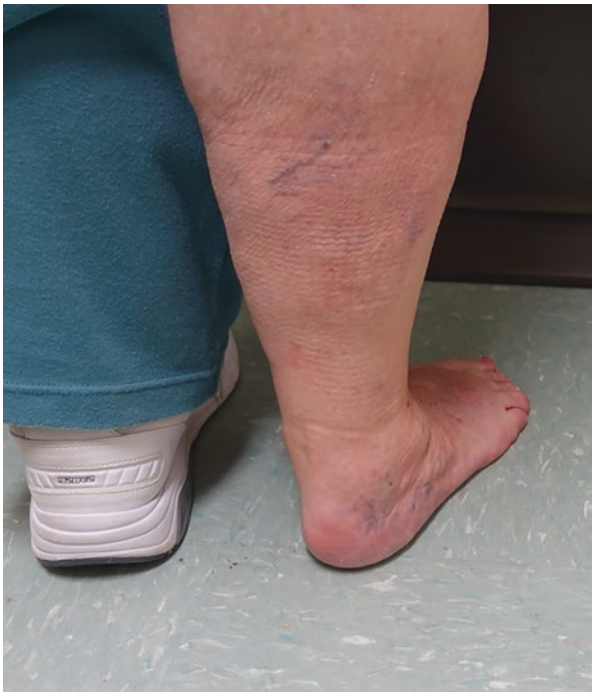

Fig. 7.16 Patient with posterior tibial dysfunction stage II or III on the right. Although it appears the photo was taken from the side, it is actually from almost directly behind this patient who has a positive "too many toes" sign

Imaging studies include weight-bearing radiographs to assess various angles (e.g., talo-first metatarsal angle varies from 0 to 10° in normal feet; greater than 10° shows loss of the normal arch) and to assess for any associated arthritis. MRIs can be helpful in determining the nature and severity of the posterior tendon pathology which in turn helps with surgical planning and managing patient expectations.

For stages I and II, some type of arch support and physical therapy is the first line of treatment. If still symptomatic, then surgery for stages I and II consists of tendon debridement, repair, or transfer. For stages III and IV, any orthotic will have to cross the ankle joint in order to take sufficient tension off the posterior tibial tendon for relief of symptoms. For any orthosis, a period of time to adjust to the orthosis may be necessary, not to mention the need to change shoe sizes (1/2–1 size larger) as well as several trips to the orthotist to make adjustments for the best fit.

Patients with stage III or IV disease unresponsive or unwilling to undergo non-operative treatment require more extensive surgery, including subtalar or triple arthrodesis with a possible calcaneal osteotomy as well. In severe cases the tibiotalar joint will need fusion [34, 35].

7.3.3.4 Cavovarus Foot (High Arch)

The causes and subsequent presentation of a patient with a cavovarus foot vary and range from central nervous system disorders (cerebral palsy, stroke, and muscular dystrophy) to the residua of untreated compartment syndrome. Treatment depends on the underlying cause as well as the patient's age, health, and activity level.

One of the more common causes is Charcot-Marie-Tooth (CMT) disease or one of the other hereditary sensorimotor neuropathies (HSMNs). Complaints include pain under the metatarsal heads, difficulty finding shoe wear, and balance difficulties. Many patients with a cavovarus foot have a positive family history as HSMNs which can be either autosomal dominant or recessive.

Physical examination in patients with HSMN may show atrophy of the hand and foot intrinsic muscles with thin legs in addition to a high arch.

Other than showing the bony degree of arch and ruling out the other causes, radiographs are not diagnostic, whereas EMG/NCS can be very helpful in diagnosing the cause of the cavovarus foot.

Treatment of the cavovarus foot depends on the underlying etiology as well as age and activity level of the patient. Details are beyond the scope of this book but consists of a variety of tendon transfers, midfoot osteotomies, and plantar fascial releases [36, 37].

7.3.4 Charcot Foot

Although the most common underlying cause of Charcot foot in the industrialized world is diabetes, any disease that can cause peripheral sensory loss, e.g., leprosy, must be considered. Patients may present early with a swollen, erythematous foot or may present later in the course of the disease with varying degrees of arthrosis, bony collapse, angular deformation, and subsequent foot ulceration.

Physical exam mirrors the above presenting complaints. Importantly there is loss of sensation and the degree of pain is highly variable. There may be no pain, or there may be as much pain as the AP would expect given the deformity.

Radiographs show varying degrees of collapse and osteoporosis, but osteoporosis may resolve in the later stages with more normal bone (Fig. 7.17).

Although diabetes is the most common cause, other etiologies for peripheral neuropathy such as heavy metal poisoning, alcohol, and leprosy can cause similar clinical and radiographic findings.

While the exact cause is not known, most agree there is a lack of protective feedback because of decreased pain perception. This results in both soft tissue and bony damage, which in itself is minor. But because the body does not protect itself, the cumulative effect is the damage similar to that seen in the radiograph above.

Treatment is twofold. First, the underlying etiology needs to be controlled (e.g., better glucose control, cessation of alcohol). Second, if the disease is caught in the early inflammatory stage, some type of total contact orthotic or walker boot can distribute the stress preventing collapse and some of the more severe deformities. A CROW (Charcot restraint orthotic walker) boot is frequently ordered (Fig. 7.18).

Surgical intervention is more common now than in the past, but still should be approached with caution as 2–3% of patients with Charcot foot will ultimately have an amputation of the affected foot. Surgery may involve excision of bony prominences to prevent ulceration or varying arthrodeses to prevent or correct any collapse [38, 39].

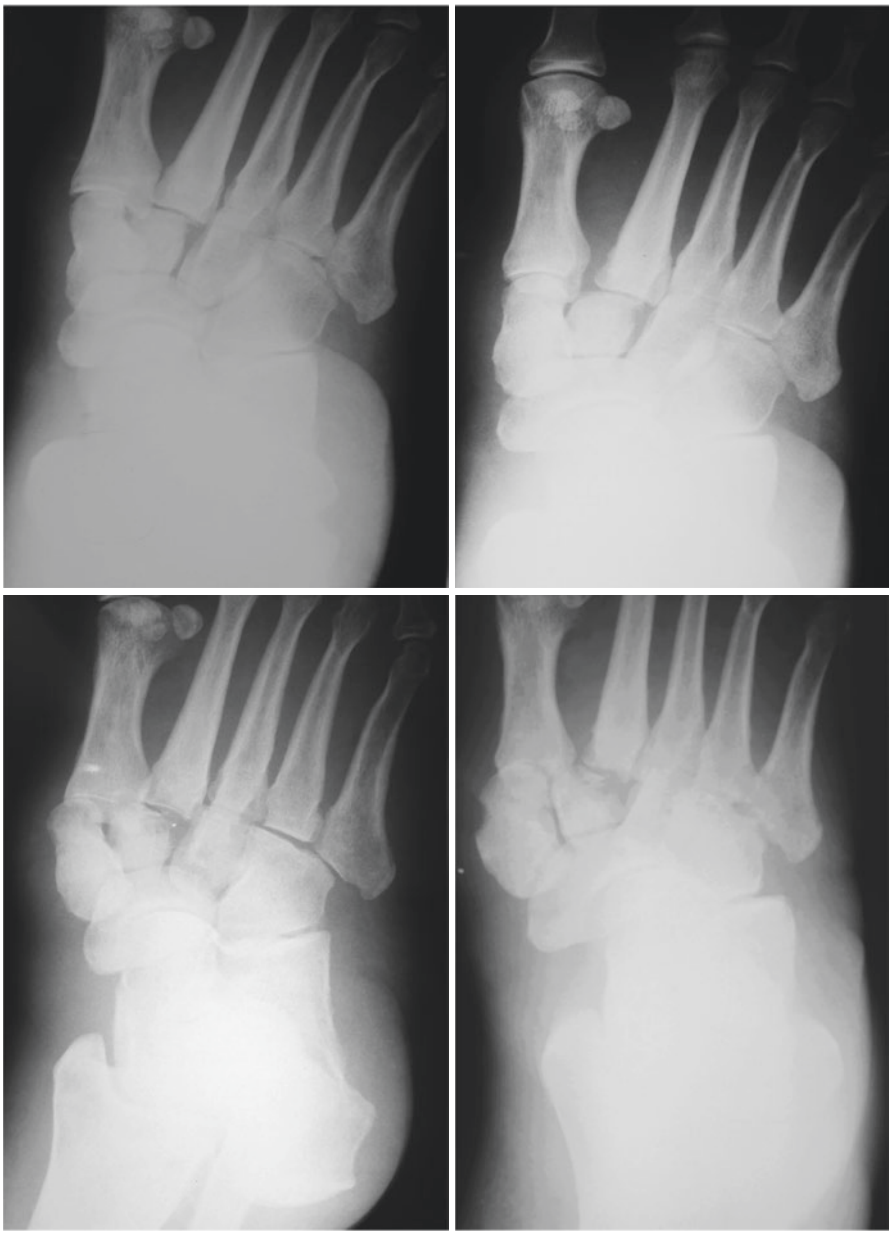

Fig. 7.17 Progression of a Charcot foot. In the initial stage, there is some minor subluxation of the second tarsometatarsal joint. By the time of the final radiographs, the same joint is obviously subluxed and the joint itself eroded. In addition the first tarsometatarsal joint has subluxed as has the calcaneocuboid joint

Fig. 7.18 A CROW boot used to support the Charcot foot until the bone remodels

7.3.5 Neurologic Disorders

7.3.5.1 Tarsal Tunnel Syndrome

Tarsal tunnel syndrome is similar to carpal tunnel syndrome (CTS) of the wrist in that the posterior tibial nerve or one of its branches is compressed beneath the flexor retinaculum, just posterior and/or distal to the medial malleolus. Unlike CTS, diagnosis can be elusive. Patients present with vague pain or paresthesia on the medial and/or plantar aspect of the foot. There may be some specific anatomical abnormality such as a ganglion or a previously displaced calcaneal fracture. The most common misdiagnosis associated with tarsal tunnel is plantar fasciitis. Differentiating the two can be difficult, but patients with plantar fasciitis usually present with plantar heel pain when first arising from a night's sleep or after standing following a prolonged period of sitting. And while plantar fasciitis symptoms subside after walking a few minutes, tarsal tunnel symptoms occur during all activities including rest and sleeping.

After obtaining the history, a physical exam may reveal a positive Tinel's over the posterior plantar nerve. Remember to ask what symptoms the Tinel's caused; not a yes/no "does this reproduce your pain?" Prolonged compression over the

nerve (~30 seconds) while holding the ankle in inversion and flexion may recreate the symptoms. EMG/NCS can be of use, but tarsal tunnel has a high incidence (relative to CTS) of being electrodiagnostically negative.

Like many foot and ankle problems, treatment is initially conservative. NSAIDs, wide-heeled shoes with cushion, or possibly some type of night splint may relieve the symptoms.

Surgical treatment is an option, but has a high failure rate, especially if some type of space occupying lesion is not identified. Surgery requires release of the posterior tibial nerve beneath the flexor retinaculum as well as all of its branches including both the medial and lateral plantar nerves. There is frequently a venous plexus inferiorly which may cause persistent oozing, both intraoperatively and postoperatively.

Of note, the deep peroneal nerve can likewise be trapped under the exterior retinaculum causing an anterior tarsal tunnel syndrome [40].

7.3.5.2 Interdigital Neuroma (aka Morton's Neuroma)

Presenting primarily in women, patients with Morton's neuroma present with vague pain between two toes in the associated web space, most commonly between the third and fourth toes. Clinical exams may reveal a "fullness" in the web space or rarely a small nodule. Medial lateral compression of the forefoot may reproduce or exacerbate the pain (Mulder's sign). AP, lateral, and oblique weight-bearing radiographs to rule out arthritis or stress fractures are helpful. MRI, ultrasound, and nerve studies are not generally useful for confirming or ruling out the diagnosis.

The underlying pathology is unclear. It may be an irritation of the common digital nerve against the intermetatarsal ligament. It is most common at the third-fourth interspace because frequently the medial and lateral plantar nerves (which are both branches of the posterior tibial nerve) come back together to form the common digital nerve for that space before dividing into the respective digital nerves for the lateral aspect of the third and medial aspect of the fourth toes, respectively.

As with many common foot problems, the first line of treatment is modified shoe wear with a wider toe box. Other options include a spacer (e.g., cotton ball) between the affected toes or a metatarsal pad, although most patients find these latter options unacceptable. A corticosteroid injection into the affected area may give long-lasting relief and, if the diagnosis is uncertain, can confirm that the clinician has the correct diagnosis. In addition a successful injection can portend a satisfied patient if the symptoms return and surgery is necessary.

Surgical treatment by excising the neuroma (from either a plantar or dorsal approach – patient and surgeon dependent) is normally successful but does leave the patient with a permanent numbness between the affected toes. The patient needs to be warned of this as well as the rare possibility of recurrence. If there are other causes of forefoot pain, the patient will have incomplete relief, so careful patient selection and counseling are necessary [41, 42].

7.3.6 Pediatric Deformities

7.3.6.1 Clubfoot (Equinovarus Foot)

Babies with a clubfoot are normally identified at birth by a unilateral foot and ankle deformity that consists of three parts. First, there is excessive adduction of the forefoot – in other words, all five metatarsals are deviated medially. Second, the hindfoot is in varus; i.e., the bottom of the heel is pointed toward the midline. Third, the ankle is in equinus, that is, pointed downward. All of these deformities are semirigid (Fig. 7.19).

The important thing to remember about a clubfoot is that it is not just a positional deformity. Even if completely corrected, the leg and foot will never be normal; the affected leg will always be smaller and never as flexible nor as strong as normal. Microscopic studies of the calf muscle of the affected limb show both decreased muscle cell size and number.

Although surgical treatment is certainly necessary in severe or late cases, most are now treated with serial short-leg casting known as the Ponzi method using plaster not fiberglass. The deformities are gently stretched and corrected, starting with the forefoot; then the hindfoot is addressed, followed by the equinus. Currently the first two are almost always corrected with casting, and most surgery is some type of

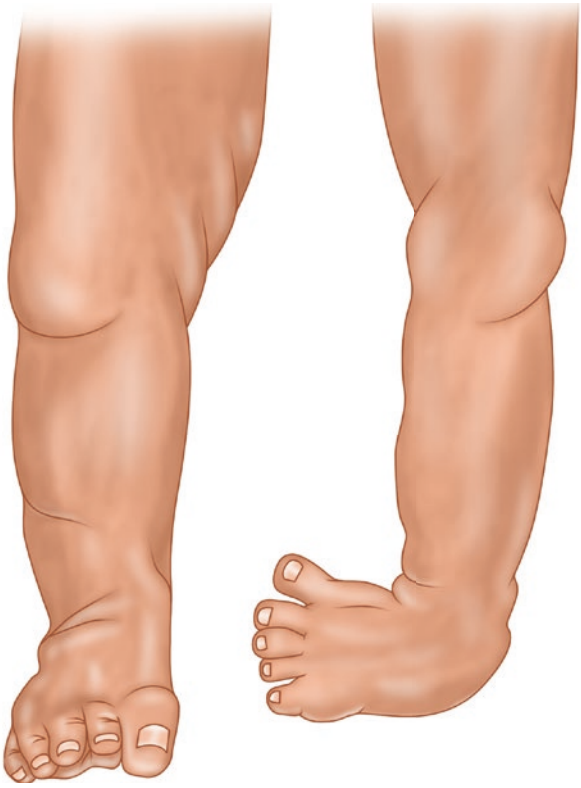

Fig. 7.19 A normal foot and a clubfoot. In addition to the foot and ankle deformity, there is significant atrophy of the calf musculature that is lifelong even if the foot deformity is completely corrected

Achilles lengthening to correct the equinus. Periodic radiographs to assess bony correction are helpful.

After correction modified, shoe wear and periodic follow-ups (especially during growth spurts) are necessary to prevent recurrence; further treatment may be necessary if the deformity recurs [43–46].

7.3.6.2 Metatarsus Adductus

Metatarsus adductus is just what it sounds like; the forefoot (metatarsals) is adducted (deviated toward the midline) (Fig. 7.20). This is normally picked up at the newborn exam or at the first (6 weeks) well-child visit.

Unlike clubfoot, metatarsus adductus does not usually have the long-term decrease in size, shape, strength, or flexibility of the hindfoot and calf.

Treatment is either parental stretching at every diaper change or serial casting, both of which are followed by a modified shoe to prevent reoccurrence. Length of time wearing the corrective shoes is patient and surgeon dependent [47].

7.3.7 Deformities of the Forefoot

7.3.7.1 Bunions (aka Hallux Valgus)

Although juvenile bunions do exist, most bunions present in middle- or older-aged women who complain of a painful prominence on the medial aspect of the first metatarsal head, associated with some deviation of the great toe laterally. There may or may not be associated arthritis of the great toe metatarsophalangeal joint.

Physical exam shows the deformity as described above. There may be secondary deviation of the lesser toes with callus or bursitis on the medial aspect of the first metatarsophalangeal joint. In more severe cases, there may also be rotational (pronation) deformities of the great toes.

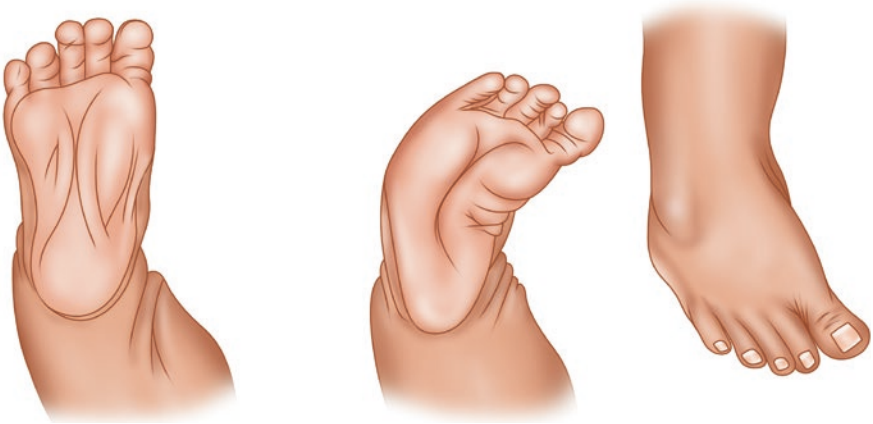

Fig. 7.20 Normal right foot viewed from the plantar aspect and a right foot with metatarsus adductus. Unlike clubfoot there is no accompanying hindfoot varus or equinus

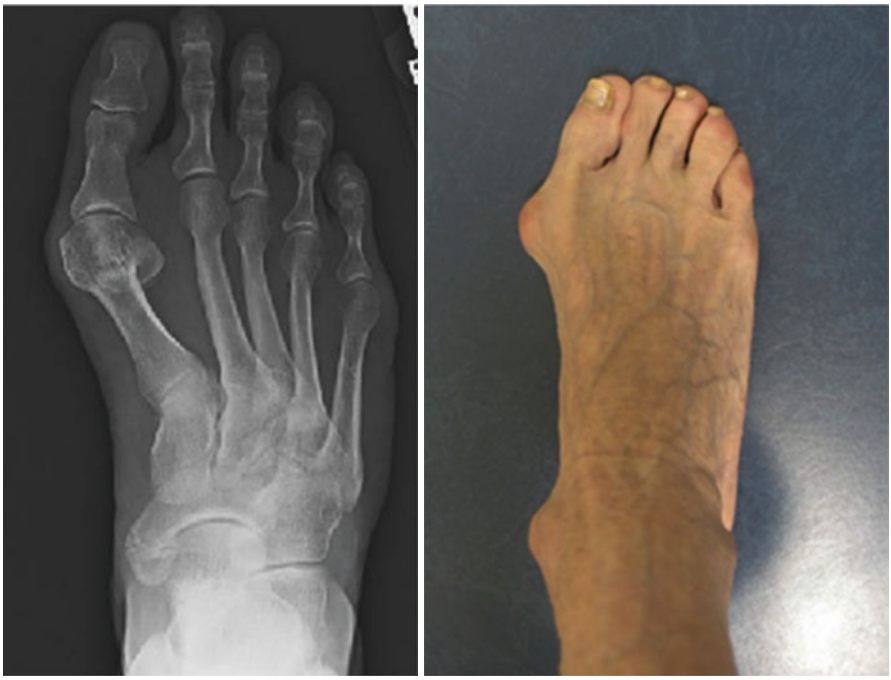

Fig. 7.21 Radiograph and photo of a bunion. Note the subluxation of the first metatarsal phalangeal joint on the left and the rotational deformity of the great toe on the right

Standard radiographs include weight-bearing AP, lateral, and oblique views of the foot (Fig. 7.21). Two particular angles should be measured: the angle between the first and second metatarsal shafts and the angle between the first metatarsal shaft and the proximal phalanx of the great toe. The normal upper limits are 10° and 20°, respectively.

If it is just a cosmetic deformity with no associated pain, surgical intervention is not recommended. If there is pain, the first line of treatment is to change footwear to minimize the heel-forefoot height differential (i.e., no high-heeled shoes) and a wide toe box to accommodate the widened forefoot. Fortunately, in the last 10–20 years, many more stylish women's shoes with a wide toe box and a normal-sized heel have come on the market.

Should accommodative footwear not work or be declined, surgical treatment is available for patients who are good candidates (be leery of operating on patients with diabetes as their complication rate, especially infection, is much higher). Factors to consider in deciding which surgical option is appropriate include any associated arthritis, degree of deformity, age, and any associated conditions, e.g., a crossover toe. Depending on how one counts, there are 110–130 different operations to correct a hallux valgus deformity. Generally speaking, the surgery involves loosening the capsule, ligaments, and tendons of the lateral aspect of the first metatarsophalangeal joint, tightening the medial capsular laxity, removing the bony

prominence, and correcting any medial deviation of the first metatarsal with an osteotomy in either the proximal or distal shaft. Recovery period is generally 6–8 weeks with crutch or walker use for 2–3 weeks while wearing a rigid post-op shoe. Many surgeons will have the patient wear a spacer between the first and second toes. The patient should be warned that it may be up to 6–12 months before recovery is finished. Other surgical options include soft tissue arthroplasty and first metatarsophalangeal arthrodesis [48, 49]. The two most common complications are recurrence and hallux varus. The latter is a result of overcorrection wherein the great toe is deviated medially making shoe wear difficult if not impossible.

7.3.7.2 Bunionette (aka Tailor's Bunion)

Similar to a bunion but not nearly so common, a bunionette presents as a painful prominence of the lateral aspect of the fifth metatarsal head. Like bunions, bunionettes can have associated calluses and bursitis (Fig. 7.22). The only diagnostic study normally needed is three weight-bearing views of the foot (AP, lateral, oblique).

Again, the initial treatment is shoes with a wide toe box. If this does not work, then several surgical options exist consisting of some type of resection of the bony prominence with or without a fifth metatarsal osteotomy depending on the degree of deformity and the fourth-fifth metatarsal shaft angle. Recovery is normally uneventful [50].

7.3.7.3 Hammertoes and Claw Toes

The smaller toes (digits 2–5) can have two primary deformities. The first is hammertoes which is a flexion deformity of the PIP joint, either rigid or fixed. There may be an associated extension contracture of the metatarsophalangeal joint (Fig. 7.23). Claw toes are similar but have a flexion deformity of the PIP and DIP joints. Often the hammertoe is isolated to a single toe, but claw toes involve three to four toes. As one would expect, the presenting complaint for both is a combination

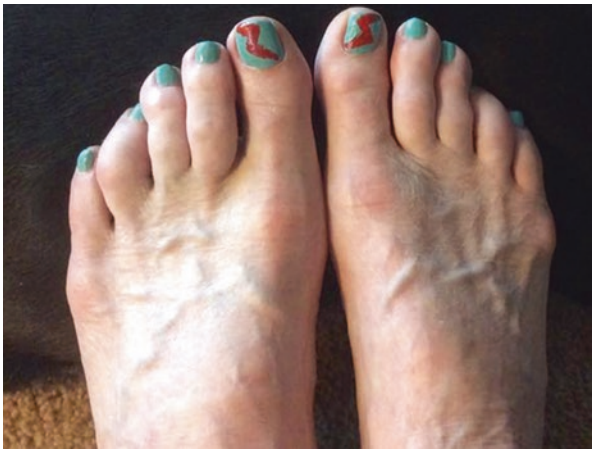

Fig. 7.22 Small bilateral bunionettes which are asymptomatic as long as this patient wears shoes with a wide toe box or when wearing sandals

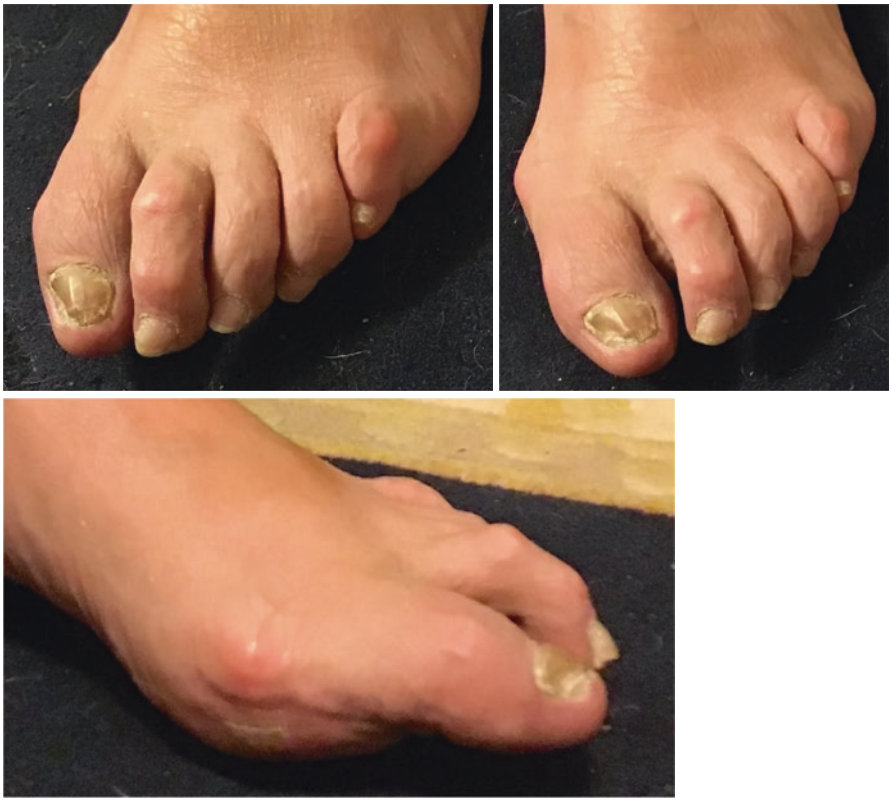

Fig. 7.23 Hammertoes with callus on the dorsum of the second and fifth toes. A shoe with a deeper toe box will frequently alleviate the symptoms

of painful calluses on the dorsum of the PIP joint and the distal end of the involved toe(s). This makes shoe wear difficult.

Hammertoes are thought to be the result of narrow poorly fitted shoes, while claw toes frequently are the result of an underlying neuromuscular disorder such as Charcot-Marie-Tooth disease.

As usual the first line of treatment for adult-onset forefoot deformities is modified shoe wear, in this case a deep toe box. Taping and splinting for hammertoes usually fail, but surgery is successful in most cases. Similarly, for claw toes, ultimately surgery will be necessary for those who are good surgical candidates and fail treatment with modified shoe wear. There are a variety of procedures to correct the deformity ranging from dorsal MTP joint capsulotomies to tendon transfer or tenotomies to partial phalangectomy [51].

7.3.7.4 Corns

Corns present as a painful callus between the toes and are usually "soft." On physical exam, in addition to the corn, the clinician can often palpate the bony

prominence in the adjacent toe. Radiographs are useful to assess the underlying bony prominences.

Corns are the result of a bony prominence on one phalanx irritating the soft tissue in the adjacent phalanx, causing a callus. The callus becomes "soft" because of interdigital moisture.

Shoes with a wide toe box or a cotton ball between the toes will relieve the symptoms for many patients. If unsuccessful then surgery consists of excision of the bony prominence which eliminates the pressure on the callus and allows the skin to heal, thus making excision of the corn unnecessary.

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The Knee and Leg

8

8.1 Fractures

8.1.1 Patella Fractures

Fractures of the patella are normally straightforward to diagnose, but disruptions of the quadriceps and patellar tendons are periodically missed, especially in the emergency room. The latter two injuries will be discussed after fractures are reviewed.

Patients with patellar fractures present after a direct blow to the knee, e.g., after a fall onto the knee or hitting the dashboard in a motor vehicle accident. Physical exam shows swelling, tenderness, and loss of active extension. As the fracture is almost always intra-articular, there will be an effusion. Skin integrity needs to be checked. In addition to looking for other injuries to the knee such as meniscal or ligamentous tears, the shafts and the joints above and below the injury should be examined. The pattern of the fracture lines depends on bone quality, energy of the injury, and most importantly the amount of knee flexion at the time of impact.

Diagnosis can be made from standard AP and lateral radiographs (Fig. 8.1). A sunrise or merchant view to clearly see the patellofemoral joint can be helpful but may be too painful for the patient to put in the proper amount of flexion. CT scan may be helpful on occasion, but it is usually not necessary. MRIs on the other hand can be helpful if the patient has marked tenderness of the patella with normal plain radiographs because bone contusions or occult fractures can be seen on MRI in addition to soft tissue injuries. In addition, an MRI may be necessary to rule out a bipartite patella although lack of tenderness over the "fracture line" seen on radiographs of the patella should be sufficient to avoid the time and expense of an MRI.

Treatment is based on the fracture line direction, displacement, and comminution. The goal is to restore a normal extensor mechanism of the knee with a smooth articular surface. For some nondisplaced, longitudinal fractures and for some nondisplaced transverse fractures, immobilization for 6–8 weeks followed by progressive range of motion and strengthening is appropriate. For displaced transverse fractures, fixation is usually cannulated screws and some type of tension band (wire

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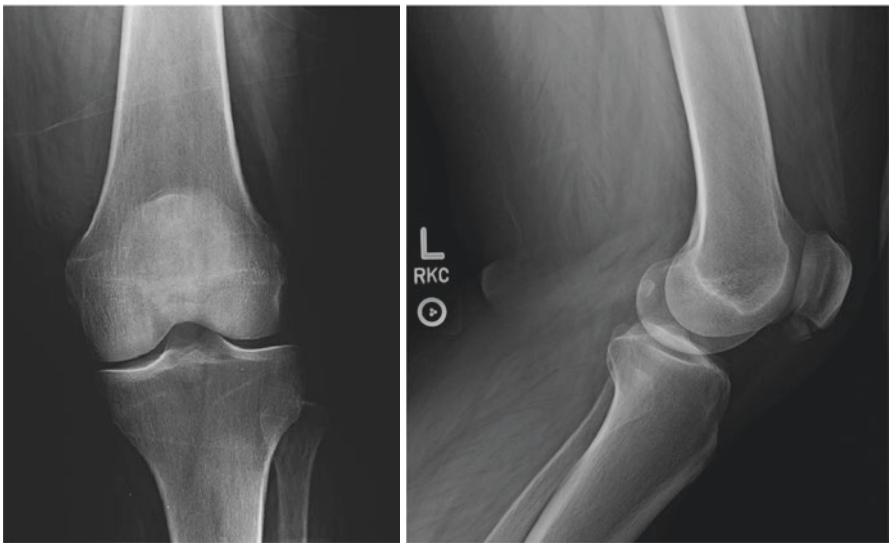

Fig. 8.1 Fracture at the inferior pole of the patella easily missed if just the AP of the knee is viewed

or cables) followed by immobilization in either a cast or knee immobilizer depending in large part on patient compliance for 4–6 weeks. This is followed by progressive range of motion and strengthening. Intraoperatively, it is crucial to get the articular surface as close as possible to anatomically normal to decrease the chance of posttraumatic patellofemoral arthrosis, although the damage done to the articular cartilage at the time of injury cannot be corrected. In addition, one should be careful to repair the medial and lateral retinacula.

For more comminuted fractures, 2.0- or 2.5-mm screws may help with fixing the smaller pieces. A portion of the patella may not be salvageable in which case excising a portion of the patella and repairing the extensor mechanism to what is left is appropriate (partial patellectomy). Rarely a complete patellectomy may be necessary which results in either an extensor lag or significant loss of flexion.

The most common complications are posttraumatic arthritis and irritation of the overlying tissues from the metal used to fix the fracture [1–4].

8.1.2 Tibial Plateau Fractures

Like their cousin, the supracondylar femur fracture, the tibial plateau fracture appears either in young adults after a high-energy injury or in the older adult after a low-energy injury. Unlike the supracondylar injury, however, with tibial plateau fractures, there is a high incidence of associated soft tissue injuries such as ligamentous or meniscal tears as well as vascular and peripheral nerve injury. Diagnosis is again straightforward, occurring after an axial load or a significant impact from the side (such as being hit by a car bumper), and can usually be seen on plain films (AP, lateral and occasional oblique views) (Fig. 8.2). The full extent of the injury as well

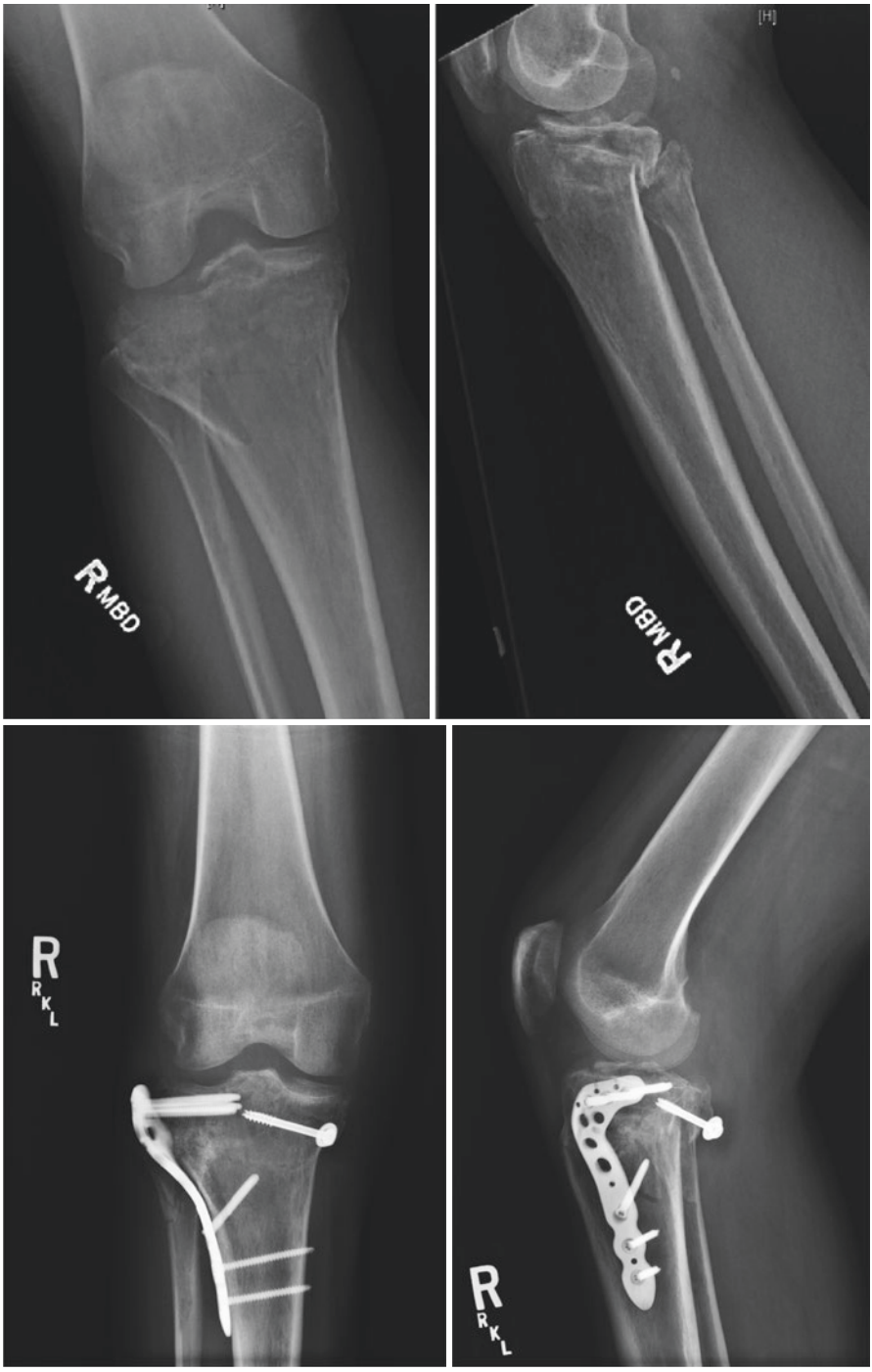

Fig. 8.2 Preop and postop films of a tibial plateau fracture

as the treatment almost always requires CT scanning (with 3D reconstruction) as well as careful exam to rule out neurologic or vascular injuries including compartment syndrome. Some injuries such as nondisplaced tibial rim fractures may only be detectable with MRI; in addition, the MRI will allow evaluation of the soft tissues for early repair either when fixing the fracture or in planning for a staged reconstruction (e.g., MCL and ACL, respectively).

In addition to a C-arm and the internal fixation device(s) of the surgeon's preference, two additional pieces of equipment may be helpful. One is a simple external fixator to maintain a constant distraction force on the joint while the pieces are being manipulated into position and fixed. The second is a headlamp for better intra-articular visualization of the posterior aspect of the joint. Many tibial plateau fractures will require some type of bone graft or bone graft substitute to fill the void left after elevating the joint line back to its anatomical position. For some fractures, e.g., central depression, arthroscopy may allow better visualization of the joint reduction while elevating the plateau through an incision in the tibial metaphysis. This can lead to better outcomes by allowing inspection of the other intra-articular structures such as the menisci and avoiding the morbidity of a large arthrotomy.

Although there are other classification schemes, the AO and Schatzker are the most commonly used. For introductory purposes, the following are the most common descriptions, central depression, unicondylar, and bicondylar, all of which are accompanied by various degrees of comminution and have a variety of soft tissue injuries as mentioned above. Care should be taken not to miss a tibial tubercle avulsion which may only be seen on CT scan [5–8].

8.2 Tendon Injuries

8.2.1 Quadriceps Tendon Injuries

Quadriceps tendon injuries result from an eccentric overload such as landing from a height greater than expected. Diagnosis can be missed because some patients can do an active straight leg raise using the retinacular tissues. However, the patient will be unable to extend the knee from a 90° flexed position. An additional physical exam finding is a palpable gap between the patella in the quadriceps tendon which may be obscured by a hematoma or not palpable with partial thickness tears. Radiographs will show a patella that is closer to the tibia than expected called patella baja. In cases of late presentation, partial tears, or diagnostic uncertainty, an MRI can be diagnostic.

Repair can be done with three drill holes placed longitudinally through the patella with one limb of medial suture passed through the medial hole, one limb of the lateral suture placed through the lateral hole and one limb of each passed through the middle hole with the sutures being tied off at the inferior pole (Fig. 8.3). Although not as time tested as transosseous suture repair, suture anchors show promising results in both cadaver and limited cases series studies. No large comparative studies have been done to date.

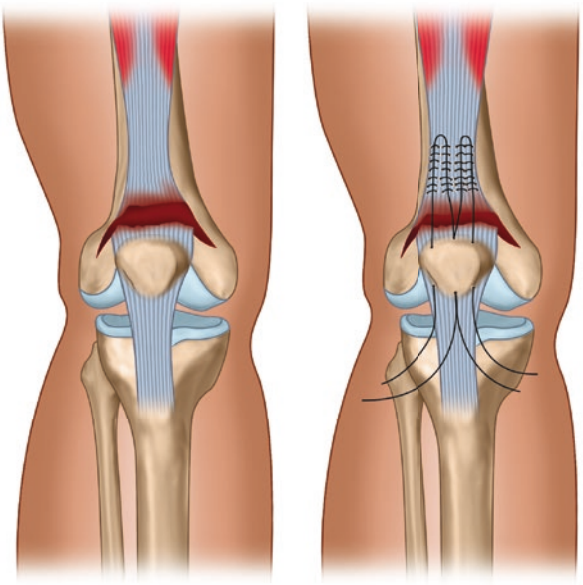

Fig. 8.3 Although some surgeons will use suture anchors in the superior pole of the patella, the traditional method has been to place two sets of nonabsorbable sutures in the quadriceps tendon with one limb of each set running through the middle drill hole. The opposite is done for patellar tendon avulsions from the inferior pole

The whole repair is oversewn with one or two running sutures taking care to ensure the retinaculum is repaired as well. Postoperative immobilization in a long leg cast or knee immobilizer is followed by hinged bracing, progressively increasing the range of motion with strengthening exercises. Long-term loss of strength is not unusual [9, 10].

8.2.2 Patella Tendon Ruptures

Patella tendon ruptures are similar in mechanism of injury to quadriceps tendon injuries, i.e., the result of an eccentric overload. Physical exam shows loss of active extension, inability to do an active straight leg raise, and a patella that is more proximal than the opposite side (Fig. 8.4). Radiographs show a high riding patella (patella alta) and may show inferior avulsion fractures.

Repair is similar to that of the quadriceps tendon with transosseous sutures, but again suture anchors are becoming more common. As with quadriceps repairs, no large outcome studies comparing suture versus suture anchors are available.

Postop recovery is similar to that of patellar fractures. There is a 3–6 weeks period of immobilization in near full extension; full extension for that period of time can be very uncomfortable. This is followed by a period of progressive range of

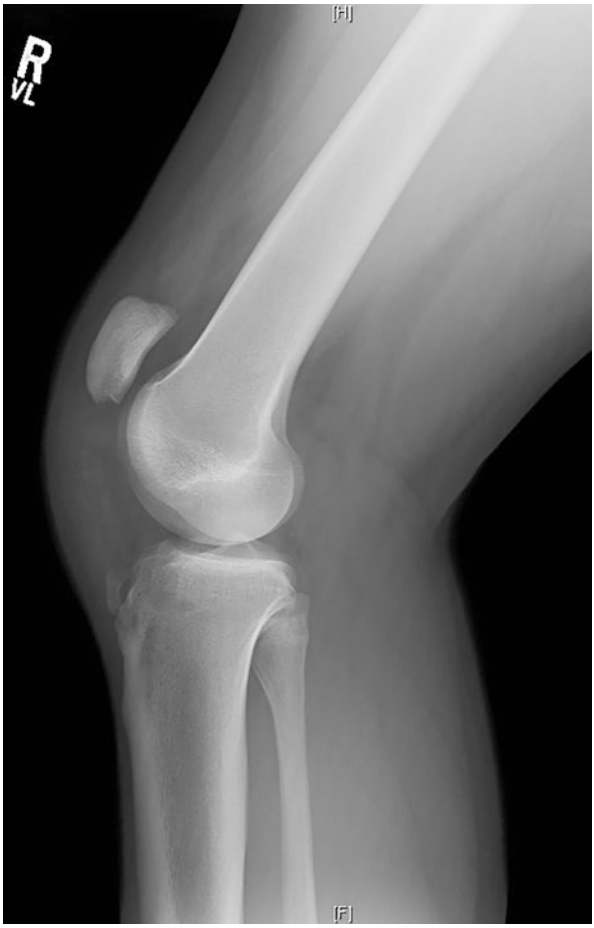

Fig. 8.4 Lateral radiograph of a patellar tendon rupture. Note the high position of the patella relative to the tibial plateau (aka patella alta)

motion and strengthening. The when and how fast depend on the stability of the repair, patient compliance, and surgeon preference.

Failure to regain knee extensor strength is normal, and loss of terminal flexion is not unusual. The patient should be not only counseled regarding both of these problems preoperatively but also reminded several times in the postoperative period [11].

8.2.3 Patellar Dislocations

Patellar dislocations are lateral with most occurring in 10- to 20-year-old patients during sporting activities. Reduction is quite simple, often performed by the patient or coach immediately after the injury, by straightening the knee, and, if necessary, placing mild medially directed pressure on the lateral aspect of the kneecap.

Radiographs to rule out associated fractures are appropriate, and an MRI may be necessary to evaluate for purely chondral fragments especially in the pediatric age group patients.

Assuming there are no osteochondral fragments that need to be addressed surgically, treatment for first-time dislocations is unclear despite several studies.

The primary pathology is disruption of the medial patellofemoral ligament (MPFL). Some advocate surgical repair of the MPFL, while others advocate a period of immobilization followed by bracing and physical therapy. Today, both groups appear to have equivalent outcomes in terms of patient satisfaction, recurrent dislocation rates, and need for further surgery. Recurrent patellar dislocation can have a variety of causes and is beyond the scope of this book [12–14].

8.3 Ligamentous Injuries About the Knee

There are four major ligaments of the knee: medial collateral ligament (*MCL*), lateral collateral ligament (*LCL*), anterior cruciate ligament (*ACL*), and posterior cruciate ligament (*PCL*). Any of these can be sprained, torn, or avulsed from either one of its two bony attachments, with or without a fleck of bone. Injury to the ligaments is from a direct blow such as being tackled in American football or force applied to the leg causing the knee to move beyond its physiologic limits such as a hyperextension force causing an ACL tear.

As with other injuries, the history of what happened is important including asking:

- If the patient heard or felt a snap or pop.
- When did swelling occur (immediate, over 24 hours, or not at all)?
- Are there any previous injuries or associated symptoms such as locking and giving way?

Physical examination cannot detect all the injuries as pain, soft tissue swelling, and effusion may obscure the findings on ligamentous testing. The most common tests are discussed under individual ligaments below. The AP should keep in mind that side-to-side comparisons can be helpful in addition to remembering more than one ligament at a time can be injured.

Imaging begins with plain films, looking carefully for avulsion fractures. MRIs are commonly ordered not only to confirm the suspected ligamentous injury but also to look for associated meniscal tears, chondral injuries, occult fractures, and bone contusions.

8.3.1 MCL

MCL injuries are the result of a direct blow to the lateral aspect of the knee, resulting in a temporary valgus deformity. Physical exam includes reproducing the

deforming force with the knee in full extension and at 30° of flexion. The amount of opening and solidity of the endpoint should be noted and compared to the contralateral knee.

MCL injuries are most often treated with a period of hinged knee bracing and physical therapy. The most common problem is ruling out accompanying injuries that will require surgery such as a meniscal tear or the rare avulsion of the MCL that requires fixation. Avulsion of the MCL normally occurs in multi-ligament injuries such as in a knee dislocation [15, 16].

8.3.2 ACL

ACL tears are the most common ligamentous injury about the knee that requires operative repair. Direct blows with accompanying MCL injury and hyperextension are the most common mechanisms of injury. Specific tests for ACL integrity include Lachman, anterior drawer, and pivot shift tests. The pivot shift test may be painful as the clinician is actually recreating subluxation of the knee. As with the MCL, the amount of laxity, endpoint, and comparison to the contralateral knee should be noted. Treatment depends on associated injuries, age, and expected demands to be made on the knee (i.e., couch potato vs elite athlete). The risk of not treating the ACL operatively is a subsequent meniscal tear. Treating the ACL operatively probably does not reduce the incidence of eventual osteoarthritis. The damage done to the articular cartilage at the time of the ACL tear (which results contemporaneously with at least a partial dislocation) is the primary contributing factor to eventual osteoarthritis. For the younger, more active population, surgical reconstruction is appropriate. In the older, low-demand population, treatment of ACL injuries with physical therapy to restore strength including appropriate quadriceps/hamstring ratio and proprioception in addition to activity modification will usually suffice. In the last few years, ACL reconstruction in over 40 population for carefully selected patients has proven beneficial.

Except for the rare avulsion injury, the cruciate ligaments do not heal after direct repair; thus, some type of graft replacement is necessary. Graft choices include autograph (a medial hamstring tendon, a portion of the quadriceps tendon, or a bone-tendon-bone (patella, middle third patellar tendon, tibial tubercle)) or allograft each with various pros and cons. Ultimately, the choice depends on the particular patient desires as well as the surgeon's preference and experience. The most difficult part of the procedure for maximal restoration of function is the preoperative and postoperative physical therapy whether conducted at home or under the supervision of a physical therapist. The important points are early restoration of terminal extension, followed by restoration of flexion and then strengthening and proprioception. The patient should be warned there may be permanent atrophy of the quadriceps muscle. Depending on the type of graft and preference of the surgeon, various lengths of time (6–12 months) will be necessary to allow the graft to mature before allowing the patient to return to full activities. The various methods of harvesting and fixing the graft are beyond the scope of this book [17–20]. For those who are

interested in injury prevention, the AAOS has an appropriate use criteria article of methods that may reduce the likelihood of ACL injury [21].

8.3.3 PCL and LCL

PCL and LCL injuries are much rarer, and other than mentioning that complete tears of these two ligaments are likewise treated with some type of graft (although acutely some LCLs are directly repairable), they will not be discussed in this text [22–24].

8.4 Meniscal Tears

Patients with meniscal tears present with a variety of symptoms including effusions, pain, catching, locking, and giving way of the affected knee. The history of injury also varies widely from no known injury, rising from a squatting position, twisting with the foot planted, to some type of impact such as being tackled while playing football. Once the AP has obtained the history of when and how the problem started, asking about the abovementioned symptoms is helpful.

Physical exam includes testing for active and passive range of motion as well as what parts of the motion are painful. Careful palpation about the knee will usually reveal joint line tenderness and any accompanying effusion. Other structures to palpate include the pes anserine bursa, lateral femoral condyle (to rule out iliotibial band syndrome), tibial tuberosity, patella and quadriceps tendon, as well as peripatellar tissues. Two specialized tests are worth mentioning: McMurray's and the Thessaly tests. McMurray's test is performed by hyperflexing the knee, placing several fingers along either the medial or lateral joint line with one hand and using the other hand on the heel to create either a valgus or varus stress on the knee (to test the lateral or medial meniscus, respectively) while twisting. A positive test includes both pain and a click or pop felt along the joint line; the examiner should make note of either or both (Fig. 8.5). The Thessaly test is done by first having the patient stand on the good leg only and squat (bending the knee about 30–45°) and gently twisting (Fig. 8.6). This establishes what is normal. The same is repeated with the symptomatic knee. Recreation of the symptoms (pain, popping, etc.) is considered to be positive. Care should be taken to examine for associated ligamentous injury as well as examine for any symptoms that may be coming from the hip such as slipped capital femoral epiphysis in teenage boys.

Radiographs are nondiagnostic for meniscal tears but are taken to rule out other conditions such as tumors, fractures, and arthritis. MRIs are the most common method of definitively diagnosing meniscal tears and are extremely helpful in eliminating other conditions such as occult tibial rim fractures, stress fractures, osteochondritis dissecans, and early arthritis. The current accuracy of high-quality MRIs in diagnosing meniscal pathology is better than 98%, possibly slightly less for open or low-strength units. If patients cannot tolerate an MRI (e.g., retained aneurysmal

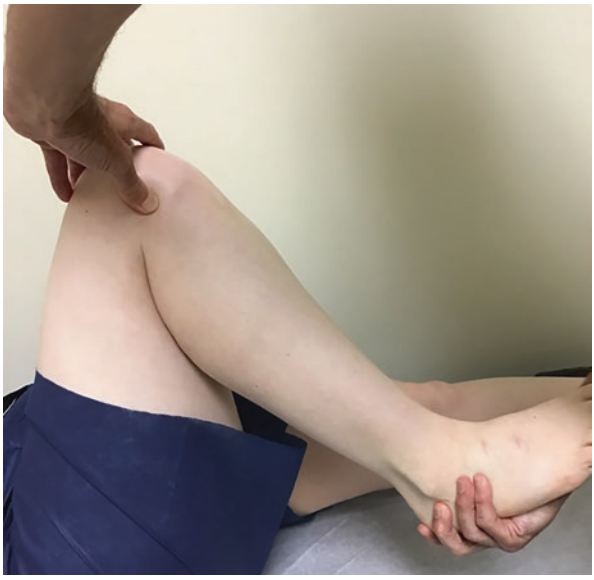

Fig. 8.5 McMurray testing is done both medially and laterally. In this patient, the knee is flexed, pushed into mild valgus with the left hand while the right hand pushes up and rotates the leg both internally and externally. Pain and a click or pop under the left thumb which is on the joint line mean there is a high probability of a lateral meniscal tear

Fig. 8.6 The Thessaly test is done by having the patient squat on one leg and then "do the twist." Patients with meniscal tears will complain of pain or be unable to perform the test. Comparison with the opposite side is helpful, and the AP should remember patients with osteoarthritis will also have pain doing the Thessaly test

brain clips or if claustrophobic), a CT arthrogram is an option, although fewer radiologists have the necessary experience.

Classification of meniscal tears is helpful in that it can guide treatment both nonoperative and operative (Fig. 8.7). The decision to be made with operative treatment is whether excision of the damaged portion or repair is best (Fig. 8.8). Repair is the best way to restore joint integrity and prevent the consequences of a meniscectomy (increased risk of arthritis) but is extremely dependent on tear size, location, pattern, and age of patient (Fig. 8.9). If repaired, the patient needs to know not only that

Fig. 8.7 Some tear types from left to right: parrot beak, radial, bucket handle, vertical

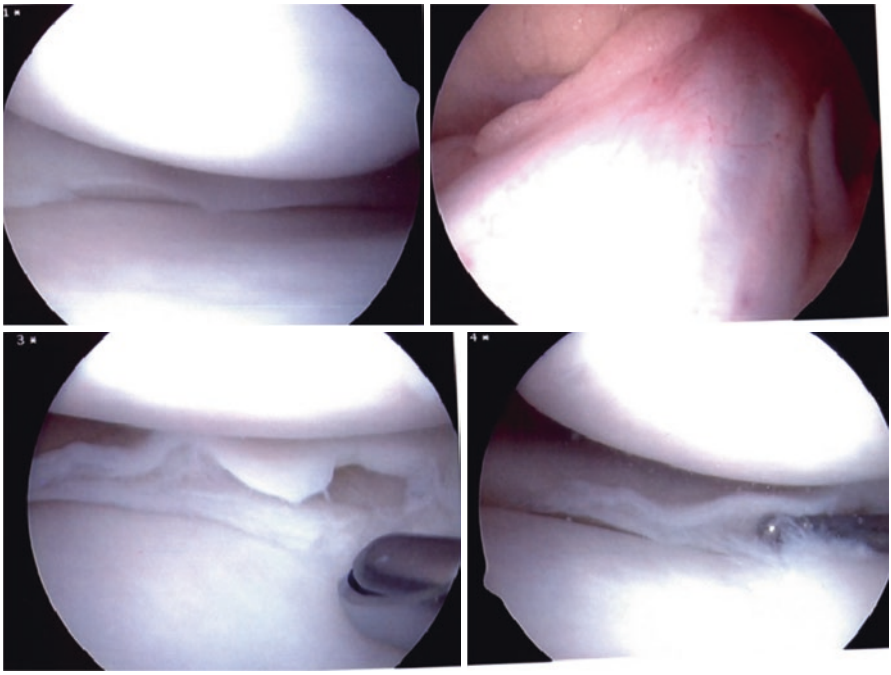

Fig. 8.8 Knee arthroscopy pictures: upper right is a normal lateral compartment. Upper right is the ACL. Lower left is a horizontal cleavage tear of the medial meniscus. For sizing purposes, the shaver in the lower left is 3.5 mm in diameter, while the probe in the lower right that is inserted in the tear is 1.5 mm in diameter

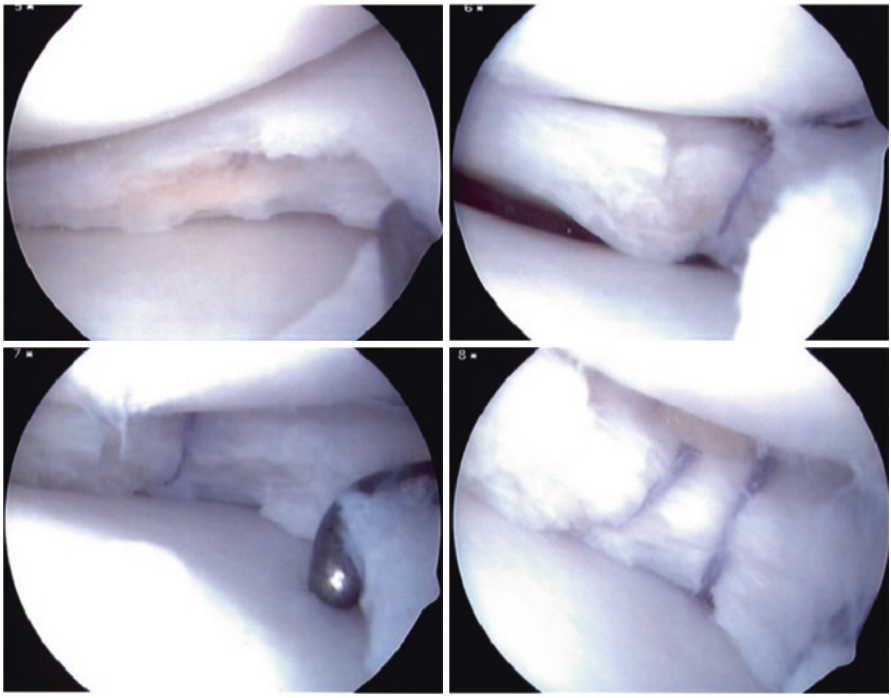

Fig. 8.9 Horizontal cleavage tear of the lateral meniscal tear in a teenager. It was repaired with no recurrence of symptoms

recovery takes longer than a simple partial meniscectomy but also that there is a significant failure rate of repair necessitating a second arthroscopic surgery.

The other tear not mentioned is the complex tear which as the name suggests has multiple tears going in multiple directions and is almost always treated by partial meniscectomy.

Treatment for most symptomatic tears is arthroscopy with repair or partial meniscectomy as indicated by the intraoperative findings. Most tears are not repairable. The ideal tear to repair is a peripheral, bucket handle-type tear through the red-red or red-white zone (indicating viable blood supply) in a young patient whose knee is ligamentously stable. Repair can be accomplished in an outside-in, inside-out, or all inside methods depending on tear location and surgeon's preference/experience.

For patients undergoing repair, weight-bearing as tolerated is optimal as the weight of the body pushes the meniscus peripherally taking stress off the repair; however, motion must be limited or the "rollback" mechanism of the femur on the tibia may disrupt the repair. To prevent this, some type of knee immobilizer or hinged knee brace with limits on range of motion is necessary. Length and limits on motion are dependent on repair stability and surgeon preference, but 3 months is not unusual.

For the patient with a partial meniscectomy (Figs. 8.10 and 8.11), crutches or walker with weight-bearing as tolerated is the norm with most patients dispensing

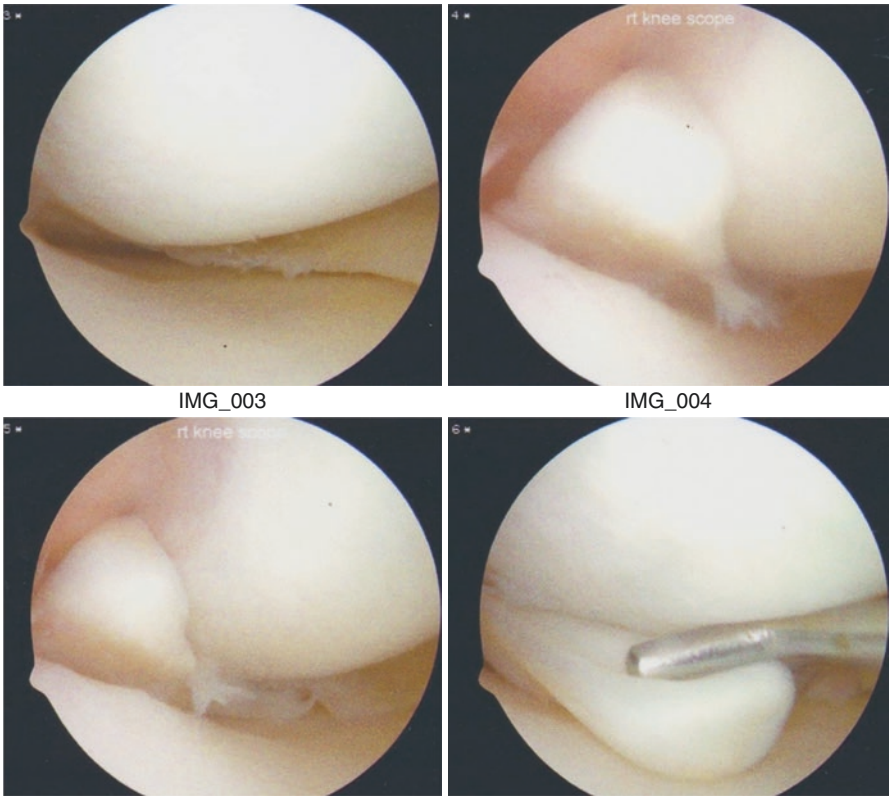

Fig. 8.10 The top left shows the normal lateral compartment, while the remaining images are of displaced parrot beak tear of the medial meniscus that prevented full extension

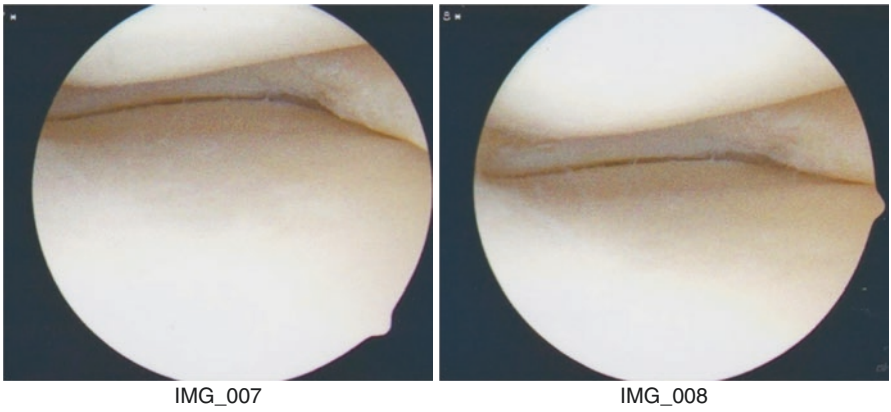

Fig. 8.11 Images after partial meniscectomy of the parrot beak tear shown in Fig. 8.10

with the ambulatory assistive device within 3–4 days postoperatively. Ice for 48–72 hours helps control both the pain and swelling. Sutures are removed at the postop visit (7–10 days) and formal rehabilitation started.

The rehabilitation process for both repaired and excised menisci is similar, although with the former the range of motion and proprioceptive exercises are of necessity delayed. In addition to ensuring maximal range of motion, quadriceps and hamstring strengthening, the therapist should also address any accompanying hip weakness. Although some patients will be capable of rehabbing themselves, most would benefit from some therapy if for no other reason than to get a formal measurement of strength and a detailed home exercise program. The frequency and duration of therapy are dependent on patient age, activity level, and desired level of function. Twice per week for 4 weeks suffices for most patients, but the AP should keep in mind that copays for physical therapy can be high and some insurance plans limit the number of physical therapy visits per year.

A significant number of tears in the older (>40–50) population are degenerative in nature, and treatment is mildly controversial. Generally, if the patient has no associated arthritis and his only symptom is pain, then physical therapy should be tried first before considering arthroscopy. If there are accompanying mechanical problems such as effusions, giving way, loss of motion, or popping, then a course of physical therapy may relieve the symptoms. Proceeding directly to arthroscopy is also acceptable. The most controversial category of degenerative tears to treat is those accompanied by osteoarthritis. For most patients, arthroscopy will probably not relieve the joint pain on a long-term basis; therefore, treating the patient as though the patient only has arthritis with NSAIDs, steroid injections, physical therapy, or joint replacement is probably best [25–30].

8.5 Non-traumatic Knee Problems

8.5.1 Prepatellar Bursitis

Prepatellar bursitis comes in two flavors. The first is an overuse injury with swelling of the prepatellar bursa and minimal pain. The patient can usually describe the circumstances; for example, the patient spent the weekend on his knees installing carpet in the spare bedroom. Treatment is symptomatic – rest, ice, and avoidance of further trauma – i.e., stay off the knee.

The second is more serious: an infected prepatellar bursa. Presentation is more acute with tenderness, erythema, fever, and occasionally lymphangitis. There may or may not be a history of trauma. Radiographs are appropriate to rule out fracture. Clinically, it may be difficult to differentiate between a swelling of the prepatellar bursa and a knee effusion, especially in large patients; careful palpation can usually reveal the difference. If the AP is uncertain if the prepatellar bursa is infected, it may be necessary to aspirate the fluid from the bursa and send the specimen to the laboratory for gram stain, cell count, crystal analysis, and culture if not grossly purulent.

The bursa either can be infected by direct trauma, puncture, or abrasion or can be "seeded" hematologically. If the body's immune system is unable to eliminate the invading bacteria, the result is infection. Because of their superficial locations, the two most commonly infected bursae are prepatellar and olecranon bursae.

Rarely infected bursae can be treated with just antibiotics if the patient is started on antibiotics early (first 24–36 hours). Most commonly however, the patient will need to be taken to the operating room for formal incision and drainage – it is usually too painful to attempt under local anesthesia, especially if excision of the walls of the bursa is necessary in more chronic or severe cases. Unless the patient is acutely septic, antibiotics should be held until cultures are obtained. Seven to 10 days of antibiotics postoperatively usually suffice, the type (po vs IV) depending on the patient's compliance, comorbidities, and antibiotic sensitivities. The patient should be warned that in severe cases a second "washout" (repeat incision and drainage) may be necessary.

Noninfected bursae are both easier and harder to treat – easier because no active intervention on the part of the healthcare provider is necessary other than making sure the bursa is not infected and harder because patients will frequently desire "something has to be done." The AP's task is to reassure the patient of the benign nature of the swelling including that it may take time to resolve and instructions to stay off the knee. Aspiration usually results in recurrence of the bursa and may cause an iatrogenic infection [31, 32].

8.5.2 Patellofemoral Pain aka Anterior Knee Pain Syndrome

The stereotypical patient with vaguely defined anterior knee pain is an active adolescent female. The problem with the diagnosis is that it tends to be a diagnosis of exclusion. A careful history, including inciting event(s), time course, recent growth spurt, aggravating factors like jumping, and associated manifestations like locking and giving way, as well as a detailed physical exam carefully palpating each structure about the knee will frequently lead to a more precise diagnosis. The AP should be sure to examine not only hip motion (to rule out slipped capital femoral epiphysis) but also hip strength, especially abduction. Weak hips are often compensated for by overuse of the quadriceps and subsequent tendinitis. Another clue that there is not a discrete mechanical cause is bilateral symptoms. Some functional testing such as deep squats, symmetrical one-legged squats, and observation of the patient while walking or running will help diagnose motor deficits.

After initial radiographs, additional imaging is not normally necessary unless the clinical history and physical exam points to something more serious like a meniscal tear. Radiographs should be examined closely for osteochondral lesions, status of the growth plates, and tumors as the latter is commonly found in the adolescent with vague complaints of joint pain.

If no specific cause can be found, the most frequent course of treatment is relative rest with a prolonged course of hip, thigh, and knee strengthening to achieve

symmetry and norms for the patient's age, weight, and height. The patient and parents should be cautioned that recovery is not quick. If the patient is diligent with both physical therapy and home exercise, there will be marked improvement by 6 weeks, but full recovery may take as long as 6 months. A few patients may require a twice weekly maintenance program on a long-term basis to prevent recurrence.

The differential diagnosis is long but not limited to the following: quadriceps or patellar tendinitis, subluxing patella (which can be the result of genu valgum, a shallow trochlear groove, or hypoplasia of the lateral femoral condyle), hip disease, ACL tears, chondromalacia patellae, osteochondritis dissecans, or a stress fracture of the patella [33, 34].

8.5.3 Baker's Cyst

A Baker's cyst is a collection of synovial fluid behind the knee. It may or may not be symptomatic, but when it first forms, it is uncomfortable because the tissues are being stretched. The incidence peaks are between 4–7 years and 35–70 years. There is no predilection for race or sex. The most common conditions associated with Baker's cyst are osteoarthritis, rheumatoid arthritis, and juvenile rheumatoid arthritis. Physical exam will reveal a fullness – ballotable – in the popliteal fossa, usually non-tender. If it ruptures, there will be a sharp pain in the back of the knee followed by swelling around the ankle. One of the differential diagnoses is a strain of the medial head of the gastrocnemius.

Plain films to rule out associated tumors and evaluate for arthritis are normally the extent of the workup. The underlying pathology is the result of a leak of the synovial fluid into the soft tissues of the popliteal space through a tear in the posterior joint capsule. The capsule tear may be associated with a meniscal tear which may or may not be symptomatic.

Treatment is reassurance. Aspiration is almost always followed by recurrence and even if attempted is difficult because of "floaters" in the cyst clogging the needle. Ultrasound may make aspiration more successful. The patient needs to be reassured of its benign nature as it usually stops hurting after the initial stretch of soft tissues. Rarely excision of the cyst is necessary because of pressure exerted by the cyst on the popliteal vessels or tibial nerve. The only important differential is a synovial sarcoma [35].

8.5.4 Osteoarthritis of the Knee

Some patients with osteoarthritis of the knee have a history of previous injury such as an ACL tear, tibial plateau fracture, or meniscal tear, but most do not. They are usually in their mid-50s to 60s and present with a history of gradually worsening knee pain, loss of motion, and occasional instability. Some patients will have bilateral symptoms.

Plain radiographs will show varying degrees of joint space narrowing, subchondral sclerosis, and osteophytes. Some surgeons prefer at least the AP radiograph to

be weight-bearing. If surgery is necessary, full-length leg films can be helpful in determining overall alignment.

Treatment is approached in a stepwise fashion, but many patients will present to the orthopedic AP after having already tried many of the following options. The patient needs to understand there is no cure and treatment is geared toward controlling or relieving the symptoms with the least risk and expense possible. Step one is weight loss (especially if the BMI is over 40), strengthening exercises for both the hip and the thigh which may require several trips to the physical therapist, followed by a consistent HEP. Acute symptoms may be controlled by acetaminophen or an NSAID. Alternative medicine treatments such as glucosamine, turmeric, or green tea have mixed results in the literature. Recommendation and results depend on both the surgeon and the patient. Step two is a corticosteroid injection, but this gives only temporary relief which can vary from a few weeks to a few months. Hyaluronic acid (e.g., Synvisc™ or Hyalgan™) was originally an extract from rooster comb but is now produced by genetically modified bacteria. Its effectiveness compared to corticosteroid injection is controversial. It is also expensive, and some formulations require three to five injections over the same number of weeks. Exactly how the hyaluronic acid relieves symptoms is unclear [36–39].

There are three surgical options. For younger patients with unicompartmental disease (medial or lateral tibiofemoral joint), a high tibial osteotomy can shift the weight of a varus knee, with medial compartment osteoarthritis, to the normal lateral compartment, and vice versa for lateral osteoarthritis (Fig. 8.12) [40, 41].

They are not as popular as a few years ago but are an option in relatively young patients without a flexion contracture.

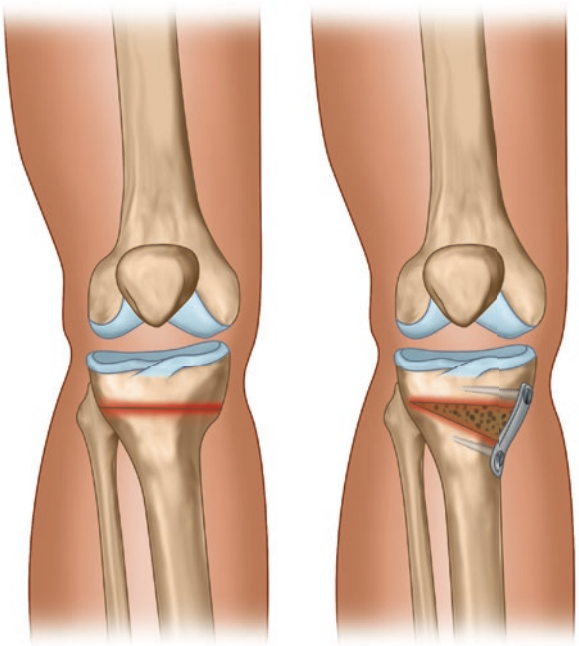

Fig. 8.12 Diagram of an opening wedge osteotomy to transfer the weight from the arthritic medial compartment to the relatively intact lateral compartment

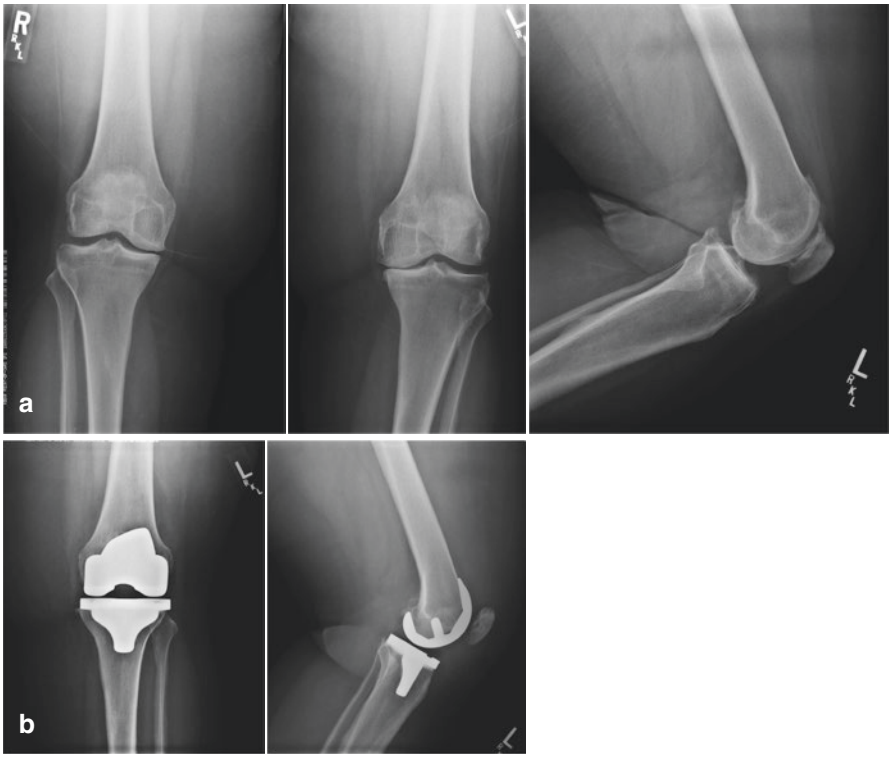

Fig. 8.13 (**a**, **b**) AP and lateral of an osteoarthritic knee especially worse in the left medial compartment. The patellofemoral joint is worn as well with superior traction osteophytes and subchondral sclerosis. The postoperative radiographs are shown below

Unicompartmental knee replacements can be done for either medial or lateral tibiofemoral disease or isolated patellofemoral arthritis but most commonly for medial tibiofemoral compartment disease. The advantage is a quicker recovery than from a total knee arthroplasty. The disadvantage is the need for revision if the disease should progress [40, 41].

Total knee replacement (arthroplasty) is for refractory cases that do not respond to nonoperative measures (Fig. 8.13a, b). Patient cooperation with the rehabilitation process is crucial in regaining motion and strength. Hospital stays vary from one to three nights although outpatient total knee arthroplasty is becoming more common. Complications that the patient needs to be aware of include infection, deep venous thrombosis [38], loss of motion, and nerve injury (especially in valgus knees with a flexion contracture). A wide variety of issues are surgeon-dependent, whether or not to resurface the patella, use of intramedullary or external alignment guides, custom-made cutting jigs, or use of computer-assisted cutting, all of which are beyond the scope of this text. Long-term results of total knee replacements are generally

excellent with a 90% or better 15-year survival rate [42]. Referencing particular articles on total knee arthroplasty is difficult, but for the AP who is interested, there are whole books on the subject [43–45].

8.5.5 Septic Arthritis

Although any joint can become infected, the knee seems to be one of the most common. Patients typically present with a 1–3-day history of increasing pain, fever, effusion, and tenderness in the affected knee. There is usually no history of trauma. Physical exam shows increased warmth, an effusion with tenderness along the joint line, and loss of motion, especially flexion in addition to difficulty weight-bearing. The radiographs show an effusion but are otherwise normal.

Diagnosis can be straightforward, but the clinician needs to keep the full differential in mind, gout, pseudogout, or a traumatic effusion which can be serous or bloody. Aspiration of the joint is the best way to make the definitive diagnosis. Microscopic examination, if bacteria are seen, makes the diagnosis surefire. It is not uncommon for bacteria not to be seen; still the diagnosis and treatment need to be made promptly because delay will cause destruction of the articular cartilage and prolonged delay may lead to osteomyelitis.

Diagnostic criteria include greater than 5 WBC per high-powered field and an aspirate glucose 50 less than the serum glucose. Any aspirate sent for analysis should include a CBC, aerobic and anaerobic gram stain cultures, and crystal analysis. If there is suspicion (e.g., the patient is from a third-world country or immunocompromised), consideration for AFB (TB) and fungal cultures should be obtained.

Treatment is irrigation and debridement which can be done with an arthroscope. For severe cases or immunocompromised patients (HIV, diabetes, poor nutrition, etc.), a second debridement is not unusual. Timing is urgent but not emergent. Drains are normally placed. Each surgeon will have a preference as to when to pull them, generally, within 24–48 hours depending on patient response and amount of drain output. If available, consultation with an infectious disease may be helpful to determine antibiotic dosage, route of administration, and duration [46, 47].

8.5.6 Osteochondritis Dissecans (OCD)

Osteochondritis dissecans is where a fragment of the bone and cartilage become detached from the joint. The fragment may remain in place or may break partially or totally free. Size varies. Patients with osteochondritis dissecans are most often male teenagers with knee complaints. However, the OCD can and has occurred in other joints, including the talus of the ankle joint, the hip, the shoulder, and the elbow. In addition to the normal teenage patient, OCD lesions can occur in adults but rarely after 50. The patient presents with vague knee pain and perhaps catching,

popping, or locking of the knee if the lesion is partially or completely loose. Physical exam may show an effusion and can simulate a meniscal tear with limited flexion or a positive McMurray's sign. If the lesion is palpable, dependent on location, it will be tender.

Radiographs, except in rare cases, are diagnostic, but for the knee, a tunnel or notch view may be necessary to visualize the OCD lesion as the most common location is the lateral aspect of the medial femoral condyle. If the lesion is primarily cartilage and has broken free to become a loose body it will not be seen on plain films. Bone scan or SPECT scans can help determine if the lesion is healing or becoming progressively worse. MRIs are the closest one can get to identifying lesion size and stability without arthroscopy (Fig. 8.14). The latter is still the gold standard for assessing lesion size, stability, and viability of repair.

Etiology is unknown. Adolescents tend to have a much better outcome than adults, so there are probably multiple pathways that lead to the same lesion.

Treatment options vary depending on patient age (including whether the physis is open or closed); activity level and compliance, size, location, and stability of the fragment; overlying cartilage integrity; and the skill and experience of the treating surgeon. Options include immobilization to allow lesions with intact cartilage to heal, excising fragments that are too small to repair, pinning the fragment back in place with metallic or bioabsorbable screws, and drilling intact lesions to establish blood flow which can be done through the cartilage or with fluoroscopic control in a retrograde fashion leaving the cartilage intact. For irreparable lesions, osteochondral autografts or osteochondral allografts can be performed.

Like other orthopedic injuries, younger patients tend to do better and adolescents much better than adults. Although most patients improve over the preoperative status when compared to the unaffected side, knee function never returns to normal.

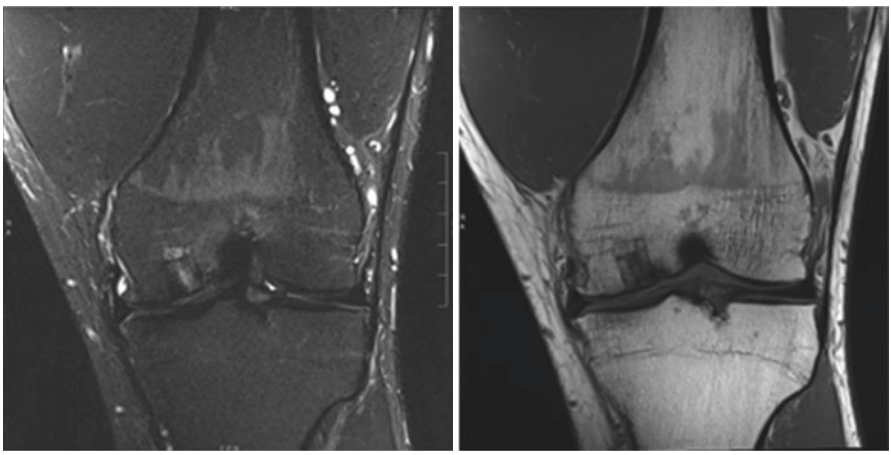

Fig. 8.14 STIR and T1 images of a large osteochondritis dissecans lesion in the medial femoral condyle. Of note, there are nonspecific marrow changes, but the significance of those marrow changes is unknown

Complications include arthritis, failure of the lesion to heal, hardware failure, and foreign body reaction to resorbable implants. Some osteochondral grafts overgrow the site of implantation resulting in a need to return to the operating room to shave the graft to its normal borders [48, 49].

8.5.7 Osgood-Schlatter Disease

Osgood-Schlatter disease is the most common apophysitis (more recently named an epiphysitis) and is found in early adolescents; males are affected far more often than females typically during or shortly after a growth spurt. The patient comes in complaining of pain either in the patellar tendon or around the tibial tuberosity, worse with activity, especially jumping or running, and relieved with rest.

Physical exam reveals tenderness of the tibial tuberosity and frequently a "camel hump" deformity (Fig. 8.15). Like other patients with knee complaints, the hip should be checked for tenderness and range of motion. Many of these patients will have "tight" hamstrings.

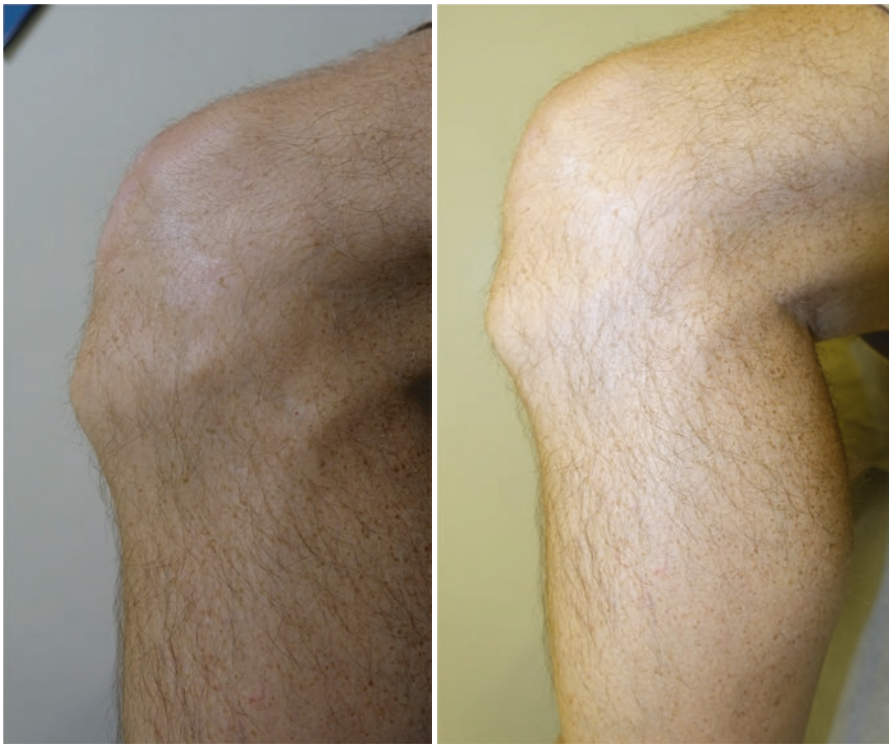

Fig. 8.15 Lateral photograph of the knee of a patient with the typical camel hump of Osgood-Schlatter disease

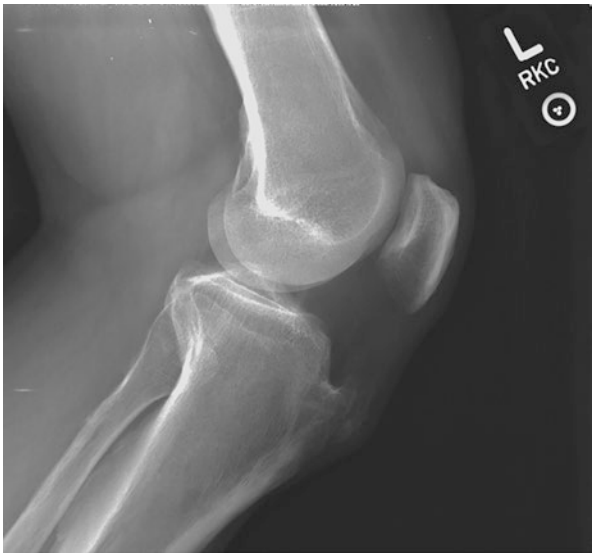

Fig. 8.16 Lateral radiograph of the residual tibial tuberosity prominence from a patient who had Osgood-Schlatter as an adolescent

Radiographs show closing growth plates as well as the prominence of the tibial tuberosity which may or may not have some fragmentation (Fig. 8.16). Other imaging or diagnostic testing is not necessary.

The underlying pathophysiology is a differential in the growth rates of the bone and tendon causing a mild traction injury to the tibial tuberosity. It is normally activity-related and the pain ceases once growth is complete. The bony prominence of the tibial tuberosity may remain.

Treatment is symptomatic and consists primarily of reassuring the patient that this condition is benign and that it is activity-related. For some severe cases or very active patients, hamstring stretching can be helpful; in order to reduce some patients' activity level, a knee immobilizer for a month or two may be necessary. Very rarely, especially in patients who ignore the pain, patellar tendon avulsion can occur [50].

8.5.8 Shin Splints

Shin splints is more of a symptom description rather than a specific diagnosis. It generally occurs in runners although aggressive walkers or hikers can develop it as well. Careful history and physical exam will usually give a more specific diagnosis, with radiographs and MRIs being ordered only to rule out more serious pathologies such as adamantinomas.

The presenting complaint is, as expected, pain in the anterior leg. Important questions to ask include the following: When does the pain occur? Is it bilateral? Does it interfere with the running or just hurt afterward? Have there been any changes in running activities in the previous 6–8 weeks such as in distance, speed, running surface (including terrain changes like more hills), increase or decrease in

body weight, or changes in running shoes? For women, inquiries about menstrual cycle, frequency, and pregnancy are appropriate [51].

Physical exam should look for specific tender spots including palpation of the anterior tibial tendon, tibial crest, posteromedial tibia, as well as a sensory exam. The AP should not neglect checking the knee and the hip for weakness including hip flexors and abductors as well as internal and external rotators. Placement of a tuning fork on or near a stress fracture or a stress reaction will often elicit more pain than simple palpation.

Imaging includes plain films of the tibia which are usually negative, although in more chronic cases periosteal elevation may be seen. MRIs can be helpful if the diagnosis is uncertain. The differential list is long, but a precise diagnosis and subsequent treatment will allow the runner to return to activity as soon as possible.

Periostitis is characterized by diffuse bony tenderness along the posteromedial tibia. Treatment is activity modification and NSAIDs. It may take up to 6 weeks to resolve.

Anterior tibial tendonitis is characterized by no bony tenderness, pain along the anterior tibial tendon usually at the junction of the middle and distal fourth of the leg, as well as pain or weakness on resisted ankle dorsiflexion. Treatment is activity modification and strengthening exercises emphasizing eccentric work.

Stress fractures or stress reactions are characterized by point tenderness with the degree of symptoms varying from:

Stage I	Hurts after running
Stage II	Hurts while running without interference of performance
Stage III	Hurts while running and interferes performance
Stage IV	Cannot run, wakes patient up at night

The most common sites for stress fractures are the second and third metatarsals, the tibial plateau, and the tarsal navicular. Any bone exposed to increased stress, via volume or load, can experience a stress fracture [51–55].

Treatment varies according to the stage, but the AP also needs to evaluate for any underlying cause such as weakness, shoe wear, osteoporosis, or reduced energy consumption. More common in women than men, relative energy deficit can contribute to any number of overuse injuries [56–58]. Once underlying causes are addressed, running can be resumed as follows:

Stage I	Cut volume by 25%
Stage II	Cut volume by 50%
Stage III	Cut volume by 75%
Stage IV	No running until symptoms resolve

No running or decreased running does not mean no activity; alternate activities include swimming, water running, and bicycling.

Exertional compartment syndrome can be the most difficult to diagnose. The patient is asymptomatic in the office but has vague complaints of leg pain and a negative physical exam. The key to diagnosis is history. Normally, the patient will

have increased training volume dramatically and will describe the pain in both legs as “tight” that subsides within 15–30 minutes of ceasing activity. Reducing the volume of running usually relieves the problem. However, occasionally, it will be necessary to have the patient run until symptoms are induced and then get serial compartment pressures to confirm the diagnosis. If the activity modification does not relieve the problem, then a fasciotomy may be necessary (but rare) [58].

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The Hip and Thigh

9

9.1 Fractures

9.1.1 Pelvic Fractures

Pelvic fractures fall into two categories: the low-energy, minimally displaced fractures in elderly patients with osteoporosis (Fig. 9.1) and the high-energy fractures in young adults. High-energy fractures are frequently associated with multitrauma with much higher morbidity and mortality; the mortality is most often from bleeding.

In the elderly patient, the traumatic event, if identifiable, is of low energy such as falling from a chair or even just stumbling. The patient may or may not be able to bear weight depending on severity, pain tolerance, and overall strength. Physical examination may show tenderness but it is often poorly localized. Careful examination of pelvic films (typically AP, inlet, and outlet views) will show osteoporosis but may not reveal the fracture. An MRI done to rule out a proximal femur fracture may show a pubic ramus fracture.

Because the pelvis is a ring, if there is one fracture, say of the right pubic rami, a very careful search will be necessary to find the "other" fracture. It may be that there is some ligamentous disruption, e.g., at the sacroiliac joint, but a second fracture of the ring should be sought first.

Treatment of these osteoporotic fractures is directed at maintaining ambulatory status with walking aids, low-dose pain medication, and physical therapy. Long-term, any underlying osteoporosis should be addressed as well. Like hip fractures in the elderly, an in-home assessment for fall prevention is often helpful [1–3].

High-energy pelvic fractures most often from a high-speed motor vehicle accident are completely different from the elderly patient's low-energy pelvic fracture. There are often many other injuries including, but not limited to, traumatic brain injuries, spine and spinal cord injuries, limb fractures, pneumothorax or hemothorax, or associated bladder and abdominal injuries.

Because of the severity of the pelvic injury and commonly associated injuries, the patient is best treated in a coordinated team approach following ATLS protocols

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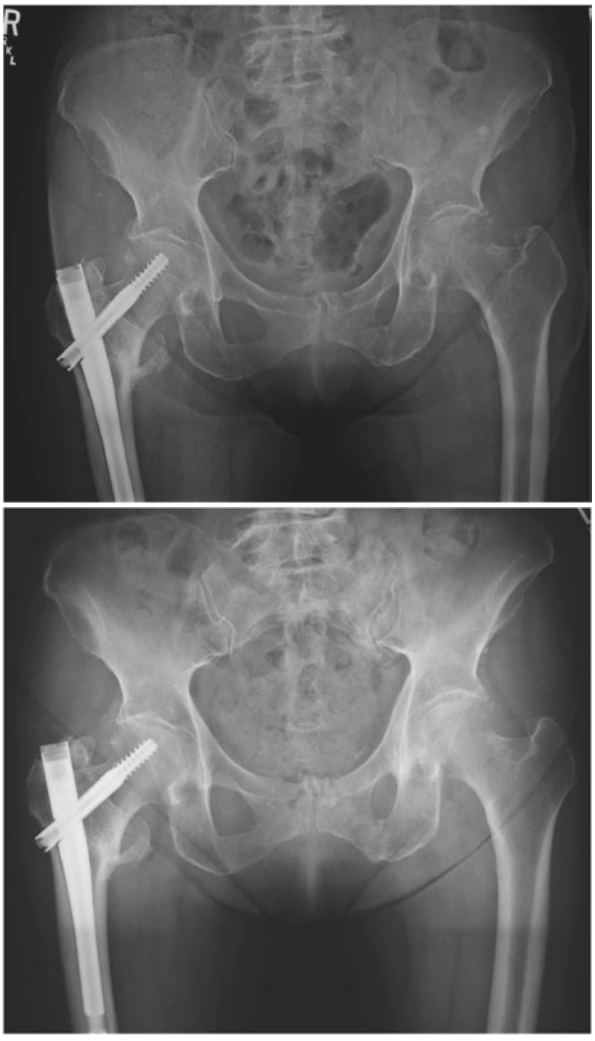

Fig. 9.1 The upper picture shows the acute upper and lower pubic rami fracture on the left with the lower showing the same approximately 6 weeks later with early callus formation. There is a cephalomedullary nail in the right proximal femur from a previous intertrochanteric hip fracture

for resuscitation and initial stabilization. The most common cause of early mortality is internal bleeding which may not be obvious during the initial survey. Careful monitoring of vital signs and repeat hematocrit levels are important. Ultrasound is being used much more frequently than in the past to assess intrapelvic, abdominal, and intrathoracic bleeding including the pericardial sac. Initial survey radiographs should include an AP pelvis in addition to chest and cervical spine films. Although the classification systems for pelvic fractures have been mostly based on the AP,

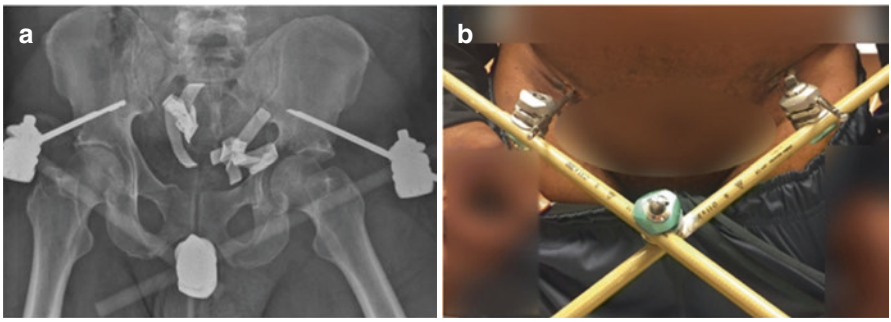

Fig. 9.2 (**a**) is of trauma patient with a left acetabular fracture an right pubic rami fractures that has been stabilized with an external fixator. (**b**) is a photograph of the external fixator in place. Not only does the external fixator stabilize the pelvic fractures but may also help tamponade the bleeding. (From Chu et al. [35])

inlet, and outlet films mentioned above, the evolving gold standard is CT scan with 3D reconstruction.

Treatment is first geared at controlling the bleeding which can be done with some combination of an external fixator to "close" the pelvic ring (Fig. 9.2), laparotomy, transfusions, or angiography with embolization.

Once the patient is stabilized, a planned reconstruction of the pelvis can be undertaken. In order to do so, the complete fracture pattern needs to be evaluated, the associated injuries planned for (e.g., was there a splenectomy or bowel injury?), and the surgical approach and fixation decided. The fixation may be as simple as a plate placed over a disrupted symphysis pubis or may involve a more extensive intrapelvic repair including restoring and fixing the sacroiliac joints. If there are associated acetabular fractures, the reconstruction is even more involved. Intraoperative fluoroscopy is necessary. Complications of pelvic fractures and their treatment include infection, neurologic injury, urologic injury including sexual dysfunction, thromboembolism, malunion, and nonunion [4–6].

9.1.2 Acetabular Fractures

Like other fractures, acetabular fractures can be present in the young adult as a result of high-energy trauma or in the older adult from low-energy trauma. There may or may not be an associated pelvic ring fracture or a proximal femur fracture. For the trauma patient, screening radiographs include the cervical spine (plain films or CT or both depending on the level and type of trauma), the chest, and an AP of the pelvis where the acetabular fracture is initially identified. In the elderly patient, the acetabular fracture is frequently identified during radiographic examination expecting to find a proximal femur fracture. Because of the minimal displacement of acetabular fractures in the elderly, a CT scan may be necessary to identify the acetabular fracture.

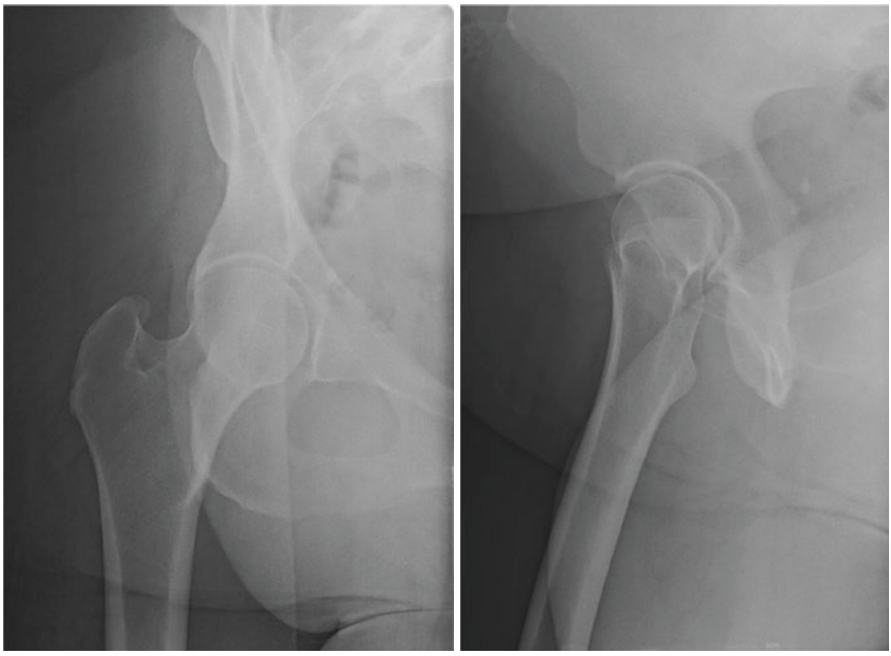

Fig. 9.3 Two screening views to evaluate an acetabular fracture (this is a normal hip). The left is an obturator oblique; the right is an iliac oblique. These views are useful for initial screening and follow-up, but surgical decisions almost always require preoperative CT scans

Once the patient is stabilized, the evaluation proceeds as follows: If there is an associated hip dislocation, it should be reduced promptly to decrease the chance of avascular necrosis. This is followed by obtaining iliac oblique and obturator oblique views (Fig. 9.3). This will give the treating surgeon a general idea of the type of fracture with which he is dealing. This is followed by a CT scan of the pelvis. For areas of the pelvis not related to the acetabulum, thicker, 4–6 mm, slices can be done, but around the acetabulum, thinner, 2–3 mm, or smaller slices should be used. Depending on the type of trauma, stability of the patient, and associated medical problems, IV contrast may be used to identify other traumas such as vascular injuries. 3D reconstruction of the bony pelvis from the CT scan is extremely helpful, but the clinician should also review the 2D images because when a 3D bony reconstruction is done, the soft tissue and associated soft tissue injuries are subtracted to allow better 3D images. MRI is not normally helpful except in occult fractures in the elderly.

The acetabular fracture pattern is determined by the relative position of the proximal femur to the acetabulum, the direction of force applied to the femur, and the amount of energy involved. The most common classification system used is that of Letournel and Judet. Briefly, the acetabulum is viewed as being at the fork of an inverted Y. The various structures are the anterior wall, anterior column, posterior

column, and posterior wall. Fractures are almost always some combination of these structures, but it takes time and experience to recognize each of the many patterns.

Treatment for most fractures is surgical, although a few patients may require prolonged femoral traction. The surgical approach can be anterior, intrapelvic, or posterior, and the reader is referred to the references for further discussion. Timing is related to other injuries but ideally within the first week.

Fracture healing takes 8–12 weeks during which time the patient's weight-bearing status will be limited. Maximal recovery may take up to 2 years. Other than limited weight-bearing, there is no clear data on the role of physical therapy in the rehabilitation of acetabular fractures.

Risk discussion should include arthritis (despite anatomic reduction) in addition to malunion, infection, nerve damage, and vascular damage; there is the significant risk of deep venous thrombosis. The type and extent of chemical prophylaxis will vary depending on other injuries, and for some patients, certain anticoagulants may increase blood loss or cause wound healing problems. Low-dose aspirin, 81 mg b.i.d., has been shown to work well after primary hip replacement for DVT and pulmonary embolism prophylaxis, but its role after acetabular fracture is still unclear. If the fracture is not well reduced or the energy of the initial injury caused significant cartilaginous, damage arthritis can occur. Heterotopic ossification can occur, and for acetabular fractures associated with hip dislocation, avascular necrosis is a concern [7–9].

9.1.3 Hip Fractures: Proximal Femur

The stereotypical patient with a hip fracture is an elderly, white female with a low-energy injury, i.e., a simple fall at home. Men have hip fractures as well but are typically a few years older. It is important to recognize younger patients can incur hip fractures from a high-energy injury such as a fall from a height or a high-speed motor vehicle accident. These may require a much more aggressive approach overall but will not be discussed in this book.

There are many contributing factors to hip fractures. As the patient ages, the bone constantly remodels, but after age 35, the amount of bone regenerated after the osteoclasts resorb old bone is insufficient for complete replacement. Then there is age-related sarcopenia. As patients age, they lose total muscle mass; since the average patient gains weight as they age, the elderly patient has less muscle trying to move more weight at age 70 than at 30 years of age. Age-related sarcopenia can be retarded but not stopped with appropriate diet and exercise. When other age-related factors are added such as loss of coordination, poor balance, diminished eyesight, and orthostatic hypertension, it is surprising more patients do not break their hips.

Specific surgical treatment depends on the type of hip fracture and will be discussed below. Two important issues that arise with almost every hip fracture patient is preoperative medical stabilization and clearance. Obviously, if something can be done to optimize the patient quickly, this should take place promptly. However, the

AP should keep in mind that prolonged surgical delay may lead to increasing complications such as pressure sores, pneumonia, urinary tract infections, or deep vein thrombosis. There is some controversy in the orthopedic community about timing of surgery after fracture, but generally speaking, surgery within 24 hours after medical stabilization and clearance seems to be optimal.

Postoperatively, the usual complications just mentioned can be reduced but not prevented. A variety of modalities are used to decrease the chances of developing a postoperative complication. Foot pumps, sequential compression devices, and compression hose are mechanical means of reducing the incidence of deep venous thrombosis, while chemical prophylaxis options include aspirin, heparin, warfarin, and other anticoagulants. Early Foley removal and early IV line removal decrease the risk of bladder infection and thrombophlebitis, respectively. Early mobilization with twice-daily PT can decrease bed sores, while pulmonary hygiene such as incentive spirometry and inhalers like albuterol when indicated reduce the chance of pneumonia. Posthospital placement varies. For some, going home with a supportive family and home health will work, but most will need placement in an inpatient rehab facility or placement in a long-term care facility. As each patient's physical and mental abilities, home situation, finances, and insurance coverage vary, early involvement and discussion with the family, physical therapist, and hospital caseworker, or social worker will be immensely helpful with discharge planning. The sad truth is that 20% of patients with a hip fracture will die within a year, and 20% will be permanent residents of a long-term care facility [10].

9.1.3.1 Femoral Neck and Subcapital Hip Fractures

Femoral neck and subcapital hip fractures are classified either according to Pauwels' type or to the amount and direction of displacement. Non-displaced, non-angulated fractures or those impacted in mild valgus can be treated with percutaneous screws, typically, in an inverted triangle with two screws superior and one screw inferior. Ideally after surgery, the patient should limit her weight-bearing until the fracture is healed, but the reality is that most do not have either the upper body strength or coordination to do so.

If the fracture is displaced (Fig. 9.4), screw fixation, even after anatomic reduction, the failure rate due to nonunion or avascular necrosis is so high that hemiarthroplasty is almost always the treatment of choice. Although most of these have been treated with hemiarthroplasty in the past (unipolar or bipolar), there has been a trend in the last few years to treat select patients with a total hip arthroplasty. The early complication rate is higher than a hemiarthroplasty, but the long-term success and patient satisfaction rates are higher with total hip arthroplasty. The surgical approaches are anterior, lateral, and posterior each with advantages and disadvantages.

The hemiarthroplasties can be cemented (Fig. 9.5) or press fit (see total hip arthroplasty for details on each). The primary advantage of cementing a hemiarthroplasty is that the stem is solidly fixed allowing weight-bearing as tolerated from day one. Unipolar stems have a large head attached to the stem that articulates directly with the acetabulum. Bipolar stems have an inner and outer head that articulate not

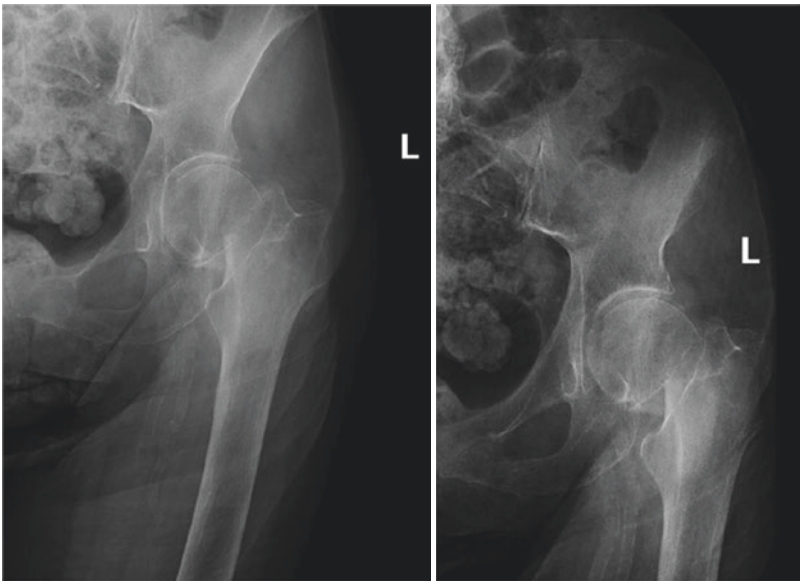

Fig. 9.4 Displaced femoral neck fracture. Because of the disruption of the blood supply to the femoral head in displaced fractures, especially ones in varus like this one, internal fixation usually fails, so hemiarthroplasty or total hip arthroplasty is the appropriate treatment

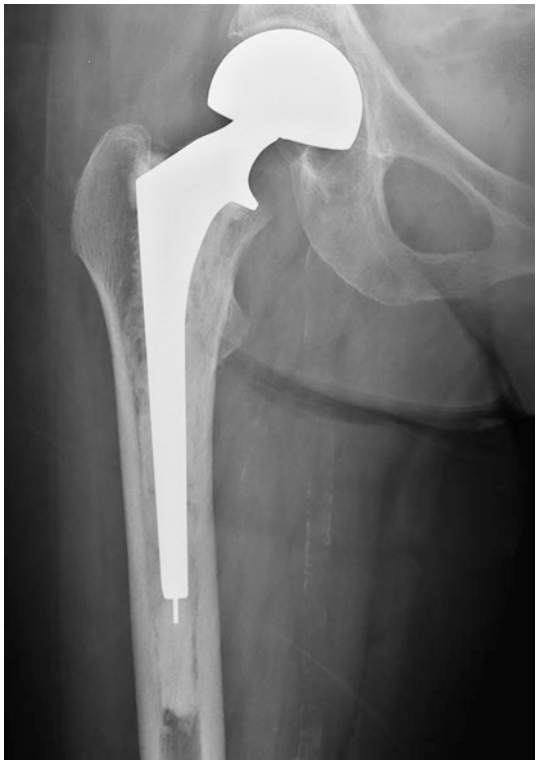

Fig. 9.5 Cemented bipolar hemiarthroplasty; the large head should not be confused with a total hip arthroplasty acetabular component [11, 12]

Fig. 9.6 The upper picture is the "head" of a bipolar hip prosthesis where the inner head pivots on the outer head which in turn pivots in the acetabulum theoretically allowing more motion before dislocation. The lower picture is of a fixed monopolar head which is less expensive. (Images courtesy Zimmer Biomet)

only with the acetabulum but also with each other (Fig. 9.6). Theoretically, this provides greater range of motion before subluxation or dislocation becomes a problem.

9.1.3.2 Intertrochanteric Hip Fractures

Intertrochanteric hip fractures (Fig. 9.7) can be treated with either a sliding hip screw (Fig. 9.8) or a cephalomedullary nail (Fig. 9.9). Long-term outcomes for the two appear to be similar. Both are done on a fracture table under fluoroscopic control. The well leg is placed in the semi-lithotomy position or in hip extension with the injured limb in foot traction. Once the fracture is reduced, the fluoroscopy unit should be checked to make sure high-quality orthogonal images of the proximal femur including the entire femoral head are possible.

The sliding hip screw is placed through a lateral of incision of 12–15 cm in length.

The cephalomedullary nails are used especially for unstable intertrochanteric or subtrochanteric femur fractures. For either procedure, be sure to prepare and drape from the iliac crest to the tibial plateau. A 2–3-cm incision is made just proximal to the greater trochanter with a second incision of 1–2 cm at the level of the trochanteric ridge for insertion of the screw into the femoral head. Overall, rod length and distal screw insertion are at the surgeon's discretion.

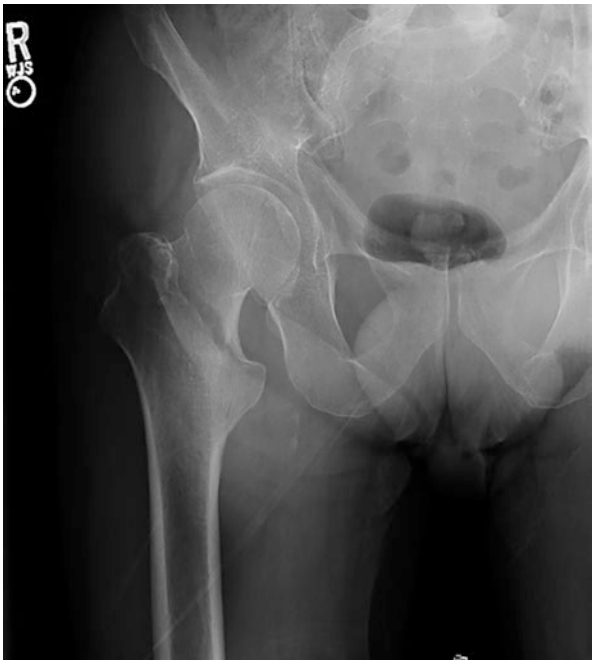

Fig. 9.7 Intertrochanteric hip fracture after reduction. Note the fracture line starts at the base of the greater trochanter and exits at the superior aspect of the lesser trochanter

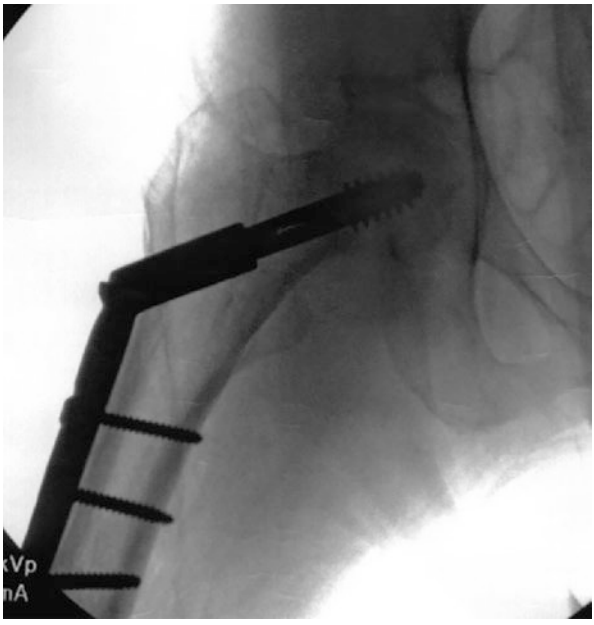

Fig. 9.8 Postoperative film after fixation of an intertrochanteric hip fracture with a sliding hip screw

Because of the osteoporotic bone, the most common complication for either a sliding hip screw or cephalomedullary nailing is failure of fixation with the screw cutting out through the superior aspect of the femoral head and neck [13, 14].

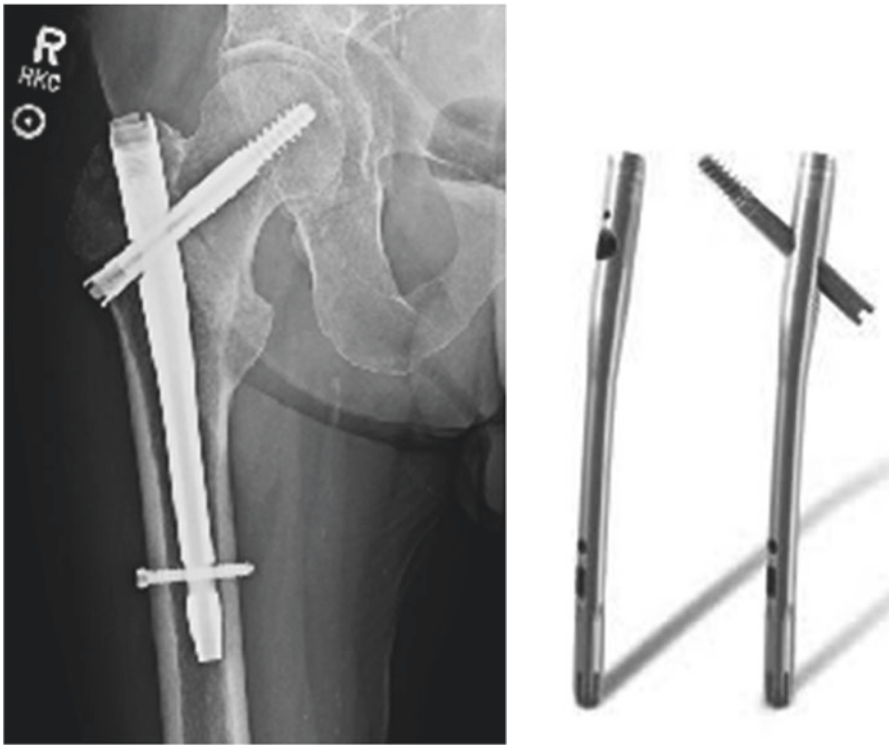

Fig. 9.9 Postoperative film after fixation of an intertrochanteric hip fracture with a cephalomedullary nail. To the right is what the implant looks like. (Image to right courtesy Zimmer Biomet)

9.1.3.3 Subtrochanteric Fracture

A special type of *subtrochanteric fracture* should be mentioned. Although most are similar to intertrochanteric hip fractures and treated successfully with a cephalomedullary nail, a small percentage of subtrochanteric fractures are associated with chronic bisphosphate usage. These patients may have a thickened medial cortex with slight beaking; more importantly, this subtype of a subtrochanteric fracture has a much higher incidence of delayed union and nonunion. Stopping the bisphosphate and checking the other hip for signs of impending fracture are important. Finally, for patients with hip pain unexplained with plain radiographs, alternate imaging including bone scan, CT, or MRI should be considered to rule out an occult fracture. MRI is the most sensitive and specific but may not be available, or the patient may not be able to use due to, for example, having a pacemaker or being claustrophobic [15].

Treatment options for patients unable to tolerate bisphosphonates or those with a subtrochanteric fracture are available in the section on osteoporosis.

9.1.4 Femoral Shaft Fractures

Unlike proximal femur fractures, e.g., femoral neck and intertrochanteric hip fractures, femoral shaft fractures (Fig. 9.10) are normally the result of a high-energy injury such as a fall from a height or a high-speed motor vehicle accident. After initial stabilization following ATLS protocols typical of any general trauma evaluation and treatment, a careful search for additional injuries should be made. This includes pelvic and acetabular fractures and especially other fractures of the femur; the most commonly missed ipsilateral fracture is a femoral neck fracture.

Diagnosis is straightforward with plain radiographs. If doubt exists about injuries to the proximal femur, pelvis, or acetabulum, CT scans will be helpful. Since many trauma patients end up getting a CT of the head, cervical spine, chest, or abdomen, it is logistically easier if the AP can evaluate the patient and plain films early so additional trips to the CT scanner are less frequent. A CT scan to rule out an ipsilateral femoral neck fracture is standard in many institutions.

For severely comminuted or segmental fractures, contralateral femur films can be helpful to determine the length to which the fractured femur needs to be restored. If the fracture is a result of a low-energy injury, then the bone should be carefully examined for other pathologies such as a tumor, osteoporosis, or osteomalacia.

Timing of surgery is generally sooner rather than later. Depending on the patient's pre-injury health, associated injuries, and the surgical team's experience, early fixation leads to earlier mobilization resulting in decreased morbidity and mortality. The standard of care is intramedullary nailing which can be done antegrade with the entry point through the greater trochanter or piriformis fossa. Some patients are

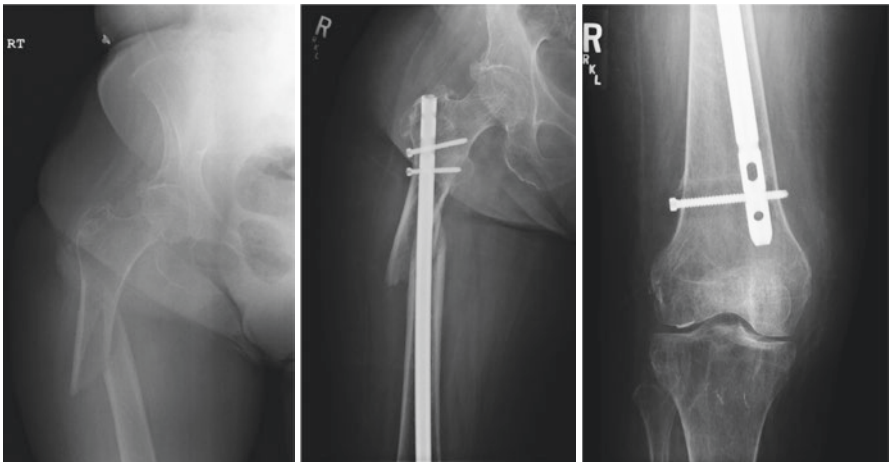

Fig. 9.10 Proximal femoral shaft fracture which was fixed in varus due to the hip abductors pull on the proximal fragment. The fracture went on to heal with no residual disability from varus positioning

better treated with a retrograde nail through the intercondylar notch. Depending on the fracture pattern, the nail may need to be locked with proximal or distal screws (or both) to prevent shortening or rotation. Operating room equipment includes fracture table, C-arm, and a variety of nails (lengths and sizes) especially for unusually small or large patients. There are two additional pieces of equipment that can aid in reducing the fracture to allow passage of the initial guide wire, reamers, and the nail. A femoral wrench looks like a giant F and is used to torque the fragments into alignment.

The second piece is a simple crutch which is used to elevate whichever fragment is posterior, usually the distal, and is especially helpful when short-handed in the operating room. Because significant traction is often necessary, the AP should ensure proper padding and placement of the perineal post.

Early postoperative complications include deep venous thrombosis, compartment syndrome, blood loss, and injuries not apparent on initial and secondary surveys. The primary late complication is nonunion which can be treated with ultrasound, electrical fields, bone grafting, or dynamization of the intramedullary rod. Not to be neglected is the associated muscle damage which may require extensive physical therapy. Ligamentous injuries of the knee may be missed until the fracture is stabilized [16–18].

9.1.5 Supracondylar Femur Fractures

Supracondylar femur fractures are another fracture with a bimodal distribution: the high-energy trauma to young adult males and the low-energy falls in elderly females. Because of the proximity of the popliteal vessels and sciatic nerve, care should be taken with a detailed neurovascular exam to make sure these injuries are not missed. Associated patella and tibial plateau fractures are not uncommon.

The diagnosis is straightforward and is almost always visible on plain films. Caution should be taken to image the entire femur to rule out additional injury such as an ipsilateral femoral neck or acetabular fracture. Better appreciation for the extent and nature of the fracture can be obtained with plain films taken while traction is applied. In all but the most straightforward of cases, a CT scan is invaluable for understanding the fracture and the operative approach and implants needed. Imaging of the contralateral limb will allow for better restoration on length and alignment in the more comminuted fractures. Although ligamentous and meniscal injuries are not unusual, MRI is not usually necessary in the acute treatment phase. Ligamentous evaluation is best done after fixing the fracture. If there is a question of vascular compromise, an early arteriogram is appropriate.

Despite the multiple classification systems, it is best to describe the fracture as supracondylar, supracondylar with intracondylar extension, or supracondylar with a coronal fracture plane through the posterior condyle (eponymously a Hoffa fracture) along with the amount of associated comminution.

Treatment for almost all of these injuries is some type of internal fixation. This can vary from lateral or medial side plates or both, intramedullary fixation, or a joint

spanning external fixator. The joint spanning external fixator is used in severe open injuries and should be viewed as temporary not definitive fixation. Osteoporotic bone may require graft of polymethylmethacrylate to ensure stability of fixation. Detailed preoperative planning is necessary to restore not only anatomic length and alignment but also rotation.

Postoperative rehabilitation includes range of motion and strengthening. How aggressive to pursue these goals as well as weight-bearing status depends on other injuries, bone quality, and stability of fixation. In addition to deep venous thrombosis, major complications include infection, nonunion, malunion (especially rotational malunion), and loss of motion [19–21].

9.2 Hip Dislocations

Hip dislocations are the result of a high-energy injury with the impaction force directed longitudinally along the shaft of the femur. The direction of a dislocation is dependent on the position of the hip; the most common is a posterior dislocation with a femur starting in the flexed and neutral or adducted position (Fig. 9.11). There may or may not be associated acetabular and pelvic fractures.

Not only are hip dislocations a relative orthopedic emergency, but there is a high association with other injuries such as patella fractures, femoral neck or head

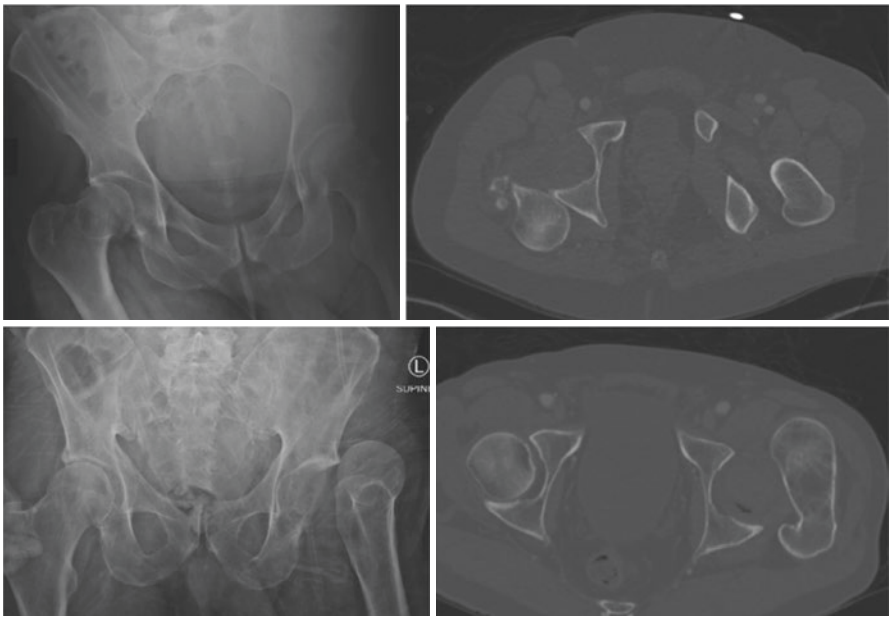

Fig. 9.11 Posterior hip dislocation plain film and CT scan in upper radiographs; anterior hip dislocation plain film and CT scan in lower. (https://link.springer.com/chapter/10.1007/978-3-030-18838-2_9)

fractures, as well as thoracoabdominal and head trauma. Early reduction of the hip is critical in reducing the incidence of subsequent avascular necrosis and attendant arthritis. It can be done closed under IV sedation, but general anesthesia may be required. Rarely there is interposed soft tissue that will necessitate an open reduction. Postreduction, a careful examination of an AP pelvis to ensure concentric, symmetric reduction has been performed. A CT scan to rule out small chips of bone or previously undetected fractures of the proximal femur is appropriate.

9.3 Hip and Thigh: Non-traumatic

9.3.1 Hip Arthritis

Hip arthritis can present at a variety of ages and from a variety of causes including avascular necrosis, posttrauma, late effects of Legg-Calvé-Perthes, developmental hip dysplasia, slipped femoral capital epiphysis, or idiopathic degenerative disease (Fig. 9.12). The stereotypical patient with hip arthritis is 50–70 years old with a gradual onset of inguinal pain which worsens with activity. Physical exam shows a painful loss of rotation especially internal which may only be apparent with the hip flexed at 90°. In late stages, there may be atrophy of the gluteal musculature. Differential diagnoses include an inguinal hernia, lumbar radicular pain, and greater trochanteric bursitis.

Imaging is normally limited to plain films and should include at a minimum an AP of the pelvis, as well as an AP and lateral of the affected hip. Unlike knee arthritis, hip arthritis is not always as obvious on routine films, so specialized views such as the false-profile view are sometimes necessary.

Treatment is symptomatic. For some patients, activity modification and weight loss will relieve the pain for a while. Physical therapy is not nearly as helpful for hip osteoarthritis as it is for knee osteoarthritis; nevertheless, it not only may be helpful to strengthen and condition the patient if surgery proves to be necessary but also may give the clinician an idea of compliance. Keep in mind however that many insurance plans limit the number of physical therapy visits per year, either per diagnosis or per patient. In addition, copays for physical therapy can run as high as $80–$100. Most patients have already tried over-the-counter NSAIDs by the time they arrive in the orthopedist's office. Although NSAIDs do alleviate pain, they do not appear to have any effect on the rate of cartilage degeneration. Ultrasound-guided, intra-articular steroid injection can be diagnostic if a diagnosis is uncertain but provides only temporary relief. Each subsequent injection appears to be less long-lasting. Most surgeons will limit the injections to two to three before recommending more invasive measures. The clinician should keep in mind that an intra-articular steroid injection within 90 days of joint arthroplasty may increase the chance of infection.

The pros and cons of various types of hip arthroplasty as well as surgical approaches have resulted in a number of books and will only be discussed briefly. Traditional total hip arthroplasty is a metal stem with a metal ball seated in a

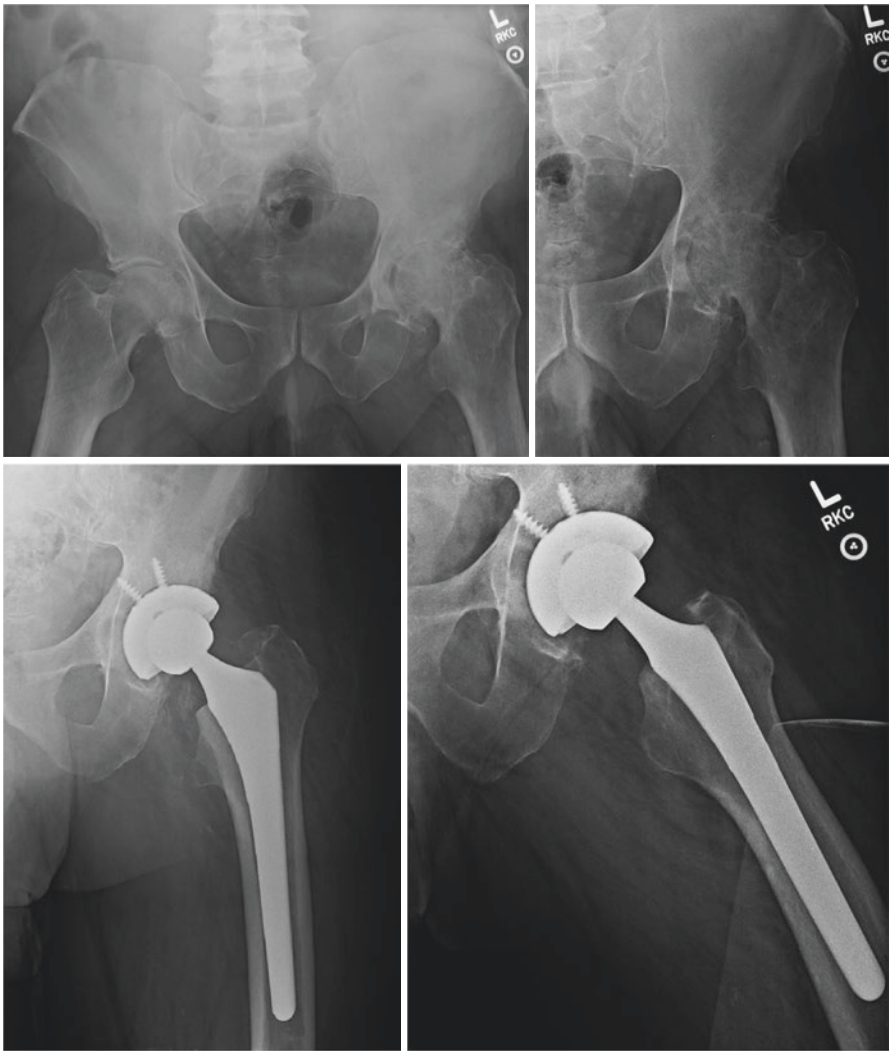

Fig. 9.12 The figure on the upper left is an AP pelvis with obvious arthritis of the left hip and a relatively short femoral neck of the right hip. The upper right shows an AP of the left hip only. The bottom two figures show an AP and lateral of the same hip after undergoing a noncemented total hip arthroplasty

polyethylene cup socket which in turn is embedded in a metal cup. The early prostheses were stainless steel but are now either a cobalt-chrome alloy or titanium. There are a variety of surgical approaches to replacing the hip, posterior, anterior, and lateral, each with advantages and disadvantages. Each also has a specific position to avoid in order to decrease the odds of postoperative dislocation. Ultimately, the approach is surgeon-dependent which in turn will require the AP to be aware of the appropriate equipment needed. Appropriate stable positioning and proper

padding not only make the surgeon's job easier but also decrease the odds of complications such as pressure sores and peripheral nerve injuries. For example, the lateral malleolus and the common peroneal nerve as it courses around the fibular neck are at risk for a pressure sore and nerve compression, respectively, if the patient is in the lateral decubitus position.

Implant choices are numerous, but ultimately the stem either is some type of press fit with bony ingrowth for long-term stability or is cemented in place. The head can be a variety of sizes and is either metallic or ceramic. The acetabular cup is normally a metal shell with either a polyethylene liner or a ceramic liner. The metal head in the polyethylene liner is the most common, but there is a problem with long-term (10–20 years) wear of the polyethylene. Ceramic components (ceramic head in a polyethylene liner or ceramic head in ceramic liner) have much less wear but are more brittle, and some squeaking with every step has been reported [22].

Immediate preoperative medication including acetaminophen, pregabalin, a long-acting narcotic, and NSAID all of which markedly ease postoperative pain making earlier rehab and discharge possible. This approach of immediate preoperative medication is used in a variety of major surgeries and is referred to as enhanced surgical recovery [23]. Intraoperatively, tranexamic acid or aminocaproic acid reduces postoperative blood loss. Postoperatively, early mobilization, ideally on the day of surgery, helps to decrease the incidence of complications. Early removal of the Foley catheter, mechanical and chemical prophylaxis for prevention of deep venous thrombosis, and use of incentive spirometry are all important to monitor that they are being done in a timely and appropriate fashion. Discharge planning should be done prior to admission with most patients going home with either outpatient physical therapy or home health. Complications to be watched for and aggressively prevented include pneumonia, infection, deep vein thrombosis, and urinary tract infections. For pneumonia, early ambulation, frequent incentive spirometry, and respiratory therapy when indicated are appropriate. Infection is best prevented by dental hygiene preoperatively, perioperative antibiotics, and careful surgical technique. The best method of DVT prophylaxis continues to be controversial, and the AP should not forget that the primary goal of DVT prophylaxis is to prevent pulmonary emboli. Current thinking is a combination of mechanical and chemical prophylaxis. The former consists of sequential compression devices, foot pumps, or antithrombotic hose. The latter is a long list and includes aspirin, warfarin (Coumadin™), heparin, and a wide variety of injectable and oral medications [24].

Activity restriction depends on the surgical approach and implant type. The most commonly asked question is regarding driving. The standard answer to driving is none for 6 weeks after left hip arthroplasty and 12 weeks after the right. Obviously, some patients will be ready sooner, others later. One suggestion is to have the patient drive in an empty parking lot and do a "panic stop" to assess the physical ability to do so.

Long-term periodic monitoring of hip arthroplasty is important to watch for early signs of prosthetic loosening and polyethylene wear, which is easier to treat if

caught early. Again, this varies according to the patient and surgeon preference, but a typical schedule would be at 6 weeks, 3 months, 6 months, 1 year, and 2 years postoperatively. The new radiographs should be compared to the original postop radiographs. After 2 years if everything appears stable, the frequency can drop to once every 2–5 years.

9.3.2 Trochanteric Bursitis

One of the many causes of hip pain is bursitis of the greater trochanter of the hip. This may be a little misleading as there are actually several bursal sacs around the hip. The patient presents with pain over the lateral hip and frequently cannot sleep on the affected side. Physical exam shows tenderness over the greater trochanter with a relatively normal range of motion without pain. Frequently, there will be weakness of the hip flexors or abductors.

Radiographs are negative although occasionally there will be some soft tissue calcification. Careful examination should be made for signs of femoral acetabular impingement, arthritis, and impending stress fractures. An MRI may reveal gluteus medius avulsion (partial or complete) from the greater trochanter.

Treatment consists of NSAIDs, physical therapy to correct hip muscle weakness or imbalances, and occasionally a corticosteroid injection into the bursa. Many patients will require a spinal needle (3 1/2 to 4 1/2 inches) to reach through the tissues to the greater trochanteric bursa. Rarely surgery will be needed which consists of an open or arthroscopic bursectomy [25].

9.3.3 Osteonecrosis

Previously known as avascular necrosis, the terminology has changed to reflect that the primary pathology is not necessarily vascular, but the death of the bone in the femoral head.

It can occur at any age but most commonly affects males from 40 to 60 years of age. The patient will present with hip pain in the inguinal area without any precipitating trauma or change in activity level indicating a possible stress fracture. Most cases of osteonecrosis are idiopathic, but further questions may reveal a clue as to an etiology. These questions include a history of chronic corticosteroid use, alcohol intake, or SCUBA diving (especially a history of the “bends”). There are also systemic diseases such as sickle cell, autoimmune diseases, and hyperlipidemias which can contribute to the development of osteonecrosis. Physical examination in the early stages shows loss of internal rotation. Late stages will show loss of motion in all planes (rotation, abduction/adduction, and flexion/extension).

In the early stages of the disease, plain radiographs may be normal, and the only clue is painful internal rotation of the hip when flexed to 90°. As the disease progresses, changes that may be seen are areas of relative radiolucency or density in the

subchondral area of the femoral head, the "crescent" sign indicating early collapse of the subchondral bone and then complete collapse with loss of joint space and destruction of the articular surfaces (Fig. 9.13). In patients without any collapse on plain films, an MRI can help delineate the extent of the disease, and if the plain films are normal, the contralateral hip should be imaged by MRI as the incidence of bilaterality is high. Bone scans have been used in the past but now are used only for patients who cannot undergo MRI or if there are multiple areas of concern.

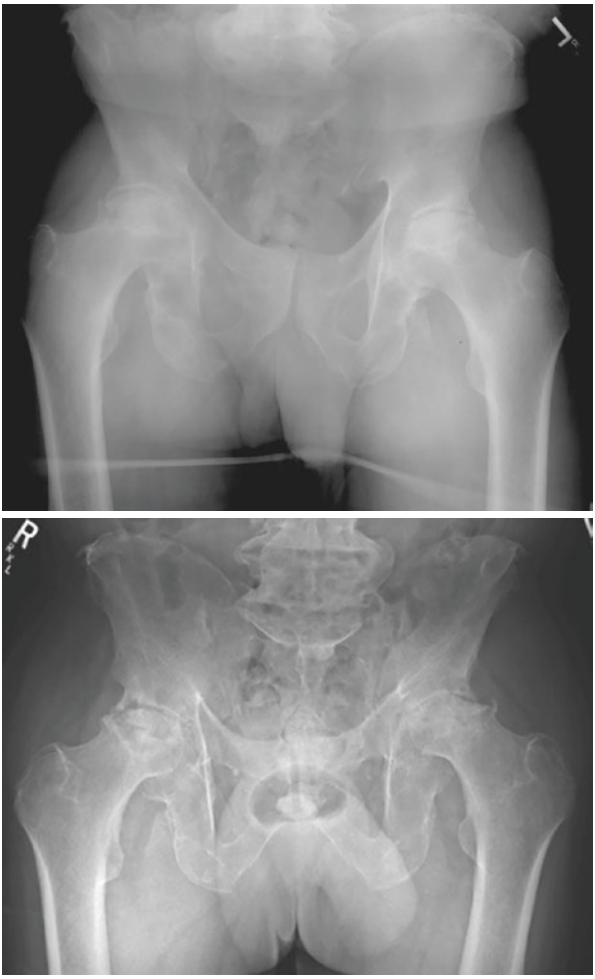

Fig. 9.13 The rapid progression of hips with osteonecrosis. In the April picture, there is some minimal collapse of the femoral head. Note that in just 4 months, the left hip collapsed resulting in total hip arthroplasty seen in December, but the right hip has also deteriorated. Because of medical problems, surgery was delayed until the following summer resulting in the near complete destruction of the right hip. The metallic object seen overlying the hip is the patient's zipper

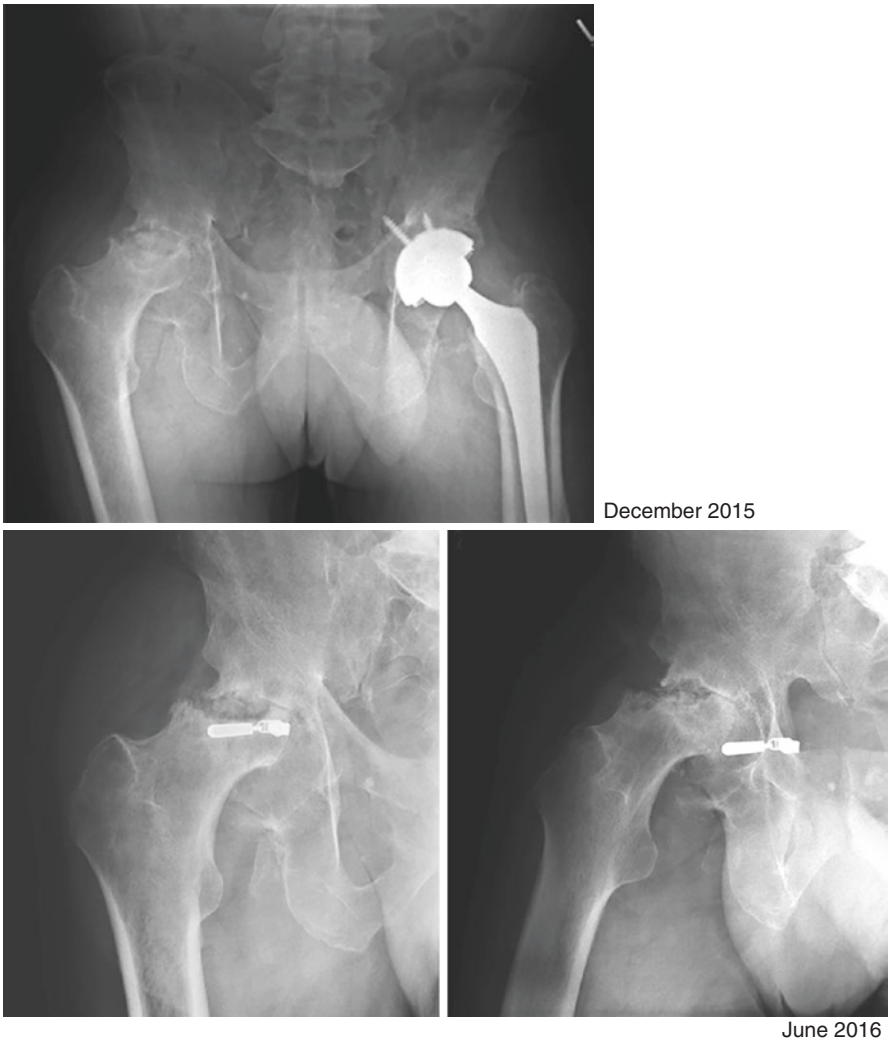

Fig. 9.13 (continued)

Osteonecrosis is most common in the hip but can also occur in the proximal humerus or the condyles of the distal femur.

There is no good explanation for the etiology of osteonecrosis. Patients without risk factors develop it, and patients with multiple risk factors do not develop it.

The two most common classification schemes are those of Ficat and Arlet, which is based on plain films, and Steinberg, which adds MRI to help determine the stage. Staging is important as the treatment varies depending on the stage. In the early pre-collapse stage, the most common treatment is core decompression (forage) with or without bone grafting. A forage procedure may arrest or reverse the disease. Under general anesthesia and fluoroscopic control, a guide pin is placed through the lateral

cortex, through the femoral neck, and into the avascular area. The increase in resistance to the guide pin and the subsequent cannulated drill bit is impressive. The drilled hole can be left empty or filled with an autogenous graft such as the iliac crest or a vascularized fibula graft or allograft. The results vary depending on the population studied with success varying from 40% to 90%. The primary complication after core decompression, besides failure to relieve pain, is fracture through the weakened bone, especially if the hole in the lateral cortex is below the level of the lesser trochanter [26].

After collapse, the options are much more invasive and limited. For small lesions, a proximal femoral osteotomy can be performed moving the lesion to a non-weight-bearing portion of the hip joint. This works best in patients under 50. For larger areas of collapse, the only viable option is a total hip arthroplasty, but the success rate and longevity for those patients with osteonecrosis are much less than that of a hip arthroplasty for osteoarthritis; whether this is because the patients are typically younger or because of some unknown underlying pathology is unknown.

9.3.4 Femoral Acetabular Impingement

FAI is a major cause of hip pain that has been much more recognized in the last decade and comes in two forms: cam and pincer (or both). FAI is an abnormality of the acetabular rim or femoral head and neck, such that during normal range of motion there is an impingement, i.e., abnormal contact between the femur and pelvis that can lead to labral tears and arthritis [27, 28].

9.3.4.1 Cam Impingement

Cam impingement is more common in males and is primarily femoral neck-based such that there is impingement at the edge of the femoral head or neck when the hip is flexed or placed in the flexed and internally rotated position. On radiographs, there will often be obvious bony prominence at the head and neck junction (seen laterally on the AP view, anteriorly on the lateral view) or just prominence of the neck (Fig. 9.14).

9.3.4.2 Pincer FAI

Pincer FAI is just the opposite. It is more common in women, and there is too much coverage of the femoral head by the acetabulum (Fig. 9.15). This can be congenital, or the result of a calcified labrum, or posttraumatic. Radiographically, the signs can be more subtle and may be limited to increased lateral center angle (Fig. 9.16) or a crossover sign. CT and or MRI scan may be necessary for definitive diagnosis and extent.

Treatment for both is dependent on the type of pathology, degree of deformity, age and activity level of the patient as well as the surgeon's experience and preference. Treatment options range from hip arthroscopy with shaving of the bone from the femoral neck, labral debridement, and labral repair to acetabular osteotomy.

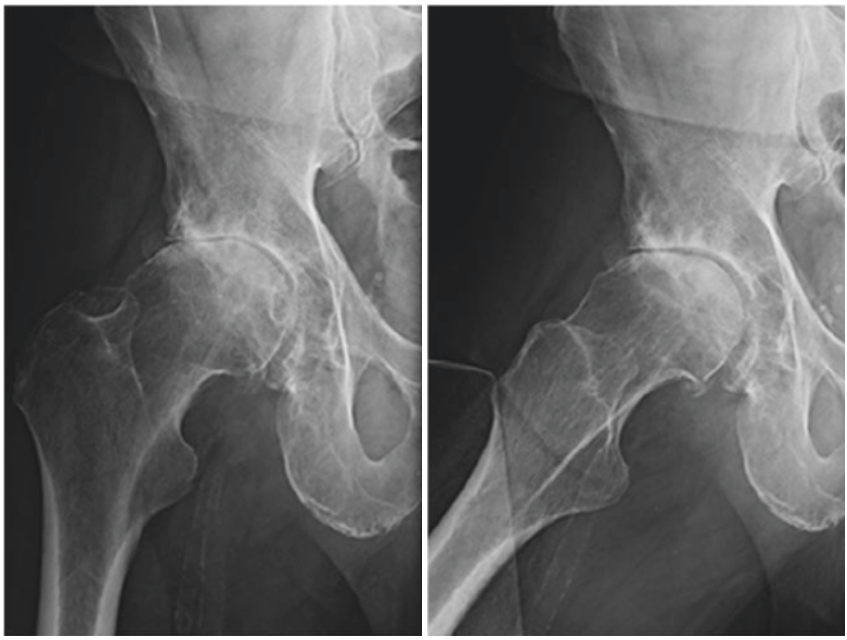

Fig. 9.14 End-stage arthritis in a patient with cam impingement of the hip. Note the lack of concavity in the femoral neck just below the femoral head which causes the head to lever out of the acetabulum on flexion or abduction. Compare to normal hips seen in Fig. 9.1

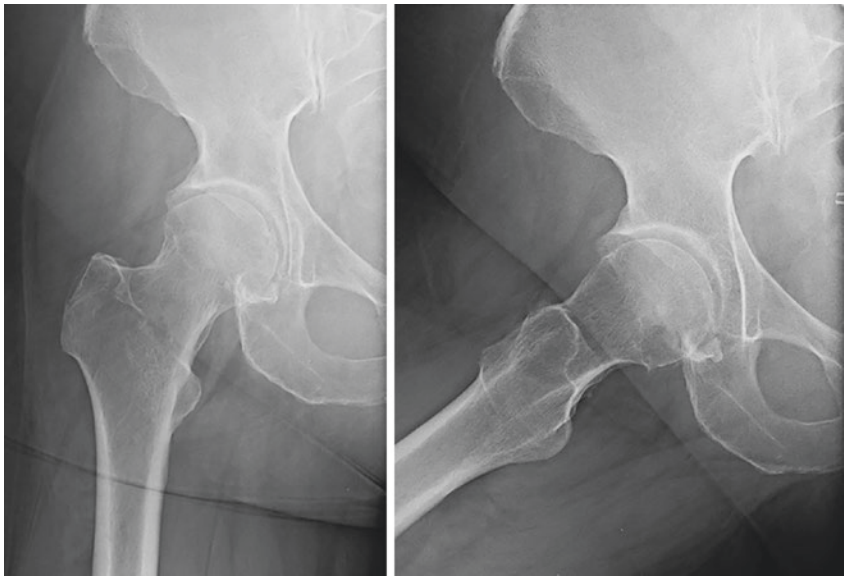

Fig. 9.15 Patient with pincer-type impingement before secondary arthritis has set in. The lateral center-edge angle is 45° (normal is 20–40°)

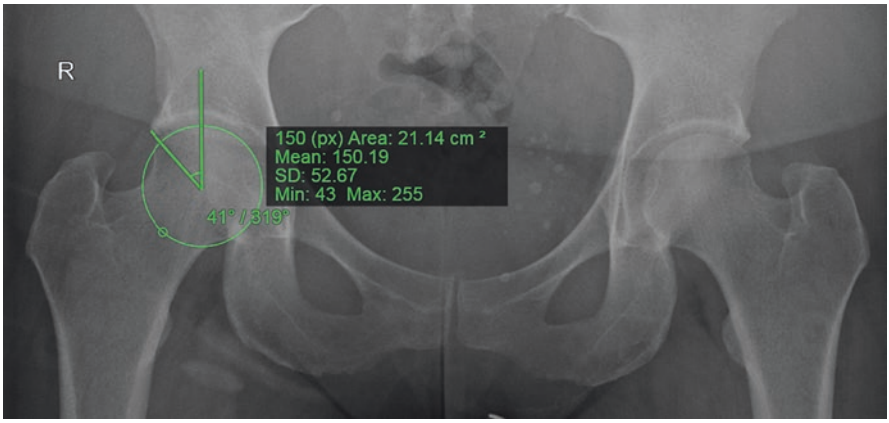

Fig. 9.16 The lateral center-edge angle is the product of a line drawn from the center of the femoral head to the lateral edge of the acetabulum and a vertical line from the center of the femoral head

9.4 Pediatric

9.4.1 Slipped Capital Femoral Epiphysis

Patients with a slipped capital femoral epiphysis (SCFE) are stereotypically 10–16-year-old obese African males, but most all patients with a SCFE are in the midst of a growth spurt. The patient normally presents with hip pain and a limp with no history of trauma, but a significant percentage will have nonspecific knee pain; so, it is especially important to check ROM of the hip in this age group to rule out SCFE as a cause of knee pain. Past medical history may show hypothyroidism, diabetes, or Down's syndrome.

Physical exam may show a limp, loss of motion (especially rotation), limb length inequality, and a positive Trendelenburg sign.

The only imaging normally required is an AP and frog leg view of the pelvis (Fig. 9.17), although additional views may be helpful in subtle cases. MRI and CT are not usually necessary.

Underlying etiology is unclear but appears to be a combination of both mechanical (e.g., acetabular retroversion and decreased neck-shaft angle or varus) and underlying physiologic abnormalities such as hypothyroidism.

SCFE can be classified based on the duration of symptoms, the amount of pain, and the amount of slip.

Treatment is surgically urgent (i.e., 1–2 days) and is generally in situ pinning with a single centralized screw without reduction. Other options depending on the patient, surgeon, and stage include closed or open reduction and pinning, as well as a variety of later reconstruction approaches to correct mechanical problems that

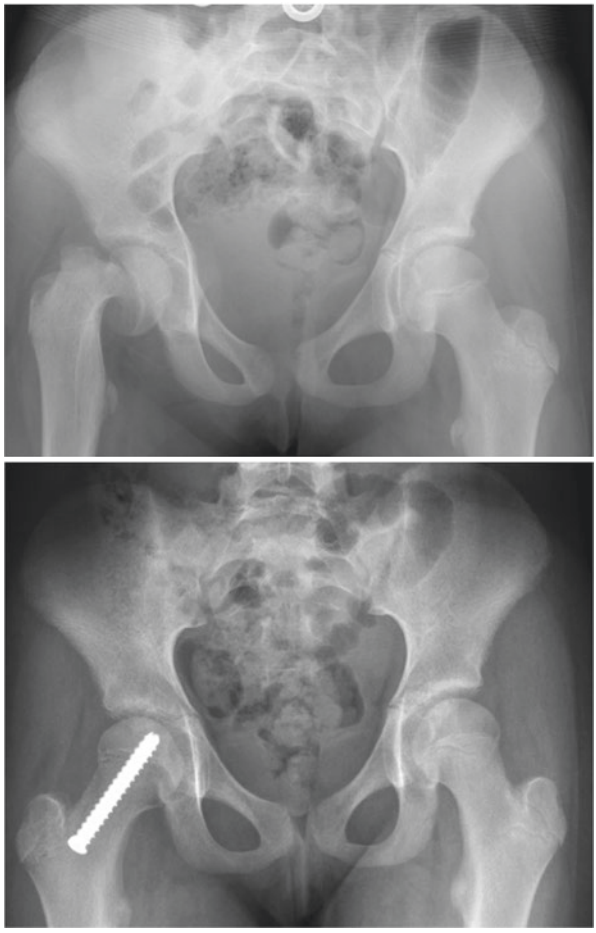

Fig. 9.17 Grade 3 slipped capital femoral epiphysis in a 13-year old. Post-reduction film with a single-centered screw is below. (Courtesy Medical College of Georgia, Department of Orthopedics)

may lead to hip arthritis. The two complications of treatment include osteonecrosis and over-penetration of the screw(s). Because there is a 10–20% chance of a contralateral slip, close follow-up to ensure this does not happen is appropriate. [29, 30]

9.4.2 Legg-Calvé-Perthes Disease (LCPD)

Legg-Calvé-Perthes disease (LCPD) is an avascular necrosis of the femoral head thought to be the result of a subtle clotting disorder, although the exact etiology is unclear. The stereotypical patient is a small for age male between the ages of 4 and 8 years old. The patient presents with some combination of a gradual onset of hip pain, a limp, or a loss of motion in the hip. When seen in adults, the femoral head is too large for the acetabulum known as coxa magna (Fig. 9.18).

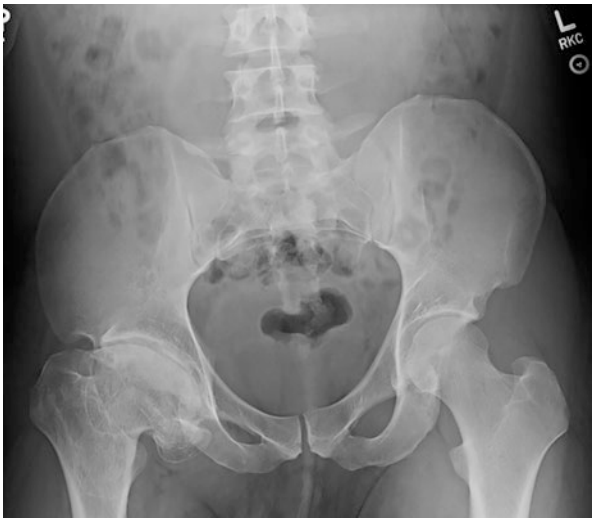

Fig. 9.18 The end result of LCP disease in a 33-year-sold male with the collapsed, coxa magna (enlarged head) that typifies LCP

Physical examination varies depending on the severity of the disease. Specific findings include loss of motion, specifically abduction and internal rotation. Severe cases may have a positive Trendelenburg sign and limb length inequality.

Imaging includes plain films and MRI. There are four or five stages of severity in the most commonly used classification systems (Waldenstrom and Stolberg respectively). MRI can show the vascularization status of the femoral head, but it is unclear how helpful this is.

Two possible causes of LCP have been proposed, neither of which are without controversy. A familial LCP in Asian families with a genetic defect in forming type II collagen is one. The other is a clotting disorder, i.e., the blood clots more than it should.

Treatment depends on age and stage (<6, 6–8, >8). For those patients less than 6 years of age, nonsurgical treatment, i.e., observation, is the most common. Figuring out which patients in this group will not do well is an enigma. Patients aged 6–8 need bracing or surgery (varus femoral osteotomy), but which produces better long-term outcomes is unknown. After age 8, either a femoral varus osteotomy or pelvic osteotomy is necessary, but again which procedure will produce better long-term results is unclear.

Importantly, when seeing a child with LCP, other disease processes must be ruled out. These include sickle cell, chronic steroid use, transient synovitis, and infection [31].

9.4.3 Developmental Dysplasia

Developmental dysplasia of the hip is used to be called congenital hip dislocation, but the name has changed in recognition that it is not always present at birth and

there is a spectrum of disease that includes dysplasia and subluxation rather than complete dislocation of the hip. Although the stereotypical patient with DDH is a firstborn breech female, all infants up to 6–12 months should be examined to ensure DDH is not present. Radiographs are not helpful as the femoral head does not ossify in the first 6 months and ultrasound screening of all infants is neither logistically possible nor cost-effective. Consequently, initial diagnosis is based on a clinical exam with questionable cases being further evaluated by ultrasound.

There are a variety of findings that may help diagnose DDH, such as asymmetric gluteal creases and unequal leg lengths. If grossly unequal, radiographs to identify proximal focal femoral deficiency may be necessary. Normal infants have full symmetric hip abduction. The two classic tests in newborns are the Barlow and Ortolani tests (Figs. 9.19 and 9.20). Both require a cooperative infant, so having warm hands and having the baby suck a bottle may be helpful. It is important to remember DDH is not painful. Both of these tests are "felt" rather than heard. Both tests can be subtle as the hip may only sublux rather than frankly dislocate.

Treatment is a Pavlik harness (Fig. 9.21). Double or triple diapering does not work. The purpose of a Pavlik harness is to hold the hips flexed and abducted, thus pointing the femoral neck and head toward the center of the acetabulum (Fig. 9.22). The harness is to be worn all the time, so repeated instruction and clinic visits to ensure appropriate fit may be necessary. Two cautions: If the straps over the shoulders are too tight, a brachial plexus palsy can develop, and if the hips are excessively flexed, avascular necrosis (bone death) of the femoral head can occur. Length of wear depends on age and severity at the time of diagnosis and when the hips are stable but typically until 6 months or until the femoral head ossifies in the appropriate position and is stable.

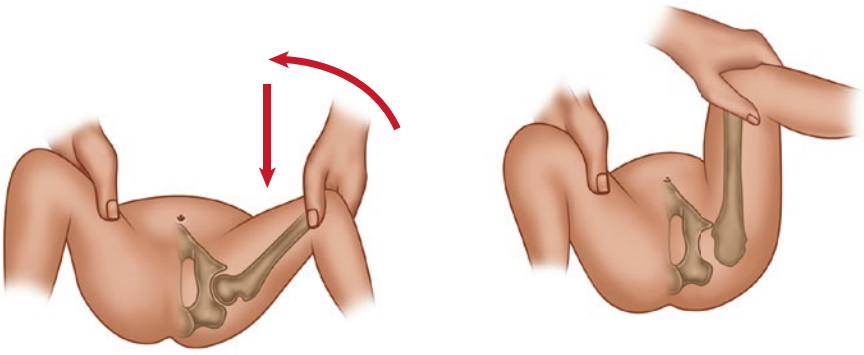

Fig. 9.19 With the Barlow, the hip is held flexed to 90° in slight adduction and pushed posteriorly, while the pelvis is held stable. The feel is one of the hip sliding or popping backward

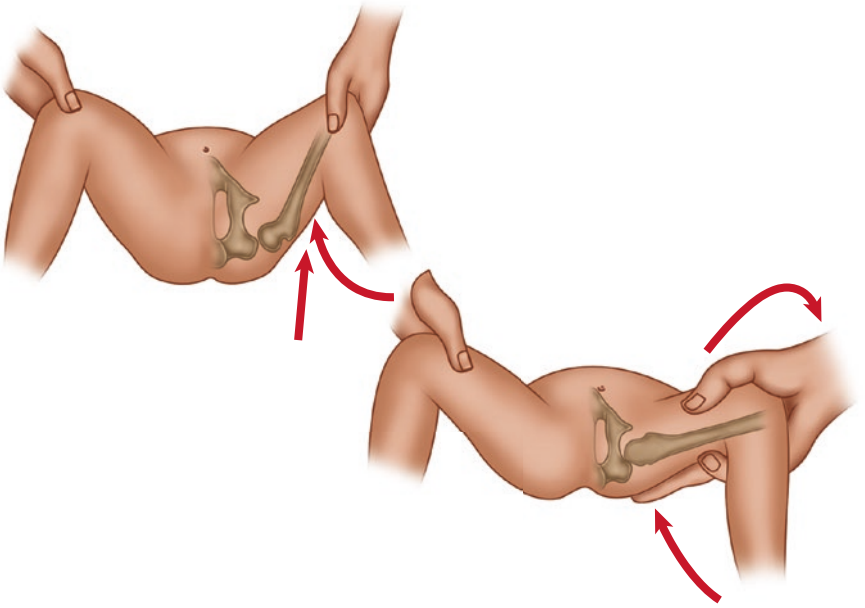

Fig. 9.20 The Ortolani test is where the hip is held flexed to 90°, abducted, and pushed anteriorly with a clunk or feel of the hip sliding back into place

Fig. 9.21 Infant in a Pavlik harness. The hips should be flexed and "fall" into abduction

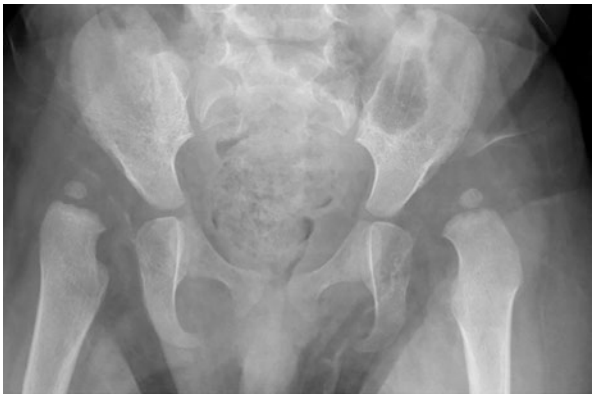

Fig. 9.22 Bilateral hip dislocation in an infant. Note that neither femoral head is pointed at the triradiate cartilage of the acetabulum. (Courtesy Medical College of Georgia, Department of Orthopedics)

Late diagnosis, as with most medical problems, makes treatment more difficult. It is beyond the scope of this book to discuss late treatment in detail. Briefly, depending on age of patient and severity of disease, closed or open reduction followed by a hip spica cast, osteotomy of the proximal femur to redirect the femoral head and neck into the true acetabulum, acetabular osteotomy, or some combination of the above are options. Left untreated, DDH results in arthritis of the hip with arthroplasty being necessary as early as the late 30s [32–34].

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The Spine

10

10.1 Spine: Traumatic

10.1.1 Cervical Spine

Evaluating the cervical spine in cases of trauma requires a high degree of suspicion, experience, careful repeated examination, and a low threshold for ordering imaging studies, other than plain films of the cervical spine. Besides the obvious complaints of neck pain or limb paresthesias, numbness, weakness, or paralysis after a traumatic incident, there are several other factors that should increase suspicion for a cervical spine injury. These include the type of injury (high-energy accidents, fall from height, motor vehicle accident) and any type of head trauma. Initial evaluation includes a neurologic examination of both upper and lower limbs. This is followed by cervical spine films including AP, lateral, and open mouth views, the latter looking specifically for an odontoid fracture of C2 (Fig. 10.1) and a Jefferson fracture of C1. In patients injured as the result of high-energy trauma, plain films of the cervical spine are frequently skipped, and a CT scan of the cervical spine (Fig. 10.2) is performed along with the CT of the chest, abdomen, or pelvis.

If the initial radiographs are negative, then the neck can be actively, not passively, put through a range of motion as long as the patient is not impaired by drugs, alcohol, or a significant head injury. If the range of motion is normal without pain or additional symptoms, the cervical spine may be considered clear. However, if motion is limited or painful, a CT or preferably an MRI may be necessary to rule out subtle fractures (Fig. 10.3) and ligamentous injuries. Obviously, if there is a mental status alteration due to drugs, alcohol, or head injury, the neck will need to remain immobilized. There are a wide variety of injuries including fractures with dislocations or just dislocations without fracture (Figs. 10.4 and 10.5).

Treatment options are varied depending on the type and extent of injury. The details are beyond the scope of this book, but some type of fusion (Figs. 10.6 and 10.7) after reduction with or without a halo is the most common.

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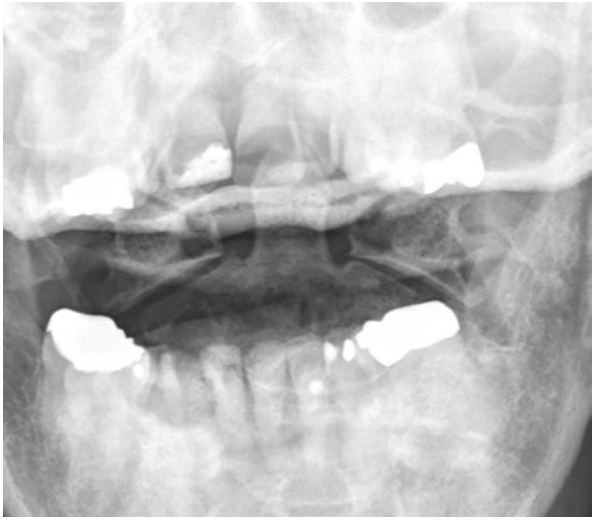

Fig. 10.1 Open mouth view of an odontoid fracture (C2). The CT scan is below in Fig. 10.2. (Courtesy Medical College of Georgia, Department of Orthopedics)

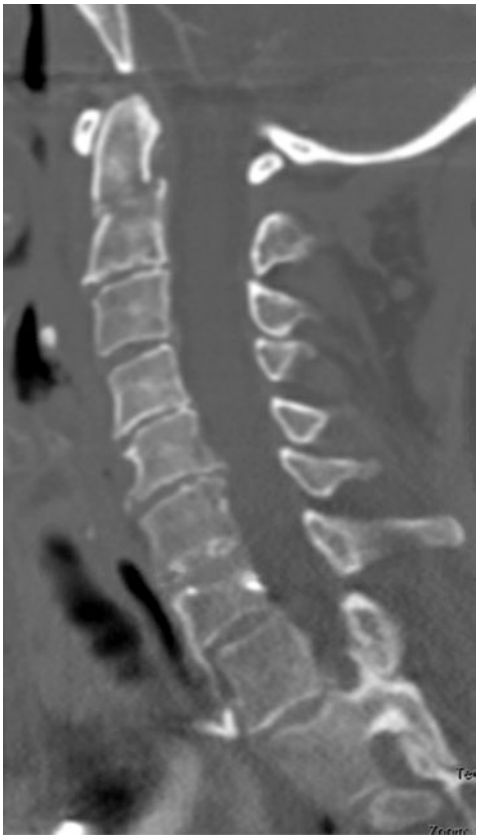

Fig. 10.2 CT scan of an odontoid fracture, i.e., the "upright" portion of C2. (Courtesy Medical College of Georgia, Department of Orthopedics)

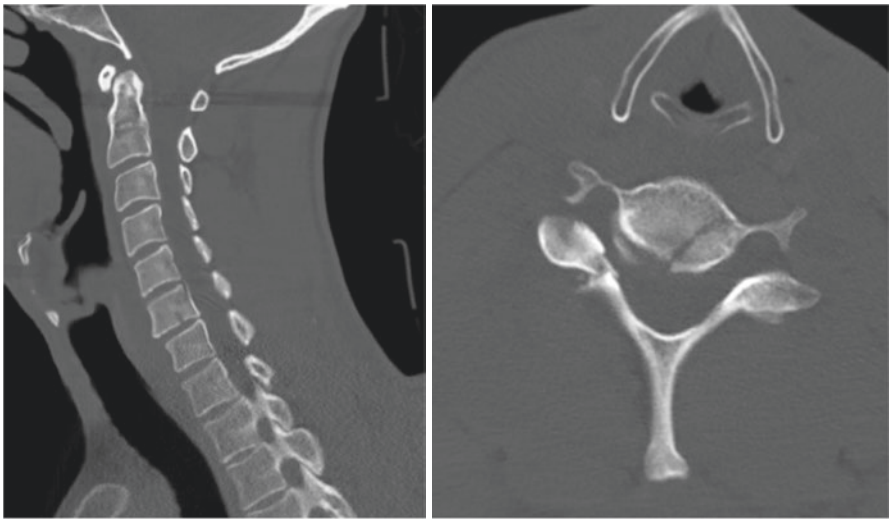

Fig. 10.3 CT scan and coronal reconstruction of a fracture of the body of a cervical vertebrae not seen on plain films. (Courtesy Medical College of Georgia, Department of Orthopedics)

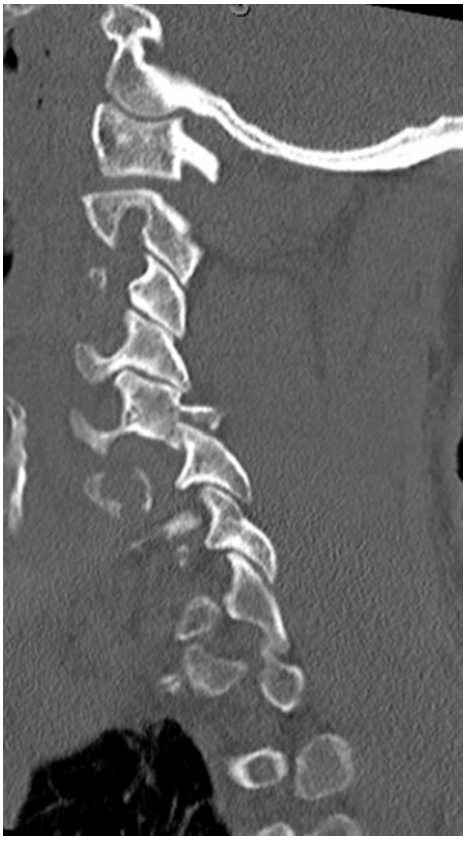

Fig. 10.4 CT scan of a unilateral "jumped" facet (unilateral dislocation) between C5 and C6. (Courtesy Medical College of Georgia, Department of Orthopedics)

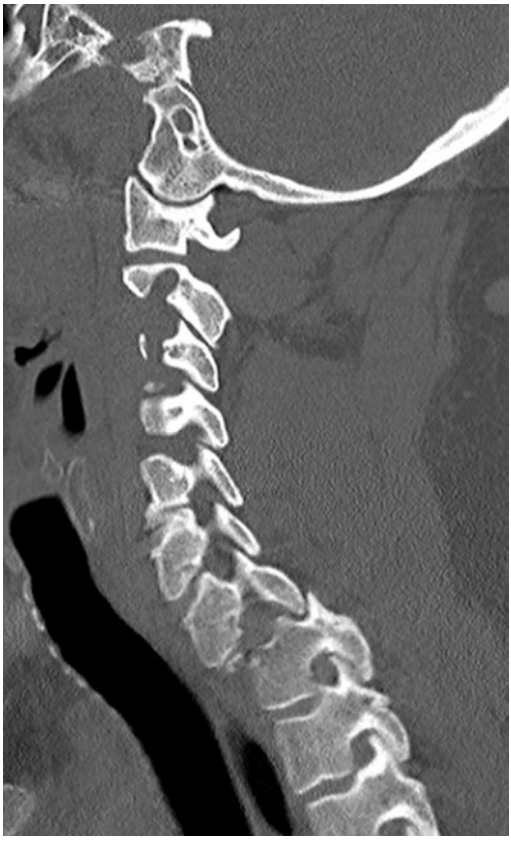

Fig. 10.5 *CT scan of* bilateral facet dislocation between C7 and T1. Note the abnormal alignment with the posterior aspect of the body of C7 nearly in line with the anterior aspect of T1. (Courtesy Medical College of Georgia, Department of Orthopedics)

Whiplash is a common injury especially following being hit from the rear in a motor vehicle accident. It is less common if the headrest height is adjusted such that the amount of neck extension is limited.

After evaluation to rule out bony and ligamentous injuries, treatment is primarily reassurance and time. It is thought that the pain from whiplash including associated headaches results from a stretch injury in the neck muscles and nerves [1].

10.1.2 Thoracolumbar Spine Fractures

Discussion of thoracolumbar spine fractures is difficult given the many different classification schemes and biomechanical concepts over the years; for example, should the spine be divided into two or three columns? Even now, there is not great agreement over a useful classification scheme for prognostic or therapeutic purposes; to complicate matters, identical spine fractures may have or may not have an associated spinal cord injury.

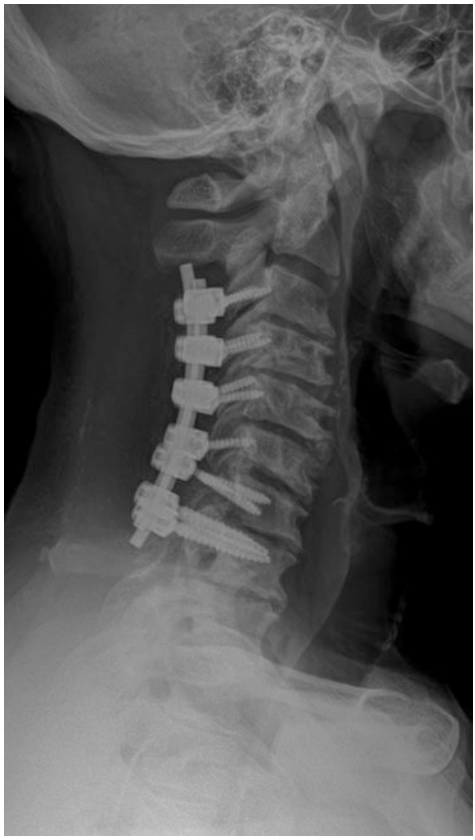

Fig. 10.6 Extensive posterior fusion with pedicle screws of the cervical spine. (Courtesy Medical College of Georgia, Department of Orthopedics)

Thoracolumbar fractures most commonly result from motor vehicle accidents or falls from a height, so after the initial trauma evaluation and stabilization, the history should include exact mechanism of injury, history of previous spine problems, and medical problems that may impact bone health such as ankylosing spondylitis or chronic corticosteroid usage. In addition to looking for other injuries, the neurologic exam should include sensation in all major dermatomes, motor strength and symmetry, reflexes at the patellar and Achilles tendons, clonus, and Babinski sign. For patients with a clear spinal cord injury, the bulbocavernosus reflex and anal wink should be documented as well. If there is a neurologic deficit, the most common grading scale is ASIA (American Spinal injury Association). It allows for complete and incomplete injuries at each level to be documented in addition to specific spinal cord injury syndromes such as central cord syndrome. Because partial spinal cord injuries are common, both the lowest level of motor and sensory function (complete and incomplete) should be mapped (Fig. 10.8).

Imaging starts with plain films. The clinician should not be distracted from looking for additional levels of injury once the initial fracture is found. Because a number

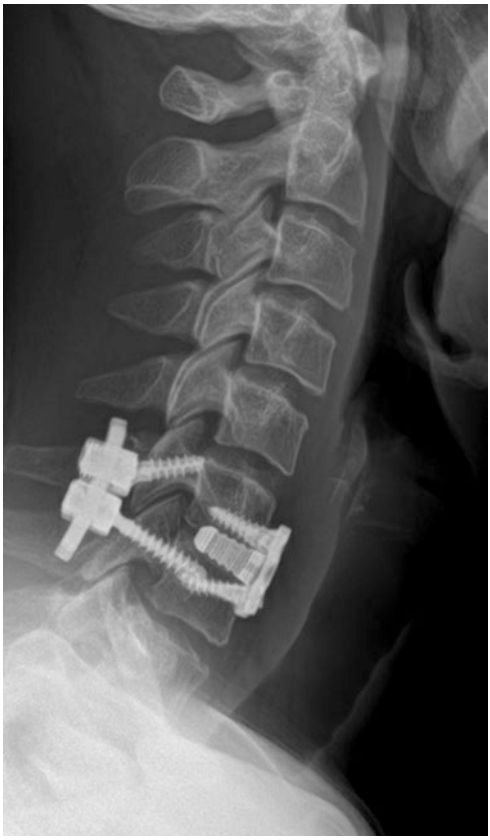

Fig. 10.7 Anterior and posterior instrumentation to fuse C6 to C7. (Courtesy Medical College of Georgia, Department of Orthopedics)

of these patients undergo high-speed CT scans to evaluate for intra-abdominal, intrathoracic, and cranial injuries, adding a CT scan of the affected area detected on plain films is prudent. CT scan evaluation of the fracture may have to wait until more pressing injuries have been addressed, but appropriate immobilization should continue until a definitive treatment plan has been devised and performed. Because of the time involved, MRIs are not usually ordered unless the supervising physician thinks it will change the treatment plan. If nonoperative (e.g., brace) treatment is chosen, repeat plain films are performed with the patient standing after the brace has been applied to look for any significant change that may alter the treatment.

10.1.3 Compression Fractures

Compression fractures do occur in the younger population (Fig. 10.9) but are much more common in the older white female population often as the result of minimal

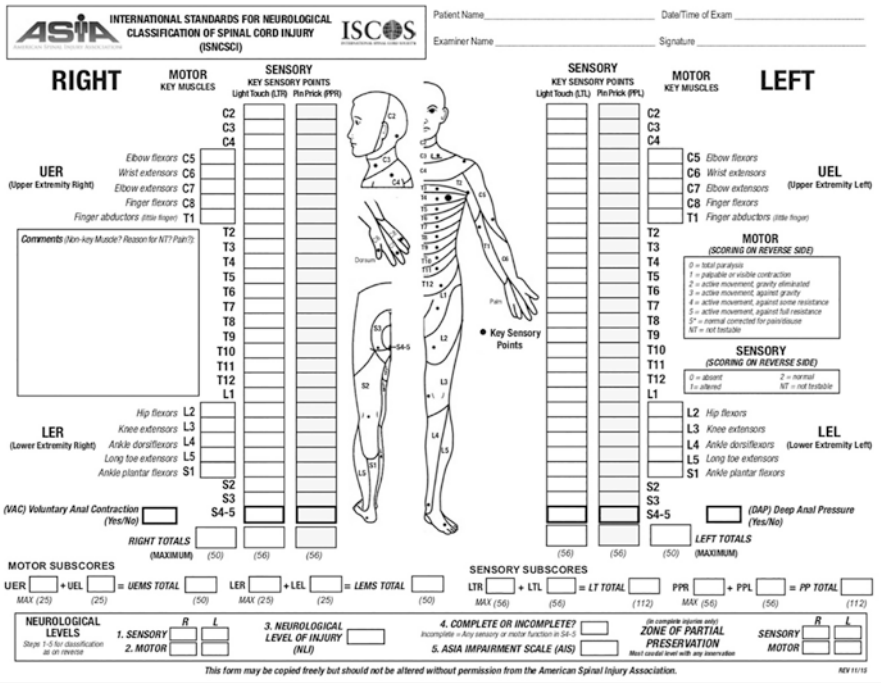

Fig. 10.8 Chart used to classify and document the level of spinal cord injury

trauma (Fig. 10.10) such as picking up something too heavy or even without trauma. The older patient often presents to the clinician (ER, PCP, or orthopedist) with a several week history of back pain after minor trauma. There are no complaints of lower limb weakness nor altered sensation and neurologic exam is normal. Plain films reveal an anterior wedge-shaped compression fracture of the vertebral body on the lateral view without retropulsion of the posterior wall of the vertebral body. The AP view shows no widening of the interpedicular distance. There may or may not be some increased soft tissue shadow (hematoma) around the fracture especially if acute. In the elderly, there is often evidence of previous fractures that have healed of which the patient knows nothing. CT and MRI are not normally needed unless there is some suspicion that it is something other than a simple compression fracture such as a fracture as a result of metastatic disease. An MRI will show increased signal intensity in the acute phase making it possible to distinguish an acute fracture from a more chronic one.

Treatment options include supportive care (e.g., walker, reassurance), bracing such as TLSO (thoracolumbar sacral orthosis) or LSO (lumbosacral orthosis) depending on the level of fracture, or balloon kyphoplasty. Periodic follow-up radiographs to ensure healing without worsening deformity are typically done at

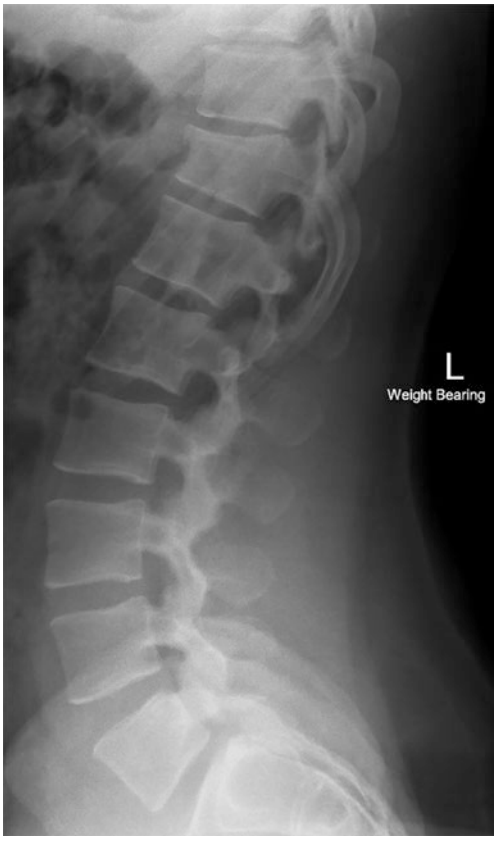

Fig. 10.9 Compression fracture of T11 in otherwise healthy 22 years old after a fall. (Courtesy Medical College of Georgia, Department of Orthopedics)

1–2 weeks, 6 weeks, and 12 weeks after injury. This can be changed depending on clinical circumstances. Vertebroplasty is the injection of polymethylmethacrylate (PMMA) through the pedicle into the vertebral body; however, this has fallen out of favor due to failure to show long-term efficacy. Balloon kyphoplasty however does show benefit in selected patients. Balloon kyphoplasty involves placing a balloon in the vertebral body through the pedicle followed by injection into the balloon of PMMA. This can be done at one or multiple levels. In addition, the older patient should be screened for osteoporosis and treated appropriately.

10.1.4 Burst Fractures

Burst fractures are the result primarily of an axial load with some degree of flexion. In addition to the anterior wedging seen in compression fractures, there is widening of the vertebral body on the AP view and disruption of the posterior vertebral

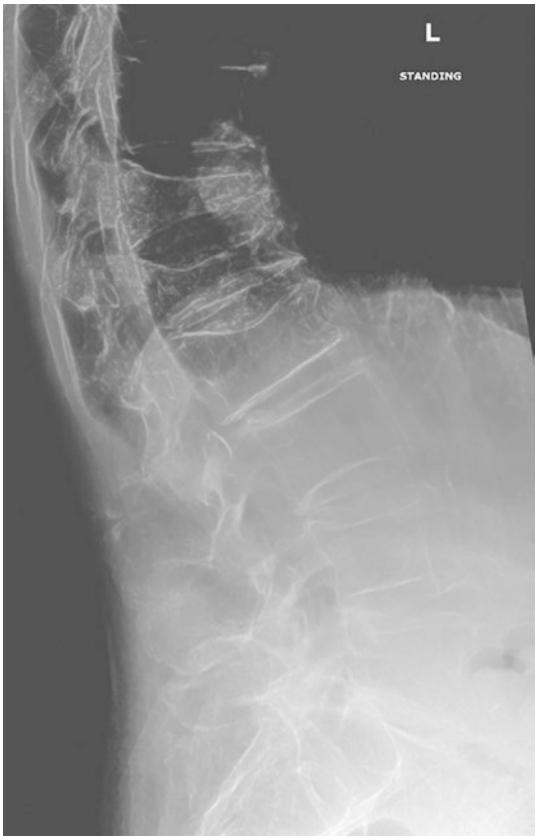

Fig. 10.10 Compression fracture. This is typically seen after an axial load injury, but in patients like this with osteoporosis, it can occur with minor loads or even gradually over time. Note the lack of retropulsion of the posterior aspect of the vertebral body. (Courtesy Medical College of Georgia, Department of Orthopedics)

body wall on the lateral view with retropulsion into the spinal canal (Fig. 10.11). The latter can cause spinal cord injury. Associated pedicle fractures and the degree of comminution are not always fully appreciated on plain films making CT scans invaluable. These are not "stable" injuries, so a careful assessment to determine treatment is appropriate. The degree of compression, spinal canal compromise, neurologic injury, level of injury (e.g., T6 vs L5), and other injuries will help determine whether brace or operative treatment is best. Like compression fractures, repeat radiographs in the standing position after bracing has started is necessary to rule out previously undetected instability. Surgical treatment may include reduction of the retropulsed fragment with posterior instrumentation (pedicle screws and rods) with fusion to restore height, normal lordosis in the lumbar spine, and normal kyphosis in the thoracic spine. In a few cases, an anterior approach may be necessary to restore stability. In neurologically intact patients, long-term outcomes are generally good.

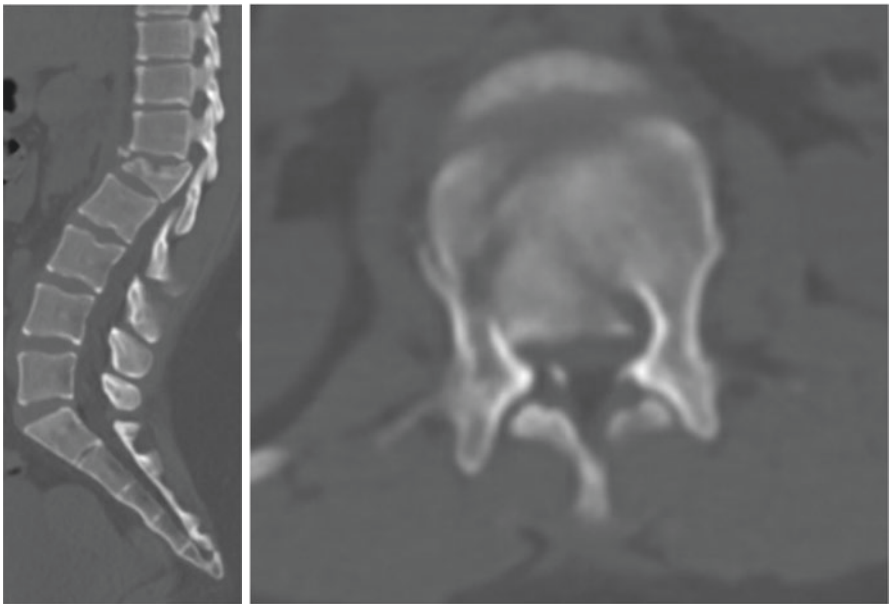

Fig. 10.11 Burst fracture of L1. Note the retropulsion of the fragments into the spinal canal. (Courtesy Medical College of Georgia, Department of Orthopedics)

10.1.5 Chance Fractures

Chance fractures are a subcategory of fractures to the thoracolumbar spine most commonly at the thoracolumbar junction. Chance fractures fall into the broader category of what are called flexion distraction injuries. In other words, a portion of the spine fails in flexion, while the rest fails in tension (distraction). Because of the fulcrum provided by lap belts (without shoulder straps), flexion distraction injuries are also known as seatbelt fractures. Chance fractures are unique among the flexion distraction spine fractures in that all of the elements of the fracture (including soft tissue) fail under tension (Fig. 10.12). The history (e.g., lap belt) should help the clinician be aware of the possibility of this injury. Physical examination may show a significant difference in the distance between the spinous processes at the injured level along with marked localized tenderness.

Treatment is generally surgical with short-segment posterior instrumentation and fusion to correct the posterior elements. The vertebral body will normally heal without additional intervention. Because of the amount of energy required to cause these injuries, abdominal injuries are not uncommon, so consultation with a general surgeon is wise [2, 3].

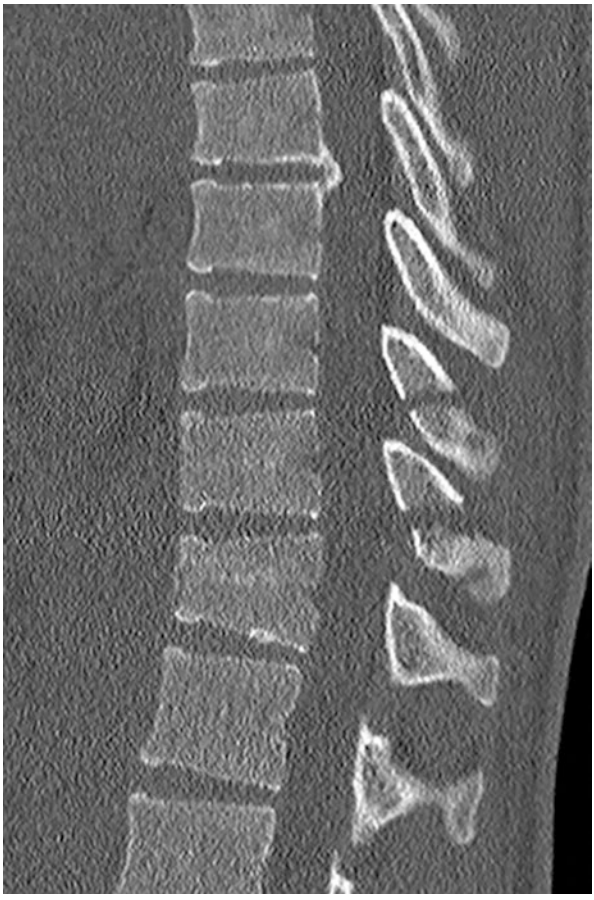

Fig. 10.12 Chance fractures of T9 and T10. Note the compression in the anterior aspect of the body with the gapping in the posterior aspect of the body and the lamina

10.2 Spine: Non-traumatic

10.2.1 Cervical Spine

10.2.1.1 Cervical Stenosis

Closely associated with cervical myelopathy, some patients will have a small cervical spine central canal either from degenerative changes or for congenital reasons. While it may be asymptomatic, it can present as a myelopathy. It is occasionally seen in MRIs of the cervical spine done on athletes and may result in the recommendation to avoid contact sports (e.g., rugby or American football) as the patient is more susceptible to spinal cord injury [4, 5].

10.2.1.2 Cervical Myelopathy

Cervical myelopathy is generally not treated nonoperatively as the natural history is one of the persistent progressions. The typical patient is older, and neck pain is a

minor complaint compared to gait difficulties like frequent stumbling with numbness in the upper limbs. Physical exam may show a positive Babinski (upgoing toes upon raking the sole of the foot), hyperactive reflexes in the lower limbs with hypoactive or absent reflexes in the upper limbs. Note that with a positive Babinski sign, careful observation is necessary as many normal patients will have initially downgoing toes (which is normal) but will then immediately extend (dorsiflex) the toes in response to irritation of the sole. Inattention may cause the AP to miss the initial downgoing toes. Motor and sensation testing may show patchy deficits. Plain films of the cervical spine are normal or may have degenerative changes. MRI will show marked compression of the cervical spinal cord, especially in the midline. Lhermitte sign can be positive in both MS and cervical myelopathy. Lhermitte sign is positive when the neck is extended (causing cervical cord compression in the myelopathic patient) and the patient complains of pain/tingling running into both upper and lower limbs and down the back.

The underlying pathophysiology is one of slowly increasing compression of the spinal cord affecting the upper limb innervation directly and the lower limb innervation indirectly, the latter by damaging the long tracts of the spinal cord which removes the dampening of the reflexes.

The only treatment is urgent (but not emergent) surgical decompression. A carefully documented preoperative examination will allow proper documentation of any improvement postoperatively. Like any neurologic injury, the older the patient, the less robust is the recovery; in fact, in some patients, all the surgery may do is prevent worsening of any neurologic deficits. The patient needs to know this ahead of time.

Differential diagnosis includes multiple sclerosis, amyotrophic lateral sclerosis (Lou Gehrig's disease), spinal tumors, and syringomyelia [6, 7].

10.2.1.3 Cervical Radiculopathy

Cervical radiculopathy refers to one of the cervical nerve roots being compressed, creating symptoms that range from neck pain or upper limb pain which may or may not be associated with weakness or decreased sensation in the distribution of the involved nerve root. The patient is typically 40 to 60 years old without any precipitating trauma. History should include the exact location of symptoms, a rough guess on the patient's part as to percentage neck pain versus upper limb pain, duration, as well as relieving and exacerbating factors. Inquiry into lower limb symptomatology is important to rule out cervical myelopathy.

Physical examination includes range of motion of the neck, testing the major motor groups of both upper limbs looking for weakness or major side-to-side differences. Sensation in each of the major dermatomes should be tested. Usually, a difference in light touch sensation will suffice, but occasionally it may be necessary to test sharp/dull. Finally, reflexes at the biceps (C5 and C6 nerve roots), triceps (C7 nerve root), and brachioradialis (C5 and C6 nerve roots) should be tested. As long as the reflexes are symmetric, hyporeflexia or hyperreflexia is acceptable.

Like other areas of orthopedics, there are several special named tests. These include axial compression and traction tests, Spurling, Lhermitte, and Valsalva maneuvers. The axial compression and traction tests are self-explanatory. With

compression on the vertex of the skull, radicular symptoms should increase while traction (~10 kg) should relieve the symptoms. A Spurling test is done by extending the neck and tilting to the affected side, thus decreasing the foraminal space which should cause an increase in symptoms. The Lhermitte was explained in the section on cervical myelopathy. The Valsalva test is done by having the patient hold his breath while attempting to exhale which should recreate the symptoms within a few seconds. It may be difficult in some patients to differentiate cervical spine and shoulder pathology, and some patients may have pathology in both areas [8].

Treatment for cervical radiculopathy is patient-specific and dependent upon symptoms, any accompanying weakness or numbness, as well as duration and progression of any signs or symptoms. Initial treatment options include NSAIDs, physical therapy, and possible light home cervical traction. Some advocate cervical epidural if the symptoms are primarily pain with minimal weakness or sensory loss. If surgery is necessary, it can be done through an anterior or posterior approach. Anteriorly, the recurrent laryngeal nerve is at risk (excessive traction of which results in hoarseness), and some loss of cervical flexion is possible with the posterior approach. Other than discectomy and fusion, for single-level disease, cervical disc arthroplasty is an option. Like other surgeries, the appropriate approach depends on the patient, the location and type of pathology, as well as the surgeon preference and experience [9–14].

10.2.2 Lumbar Spine

10.2.2.1 Background

Diagnosing diseases of the lumbar spine is not as straightforward as other areas of orthopedics for three reasons. First, the complaints can be nonspecific with no localizing symptoms on history or signs on physical exam making decisions about imagining difficult. Second, up to one-third of the asymptomatic population will have abnormalities on lumbar MRI. Third, for reasons that are unclear, there seems to be a significant psychological component in many patients with back pain, and secondary gain issues are especially prominent in those patients injured at work.

The lumbar spine is made of five lumbar vertebrae with the spinal canal proper ending in adults at L1-L2. The spinal canal distal to L2 contains nerve roots, i.e., lower motor neurons having their cell bodies in the anterior horn of the spinal cord and the sensory cells of the spinal cord having their cell bodies at the dorsal root ganglia. The sensory cells are located at the level of the intervertebral foramen. Normally, the lumbar spinal canal is large enough to be much more forgiving with regard to acute or gradual decrease in size (from traumatic or degenerative conditions) than is the thoracic spine. The nerve roots and associated dermatomes are named for the lumbar vertebrae from below which they emerge, unlike the cervical nerve roots which are named for the vertebra above which they emerge. The exception is the C8 nerve root which emerges between the seventh cervical vertebra and the first thoracic.

Like the brachial plexus, the lumbar and sacral nerve roots divide and combine forming the lumbosacral plexus before innervating the lower limb primarily through the femoral, the obturator, and the sciatic nerves, the latter of which divides into the tibial and the common peroneal nerve at the popliteal space.

Neurologic exam of the lower limbs consists of sensory, motor, and reflex components as well as some special tests including what are called nerve tension signs. Especially important are side-to-side differences in strength and reflexes.

Motor examination should cover all the nerve roots by including testing hip flexion, knee extension and flexion, ankle plantar and dorsiflexion, and extension of the great toe. Any abnormal findings should be followed up with a more detailed exam or should be retested later in the exam.

Reflexes include the patellar tendon reflex (L2, L3, L4) and the Achilles tendon reflex (S1). Some patients' reflexes are sensitive enough that a posterior tendon reflex can be elicited (L5). For patients who are inhibiting their reflexes involuntarily, it may be helpful to have them hook their fingers together and pull while the practitioner retests the reflex. The use of the ASIA chart may be helpful for thorough documentation in patients with other than single nerve root findings.

The most common nerve tension sign is the straight leg raise. This should be done in both sitting and supine positions. If the patient complains of pain or increased pain, note the angle at which the pain is produced and location of the pain. Some patients will lean back placing their hands behind them when the straight leg sign is performed in the sitting position; this is called the tripod sign.

Ankle clonus is when the ankle is forcefully dorsiflexed by the examiner and the ankle repeatedly plantar flexes despite the examiner holding the foot in the dorsiflexed position. Anything more than three to five beats is considered pathological and indicates a "long-tract" sign. In other words, something in the spinal cord proper or the cerebellum is no longer inhibiting ankle clonus. The other special sign is the Babinski reflex. Scraping the sole of the foot should elicit flexion of the toes, but a positive Babinski is the great toe extension. Careful observation is in order as many patients will momentarily flex the great toe before extending it in which case the Babinski is considered negative or normal.

10.2.2.2 Low Back Pain

The vast majority of patients will suffer from lower back pain at some point in their lives (>90% in some studies), and the AP's task is twofold. The first objective is to make sure nothing more serious is happening (such as a tumor or a progressive neurological deficit) and second to reassure the patient that the natural history of most low back pain is one of resolution in 4 to 6 weeks.

History-taking in a patient who presents with low back pain includes the following questions: where is the pain, how long has the patient had it, is it getting better or worse, any radiating pain, any numbness or weakness, and any bowel or bladder continence. Other questions include previous testing (imaging and electrical studies) and treatment which may include chiropractic, physical therapy, acupuncture, or other nontraditional remedies. The AP should also ask about past cancers, steroid use, and osteoporosis.

The etiology of low back pain is unknown. Some researchers relate it to a degenerative disc, but a large number of patients have a degenerative disc without pain. It may be a simple muscle strain. Physical exam may show some localized tenderness and limited range of motion of the lumbar spine, but otherwise the exam is normal.

For patients with acute (less than 4–6 weeks) localized pain with a normal neurologic exam and a negative history, imaging is not normally required. In the older population, radiographs to rule out previously unknown metastatic disease or osteoporotic compression fractures may be appropriate. Some patients may want imaging to make sure nothing more serious is wrong, and the AP should not overlook the psychological benefit this may provide in some patients.

Treatment consists of reassurance, home exercise, and over-the-counter analgesics. Some patients may benefit from a short course of physical therapy.

Finally, because some patients with hip arthritis present with low back and buttock pain, examination of the hips should be performed [14–16].

10.2.2.3 Lumbar Stenosis

Lumbar stenosis is exactly what it sounds like. The spinal canal becomes small ultimately compressing the spinal cord and cauda equina. Although cervical and thoracic stenosis are also valid diagnoses, spinal stenosis is most commonly present in the lumbar area in patients over 50 years of age. Depending on the extent and location of the stenosis (foraminal, lateral recess, or central canal or combination), presenting symptoms vary but include some combination of back pain, lower limb weakness or sensory deficits, and urinary incontinence. One key that the diagnosis is stenosis rather than a herniated disc is the lack of a dermatomal pattern. In addition, many patients present with neurogenic claudication. That is, the symptoms are worse with prolonged walking but are relieved with rest. Given the anatomy, it is not surprising that walking uphill or leaning on a grocery cart relieves or prevents symptom onset as both increase the volume available to the spinal cord.

The most difficult part of diagnosing spinal stenosis is the variety of symptoms. Several additional clues may be helpful. When rested, the neurologic exam is negative (motor and sensory) with a negative straight leg raise. The clinician may have to ask the patient to walk for 10 to 30 minutes to precipitate the symptoms and reexamine the sensory and motor components.

It is important to differentiate neurogenic from vascular claudication. The latter presents with calf pain relieved with a short period of rest. A tobacco smoking history is common, and physical exam in patients with vascular claudication shows decreased or absent hair on the foot and leg with weak or absent posterior tibial and dorsalis pedis pulses. Some unfortunate patients may have both.

Diagnostic imaging starts with two to three views of the lumbar spine looking for facet arthritis, disc space narrowing, and spondylolisthesis. Both CT and MRI scans are helpful in confirming the diagnosis, but imaging criteria alone should not be used because a large percentage of the population have stenosis on imaging but are asymptomatic. Although myelograms are invasive, a CT myelogram frequently gives more information than CT alone. In addition, the patient may need to be

positioned with the lumbar spine in extension which is now possible with high-speed CT scanners.

The cause of lumbar stenosis is multifactorial but primarily the result of degenerative changes resulting from disc herniation and facet arthritis with resultant hypertrophy that impinges on the nerve roots. Finally, the ligamentum flavum (the yellow tissue posterior to the dural sac but ventral to the lamina) can become hypertrophied or calcified.

Unless there is progressive deterioration, initial treatment is nonoperative. This includes physical therapy with emphasis on core strength and aerobic exercise. Epidural steroids may provide short-term symptomatic relief but do not appear to be a long-term treatment option.

Surgery appears to give good results with regard to relieving lower limb symptomatology, but the patient should be warned that back pain may be unchanged or worsened. Briefly, the surgery involves relieving all the areas of compression. Depending on the pathology specific to each patient, this could involve laminectomy, discectomy, and facet removal (partial or complete) at one or more levels. Depending on the extent of decompression, this may destabilize the spine resulting in the need for fusion with or without instrumentation.

Postoperatively, care should be given to preventing pneumonia via incentive spirometry and preventing deep vein thrombosis with mechanical or chemical prophylaxis or both. The former consists of foot pumps or sequential compression devices. Pharmacologic prevention is dependent on patient risk factors and surgeon preference as there is the risk of an epidural hematoma. Early postoperative checks that show worsening neurologic status may indicate an epidural hematoma [17, 18].

10.2.2.4 Lumbar Spondylolisthesis

Spondylolisthesis refers to the slippage of one vertebra forward in relation to the one below, typically L5 slipping forward relative to S1, but can also occur at other levels (Fig. 10.13). It comes in several varieties including dysplastic, isthmic, degenerative, traumatic, and pathologic. Isthmic lumbar spondylolisthesis presents in the adolescent with a patient complaining of low back pain, worse with activity but usually no radiating symptomatology. Because of the amount of hyperextension in the lumbar spine, it is a common malady among offensive linemen and female gymnasts. Physical exam will show a flat back, i.e., the normal lumbar lordosis is absent or vastly decreased. In addition, the hamstrings are tight but neurologically the patient is intact.

Radiographs show varying degrees of slippage of L5 on S1, with a slip being graded 1 to 5 based on the percentage slip (less than 25%, grade 1; 25 to 50%, grade 2; 50 to 75%, grade 3; 75% to 100%, grade 4; and over 100%, grade 5) [19]. For many patients, activity restriction will relieve the symptoms. For others with persistent, significant pain, fusion can be helpful. There is persistent controversy about whether it should be an instrumented fusion or not. Somewhat less controversial is whether the slip should be reduced. Most think the slip should not be reduced as there is both dangers of neurologic injury and reduction does not seem to change the long-term outcome in terms of pain or function.

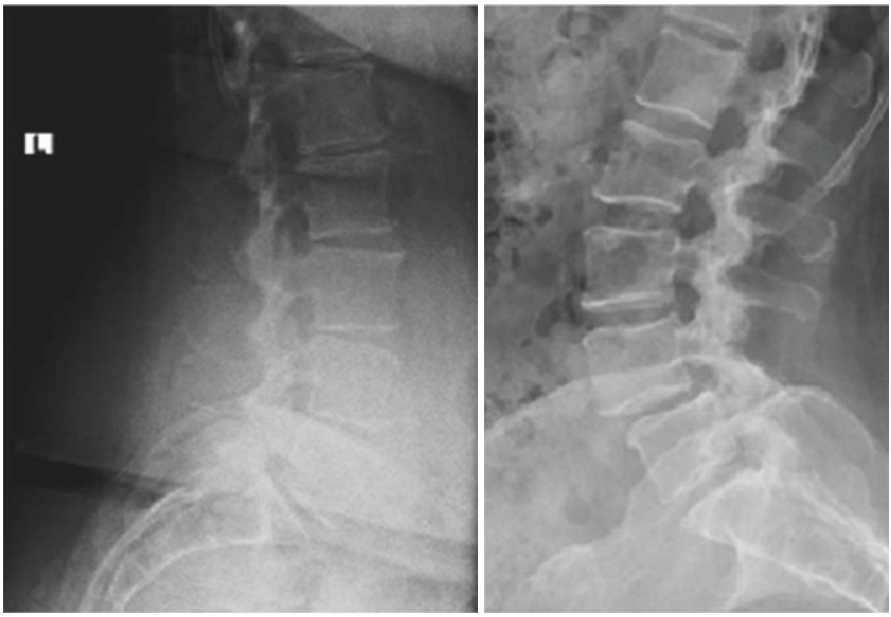

Fig. 10.13 Grade 1 slip of L4 on L5

The underlying pathology is a deficit of the pars interarticularis which can result from an acute or a chronic stress fracture or repetitive stress from repeated hyperextension causing the pars interarticularis to "stretch."

Adults with isthmic spondylolisthesis may or may not have the spondylolisthesis as the cause of their symptoms. The source of their symptoms may just be mechanical low back pain. Some will have an L5 radiculopathy, but this may result from a herniated disc and have nothing to do with a spondylolisthesis especially if it is low grade. Making the picture more confusing is that some patients with spondylolisthesis will have hip arthritis that may actually be the primary source of their symptoms. As mentioned before, treat the patient, not the radiograph. If hip pain is primary, treat that, and the back pain may resolve or at least be ameliorated. On the other hand, if there are progressive neurologic problems, then the back should be addressed first.

Specifics of operative treatment are beyond the scope of this book. Generally speaking, the outcomes are positive in 80 to 90% of patients but depend on obtaining a solid fusion which is in part technique-dependent. Risk factors for nonunion include smoking, diabetes, and osteoporosis. The extent of the surgery will depend on the patient's pathology and anatomy with adequate decompression of the nerve roots if there are neurological symptoms. The decision to use instrumentation is still debated. Some patients with inadequate bone posteriorly will require both anterior and posterior fusions.

Degenerative spondylolisthesis is more common in African women over 50 years of age and unlike isthmic spondylolisthesis affects the L4–L5 level much more

frequently. Theories abound as to the exact cause, but the etiology remains unknown. Unlike isthmic, degenerative spondylolisthesis does not have any type of defect of the pars interarticularis, but some type of slip is present. Probably because of the age, there is usually facet arthritis and disc disease, all of which contribute to the accompanying spinal stenosis.

Initial treatment is nonoperative because the disease tends to progress slowly, if at all. Time can be taken to try a variety of options before deciding on operative intervention. Any physical therapy or home exercise program should avoid lumbar extension exercises as this will narrow the canal and make symptoms worse. Aerobic exercise, surprisingly, reduces the symptoms in some patients, and if surgery is necessary, the patient will be in a better cardiovascular state to recover from surgery. Epidural steroids may help with radicular symptoms, but the role of epidural steroids just for stenosis symptoms is unclear [20, 21].

10.2.2.5 Lumbar Radiculopathy

Frequently known as sciatica, patients with lumbar radiculopathy present with varying degrees of back pain that radiates into one or both lower limbs. The clinician should ask open-ended questions to determine how much pain is in the back, buttocks, and lower limbs. In addition, the amount of radicular pain that is below the knee is helpful to know. Most frequently, a result of degeneration of lumbar intervertebral disc, the outer annular disc material either bulges or ruptures allowing the nucleus pulposus to herniate, both of which result in pressure on a nerve root and thus the presenting complaint of both back and lower limb pain. There may or may not be any precipitating event or trauma; the onset may be abrupt or insidious. Although rare, questions about new-onset bowel or bladder incontinence should be routinely asked.

Physical exam includes observing gait and range of motion of the back and hips as well as testing of sensation, muscle strength, and reflexes. The physical exam should help the AP localize the level and side. The radiographs are frequently normal although degenerative diseases such as facet arthropathy, disc space narrowing, and spurring may be seen. Unless there is a severe neurologic deficit or progressive neurologic changes, initial treatment is nonoperative with reassurance, physical therapy, activity limitation, and OTC analgesics. Some patients may be in enough pain that a short (less than three day) course of narcotics is indicated, but this should be done with care as drug seekers have become extremely sophisticated.

If symptoms persist, then MRI, CT scan, and lumbar myelogram are tests to consider. The imaging study should confirm the clinician's impression of the level of pathology. The difficulty is twofold. First, the degree of nerve root compression does not always correlate with the severity of the symptoms. Second, especially in greater than 50- to 60-year-old population, a high incidence of pathology can be seen on any spine imaging study, especially MRIs, in the asymptomatic population. This can be as high as 30–60% in some studies [22, 23].

Treatment beyond the noninvasive means discussed above is somewhat controversial and in large part dependent on the specific patient's pathology. For example, in the face of progressive neurologic compromise, few would disagree that urgent or

emergent surgical intervention is necessary. For the patient with mild discomfort that does not interfere with his activities of daily living, reassurance and periodic observation may be the best option. Most patients fall in between. Generally speaking, operative intervention works best if done in the first 6 months of symptoms. The patient should be cautioned that a flare of the pain 5 to 8 days after surgery is not unusual and will usually subside. Second, the patient should be counseled that the surgery is done to relieve leg pain and weakness with postoperative physical therapy or home exercise being necessary to relieve associated back pain. Three major studies came out as a result of a large study conducted by Dartmouth University under the acronym of SPORT which stands for Spine Patient Outcomes Research Trial, all of which are worth reading in detail if the AP sees back pain on a regular basis [24–26].

Three additional points to remember: First, the natural history of lumbar radiculopathy is one of resolution over 2–5 years; the primary difference is that patients who undergo surgical intervention experience relief sooner. Second, for some patients, a single-level epidural steroid injection done under fluoroscopic control may give sufficient relief of the symptoms to allow time for the natural history to resolve the symptoms. Third, a few patients with radicular pain may have piriformis syndrome where the sciatic nerve is pinched as it comes through the sciatic notch by a tight or scarred piriformis muscle. Differentiating features are radicular-type pain recreated on resisted external rotation of the hip while in the neutral position and lack of back pain. Treatment is primarily physical therapy, massage, mobilization, and stretching with surgical release being reserved for recalcitrant cases [27, 28].

10.3 Diseases of the Spine

10.3.1 Arnold-Chiari

Though not strictly considered an orthopedic problem except among some spine specialists, the AP should have some familiarity with the disease. There are four subtypes of Arnold-Chiari malformations, all of which result from an abnormally small space for the cerebellum at the base of the skull and resulting in poor flow of cerebrospinal fluid. A wide variety of neurologic symptoms can develop and may be relieved by enlarging the area for the cerebellum or by creating a shunt for the excessive cerebrospinal fluid by a neurosurgeon. Orthopedically, type II is commonly associated with spina bifida [29].

10.3.2 Ankylosing Spondylitis (AS)

Ankylosing spondylitis is most commonly treated by rheumatologists but may be initially diagnosed by an orthopedic surgeon or AP. The initial onset of ankylosing spondylitis is in males (2:1) at about 30 years of age. The initial symptoms are back pain of gradual onset with gradual onset of stiffness. The patient may complain of

pain in the sacroiliac joints, back, or pelvis. The pain is improved with exercise and worsens with rest. There is often accompanying arthritis of the hips and less commonly the shoulders. The stiffness is gradually progressive starting at the sacral-lumbar junction, progressing to loss of normal lumbar lordosis, then to the thoracic spine. Other organ systems that may be affected include pulmonary, cardiac, ophthalmologic, and urologic.

Two additional clinical tests to consider for presumptive diagnosis of ankylosing spondylitis are the Schober test and chest expansion. The Schober test is performed by looking for increased distance above and below the L5 spinous process when the patient goes from maximal spine extension to maximal flexion. Classically, this is done by measuring a spot 5 cm below L5 and 10 cm above L5, and upon maximal flexion, the normal increase should be at least 5 cm. Chest expansion of less than 1 inch when going from full exhalation to full inhalation is another indication the patient may have AS.

Imaging of the spine reveals a prototypical bamboo spine (Fig. 10.14). The changes on the sacroiliac joints may be difficult to see in the first few years on plain films, so the clinician will have to decide if a CT of the pelvis is appropriate for further diagnostic purposes.

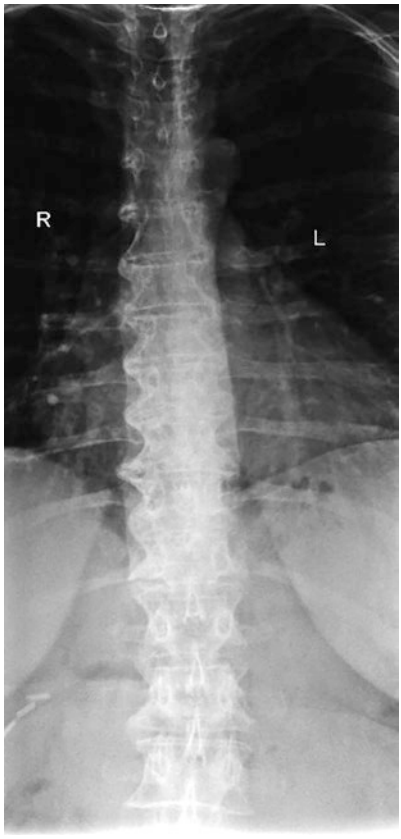

Fig. 10.14 Spine of patient with ankylosing spondylitis; note the bridging osteophytes on the lateral borders of the vertebral bodies giving rise to the term bamboo spine

Laboratory tests are positive for HLA-B27, occasional elevated ESR, and anemia. It is important to remember that the HLA-B27 test is associated with AS but not diagnostic of AS.

Medical treatment consists of NSAIDs, TNF inhibitors, and pamidronate. The most common orthopedic procedure is total hip arthroplasty. Because of the stooped kyphotic posture, there may be a higher incidence of posterior hip dislocation. In addition, these patients are frequently osteoporotic. Osteotomies of the spine to correct severe deformities can be performed in appropriate patients. In cases of spine trauma, because of the relative inflexibility of the vertebral column, benign-appearing fractures may be much more severe than they appear on plain films.

Because the kyphosis and hip flexion contractures can progress to the point where the patient can only look straight down while walking, maintaining spine extension flexibility is important. This includes daily stretching of the hip in extension and sleeping with the spine extended. Unfortunately, these measures only slow the progress of the disease but do not halt it. Early referral and involvement of a rheumatologist are helpful [30, 31].

10.3.3 Scoliosis

Scoliosis is commonly thought of as an abnormal curvature of the spine in the frontal or coronal plane; however, there is almost always an associated deformity in the sagittal plane with excessive kyphosis or lordosis and some rotation in the transverse plane.

The most common type is idiopathic adolescent scoliosis which is far more common in females than males. So much so that if seen in a teenage boy, an extra careful search for an underlying cause such as a tethered cord should be made. School screening was a common method of detecting scoliosis; however, the role of school screenings has vastly decreased in the past decade because the false-positive rate was too high. This resulted in unnecessary expense and anxiety for families whose children did not have scoliosis, as well as unnecessary radiation exposure from any accompanying spine films.

At present, the typical patient presents at age 10–13 with the mother having noticed one shoulder higher than the other, a dress or skirt that hangs unevenly, or with the complaint that her daughter's back does not look right. The AP may get a referral from a PCP to evaluate the patient for possible scoliosis. Curves typically progress the fastest during the adolescent growth spurt, so historical questions to ask include age of onset of menses and whether there has been a recent growth spurt. The AP should make sure there is either a female chaperone or mother in the room while performing the exam. Physical exam is best done with the patient barefoot, first checking for a level pelvis. Tanner staging of axillary hair and breast development is useful to determine in which stage of growth the patient is. While the patient is standing erect, run two fingers along either side of the spinous processes looking for deviation from a straight line in the frontal plane. In addition, check for overlying skin abnormalities such as a hairy patch that may indicate an

occult spina bifida deformity or other neural tube defects. The AP should look for café au lait spots to rule out neurofibromatosis. Finally, have the patient bend forward at the waist, and look along her upper back to see if one set of ribs is higher than the other. In addition, a routine neurologic exam to test motor, sensation, and reflexes should be performed.

Radiographic exam consists of full-length spine films (base of the skull to the pelvis) in both the AP and lateral planes with shielding for the breast tissue. After making sure there are no anatomical abnormalities, the curves are designated as primary (bigger curve) and secondary (or compensatory) and measured via the Cobb method. That is done by measuring the angle between the superior endplate of the most tilted superior vertebra and the lower endplate of the most tilted lower vertebra. In the clinical note, it should be mentioned from which vertebrae the measurements were taken so that the next radiograph will be measured identically. In addition, mention should be made of the Risser stage of the pelvic apophyseal growth plate.

Treatment recommendations vary depending on the degree of curvature, rate of progression, skeletal maturity, and clinical judgment. Generally speaking, anything less than 15° is just observed (Fig. 10.15); 15–30° is observed for progression or

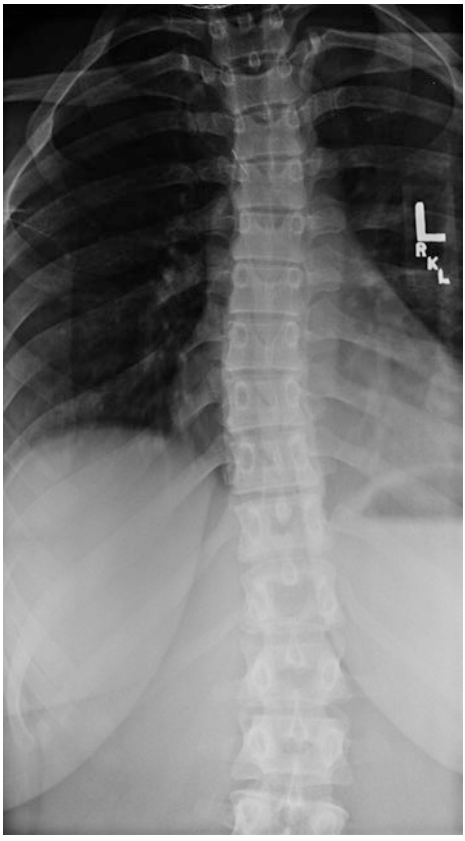

Fig. 10.15 Thoracic curve of less than 15°. It did not progress and no treatment was needed

braced; greater than 30° curves especially with progression are fused (Fig. 10.16). Bracing just slows or halts progression of the curve but does not correct the curve. With fusion, some degree of straightening can be expected but not completely. The patient is monitored intraoperatively by a neurologist with somatic sensory evoked potentials and neurogenic motor evoked potentials (SSEP and MEP, respectively). If this changes, the correction can be lessened or undone. The incidence of neurologic injury during scoliosis surgery is less than 1%.

There are several other types of scoliosis:

Congenital scoliosis is the result of the failure of formation or the failure of segmentation of the vertebrae. One of the more common is a hemi-vertebra which may

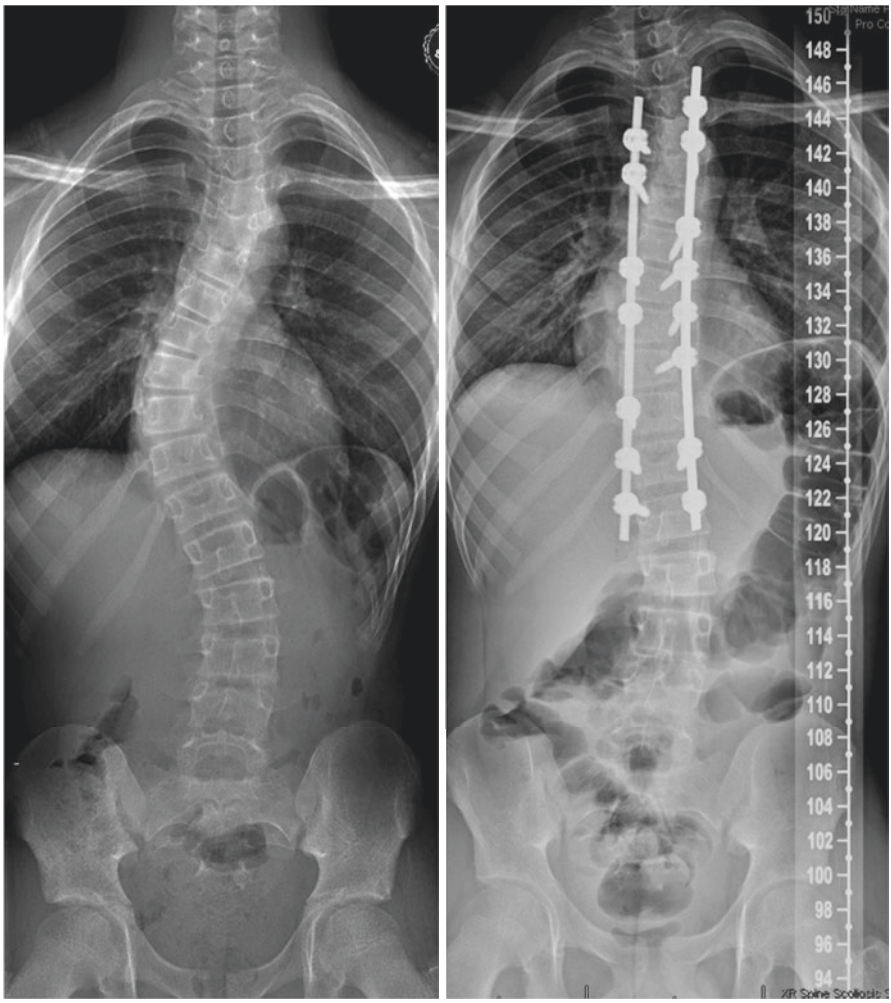

Fig. 10.16 Preop and postop films of an adolescent with idiopathic scoliosis. Note the curve is markedly improved but not completely normal. Courtesy Medical College of Georgia, Department of Orthopedics

or may not be compensated for by a second "opposite" vertebrae. Less common is a failure of segmentation where one side of a set of vertebrae fails to separate allowing excessive growth on the contralateral side. These patients may have a number of congenital defects affecting other organ systems including cardiovascular and genitourinary defects.

10.3.4 Idiopathic Scoliosis

Idiopathic scoliosis has two additional subsets in addition to the most common category of adolescence. *Infantile scoliosis* occurs at less than 3 years of age, while *juvenile scoliosis* occurs from ages 3 to 10 years of age. Generally speaking, curves in these age groups are observed until they reach 20° and then braced until 30°. Many resolve spontaneously. Curves greater than 50° are generally fused. Even if the curve does not progress, the patient should be monitored until adulthood as the incidence of adolescent scoliosis is higher in this population [32–36].

Finally, there is *degenerative scoliosis*. Remembering that a high percentage of the older (>60) population have some abnormal findings on plain films or MRI, it can be difficult to ascertain if the deformity is indeed the cause of the pain.

The patient with degenerative scoliosis [37] is more commonly female and greater than 60–70 years of age. She will complain of back pain and may have some degree of spinal stenosis symptoms, and radiographs reveal arthritis of the facet joints and disc space narrowing. Nonsurgical treatment options include core strengthening, NSAIDs, epidural or nerve root corticosteroid injections, and bracing both to relieve pain and potentially to slow the progression of the curve. If symptoms are severe enough, fusion to prevent progression with associated decompression (removing laminas, possibly widening the foramen, and discectomy) to relieve stenosis symptoms is appropriate. Unlike adolescent scoliosis, curve correction is more difficult and riskier because the bone is osteoporotic and the soft tissues stiffer. For large degrees of correction, anterior and posterior approaches may be necessary. This can be done in a single or staged surgery.

10.3.5 Scheuermann's Disease

Scheuermann's disease is a kyphotic (hunchback) deformity of the thoracic (occasionally thoracolumbar) spine. The typical patient is a male in early adolescence who presents with deformity of the thoracic spine and associated pain. Some patients have been told they have poor posture.

Physical exam shows a more angular deformity than the simple rounding of the spine one sees on bending over. In addition, the deformity does not correct when lying in the supine position.

Radiographs may show some scoliosis, but the diagnosis is made by at least three vertebrae showing equal or greater than 5° of anterior wedging between the upper and lower end plates or greater than 50° of kyphosis seen on the lateral radiograph

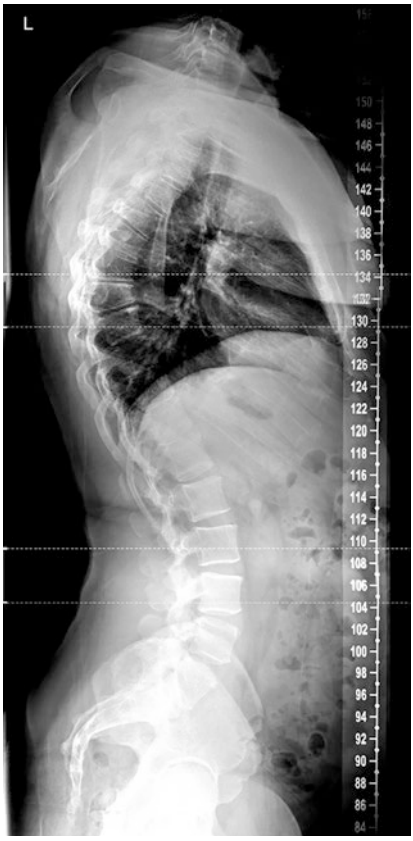

Fig. 10.17 Scheuermann's kyphosis. Note the sharp angulation in the mid-thoracic spine as opposed to the more normal thoracic kyphosis. (Courtesy Medical College of Georgia, Department of Orthopedics)

as measured by the Cobb method (Fig. 10.17). Taking a lateral radiograph with the patient in the supine position over a pad will help determine the flexibility of the deformity. There is often an accompanying lumbar hyperlordosis to compensate.

Treatment varies from observation and reassurance to bracing to surgery with instrumented fusion, all of which depend on the degree of deformity, progression, neurologic deficits, or persistent pain that interferes with activities of daily living [38, 39].

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Tumors

11

A. Luke Shiver

11.1 Background

Many bone tumors are asymptomatic and are discovered incidentally when making radiographs for other problems (such as nonossifying fibroma of the distal tibia when taking radiographs of a patient with suspected ankle sprain or fracture) or are discovered because the patient suffers a pathologic fracture due to decreased bone strength (such as a humeral fracture through a unicameral bone cyst in a child). Tumors can be benign, aggressive, or malignant. Most can be diagnosed based on patients' age and radiographic appearance, but sometimes biopsy will be necessary. The amount of "workup" done depends on the presumed diagnosis and the surgeon's "comfort" level. If there is a possibility that the tumor is aggressive or malignant, most studies show better outcomes if the diagnostic biopsy is done by the same surgeon who will do the definitive surgery [1].

11.2 Benign Bone Tumors

As would be expected, both benign and malignant bone tumors occur when bone growth is rapid, i.e., the first two to three decades of life. Benign bone tumors may be painful or cause pathologic fractures but by definition do not metastasize nor grow in an uncontrolled fashion into surrounding tissues [2–4].

11.2.1 Osteoid Osteoma

Patients with osteoid osteomas complain of localized pain (typically lower limbs or the spine) that is worse at night and relieved by NSAIDs. Physical exam is

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unremarkable. Radiographs show a small nidus of the bone surrounded by an area of radiolucency, which is in turn surrounded with a shell of reactive bone; the whole lesion is less than 1.5 cm in size. A CT scan may be necessary to clearly identify it, especially in the spine.

Treatment options include long-term NSAIDs, as the lesion usually resolves in less than 5 years. If the pain is not controlled, percutaneous radiofrequency ablation or open excision can be considered [5].

11.2.2 Bone Islands

Bone islands are exactly what they sound like, a small ovoid area of dense bone found within the cancellous medullary canal (Fig. 11.1). They are benign in

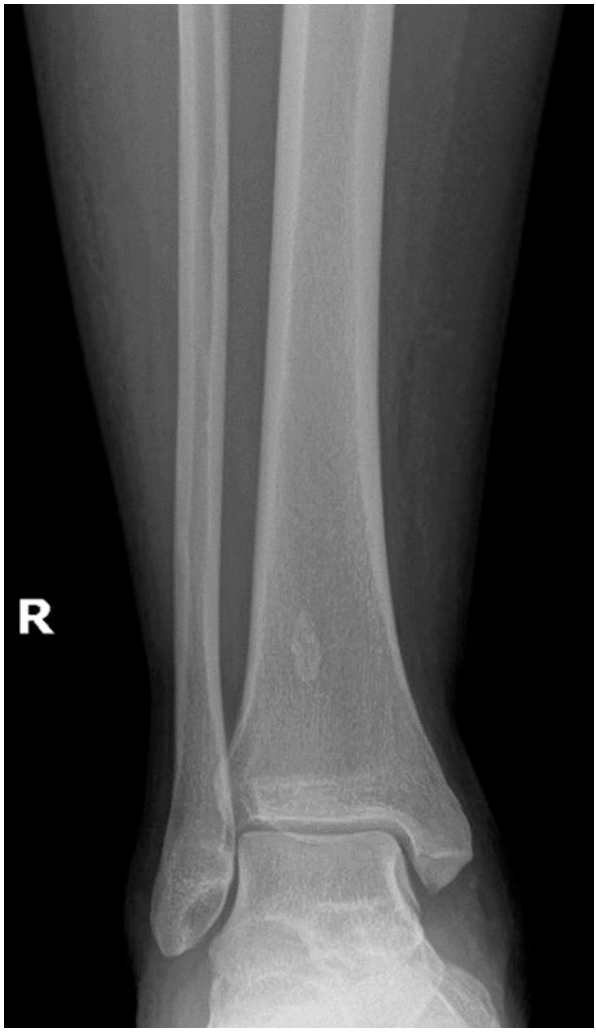

Fig. 11.1 Bone island in the distal tibia, no further evaluation or treatment needed. (Courtesy Medical College of Georgia, Department of Orthopedics)

appearance, and repeating radiographs in 4–6 months is all that is usually necessary. They are almost always an incidental finding, but if painful, consideration for a more aggressive workup may be appropriate to rule out a more malignant condition such osteosarcoma.

11.2.3 Osteochondroma

Patients with osteochondromas present with a bony prominence usually in the distal femur, proximal tibia, or fibula or on the proximal humerus during adolescence (Fig. 11.2). Although the mass itself is not typically painful, it may cause bursitis

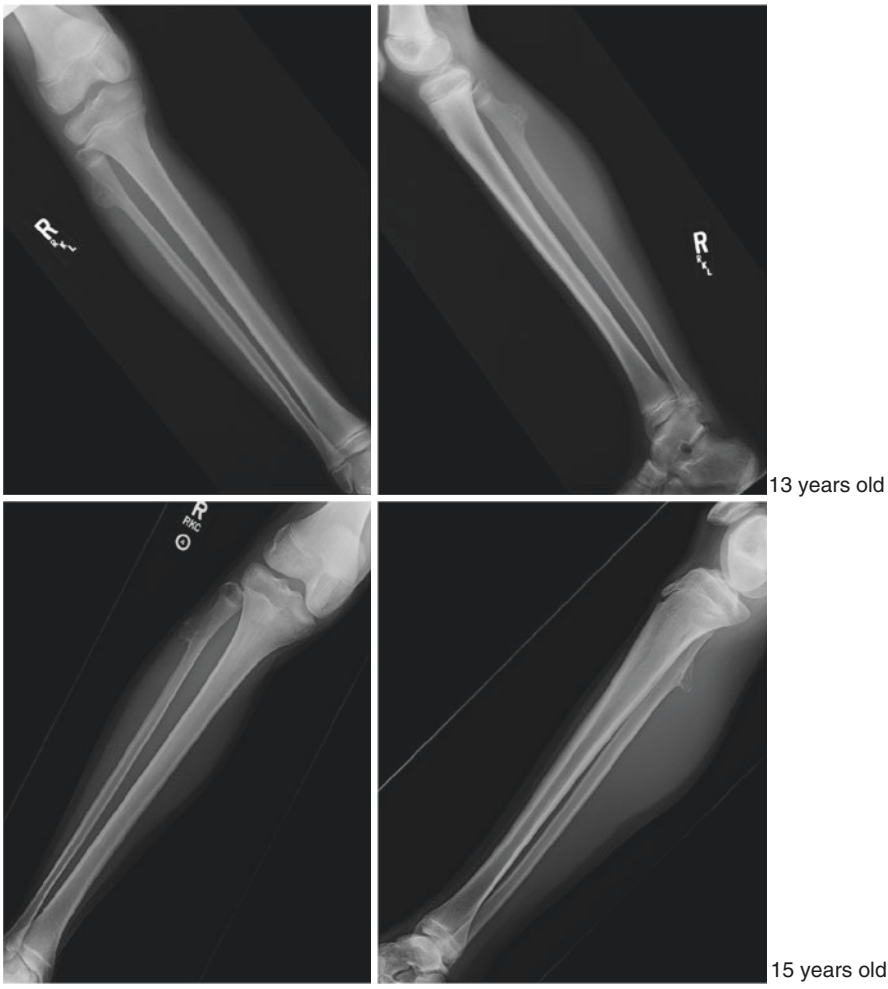

Fig. 11.2 Benign osteochondroma: note its gradual move away from the physis as the patient aged

due to protrusion into the overlying tissues. If a patient has more than one mass, the diagnosis of multiple hereditary exostoses should be considered.

Radiographs show a sessile bony prominence with continuity of the medullary canal with the inner aspect of the osteochondroma. An MRI may be helpful if near neurovascular structures or to look at the thickness of the cartilaginous cap.

For a symptomatic lesion, surgical excision is appropriate and recurrence is rare. Suspicion of malignancy should be heightened if the overlying cartilage cap is thicker than 2 cm or if previously asymptomatic osteochondromas in adults start growing or become painful. Asymptomatic osteochondromas are normally just observed. The chance of malignant transformation is low.

11.2.4 Fibrous Tumors

Nonossifying fibromas are found most commonly as an incidental finding when radiographs are taken for other reasons (Fig. 11.3). They show in the metaphyseal region of long bones (mostly femur, tibia, and fibula), are eccentric with well-defined borders, and have no periosteal reaction unless there is an associated fracture.

Because of their benign nature, periodic radiographs to ensure diagnosis are all that is necessary. They normally disappear by early adulthood. If there is a displaced pathologic fracture, then curetting out the lesion while fixing the fracture can be

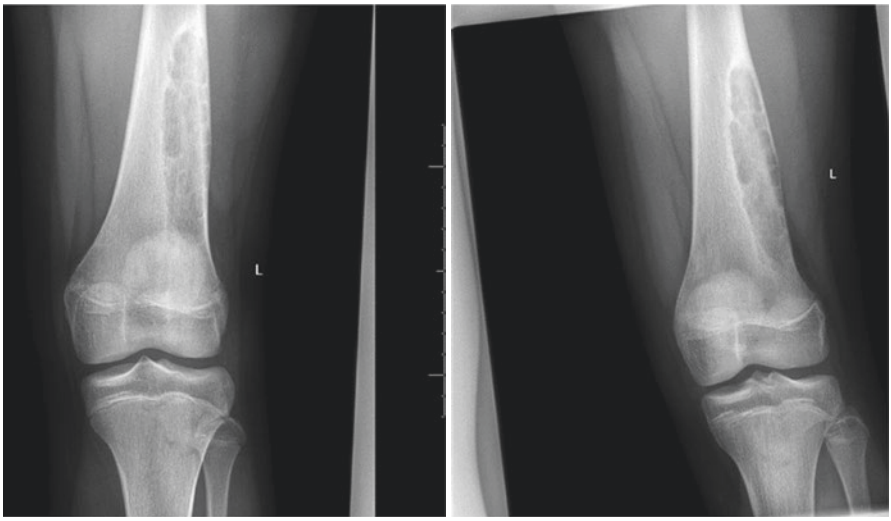

Fig. 11.3 Nonossifying fibroma. Periodic observation is all that is normally necessary although there is a risk for pathologic fracture. These tumors are most often seen in adolescence when plain films are taken to differentiate ankle sprains from ankle fractures. (Courtesy Medical College of Georgia, Department of Orthopedics)

considered. If the lesion is large enough, then bone graft (autograft, allograft, or artificial) may be necessary. Other names for a nonossifying fibroma include fibrous cortical defect and fibroxanthoma [6].

11.2.5 Unicameral Bone Cyst

Unicameral bone cysts are either found incidentally or as a result of pathologic fractures, classically in the proximal humerus (Fig. 11.4) but also in the proximal femur and other long bones (Fig. 11.5). Fractures through the cyst frequently

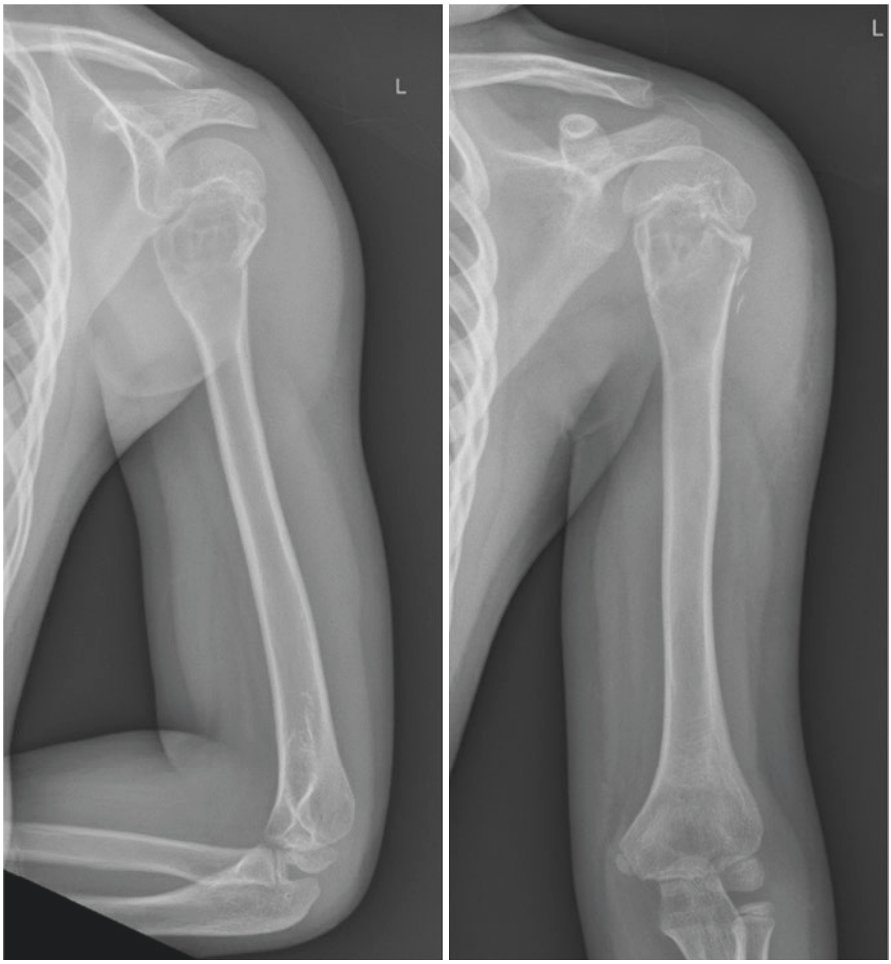

Fig. 11.4 Most commonly seen in the humerus, unicameral bone cysts are often seen as the result of a pathologic fracture as seen here. (Courtesy Medical College of Georgia, Department of Orthopedics)

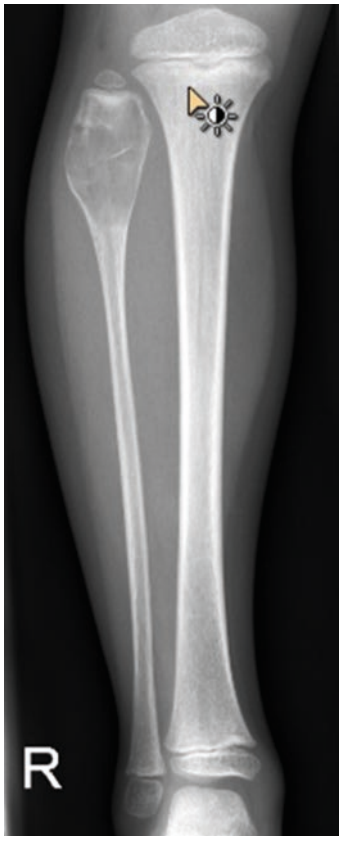

Fig. 11.5 Although most commonly seen in the humerus, unicameral bone cysts can also occur in other bones such as here in the proximal fibula. (Courtesy Medical College of Georgia, Department of Orthopedics)

stimulate healing of the lesion with resolution by adulthood. Plain radiographs are usually diagnostic showing a well-circumscribed centrally located cyst, more diaphyseal than metaphyseal as opposed to the eccentric, metaphyseal non-ossifying fibroma. A term unique to unicameral bone cyst is the fallen leaf or fallen fragment sign wherein a piece of cortical bone has eroded off its origin and fallen to the bottom of the cyst.

Treatment options vary. For small lesions, observation may be all that is necessary. Fractures often initiate the healing process and result in resolution of the cyst. Other options include curettage (with bone grafting), prophylactic fixation especially in large lesions of the weight-bearing bones, or aspiration followed by injection of corticosteroids.

It is important to remember this is a lesion of childhood or adolescence. If a bone cyst is seen in adults, the differential is much different and includes plasmacytoma and multiple myeloma [7, 8].

11.2.6 Enchondroma

Most enchondromas are benign cartilaginous tumors but can occasionally be difficult to differentiate from the malignant chondrosarcoma. Most patients with enchondromas are between 10 and 40 years of age and usually present with swelling of the involved finger, which may or may not be painful. It is not unusual for it to be found incidentally on hand films (Fig. 11.6) taken for other reasons or because of pathologic fracture. Plain radiographs are normally diagnostic and no further imaging is necessary. The enchondroma appears as a benign cyst with some calcification contained within the bone (proximal phalanx most commonly, metacarpal second, and middle phalanx third). If it appears to extend into the soft tissue, a more malignant lesion should be suspected. Like bone islands, serial radiographs are usually all that it is necessary to rule out malignant transformation or more aggressive tumors.

If the enchondroma is small, treatment is observation; if it is large, the treatment consists of curettage. The defect can be left empty or filled with autograft, allograft calcium phosphate, or polymethylmethacrylate. Fractures are treated by pinning. Curettage of the lesion can take place at the time of fracture treatment or after the fracture has healed. Rarely is complete surgical excision indicated [9].

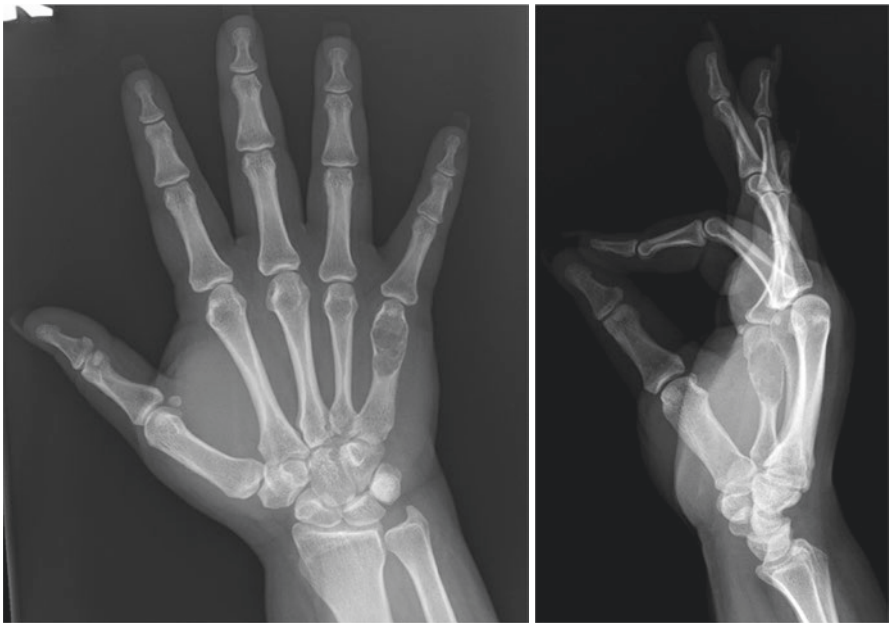

Fig. 11.6 Enchondroma in the hand in the distal metacarpal. (Courtesy Medical College of Georgia, Department of Orthopedics)

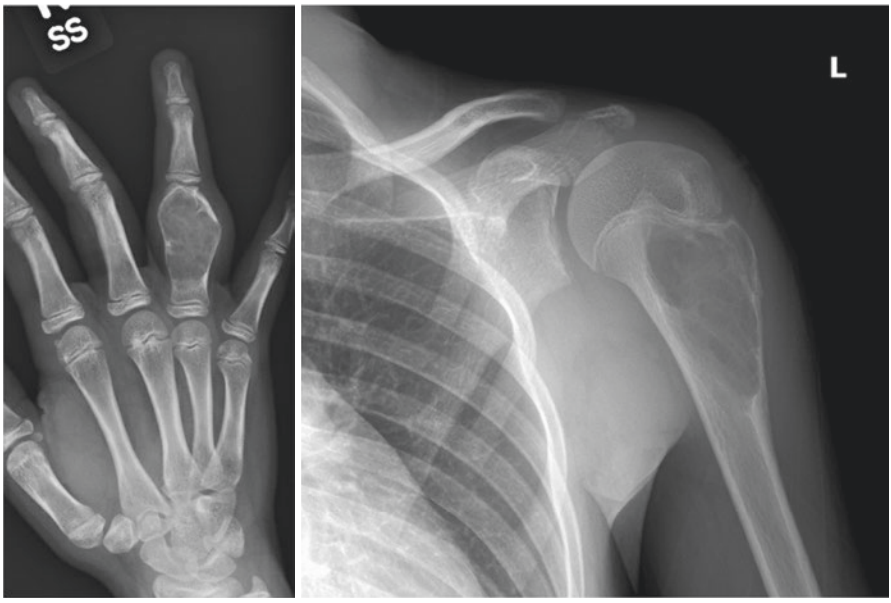

Fig. 11.7 Aneurysmal bone cysts: one in the proximal phalanx and the other (different patient) in the proximal humerus. Compare to the unicameral bone cyst in Fig. 11.4. Note the ballooning and thinning of the cortex. (Courtesy Medical College of Georgia, Department of Orthopedics)

11.2.7 Aneurysmal Bone Cysts (ABC)

Like unicameral bone cyst, ABCs are most common in the proximal humerus (Fig. 11.7) but also occur around the knee and in the spine and even in the hand. Patients are usually less than 20 and unlike patients with unicameral bone cyst may complain of pain associated with the ABC. Because of the pain and radiographic appearance, a malignant lesion is often in the differential.

Radiographs show a cystic lesion in the metaphysis but unlike unicameral bone cyst or nonossifying fibromas the cortex is often ballooned and very thin.

Treatment is curettage and bone grafting. As the lesion may be too large for autograft to be available in sufficient supply allograft, demineralized bone matrix, calcium sulfate, or other artificial graft materials will need to be available in sufficient quantity. Because of the potential for bleeding tourniquet, the use or preoperative embolization of a blood supply to the ABC should be considered [10].

11.2.8 Giant Cell Tumor

Patients with giant cell tumors present in middle age, 30–50 years of age, with insidious and vague symptoms. Nocturnal pain and pain at rest are both concerning symptoms for “bone pain.” Fifty percent of these present about the knee

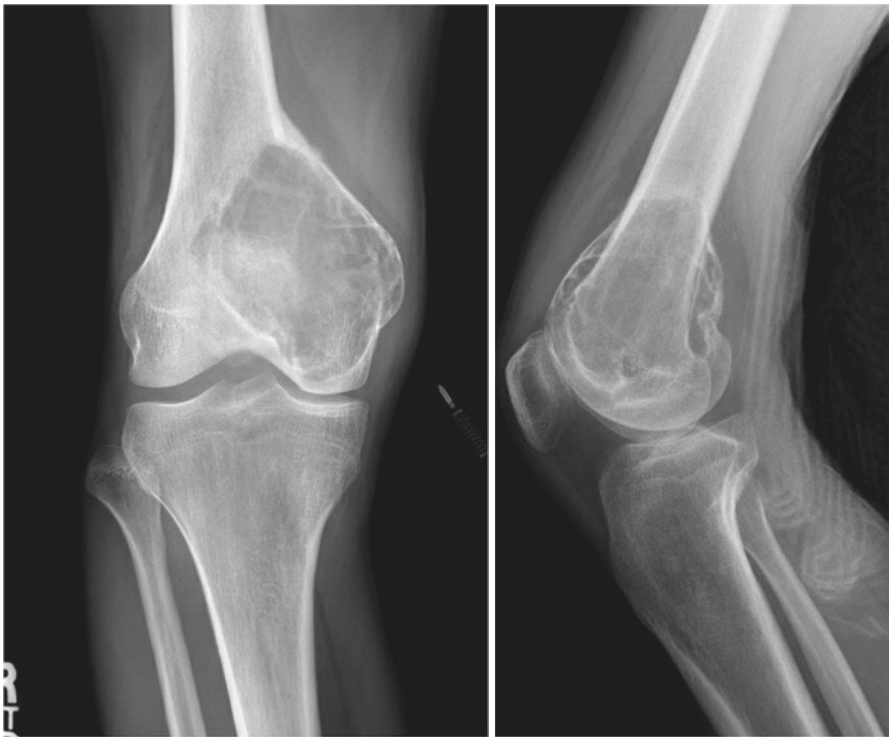

Fig. 11.8 Giant cell tumor in the distal femur. Note the reactive rim of the bone trying to limit the tumor's spread. (Courtesy Medical College of Georgia, Department of Orthopedics)

(Fig. 11.8); however, these are also found in both axial skeleton and other appendicular locations. On physical exam, the AP may find a mass, tenderness to palpation, and effusion if the lesion is periarticular. Clinical evaluation should include plain radiographs, chest radiograph to evaluate for the rare incidence of pulmonary metastases, as well as computed topography of both the lesion and pulmonary bed. Magnetic resonance imaging is helpful to delineate the extent of the lesion and evaluate for cystic changes. Imaging characteristics typically demonstrate a lytic, eccentrically based epiphyseal/metaphyseal lesion commonly extending to the sub-articular/subchondral bone. Treatment generally entails extensive curettage with adjuvant ablative methods (e.g., burr or argon beam therapy), grafting, and stabilization in the lower extremity. Medical management is also often employed as giant cell tumors are amenable to treatment with bisphosphonate therapy and denosumab. Medical treatment may be pursued both presurgical and postsurgical interventions. The hallmark histologic findings are "giant cells" which are found in abundance, although it should be noted these are not unique to this lesion. These patients should have long-term follow-up for recurrence and secondary lesions [11].

11.3 Malignant Bone Tumors

Malignant primary bone tumors are rare except for hematologic malignancies – lymphoma and leukemia. The most important thing for the AP to keep in mind is that although rare (e.g., one to three new cases per million patients for osteosarcoma), they do occur and will often present to the primary care provider with pain complaints. Sadly, there is often a delay from symptom onset to presentation and then from presentation to the primary care provider before radiographs taken and the diagnosis made. The most common malignant bone tumors will be briefly described along with general treatment and prognosis. Like all malignant tumors, overall health, age, location, size, grade, and associated metastatic disease will play a role in determining treatment and prognosis. The most common non-hematologic malignant primary bone tumors are, in order, osteosarcoma, chondrosarcoma, and Ewing's sarcoma. Other than adamantinoma other malignant tumors not discussed but the AP should recognized the following are also malignant tumors: chordoma, angiosarcoma, and fibrosarcoma (also known as malignant fibrous histiocytoma) [12, 13].

The three malignancies to be discussed have the following in common:

- They look "bad" on radiographs with a mixture of destructive (lytic) lesions and "out-of-control" bone growth.
- They all present with progressive pain, slightly more common in males. *Osteosarcoma and chondrosarcoma* have no particular racial preference, but *Ewing's* sarcoma is extremely rare in patients of African origin.
- Finally, delay in diagnosis of several months is common with osteosarcoma and Ewing's, but chondrosarcomas often have a delay in diagnosis of several years.

11.3.1 Osteosarcoma

As you would expect with a bone tumor, osteosarcomas are most common in teenagers when rapid growth occurs, and although they can occur in any bone, they are most common in the proximal humerus, distal femur (Fig. 11.9), and proximal tibia. By the time of diagnosis, most patients already have metastatic lesions, but the metastatic lesions may not be obvious. Workup includes plain films, MRI to evaluate soft tissue extension and "skip lesions" in the medullary canal of the bone in which the primary lesion is found, and a CT of the chest looking for metastases. Treatment currently includes preoperative chemotherapy followed by wide or radical resection of the tumor followed by more chemotherapy. Postoperative chemotherapy is adjusted based on the amount of tumor necrosis found on pathologic examination of the resected tumor. Osteosarcomas are not radiation-sensitive. Long-term prognosis is 60–90% survival if there are no gross metastases on presentation.

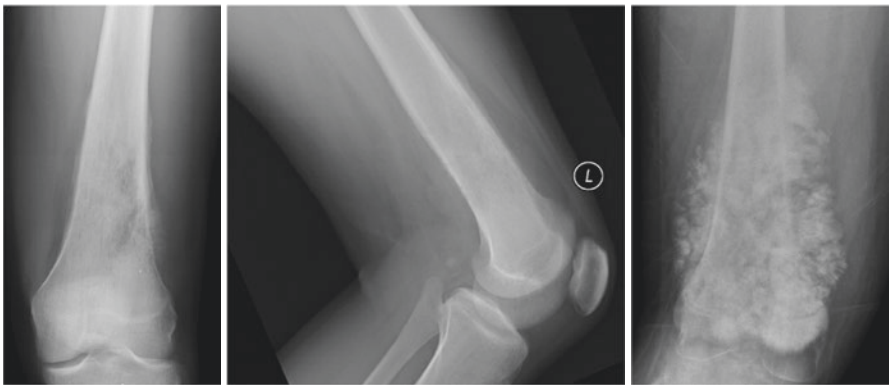

Fig. 11.9 Osteosarcoma: note its aggressive, "ugly" appearance compared to a nonossifying fibroma or unicameral bone cyst. In the second radiograph, the tumor's presence is mostly noted by the fuzziness and periosteal elevation. The third picture is one in a much more advanced stage. (Courtesy Medical College of Georgia, Department of Orthopedics)

Two special cases of osteosarcoma deserve attention. Patients with Paget's disease have a higher incidence than the general population of osteosarcomas (1–5%), and if present, the overall prognosis is worse. The second category is those patients who have undergone radiation therapy for other cancers can develop osteosarcomas in unusual spots making diagnosis and resection difficult [14, 15].

11.3.2 Chondrosarcomas

Chondrosarcomas are the slowest growing of the three malignancies discussed, and it is not unusual for it to be several years before they are diagnosed. They are most common in the 40- to 60-year-old age range with most being in the proximal humerus, proximal femur, or pelvis (Fig. 11.10). Treatment is wide or radical resection of the primary tumor and wide or radical resection of the isolated pulmonary metastases. Chondrosarcoma is not sensitive to either radiation or chemotherapy. Prognosis is very dependent on grade and metastases; subsequently, the 10-year survival rates range from 20 to 90%.

Two special cases of secondary chondrosarcomas should be remembered. Those are in patients with Ollier's disease and Maffucci's syndrome both of which have a very high incidence of chondrosarcomas arising from their enchondromas. Patients with isolated osteochondromas may have a higher incidence as well, although firm data on degeneration of osteochondroma to chondrosarcoma is not available [16, 17].

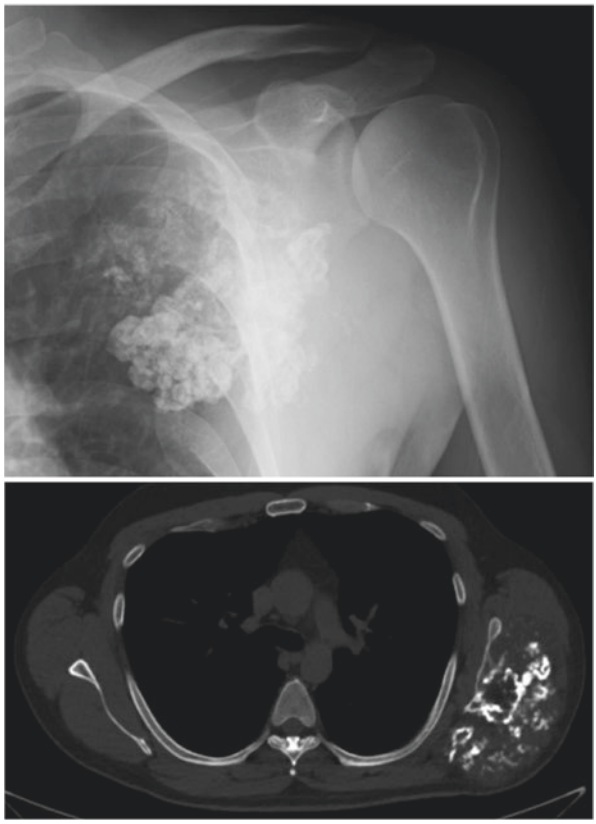

Fig. 11.10 Chondrosarcoma of the scapula, plain film and CT scan. (Courtesy Medical College of Georgia, Department of Orthopedics)

11.3.3 Ewing's Sarcoma

Ewing's sarcoma is the third most common malignant bone tumor and is a small round cell tumor occurring mostly in the young (less than 25 years old) and is slightly more common in males. Unlike osteosarcomas and chondrosarcomas, it almost never occurs in individuals of African heritage. Pain is the presenting complaint, but the patient may also have symptoms consistent with osteomyelitis (fever, elevated erythrocyte sedimentation rate, elevated C-reactive protein, and an elevated white count). It can appear in any region of the bone. It more commonly starts in the metaphysis (Fig. 11.11) but often not noticed until the disease affects the diaphysis. Evaluation includes MRI to detect the full extent of the bone involvement and any soft tissue extension. CT of the chest is done looking for metastases.

Treatment is either surgery for the primary lesion or radiation therapy; pretreatment and posttreatment chemotherapy is used with both options. Radiation is used for the more difficult areas to resect, e.g., the sacrum, but there is debate as to which ultimately works better.

Five-year survival rate if there are no metastases is around 70%, but if there are metastases, the survival rate at 5 years drops to an abysmal 15–20% [18].

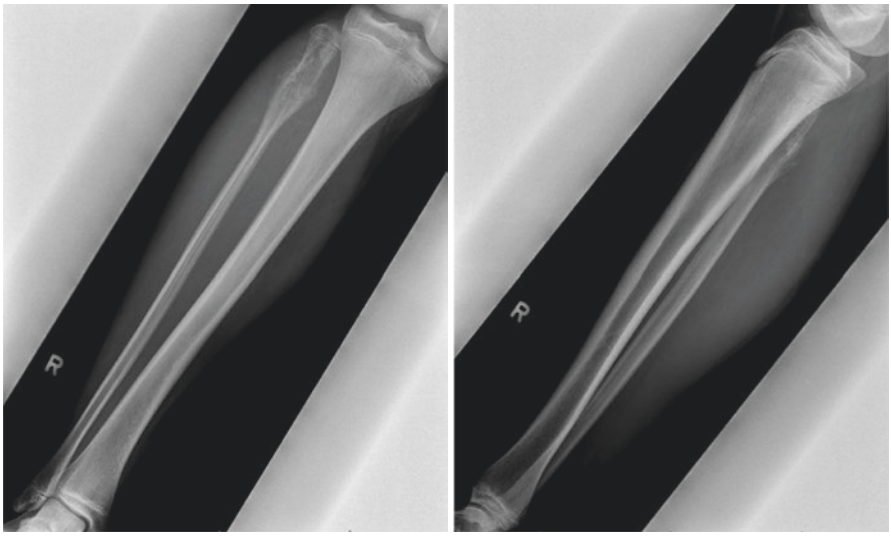

Fig. 11.11 Ewing's sarcoma of the proximal fibula. (Courtesy Medical College of Georgia, Department of Orthopedics)

11.3.4 Adamantinoma

This entity has been almost exclusively described in the tibial diaphysis. It presents in a similar age group to giant cell tumors ranging from 20 to 40 years of age. This has been described as a low-grade malignant, locally aggressive process with epithelial derivation. Presentation typically includes a prolonged history of localized pain accompanied by clinically deformity and mass. Radiographs demonstrated a diaphyseal lesion with multiple well-circumscribed lucencies with interposed sclerotic bone primarily in the cortical bone. Cortical destruction may accompany the lesion. There is usually no periosteal change. Biopsy typically demonstrates nests of epithelial-appearing cells in a glandular or palisading pattern in a fibrous background. Treatment of this lesion consists of a wide margin resection with allograft or a megaprosthesis. Given its low grade, chemotherapy and radiation therapies are not pursued; however, monitoring for distant pulmonary metastasis is typical [19, 20].

11.4 Metastatic Cancer to the Bone

In adult patients over 35–40 years of age who present with pain and a bony lesion on radiographs, the clinicians' assumption should be that it is either metastatic cancer or multiple myeloma (which can also present as a solitary plasmacytoma) until proven otherwise. Even if the primary cancer is known, the AP should be careful before automatically concluding that the bone lesion is the same as the known

primary. In order of frequency, the primary carcinomas that metastasize to bone are prostate in men and breast in women, followed by lung, renal cell, and thyroid in both sexes.

Diagnostic studies in addition to the usual blood work include a whole-body bone scan, looking for other metastatic lesions. If the primary tumor is unknown, a serum protein electrophoresis to rule out multiple myeloma is done, in addition to a chest radiograph, thyroid studies, and a CT of the thorax, abdomen, and pelvis.

Treatment is a team effort involving the orthopedist, the oncologist, possibly the radiation oncologist, the primary care physician, as well as the patient and family. For some lesions, especially those of the upper limb, treatment is directed at the primary cancer through additional chemotherapy and localized radiation. For an isolated metastasis with the primary under good control, resection of the tumor may be appropriate. One of the more difficult issues to decide is when to prophylactically fix a bone that is weakened by metastatic cancer before it breaks. Ideally the fixation should be done before it breaks as blood loss, morbidity, and mortality all increase when trying to fix a fracture of a bone weakened by metastatic disease. Preoperative embolization should be considered for renal cell metastatic lesions as renal cell metastatic lesions can bleed profusely.

Since predicting survival on an individual basis can be extremely difficult, the clinician should approach the patient with a realistic, but not fatalistic or pessimistic, approach. Mears et al. came up with a point system to determine if a fracture should be fixed, but each patient's case needs to be approached with the individual's health, desires, needs, and expectations in mind [21, 22].

Two methods of determining the need for prophylactic fixation are used in general but neither are absolute. One is a scoring system based on the site, amount of pain, size, and nature of the lesion (blastic vs lytic). The other accepted criteria are those lesions that are any of the following: painful AND unresponsive to radiation therapy, destruction of more than 50% of the cortex, greater than 2.5 cm, or avulsion of the lesser trochanter of the proximal femur. As always, these criteria are general, and the specific needs, wants, and condition of the individual patient should be kept in mind.

11.5 Benign Soft Tissue Tumors

11.5.1 Ganglion Cyst

Patients with ganglion cysts most commonly present with a painful or non-painful, small (less than 1.5 cm) round mass on the dorsal aspect of the wrist. There is no antecedent trauma for most patients. Some patients just want to know what it is, while others may want it removed for cosmetic reasons, and for others, despite its small size, it can be very painful. Physical exam shows a smooth round mass that is not usually painful. A light placed against the mass will allow some light passage as the ganglion is translucent. If desired, the mass can be aspirated obtaining what

looks like and has the consistency of pale apple jelly. When aspirated, the mass often recurs. Radiographs are unremarkable.

The exact cause of the ganglion is unknown. The best explanation is an outpouching of the joint capsule with a one-way trapdoor allowing joint fluid into the cyst but not vice versa. The cyst may be especially painful when first forming as the tissue is being stretched, but then the pain subsides.

Treatment depends on the patient. Doing nothing is an excellent approach as these do not undergo malignant degeneration. Aspiration has a high recurrence rate but is not as expensive as a trip to the operating room. Operative excision involves removing the cyst and exercising a small portion of the joint capsule where the cyst is attached via a stalk. This works 85 to 90% of the time.

Complications of surgery include recurrence; stiffness; injury to the dorsal sensory nerves of the hand, both ulnar and radial; and unsightly scars. The differential diagnosis includes tenosynovitis, a small lipoma, as well as the rare soft tissue sarcoma. Care must be taken not to mistake an arterial aneurysm on the volar aspect of the wrist for a benign ganglion cyst.

Although dorsal ganglion wrist cysts are the most common, they can occur near any joint. They may or may not be symptomatic and if in the right place can cause other symptoms such as tarsal tunnel syndrome in the ankle, compression neuropathy of the inferior branch of the suprascapular nerve (which supplies the infraspinatus muscle), or vascular compression.

The largest ganglion is a popliteal cyst or Baker's cyst in the posterior aspect of the knee. Some of these cysts are simply an inflamed bursa in the posterior aspect of the knee, while others are a true cyst extending from the posterior capsule of the knee joint. Most that come from the knee have some associated pathology such as arthritis or a tear in the posterior horn of the medial meniscus. Correcting the intra-articular pathology may or may not cause the cyst to subside or at least become less symptomatic. Although excision of a popliteal cyst can be done, it is to be approached cautiously given the close proximity of the popliteal vessels in addition to the tibial and peroneal branches of the sciatic nerve. Once the cyst has stopped expanding, the pain associated with the stretching of the soft tissue normally subsides. With reassurance to the patient of the benign nature and natural history of a popliteal cyst, excision is rare. Differential diagnosis of the popliteal cyst includes soft tissue tumors such as lipoma and fibrosarcoma [23–26].

11.5.2 Lipoma

Patients with lipomas are typically middle-aged women who present with a painless mass that varies in size and feels fatty. There is no history of trauma, and on physical exam, the overlying skin is normal, the mass is nontender and feels firm, not cystic. It does not transilluminate.

Radiographs may show some soft tissue swelling but are otherwise unremarkable. On MRI, the lipoma shows the same signal intensity as the subcutaneous fat.

Treatment options include observation or marginal excision. The difficulty is that a few of these may be liposarcomas. The malignant liposarcomas tend to be larger and deeper and occur more often in males. Thus, any lipoma needs to be examined carefully by the pathologist to rule out liposarcoma. If the lipoma does turn out to be a liposarcoma, then a wide rather than marginal excision is indicated as radiation and chemotherapy have no effect [27–29].

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Pediatric Orthopedics

12

12.1 Physeal Injuries: Salter-Harris Fractures

Infants, children, and adolescents have growth plates, and in some cases, the epiphysis has not yet ossified which can make diagnosis of fractures involving the physeal plate difficult. If the epiphysis is ossified, fractures involving the growth plate have five classifications as designated by Drs. Salter and Harris [1]. It is important to remember the Salter-Harris classification only describes the location of the fracture line, not any associated displacement of the fracture fragments. Salter-Harris I fractures are through the growth plate. Salter-Harris II fractures are partially through the growth plate and then angle out through the metaphysis and are most commonly seen in fractures of the distal radius. Salter-Harris III fracture patterns are through the physeal plate but exit ultimately through the epiphysis. The most common example of a Salter-Harris III is a juvenile tillaux fracture of the distal tibia. Salter-Harris IV fractures course through the epiphysis, the physis, and the metaphysis. A triplane fracture of the distal tibia is the classic example of a Salter-Harris IV. Finally, a Salter-Harris V is a crush injury to the physeal plate (Fig. 12.1).

For nondisplaced Salter-Harris I fractures, radiographs may be negative except for some soft tissue swelling or slight widening of the growth plate. Thus, the diagnosis may have to be made based on history and point tenderness over the physis. Except for Salter-Harris V fractures, the physeal plate tolerates injury surprisingly well, but when reducing the fracture, care should be taken to keep manipulation to a minimum. Some of these fractures will require pinning to maintain reduction, but the pins should be removed as soon as the fracture is thought to be stable (e.g., supracondylar fractures of the distal humerus) [2].

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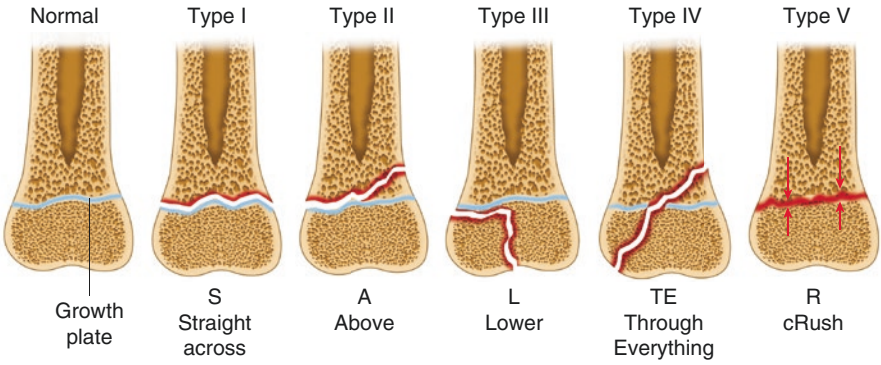

Fig. 12.1 The five different Salter-Harris fracture types. The AP should remember this only describes the fracture line location, not the amount of displacement

12.2 Developmental and Genetic Conditions

12.2.1 Cerebral Palsy

Cerebral palsy is a term used to cover a wide variety of clinical manifestations that all originate from a brain injury, malfunction, or disease that affects children less than two but most commonly is present at birth. Although the brain injury does not progress with time, the clinical manifestations may worsen as the patient matures. For instance, the patient may be able to crawl or inchworm across the floor but never develop the coordination needed to stand or walk. In many cases, a specific cause is never identified, although a number of risk factors have been. The latter include perinatal or prenatal hypoxia, low birth weight, drug or alcohol use by the mother, and genetic abnormalities among others.

Cerebral palsy can be classified according to the associated neuropathy or the anatomic regions afflicted. The neuropathic types are *spastic*, *athetoid*, *ataxic*, and of course *mixed*. The *spastic* is most common and is the one most laypeople think of when cerebral palsy is mentioned. The spastic muscles are under poor control and despite spasticity can be weak and fatigue easily. Patients with the *athetoid* type are those patients who, like adults with Huntington's chorea, have uncontrolled writhing motions of the limbs, neck, and tongue. *Ataxic* cerebral palsy, the least common of the CPs, manifests in lack of coordination, tremors, and poor balance. *Mixed* is self-explanatory. All patients with CP may or may not have some type of mild to severe mental retardation. The severity of the disease varies with some patients having barely detectable disease to others being wheelchair bound for life.

Anatomic classification of CP looks at which combination of limbs are involved. Quadriplegic CP affects all four limbs and may affect speech and swallowing as well. Diplegic cerebral palsy affects primarily the lower limbs, although there is some upper limb involvement as well. Finally, hemiplegic affects one side of the

body, usually the upper limb more than the lower; there may be limb length inequality with the affected side being shorter. The clinician should keep in mind both the neurologic and the anatomic type.

Orthopedically, the two most common areas to address are spine deformities and hip dislocation. In addition, patients with CP may have joint contractures or chronically spastic muscles that can be addressed with capsular releases, tenotomies, or tendon lengthening. Timing of what may be multiple surgeries is important so that the number of hospitalizations can be minimized. Physical therapy is crucial to help patients and families learn adaptive gait patterns and minimize joint contractures. The speech may be affected even though mental function is otherwise normal.

Finally, it is important for the family to understand that cerebral palsy is a brain dysfunction, and although orthopedic treatment can improve function, the underlying disease is unchanged, and the patient will never be normal [3–5].

12.2.2 Charcot-Marie-Tooth Disease (CMT)

CMT is one of the seven different hereditary motor sensory neuropathies (HSMN). HMSN I and II are the two variants that are clinically manifested as CMT. Type I is inherited in autosomal dominant fashion. The most common manifestation is a cavovarus foot such that any patient with unusually high arches should be evaluated for HMSN. There is associated calf atrophy, and in adult-onset forms, there may be wasting of the intrinsic muscles of the hands or the feet.

Treatment varies depending on the severity and expected remaining growth and ranges from various tendon transfers to osteotomies or arthrodesis. Hip dysplasia and scoliosis are also more common in this population. Like cerebral palsy, the severity can vary [6, 7].

12.2.3 Down Syndrome

Trisomy 21, Down syndrome, occurs in patients who have three copies of the 21st chromosome. This affects multiple organ systems and is normally diagnosed at birth. Physical examination shows one palm crease (rather than the normal two) called a simian crease, a flattened face, and upward slanting eyes. Developmental milestones such as walking are delayed, and some degree of mental retardation is normal. Congenital heart disease (atrial or ventricular septal defects), duodenal atresia, leukemia, and hypothyroidism are present in many patients.

Orthopedically, there are a number of cervical spine abnormalities, the most common of which is instability between C1 and C2 manifested as a widened atlanto-dens interval. It is usually asymptomatic, so treatment is controversial. Half of patients with Down will develop scoliosis. Although developmental hip dysplasia is rare, these patients do sometimes develop subluxation of the hip which can lead to dislocation starting in late childhood. It appears to be the result of abnormal pelvic and acetabular growth. Slipped capital femoral epiphysis is more common,

perhaps due to the higher incidence of hypothyroidism in these patients. Finally, Down patients tend to have flexible flat feet, thus increasing their risk for developing bunions [8, 9].

12.2.4 Dwarfism

Dwarfism falls under a broad category called skeletal dysplasias which includes over 200 different conditions, all of which are characterized by short stature and other associated deformities. When reading about skeletal dysplasias, a few terms are helpful. The short stature can be the result of a disproportionately short trunk or just short limbs. *Rhizomelic* dwarves have short femurs and humeri. *Mesomelic* dwarves have shortened tibias and forearms, while *acromelic* dwarves have shortened hands, feet, fingers, and toes.

The most common dwarfism is achondroplasia, and even it is relatively rare with only 6000–10,000 patients in the United States. It can be inherited as an autosomal dominant condition, but about 80% are the result of spontaneous mutations of the fibroblast growth factor receptor-3 gene which affects the cartilage growth. Their short stature is due to rhizomelic shortening of the upper and lower limbs, but they also have extra space between the middle and ring fingers resulting in a "trident" hand. The face shows overgrowth of the forehead, so called frontal bossing with undergrowth of the lower two-thirds of the face. Lumbar lordosis is present and worsens with age; the knees are usually in varus but can be in valgus. Intelligence is normal but motor development is delayed; the latter may be related to a small foramen magnum at the base of the skull. Ear, nose, and throat problems include sleep apnea, and respiratory difficulties are manifested by decreased vital capacity; they may have hydrocephalus requiring a ventriculoperitoneal shunt. With all these potential problems, caring for patients with achondroplasia and other forms of dwarfism management is a truly team approach.

Orthopedically, treatment of spine deformities such as kyphosis or lordosis and spinal stenosis is common. If the genu varum (or more rarely, genu valgus) is severe, osteotomies may be necessary to correct the deformity. Bracing will not work due to lax ligaments and a short thigh. Currently, some patients are opting for limb lengthening; this is a huge time commitment of up to 2 years with only a 25-cm gain in height [10, 11].

12.3 Child Abuse

Child abuse can be difficult to diagnose, as few of us like to think that parents, relatives, and other adults will physically abuse or sexually assault defenseless children. In addition, no clinician wants to damage the trust that exists between a clinician and a caregiver (e.g., parent or grandparent) by mistakenly accusing someone of child abuse.

A careful history and thorough physical examination is necessary in all cases of suspected abuse keeping in mind both sexes and people from all socioeconomic classes can be guilty. Items obtained during the history that may cause increased suspicion include a history inconsistent with the injury or injuries, changing history, or different history depending on who is questioned. Family background with significant stress such as job loss, divorce, death in the family, and drug or alcohol abuse should raise suspicion. Delay in seeking treatment may be another clue. Fractures from falling out of bed are rare.

Physical examination may show a variety of soft tissue injuries (scabs, bruises, burns) all in different stages of healing. Keep in mind that some children, especially boys, are overly energetic. Head injuries, especially in those patients less than two, need to be carefully evaluated with serious consideration given to obtaining a CT scan. Multiple fractures in various states of healing are common; some previously undiagnosed or untreated are another clue. Obvious callus on a long bone fracture at initial presentation is another warning sign as fractures of the humeral or femoral shaft in patients less than 2–3 years of age are rare. Rib fractures are also common among child abuse victims. A skeletal survey may be necessary to document any other fractures but only in cases with strong suspicion.

Before concluding that the injuries of soft tissue or bone are the result of abuse, the following diagnoses should be considered. Bruising could be the result of a coagulopathy like hemophilia or a blood dyscrasia like lymphoma or leukemia not to mention a nutritional deficiency like scurvy. The list of possible underlying bone diseases is even longer and includes osteogenesis imperfecta, rickets, leukemia, osteopetrosis, fatigue fractures (especially as parents push the children into organized sports at a very early age), various tumors, and congenital indifference to pain.

All states now have laws stating that if there is "reasonable suspicion or belief" that child abuse has occurred, reporting is mandatory. States have also granted immunity from civil suits to healthcare providers who report abuse, but many hold the healthcare provider liable for not reporting. Confidentiality laws are overridden in cases of suspected abuse [12–14].

12.4 Connective Tissue Disorders

Two types of connective tissue disorders are of interest to the orthopedic practitioner: *Ehlers-Danlos syndrome* and *Marfan syndrome*. The former has at least 12 subtypes while the latter has at least 4.

12.4.1 Ehlers-Danlos

Ehlers-Danlos syndromes are a collection of genetic collagen disorders that appear as a variety of combinations of some or all of the following: lax skin, lax ligaments, easy bruising, osteoporosis or osteopenia, and calcification of the soft tissues. These

patients may first be diagnosed in the orthopedic clinic with excessive joint laxity or scoliosis. In some subtypes, joint laxity is so severe that arthrodesis of the affected joints is required. Most cases of Ehlers-Danlos are either autosomal dominant or recessive except type V which is X-linked. Expression, i.e., severity for some types, is variable. Some have had the specific gene mutation identified.

12.4.2 Marfan

Marfan patients are often first diagnosed in the orthopedic clinic presenting with sprained ankles or scoliosis. Clinically, these patients are tall with abnormally long fingers, long narrow limbs, the previously mentioned scoliosis, and pectus excavatum or carinatum. It is important to remember that eye problems (lens displacement) and cardiac abnormalities are common, and it is imperative to involve a cardiologist to screen for the latter as some of the cardiac abnormalities like aortic dilation or aneurysm can contribute to sudden death, especially in athletic events. Ophthalmologic exams should be routine.

Neither the scoliosis nor the ligamentous injuries are treated significantly different from normal orthopedic patients except for awareness of associated cardiac abnormalities. Like many orthopedic conditions, even though it is an autosomal dominant trait, severity clinically can vary widely [15, 16].

12.4.3 Fibrous Dysplasia

Fibrous dysplasia is a difficult diagnosis to categorize as it acts as both a benign neoplasm and being associated with endocrine dysfunction. Like many other orthopedic diseases, it comes in different forms with varying degrees of severity. The monostatic form is frequently discovered incidentally when radiographs are being taken for other reasons. This form is not associated with endocrine disease and does not need treatment unless there is a pathologic fracture. One location that can cause significant difficulty is the proximal femur (Fig. 12.2) where the bone remodeling problem of fibrous dysplasia can result in a severe varus deformity known as a shepherd's crook.

Polyostotic disease is fibrous dysplasia that can be associated with endocrine disease also known as McCune-Albright syndrome. Frequently, the patient will have light brown macular irregularly shaped skin lesions unlike neurofibromatosis where the skin lesions have smooth borders.

The bone pathology is a remodeling problem, that is, there is less bone formation and more bone resorption similar to age related to osteoporosis. However, the bone that is formed is formed by the intramembranous route rather than the more normal endochondral route. Radiographically, this results in a "ground glass" appearance. The weak bone, deformity, and associated pathologic fractures are difficult to treat. Both autograft and allograft are used, but intramedullary fixation is almost always necessary as the cortices are thin and are not strong enough for screw fixation.

Some research has been done with bisphosphonates, but long-term outcomes are still pending [17].

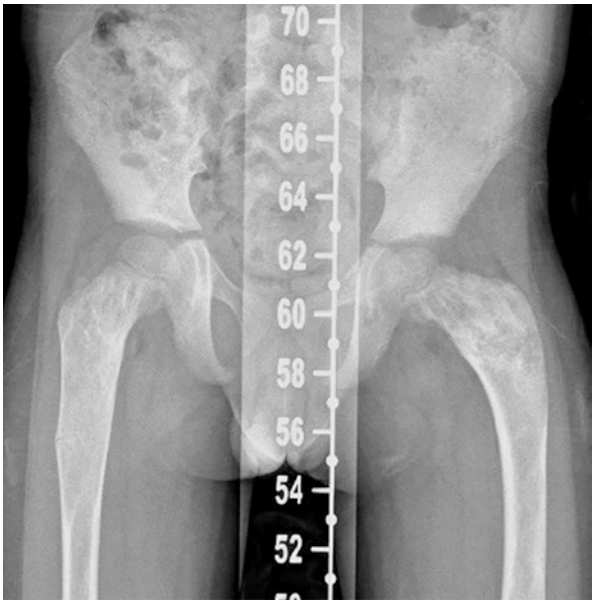

Fig. 12.2 Typical example of a "shepherd's crook" in the proximal femur in a patient with fibrous dysplasia. (Courtesy Medical College of Georgia, Department of Orthopedics)

Table 12.1 Adapted from Lovell and Winter's *Pediatric Orthopaedics* [18]

The major muscular dystrophy inheritance patterns:
Duchenne, Becker, Emery-Dreifuss: sex-linked
Limb-girdle, infantile: autosomal recessive
Facioscapulohumeral, distal, ocular, oculopharyngeal: autosomal dominant

12.4.4 Muscular Dystrophy

There are a whole host of muscular dystrophies where the muscle does not function or does not function properly, and unlike cerebral palsy, this is a true muscular problem, not a neurologic disorder that results in muscular dysfunction. The most common way to sort the muscular dystrophies into categories is by their inheritance patterns: X-linked, autosomal recessive, and autosomal dominant (Table 12.1).

Diagnosis of muscular dystrophy and the specific type depends, as usual, on history (especially family history) and physical examination supplemented by blood work, EMG/NCS, and muscle or nerve biopsy. Physical exam should look for gait and sitting abnormalities. A positive Gower sign is when a child stands from a sitting posture by using his hands to "walk up" his thighs to obtain the erect position. Treatment will depend on the type and severity of the disease but may include both bracing and physical therapies to maintain strength and prevent contractures. Surgery may be necessary for the contractures, and some patients with muscular dystrophy will require scoliosis correction. Wheelchairs are eventually necessary in some and cardiopulmonary intervention in other types [19].

The most common muscular dystrophy is Duchenne and will be discussed here just enough to give the AP student an idea of the extent of the disease and treatment options.

12.4.5 Duchenne Muscular Dystrophy

Duchenne muscular dystrophy is the most common of the dystrophies and is X-linked, meaning it is only present in males. Because it is frequently a result of a mutation in the X chromosome, family history will be positive only about 65% of the time.

The patient will be brought in by the family, usually between 3 and 6 years of age with the complaint of delayed walking or excessive clumsiness, i.e., more falling than expected for someone in the immediate post-toddler stage. A common finding is a positive Gower's sign where the toddler brings himself erect by "walking" his hands up his legs as his hip muscles are too weak to do the work. Since Duchenne affects the proximal muscles first, the hip muscular weakness causes gait changes including a wide-based circumduction gait with excessive shoulder swaying, the latter to help with balance difficulties because the pelvic girdle musculature is weak. The shoulders become weaker several years after the hip and thigh muscles preventing the significant use of crutches. Since it is a muscular disease, sensation remains normal.

Once the diagnosis has been confirmed, physical therapy involvement early on is important. The therapist has several goals involving implementing a daily strengthening program as even a short period of disuse such as being in bed sick for several days can result in significant and permanent loss of strength. Other physical therapy functions include stretching and brace application to prevent contractures and teaching eventual wheelchair use.

Fractures can be difficult to manage because any immobilization can result in significant strength loss or contractures. Contractures, if prevented or delayed, can prolong the ability to walk in some patients. Most patients develop scoliosis once they stop walking, and although the curve can be slowed with bracing, it cannot be stopped. Surgical fusion before the associated cardiopulmonary dysfunction is too severe is generally recommended. Death occurs in the early 20s from either pneumonia or heart failure as the cardiac muscle is affected in addition to the skeletal muscle [20, 21].

12.5 Neural Tube Defects

12.5.1 Myelomeningocele

Myelomeningocele is one of the four categories of what are referred to as *neural tube defects*. Patients with a myelomeningocele are best treated in specialized centers where neurosurgeons, orthopedic surgeons, psychiatrists, pediatricians, urologists, and various support staff such as social workers, occupational therapists, and

physical therapists are available. This section will give only a brief overview to introduce the AP to the nature of the problem.

The four types of neural tube defects are *meningocele*, *myelomeningocele*, *lipomeningocele*, and *rachischisis*. There is some debate about whether the problem arises from a failure of the neural tube to close or a later failure such that the tube "opens" up again. From a prevention standpoint, avoidance of teratogenic agents and supplementation with folic acid prior to and during pregnancy seem to work best.

A meningocele is simply a cyst that does not have any associated neurologic injury. Closure by a neurosurgeon is the only treatment needed. A myelomeningocele is a cyst that has neurologic elements included with subsequent neurologic abnormalities. It is important to remember that it is a disorder of the entire central nervous system. There are three important associated problems: a tethered cord (which can "retether" after being freed), hydrocephalus (which may be the result of closing the myelomeningocele as the cerebrospinal fluid then has nowhere to go), and an Arnold-Chiari malformation. An Arnold-Chiari (which has three subtypes) is herniation of the brain stem with or without a portion of the cerebellum through the foramen magnum. Muscle function may or may not be present but is frequently uncoordinated when present. Most patients with myelomeningocele remain in a wheelchair for life depending on the level of functional motor control. Common problems include scoliosis, hip dysplasia, knee hyperextension and flexion contractures, and a variety of foot abnormalities.

A lipomeningocele is a cyst that includes a lipoma intertwined with sacral nerve roots. Neurologic function starts off normal or near normal, but careful monitoring is appropriate as rapid progression of the neurologic dysfunction happens frequently.

Finally, rachischisis is the worst as there is a wide-open neural tube defect where the muscles, bone, nerves, and spinal cord have no covering tissue [22–25].

12.6 Neurofibromatosis

Neurofibromatosis is the most common single-gene defect and is autosomal dominant although up to half are the result of spontaneous mutation thus not inherited. Like other orthopedic disorders, there are several subtypes (four) but only type I, also known as von Recklinghausen disease (Table 12.2), will be discussed here. The diagnosis is not usually made at birth except in patients born with pseudo-arthrosis of the tibia. By 5 years of age, the criteria necessary to diagnose neurofibromatosis

Table 12.2 Items needed to diagnose von Recklinghausen disease (two out of seven)

Six cafe-au-lait spots
Two neurofibromas
Freckles in the axilla or groin area
Optic glioma
Hamartoma of the iris (at least two)
Bone changes such as cortical thinning
Relative with von Recklinghausen (brother, sister, or parent only)

Adapted from Lovell and Winter's *Pediatric Orthopaedics*

type I become apparent. Unlike fibrous dysplasia, the brown "cafe au lait" spots have smooth borders in neurofibromatosis, whereas fibrous dysplasia skin lesions have irregular borders (referred to as coast of California and coast of Maine lesions, respectively).

The most common orthopedic problems are scoliosis, congenital pseudarthrosis (of any long bone), nonunion of fractures, and localized overgrowth. Half the scoliosis cases are idiopathic and can be treated as one would normally treat adolescent idiopathic scoliosis. The other half are sharply angular with vertebral body abnormalities and need to be treated aggressively with surgery as bracing will fail. Although pseudarthrosis can affect any long bone, it is most common in the tibia and can be present at birth presenting as an anterolateral bowing of the tibia at the junction of the middle and distal thirds. If not already fractured, the cortices are extremely thin. Full-time total contact arthrosis may prevent fracture. If a fracture occurs, it can be extremely frustrating to treat and may ultimately lead to amputation. The pathologic bowing of the tibia in neurofibromatosis is not to be confused with the much more benign posteromedial bowing that corrects itself with time. (Remember anterolateral is always lousy.) [26]

The neurofibromas can become malignant neurofibrosarcomas, so any change in size or development of pain in a previously non-painful neurofibroma should be viewed with suspicion.

Non-orthopedic problems such as hypertension, precocious puberty, short stature and mental impairment (not necessarily mental retardation), and attention deficit disorder can also occur [27].

12.7 Metabolic Disorders of the Bone

12.7.1 Osteogenesis Imperfecta (OI)

As the name implies, osteogenesis imperfecta is a genetic defect wherein the bones are not normal – they are fragile and imperfect. The diagnosis should be kept in mind when deciding if a child's fracture is the result of abuse or are the bones just weak. There are four types of OI, two inherited as autosomal recessive and two as autosomal dominant. Fracture rate, mortality, ambulatory ability, and long-term outcomes vary depending on the type and severity. Etiology is a gene defect in the seventh or 17th chromosome with type I producing insufficient but normal collagen, while types II, III, and IV produce abnormal collagen.

In addition to weak bones, typical features may include any of the following depending on the type and expression of the disease: blue sclera (type I), dental abnormalities (brown teeth), deafness, or a small, triangular face. Of note, the fractures heal normally but are still weak. Type II is universally lethal.

Fractures should be treated with lightweight bracing to prevent stress fractures in adjacent bones. Consideration should be given for performing osteotomies and intramedullary rodding for deformity or recurrent fractures. Finally, any scoliosis is notoriously difficult to treat due to the osteoporotic nature of the spine [28].

12.7.2 Osteopetrosis

Osteopetrosis (marble bone disease) appears to be the opposite of osteogenesis imperfecta, with radiographs of long bones and tibia showing little or no intramedullary space: so called chalk bones (Fig. 12.3).

There are three subtypes, two of which are autosomal recessive, one autosomal dominant. Despite their thick appearance, the bones are actually quite fragile. Because of poor blood flow, osteomyelitis is much more common [29].

12.7.3 Rickets

Rickets is a childhood form of osteomalacia. Both are the end result of poor calcium or phosphorus (or both) utilization in building bone. The causes are numerous including vitamin D deficiency or malabsorption, calcium deficiency, and kidney disease.

Severe cases are easy to recognize, but in the first world, the signs may not be so obvious. Children with severe disease can sit for a long time but have a short attention span. They are below the third percentile for height but weight is normal. On physical exam, the forehead is large known as frontal bossing. Younger children have widened or delayed closure of the suture lines of the skull, dental caries, enlargement of the cartilaginous portion of the ribs, and pectus carinatum. The limbs are weak as are the abdominal muscles, the latter contributing to a pot belly. The patient may have short limbs and genu varum in addition to enlarged joints.

Diagnosis is made on the basis of physical exam and radiographs, but determining the cause (e.g., hypophosphatemic rickets vs simple vitamin D deficiency) may require an extensive workup. Treatment is directed at the underlying cause in addition to treating fractures and any associated deformities. Many deformities may correct spontaneously with treatment of the underlying cause [30, 31].

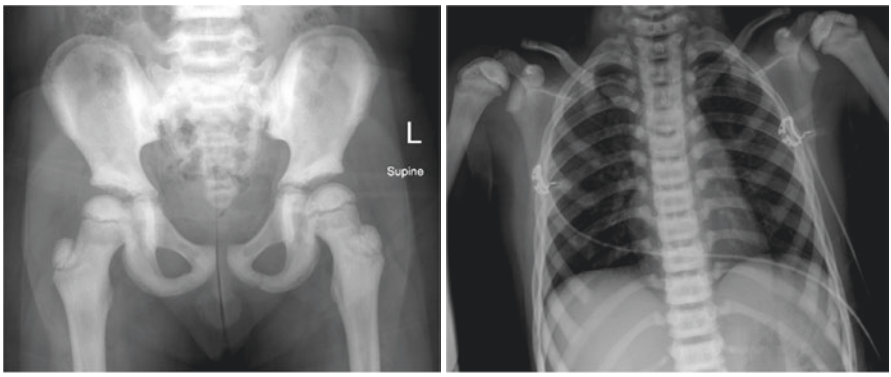

Fig. 12.3 Pelvis and chest radiographs of an infant with osteopetrosis. Note the essentially uniform density of the bone with almost no medullary canal being visible. (Courtesy Medical College of Georgia, Department of Orthopedics)

12.7.4 Scurvy

Mentioned for completeness, scurvy is rare in the developed world. The lack of vitamin C (which both humans and guinea pigs are unable to make) results in poor-quality collagen which affects most organ systems of the body. The result in children is weakness, easy bruising, and osteoporotic-appearing bone.

12.7.5 Paget's Disease

Paget's disease is thought to be of a viral origin yet only affects patients over 55 to 60 years of age and of Anglo-Saxon descent. It can be localized to one bone or be in multiple locations (the latter is known as polyostotic).

The underlying pathology is excessive osteoclast activity (bone resorption) and excessive osteoblast activity (bone deposition) activity resulting in the stereotypical bone appearance of thick trabeculae. Treatment is primarily medicinal consisting of NSAIDs, calcitonin, and bisphosphonates. Despite the extensive bone activity, the bone is weaker than expected, fracture healing is impaired with greater than expected blood loss, and joint arthroplasty results are poorer than expected. The patient should be monitored as there is a chance (1% is the figure usually quoted) of the bone with Paget's transforming to osteosarcoma [32].

12.8 Sickle Cell Disease

Sickle cell anemia is a common disease among African Americans (1 in 500) [33]. There are other related diseases including thalassemia and hemoglobin SC disease that will not be discussed here. As is well-known, a point mutation of valine for glutamic acid in the gene coding for the β (beta) chain of the hemoglobin molecule results in a distortion of the hemoglobin molecule when the oxygen it is carrying is removed. This causes the erythrocyte to become sickle in shape, clogging up the smaller blood vessels. Clinically, the manifestations can be in any organ system (Table 12.3).

A sickle cell crisis is a localized phenomenon where the blood flow is impaired causing a great deal of pain. Treatment is oxygenation, hydration, with

Table 12.3 Most common organ systems affected by sickle cell anemia

Bone: Infarcts, cortical thinning, osteomyelitis
Fingers: Dactylitis (swollen fingers)
Joints: Septic arthritis, osteonecrosis
Genitourinary: Enuresis, priapism
GI: Cholelithiasis
Pulmonary: Acute chest syndrome (variety of causes, potentially fatal)

consideration for a partial exchange transfusion; however, a sickle cell crisis may be difficult to differentiate from an acute case of osteomyelitis. Unlike the normal population, salmonella is the second most common cause of osteomyelitis in sickle cell patients although staphylococcus aureus is still the most frequent. Gram-negative organisms run a close third. Avascular necrosis of the femoral and humeral heads is not uncommon [34].

12.9 Infection

12.9.1 Transient Synovitis of the Hip

Patients with transient synovitis of the hip can range in age from toddlers to adolescents, but most are in the 3- to 8-year-old age range and present with an acutely painful hip (always unilateral) and difficulty weight-bearing. There may or may not be a history of preceding infection such as strep throat or a viral cold or trauma. There is a 2:1 male-to-female ratio.

On a physical exam, the patient holds his hip in the mildly abducted externally rotated position with little to no fever. Other than the hip exam, the patient appears healthy.

Radiographs are normally unremarkable, but ultrasound will show an effusion. Laboratory values looking for infection will show little if any elevation in the white blood cell count, a normal ESR, and a normal CRP.

Etiology is unknown with viral synovitis, postbacterial infection synovitis, and trauma all having been put forth without solid conclusions.

Treatment consists of bed rest until symptoms resolve. For cooperative patients, crutches with touchdown weight-bearing are an option. Returning to activities too soon will prolong the time until the pain and limp disappear. If symptoms are severe, NSAIDs in weight appropriate doses can be used, but steroids and antibiotics are not indicated.

The most important differential for transient synovitis of the hip is infection of the hip joint space. In most cases, telling the difference is straightforward as those patients with infection will be “sick” with fever and elevated serum markers of infection. However, there are patients in whom distinguishing infection from transient synovitis can only be done by aspiration of the hip. Because of the age and painful nature of the aspiration, this is done under general anesthesia with preparation and consent for surgical drainage if the results of the aspiration show acute infection.

Other differential diagnoses to consider include juvenile rheumatoid arthritis, Perthes disease in the younger, and slipped femoral capital epiphysis in the older patient, as well as osteomyelitis of the pelvis or acetabulum and proximal femur [35, 36].

12.9.2 Hip Infections in Children

For reasons that are unknown, although any joint can be infected, the hip is more commonly the site of bacterial infection in children than are other joints. The patient presents with refusal to bear weight on the infected limb, a fever, and is systemically ill, that is, he may have diarrhea or loss of appetite. Risk factors include any disease that lowers overall immunity such as diabetes, hemophilia, or AIDS, in addition to low socioeconomic status.

Radiographs may show blurring of soft tissue planes but are usually normal. Ultrasounds are helpful to detect effusions, but without aspiration they are not able to differentiate hip joint infection from transient synovitis. MRI can show an effusion and any changes in the surrounding bone, but whether those bony changes are reactive or a result of osteomyelitis is not always clear. The radionuclide scans (technetium) are more useful in diagnosing and localizing osteomyelitis than diagnosing joint space infections.

The most common organisms are *Staphylococcus aureus* and *Haemophilus influenzae*. Certain medical conditions predispose to other bacterial infections, for example, sickle cell anemia to *Salmonella* and IV drug use in adolescents to gram-negative bacilli such as *Pseudomonas*.

Early diagnosis and aggressive treatment are critical as delay can result in not only chronic osteomyelitis but also destruction of the articular cartilage. Ideally, cultures should be obtained before antibiotics are given, but if the patient is septic this may not be possible. Surgical drainage followed by appropriate antibiotics is the treatment of choice. In a significant number of cases, the cultures will show no growth even though the joint was obviously septic with a high systemic white count, elevated CRP, and gross purulence on both drainage and aspiration. If there is accompanying osteomyelitis, the time course of antibiotics will be longer. Nonlimited or limited weight-bearing until the articular cartilage has recovered from the damage is the final part of treatment.

Differential diagnosis is similar to that of and includes transient synovitis of the hip: Legg-Calves-Perthes, slipped femoral capital epiphysis, as well as osteomyelitis [37].

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Rheumatological Disorders

13

13.1 Bone

Although orthopedists do not treat rheumatic diseases except where surgically indicated, no introduction to orthopedics would be complete without a brief overview of rheumatologic diseases and a summary of treatment options.

13.1.1 Osteoporosis

Several terms need explanation before osteoporosis can be discussed: First is *osteomalacia*; this means the bone is not normal, i.e., the quality is poor, and even though the amount of bone may be normal, it is more easily fractured. A typical example is rickets or Paget's. *Osteopenia* is when the amount of the bone is more than one standard deviation below normal – typically stated as bone density whether measured by CT or DXA scanning. Finally, *osteoporosis* is when the amount of the bone is more than 2.5 standard deviations below normal. Confusion can arise as the last two terms, osteoporosis and osteopenia, are often used interchangeably in non-orthopedic literature, in radiology reports, and by patients. Adding to the confusion, the diagnosis of osteoporosis can be made if there is a fragility fracture in the presence of osteopenia. For example, if a 75-year-old woman with known osteopenia falls and fractures her hip, she can be diagnosed with osteoporosis even though her bone density is not more than 2.5 standard deviations below normal. For the most part, the diagnosis of osteopenia or osteoporosis is not made by the orthopedist except in the presence of a fragility fracture. The latter is a low-energy injury most often resulting in a fracture of the distal radius or hip. The gradually increasing kyphosis seen in older women and some men is the result of vertebral microfractures of osteoporotic or osteopenic bone with gradually increasing deformity.

Osteoporosis is most commonly seen in elderly white women with the complaints as mentioned above: either a fragility fracture or increasing kyphosis. The patient may or may not be aware of the associated diagnosis.

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The current method of diagnosing osteoporosis is with a DEXA scan. Using the hip and lumbar spine as the primary sources of data, a carefully calibrated radiograph is taken, and the amount of radiation that does not pass through is compared to standards and an absolute value calculated expressed in bone/cm^3. This is compared to the average 30-year-old of the same sex as the patient and is expressed as the T score. The bone density reading is also compared to the average person of the same age and sex as the patient and expressed as the Z score. T and Z scores are expressed as standard deviations from the mean.

13.1.2 FRAX Score

The FRAX score (Fig. 13.1) gives the odds of a minor and major fracture over the next 10 years. The following information is used to calculate the FRAX score:

In addition to a DEXA scan and FRAX score calculation, laboratory studies for evaluation of bone quality and quantity include a comprehensive metabolic panel looking at protein levels for evidence of malnutrition, calcium levels, and a vitamin D level.

The underlying problem is one of aging. Up to the age of about 35 years, the human body continually remodels the skeleton typically adding more bone than is removed. After age 35, the process continues, but more bone is removed than replaced, leading to a gradual thinning of the bone. The process can be slowed by

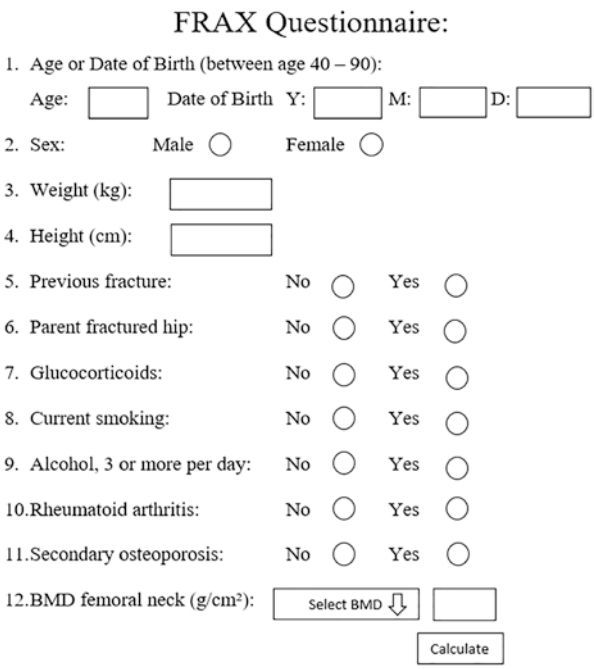

Fig. 13.1 Chart used to calculate the FRAX score. The score is then compared to the WHO's statistics to determine minor and major fracture risk

weight-bearing exercise, weightlifting, good nutrition, and avoidance of certain behaviors like smoking but cannot be stopped.

Treatment depends on severity. Whole books have been written on nonmedical treatment (see *Non-Pharmacological Management of Osteoporosis: Exercise, Nutrition, Fall and Fracture Prevention*) [1]. Advice for regular exercise and smoking cessation is difficult for patients to hear and follow once 50- to 60-year-old habits and lifestyle are established. The most common class of drugs used to treat osteopenia or osteoporosis are bisphosphonates. This includes etidronate (Didronel™), alendronate (Fosamax™), risedronate (Actonel™), alendronate sodium (Binosto™), ibandronate (Boniva™), and zoledronic acid (Reclast™). The first four are given by mouth, ibandronate orally or IV, and zoledronic acid IV once every 6–12 months. These drugs are classified as antiresorptive; that is, they decrease bone turnover by preventing some bone resorption. Of course, this means new bone is being laid down on top of "old" bone, so the resulting quality is not as high. But quantity has a quality of its very own. Long-term studies show the incidence of fractures is decreased in comparable patient groups taking the biphosphonates. Two relatively rare problems associated with the bisphosphonates are osteonecrosis of the jaw [2] and atypical subtrochanteric femur fractures [3].

Another class of drugs are the derivatives of the parathyroid hormone which stimulates the body to lay down additional bone. The two drugs in this class are teriparatide (Forteo™) and abaloparatide (Tymlos™). The drawbacks are the drugs are expensive ($3500 per month), can only be used for 2 years in a lifetime, and require daily subcutaneous injections for one course of treatment that lasts 6 months.

Finally, denosumab (Prolia™) is a monoclonal antibody which attaches to the osteoclast cell surface preventing it from resorbing bone. Again, the cost is high ($800 per injection) but is given as a subcutaneous injection once every 6 months.

Who should be screened for osteoporosis in the absence of a fracture? Answers vary but postmenopausal Caucasian women should have a baseline test, and if normal, it does not need to be rechecked for 5 years [4].

13.2 Crystal Disease

13.2.1 Gout

Gout is the localized deposit of uric acid crystals in a joint with accompanying inflammation. Although most common in the great toe metatarsal-phalangeal joint, it can occur in any joint. The patient presents with an acute onset of pain, swelling, and redness in one joint usually without fever. The obvious difficulty is in differentiating gout from an acute joint infection. There are several ways of differentiating the two, including fever, previous history of gout, CBC, C-reactive protein, and erythrocyte sedimentation rate. The prototypical patient is an overweight middle-aged male who drinks red wine and eats red meat and cheese. The most common joint is the first metatarsophalangeal joint. Unfortunately, the best way to tell is by

aspirating the joint and examining the fluid under polarized microscopy. Patients with gout will have negative birefringent needlelike crystals that may be yellowish or inside white blood cells. Obtaining a good microscopic exam at night or weekends in the emergency room is difficult.

The underlying pathology is deposition of uric acid crystals. The AP should not be misled into thinking that all patients with gout have an elevated uric acid level (they do not), nor do normal blood uric acid levels mean the patient does not have gout. Levels greater than 7.0 mg/dL should, however, raise suspicion.

Treatment varies. For the acute attack, treatment is to reduce the inflammation and the uric acid load. A strong NSAID such as indomethacin or a short course of oral steroids will reduce the inflammation and pain, but care must be taken to avoid gastrointestinal bleeding. Colchicine can be given acutely to reduce the uric acid level but will not actively reduce the pain. Long term there are both dietary and medical treatments to reduce the uric acid level by decreasing production and increasing excretion. Diet should restrict red meats, yellow cheeses, shellfish, and beer (foods high in purines). Like most orthopedic conditions, achieving and maintaining a normal weight is helpful. Both probenecid (also used to increase the effectiveness of penicillins) and allopurinol increase renal excretion of uric acid and are used in patients with recurring cases of gout to prevent attacks.

Two additional points about gout should be considered by the AP. First, this is predominantly a male disease (estimates range from 3:1 to 9:1) and is essentially unheard of in premenopausal women. Second, the following drugs raise serum uric acid levels, and this should be considered when treating patients with recurrent episodes of gout: aspirin, niacin, and thiazide diuretics [5].

13.2.2 Pseudogout

Pseudogout shares some similarities with gout. It presents acutely with pain, swelling, erythema, and tenderness of a single joint, but unlike gout the most commonly affected joint is the knee (followed by the shoulder, hip, and wrist). Patients are older than those with gout and male-to-female ratio is roughly equal. Attacks tend to last longer. The cause is deposition of calcium pyrophosphate crystals and the subsequent inflammatory response. Again, the important differential is an acute septic joint. The definitive diagnosis is made by aspirating the joint and looking for positively birefringent crystals that are "blocky."

Associated diseases include hemochromatosis, hypothyroidism, and hyperparathyroidism. The cause for pseudogout is unknown but thought to be primarily genetic.

Treatment is medical with no known dietary restrictions; helpful medicines include NSAIDs, colchicine, and steroids. Severe recurrent or chronic cases should be referred to a rheumatologist who may prescribe methotrexate or anakinra (interleukin-1 receptor antagonist).

13.3 Autoimmune Disease

13.3.1 Rheumatoid Arthritis

The most important thing to remember about rheumatoid arthritis is that it is not just a disease of the joints but is a multi-organ disease which can affect the eyes, heart, lungs, and blood (anemia).

The average patient is female (3:1 female/male) and usually presents between 40 and 60 years of age. The patient will have relatively symmetric complaints involving multiple joints. One of the keys to diagnosing R.A. early is the accompanying systemic signs that are not present with osteoarthritis. These include fatigue, weight loss, low-grade fever, and anemia. Patients may or may not have rheumatoid nodules. In addition, the patients will complain of stiffness in the morning with a "warm-up" time of more than an hour.

Physical exam of the hands shows swelling of the PIP and MCP joints but not the DIP. As the disease progresses, the sagittal bands that allow the extensor tendons to extend the MCP joints of the four fingers erode or stretch on the radial side allowing the extensor tendon to slip ulnarly causing an ulnar drift of the fingers and the inability to actively extend the MP joints.

Both swan neck and boutonniere deformities of the fingers are common (Fig. 13.2).

As mentioned above, rheumatoid arthritis can affect multiple organ systems not just the joints (Table 13.1).

Laboratory tests include rheumatoid factor (RF) and anti-cyclic citrullinated peptide (anti-CCP); the former is only positive about 80% of the time, so a patient can have a negative RF test and still have rheumatoid arthritis. A negative anti-CCP test on the other hand means the patient almost certainly does not have rheumatoid arthritis. The C-reactive protein should be normal but the ESR is elevated (Table 13.2). The CBC is usually normal except for anemia in some patients [6].

Radiographs will show osteopenia and periarticular erosions as well as decreased joint space. The underlying pathology is some type of autoimmune disease with genetic predisposition. The trigger is unknown but may be viral with the most common suspect being the Epstein-Barr virus. The joint problems are caused by a hyperplasia of the synovium resulting in a pannus that destroys bone, articular cartilage, and may cause laxity of the ligaments. As mentioned above, this is a multi-organ disease.

Treatment is primarily medical with surgical intervention as needed (see below). The first line of treatment is to rest the affected joint and then start a focused strengthening program which may involve a physical therapist. The current gold standard of medical treatment is DMARDs (disease-modifying antirheumatic drugs). Although NSAIDs may alleviate symptoms, they do not change the course of the disease. The most common initial treatment is methotrexate given weekly orally. Other drugs given include gold, cyclosporine, sulfasalazine,

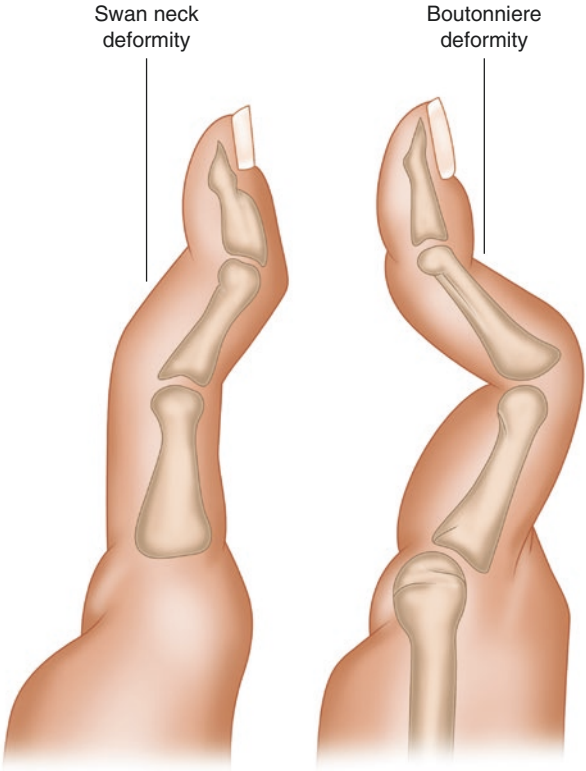

Fig. 13.2 Swan neck deformity is hyperextension at the proximal interphalangeal joint with resultant flexion at the distal interphalangeal joint. Boutonniere deformity is just the opposite: a flexion deformity of the proximal interphalangeal joint and a hyperextension deformity of the distal interphalangeal joint

Table 13.1 Organ systems potentially involved in patients with rheumatoid arthritis

Eyes: Keratoconjunctivitis sicca (dry eyes)
Heart: Pericarditis with increased incidence of coronary artery disease
Pulmonary: Pleural effusions, bronchiectasis
Nervous: Compression neuropathies including carpal and cubital tunnel
Hematologic: Anemia, vasculitis
Skin: Rheumatoid nodules, rash

Table 13.2 Diagnostic criteria for rheumatoid arthritis adapted from the American College of Rheumatology. Each has a point value assigned, and the diagnosis is considered if the patient has 6 or more points

Diagnostic criteria for rheumatoid arthritis
Symptom duration
Number of large joints involved
Number of small joints involved
Positive blood work to include CCP (anti-cyclic citrullinated peptide), rheumatoid factor, ESR, and C-reactive protein

hydroxychloroquine (Plaquenil), minocycline, azathioprine, and leflunomide. Another subclass of drugs given are the "biologics." These are tumor necrosis factor (TNF) inhibitors and are very expensive (~ $4000 a month or more) and include etanercept (Enbrel™), infliximab (Remicade™), and adalimumab (Humira™). Interleukin-1 receptor antagonists, like anakinra (Kineret™), and manufactured antibodies, like abatacept (Orencia™) and rituximab (Rituxan™) which interfere with T-cell and B-cell function, respectively, are other "biologics" and are similarly expensive.

Orthopedically, there are several things to remember. Because rheumatoid disease can affect the stability of ligaments, the cervical spine should be examined with flexion/extension films, and if questions of stability arise, then either a spine surgeon should be consulted or consideration given to fiber-optic intubation. Because of the associated osteoporosis and effects of RA on bone metabolism, any major joint arthroplasty should be cemented as bone ingrowth may be impaired. Because most of the drugs for RA interfere with immune function and because patients with RA are more susceptible to infection, care must be given to timing of cessation and resumption of medical therapy in the perioperative period [7].

13.3.2 Juvenile Idiopathic Arthritis (JIA)

Formerly called juvenile rheumatoid arthritis, now called juvenile idiopathic arthritis, JIA is an autoimmune inflammatory condition but unlike multi-system adult RA primarily affects just the joints with an age of onset of less than 16 years. The onset of joint pain is accompanied by a fever often greater than 102 °F. There may or may not be a rash due to scratching (Koebner's phenomenon).

Radiographs are usually benign, and laboratory tests for RF and ANA (antinuclear antibody) are positive less than 50% of the time. Before diagnosing JIA, it is important to rule out other causes such as multifocal osteomyelitis and septic arthritis. The differential is long and can include a variety of subtypes of JIA, in addition to arthritis associated with inflammatory bowel disease, neoplasms, and other systemic inflammatory diseases.

Treatment after proper diagnosis includes NSAIDs, methotrexate, and corticosteroids. As with other childhood diseases, aspirin should be avoided because of the potential to cause Reye's syndrome [8].

13.3.3 Reiter's Syndrome

Patients with Reiter's syndrome, more properly called reactive arthritis, are almost never seen by orthopedic practitioners despite the joint involvement. The patient presents with a triad of symptoms: urethritis, conjunctivitis, and arthritis (can't pee, can't see, can't climb a tree) after a gastrointestinal or genitourinary infection with one of several bacteria (*Shigella*, *Salmonella*, or *Chlamydia*).

Physical exam will show swollen digits (dactylitis) and ulcers in the mouth, on the palms, or on the soles of the feet. Laboratory tests show an association with HLA-B27.

Treatment is medical with symptoms resolving in 6 to 13 months, but the disease itself is lifelong. Drugs used to treat Reiter's syndrome include NSAIDs, methotrexate, sulfasalazine, and azathioprine with some authorities recommending antibiotics. The role of antibiotics is unclear [9].

13.3.4 Psoriatic Arthritis

Psoriatic arthritis is an inflammatory/autoimmune arthritis that is rheumatoid factor-negative and is accompanied by a skin condition known as psoriasis (Fig. 13.3). Unlike other inflammatory arthritides, psoriatic arthritis is gender neutral and can appear at any age including childhood but is most commonly diagnosed between ages 30 and 55. Like other inflammatory arthritis, it is a multi-symptom disease affecting the skin, nails, and eyes including conjunctivitis and anterior uveitis. The psoriatic rash can show up years before the arthritis and is normally a rash on the extensor surfaces (e.g., posterior elbow, anterior knee).

It can be distinguished from rheumatoid arthritis by involvement of the DIP joints, fat sausage fingers, and asymmetric joint involvement. In common with ankylosing spondylitis, the patient may have sacroiliitis.

Laboratory values, in addition to being rheumatoid factor-negative, are remarkable for an elevated erythrocyte sedimentation rate and anemia.

Treatment is similar to rheumatoid arthritis and includes NSAIDs, DMARDs, and biologics.

Orthopedically, the hands are often involved, the risk for infection is higher, and operating through the psoriatic lesion may make healing difficult. Total joints are normally cemented as the press-fit, bony ingrowth implants do not seem to last as long before loosening [10].

13.3.5 Systemic Lupus Erythematosus

Systemic lupus erythematosus occurs predominantly in females and affects African Americans more than Caucasians. Like other inflammatory arthritides, it is an autoimmune disease that affects multiple organ systems. Classically, the patient presents with a butterfly rash over the bridge of the nose and a variety of systemic complaints, depending on the organ system involved (Table 13.3).

In addition to the clinical features, other laboratory values that may be positive are anti-smith antigen, anti-double-stranded DNA, low C3 or C4 (complement proteins) (Table 13.4).

Treatment includes sunscreen to decrease rash and photosensitivity, NSAIDs for fever and joint pain, antimalarial drugs like hydroxychloroquine for fatigue and arthritic pain, and corticosteroids.

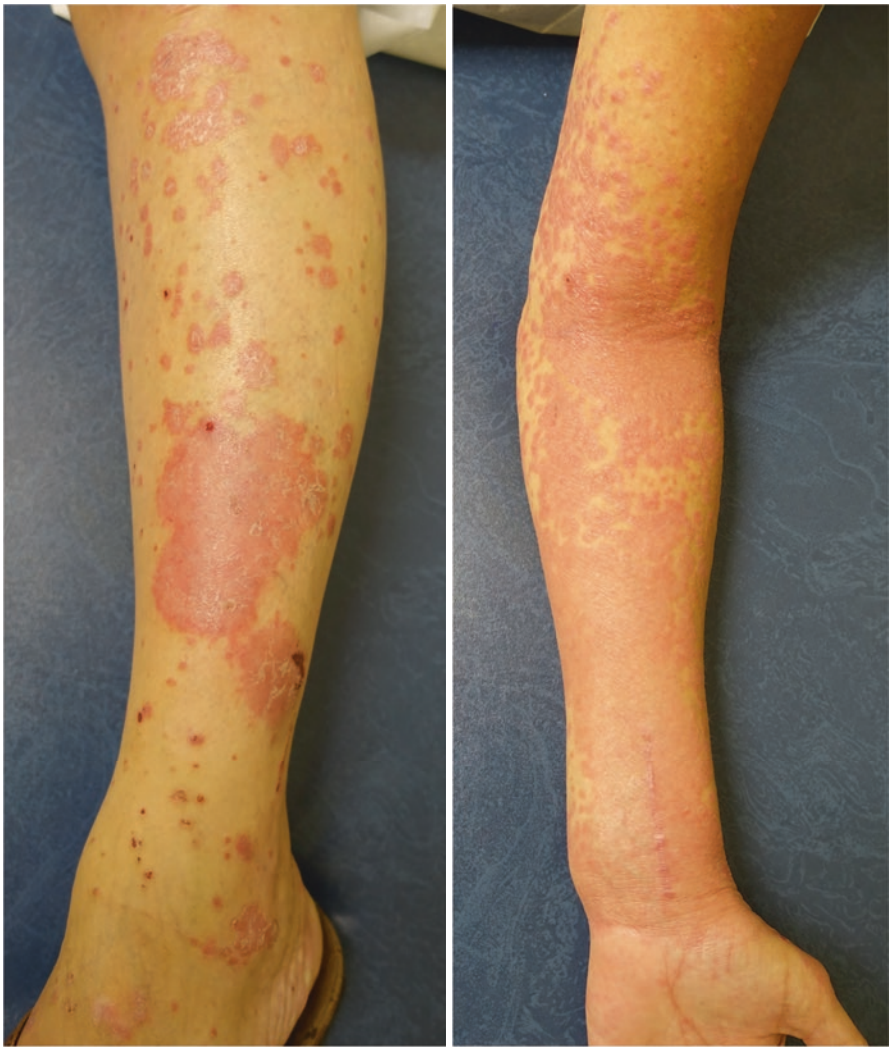

Fig. 13.3 Rash associated with psoriatic arthritis. The left is on the extensor surface of the leg but on the right is atypically on the flexor surface of the forearm. Her rash was exacerbated as a result of being in a short arm cast after distal radius fracture ORIF

Table 13.3 Organ systems that can be affected in patients with SLE

Systemic lupus erythematosus and potential affected organ systems
Skin: Rash, photosensitivity
Nervous: Headaches, depression, psychosis, seizures
Heart: Pericarditis, myocarditis
Pulmonary: Pleuritis, hemoptysis, pulmonary hypertension
GI: Nausea, vomiting, pain, elevated liver function tests
Renal: Nephritis, proteinuria
Hemopoietic: Hemolytic anemia

Table 13.4 Diagnostic criteria for systemic lupus erythematosus adapted from the European League Against Rheumatism/American College of Rheumatology. To qualify, the minimum is a positive ANA test with each of the other criteria having points assigned. A score greater or equal to 10 points is considered diagnostic

Diagnostic criteria for SLE
Positive ANA (required)
Fever
Hematologic changes such as thrombocytopenia
Neuropsychological symptoms: e.g., seizures
Skin or mucosal changes such as alopecia, oral ulcers, or rash
Serosal changes such as pericarditis
Musculoskeletal, i.e., joint involvement
Renal such as nephritis or proteinuria
Laboratory tests positive for antiphospholipid antibodies

Of note, SLE can be induced by the drugs procainamide, hydralazine, and isoniazid.

Orthopedically, like other patients with autoimmune disease, these patients are at higher risk of infection [11].

13.3.6 Raynaud Phenomenon

Raynaud's phenomenon is a response to cold temperature that results in excessive vasoconstriction such that fingers and toes may turn white (then blue, then red as the digits rewarm). It is to be distinguished from Raynaud's disease where spontaneous digital blood vessel constriction occurs not necessarily in response to cold.

Patients are typically greater than 30 years old; the phenomenon is symmetric with a normal rheumatologic workup (including negative ANA, normal ESR). There should be no peripheral vascular disease which would then make it secondary Raynaud's disease.

Treatment is obvious: The patient should avoid cold temperatures which may include wearing gloves and two pairs of socks when the temperature is cool. For patients with severe disease, calcium channel blockers and daily aspirin may be appropriate.

There is nothing particularly "orthopedic" about this condition except it may show up in the office [12].

13.3.7 Scleroderma (Systemic Sclerosis)

Scleroderma is another autoimmune disease that is not usually seen in the orthopedic clinic, but these patients, like others with autoimmune dysfunction, are at higher risk of infection postoperatively.

The disease is characterized by excessive collagen deposition in females between the ages of 30 and 50. This results in a variety of symptoms including Raynaud's

Table 13.5 Diagnostic criteria for Scleroderma adapted from the European League Against Rheumatism/American College of Rheumatology. Like RA and SLE, each is assigned a certain point value, and a score of 9 or greater is considered diagnostic for scleroderma

Diagnostic criteria
Skin thickening (which may extend onto the trunk)
Fingertip lesions
Telangiectasia
Pulmonary hypertension or fibrosis
Raynaud's phenomenon
Laboratory values: Positive anti-centromere, anti-topoisomerasel antibodies

phenomenon, gastroesophageal reflux, swollen fingers, and joint pain. There is no particular laboratory test for scleroderma. If the patient has marked thickening and tightening of the skin, especially in the dorsal aspects of the metacarpals or metacarpophalangeal joints, the patient is considered to have scleroderma (Table 13.5).

The significant lab findings are positive antinuclear antibody anti-centromere 3, anti-topoisomerase, and anti-RNA polymerase III.

Like other rheumatologic diseases, scleroderma can affect multiple organ systems including the esophagus, lungs, kidneys, and heart. Treatment will involve multiple specialists but not usually orthopedics. ACE-I drugs may help with kidney disease, and various antihypertensive medications may decrease the incidence of lung issues in addition to reducing the severity of Raynaud's phenomenon.

A subtype of scleroderma is CREST syndrome which is a mnemonic for:

C: Calcinosis.
R: Raynaud's phenomenon.
E: Esophageal dysfunction with reflux.
S: Sclerodactyly – skin thickening on the face and hands.
T: Telangiectasia – capillary swelling causing red spots on the skin.

Like systemic scleroderma, lab tests are positive for anti-centromere antibody. Treatment is similar to scleroderma [13, 14].

13.3.8 Sjogren's Syndrome

Sjogren's syndrome is another autoimmune disorder that affects females much more than males and starts later in life (typically after 50 years old). Diagnosis consists of the clinical triad of dry eyes, dry mouth, and large salivary glands (which can result in difficulty swallowing). Positive laboratory findings include a positive antinuclear antibody, rheumatoid factor, and antibodies to the Ro (SSA) and La (SSB) antigens.

Although the treatment is symptomatic, patients with Sjogren's are at five to nine times higher risk for lymphoma.

13.3.9 Polymyositis

Polymyositis is technically a muscular dystrophy but falls in the category of an inflammatory myopathy that affects women more than men, usually after the age of 30. The cause is idiopathic. Clinically, the disease is marked by proximal limb muscle weakness that is painless. The patient may complain of difficulty putting things in overhead cabinets and difficulty standing up from a seated position or climbing stairs but will have a normal grip strength. Patients may have difficulty swallowing or arthritis. The only abnormal laboratory tests are elevated muscle enzymes such as CK/CPK (creatinine phosphokinase), AST or ALT (aka SGOT or SGPT that is the transaminases), LDH (lactic acid dehydrogenase), and aldolase. EMGs will show myopathy. If a muscle biopsy is obtained, there will be inflammatory cells.

One additional organ system that can be affected is the lung. If there is a skin rash, the disease is reclassified as dermatomyositis. Patients with the latter will have purple swollen eyelids as well as Gottron papules.

One of the problems in diagnosing polymyositis is there is an extensive differential diagnosis: hypothyroidism, Cushing's, Lyme disease, other muscular dystrophies, ALS (amyotrophic lateral sclerosis: Lou Gehrig's disease), myasthenia gravis, and sarcoidosis in addition to reacting to the statin class of cholesterol-lowering drugs.

Treatment, like other inflammatory diseases, starts with steroids but also can include methotrexate and hydroxychloroquine [15].

13.3.10 Polymyalgia Rheumatica

Like polymyositis, patients with polymyalgia rheumatica are female more often than male and have proximal limb weakness but describe pain as being the predominating symptom rather than weakness. The shoulders are always involved but not necessarily the hips. Other complaints may include depression and fatigue with physical signs of fever and weight loss (Table 13.6).

There is no known cause, although it is more common in those of Scandinavian descent

Laboratory tests are negative including those for muscle enzymes except for an elevated ESR or CRP. Treatment is steroids [16].

Table 13.6 Diagnostic criteria for polymyalgia rheumatica adapted from the American College of Rheumatology [17]

Diagnostic criteria
Required: >50 year old, bilateral shoulder pain, elevated ESR, C-reactive protein.
Other: morning stiffness
Hip pain or loss of motion
Absence of RF or ACPA (anti-citrullinated peptide antibody)
Lack of other joint involvement
Ultrasound findings: subdeltoid bursitis, biceps tenosynovitis, glenohumeral synovitis, hip synovitis, or trochanteric bursitis

Table 13.7 Diagnostic criteria for polyarteritis nodosa adapted from the American College of Rheumatology. Normally at least three of the listed criteria must be positive to be considered to have the diagnosis of polyarteritis nodosa

Diagnostic criteria
Unexplained weight loss >4 kg
Skin rash (livedo reticularis)
Testicular pain or tenderness
Myalgias, weakness
Mononeuropathy or polyneuropathy
New-onset hypertension (diastolic BP >90)
Elevated BUN or creatinine
Hepatitis B
Arteriographic abnormality
Histopathologic abnormality (arterial biopsy)

13.3.11 Polyarteritis Nodosa

Polyarteritis nodosa affects men more than women and usually starts after age 40. The patients will complain of at least 9–10 pounds (4 kg) of unintended weight loss, fever, and anorexia in addition to abdominal pain and joint aches. Physical examination may reveal hypertension, sensory or motor neuropathy or both, skin changes, and congestive heart failure.

Laboratory tests show increased ESR and CRP. The most common organ system involved is the kidneys with proteinuria, elevated BUN, and elevated creatinine. Definitive diagnosis requires biopsy of an artery which will show a necrotizing vasculitis with infiltration of the cell wall by white blood cells (Table 13.7).

Treatment includes steroids and immune suppression drugs like cyclophosphamide, azathioprine, or methotrexate [18].

13.4 Vasculitis

As would be expected, there are three categories of vasculitis depending on whether the vasculitis is affecting large, medium, or small vessels.

13.4.1 Large Artery Vasculitis

There are two types of *large artery vasculitis*. *Giant cell* arteritis is the most common arteritis and is also known as temporal arteritis. The second is *Takayasu's arteritis*.

Other symptoms may include general malaise, anemia, arthritis, as well as blurred or double vision.

Laboratory values may show an elevated ESR or anemia. Giant cell arteritis can be associated with polymyalgia rheumatica or thoracic aneurysms (Table 13.8).

Treatment is corticosteroids and methotrexate.

Table 13.8 Diagnostic criteria for giant cell arteritis adapted from the American College of Rheumatology – 1990. At least three must be present for GCA to be diagnosed

Diagnostic criteria
Age >50 years
New-onset headache
Temporal artery abnormalities
ESR >50
Histologic evidence of arteritis on biopsy

Takayasu's arteritis is a rare disease of young women with aneurysms and inflammation of the aorta as well as other large vessels. The inflammation may cause heart valve stenosis or coronary artery disease.

13.4.2 Medium Cell Arteritis

Medium cell arteritis has three types: *polyarteritis nodosa*, *Buerger's disease*, and *Kawasaki disease*. Buerger's disease risks and effects are magnified by smoking and frequently result in upper and lower limb amputation due to gangrene. Kawasaki disease affects children under 5 affecting the skin, mouth, and lymph nodes with treatment being immune globulin and aspirin. See Sect. 13.3.11 for discussion of polyarteritis nodosa.

13.4.3 Small Cell Arteritis

Small cell arteritis has two subtypes: *Wegener granulomatosis* and *Behcet's disease*.

Wegener's granulomatosis (now more properly called granulomatosis with polyangiitis) is a multi-organ disease resulting from inflammation of the small arteries. It is a rare disease normally affecting people older than 40. Symptoms include fever, weight loss, fatigue, and joint aches. Signs include hemoptysis, sinusitis with either congestion or bleeding, and decreased pulmonary capacity. The kidneys are affected by glomerulonephritis.

In addition to lab studies reflecting poor pulmonary or kidney function, there is a positive ANCA titer (antineutrophil cytoplasmic antibodies). The ANC antibodies result in the patient's immune system attacking its own neutrophils. Definitive diagnosis may require a lung biopsy which will show granulomatosis vasculitis.

Treatment is corticosteroids and other immune-suppressing drugs such as methotrexate and cyclophosphamide.

Behcet's disease is extremely rare in the United States but is common in the Middle East, thus the eponym Silk Road disease. Symptoms include oral or genital ulcers, uveitis causing blindness with a few patients having arthritis. Cause is unknown with the HLA-B51 gene being associated with Behcet's but the disease is neither contagious nor inherited. Treatment is corticosteroids and colchicine for mild cases with immune suppression agents such as TNF-alpha inhibitors for severe cases [19].

13.5 Pain Syndromes

13.5.1 Complex Regional Pain Syndrome

Complex regional pain syndrome (CRPS), previously known as reflex sympathetic dystrophy, causalgia, or shoulder-hand syndrome, has two major subtypes of concern in the orthopedic world. Type I is the more troublesome and common. Type II is the result of damage to a nerve. The sine qua non of CRPS is pain out of proportion to the underlying injury or surgical procedure. The cause of type II can be traced to damage caused by traction, compression, or even laceration of a peripheral nerve, whereas the cause of type I is unclear.

The major problem with CRPS type I is diagnosis. Although pain is the major component, other signs and symptoms must be present to varying degrees. Signs and symptoms include hypersensitivity to pain or allodynia (a pain response to nonpainful stimuli), asymmetric skin temperature or skin color changes, excessive swelling or sweating, and loss of motion.

Unfortunately, there are no definitive diagnostic tests available. Radiographs in later stages may show localized osteoporosis, and technetium bone scanning frequently shows localized increased uptake.

Because there is no way to definitively diagnose CRPS, the clinician should be alert to patient complaints of pain that appear to be in excess of the norm and not automatically assume the patient has a low pain threshold or is a drug seeker. Asking questions about the aforementioned symptoms and examining the involved limb compared to the uninjured side for temperature or skin changes and assessing range of motion of noninjured joints (e.g., the fingers in wrist fractures) are crucial. In the 24–48 h after injury or surgery, the differential includes compartment syndrome, so any tight or compressive dressings will need to be removed.

Like the diagnosis, there is no clear treatment; however, it may be helpful to recognize that some cases of CRPS are mediated through the sympathetic nervous system, while others are not. To make things even more complicated, the sympathetically mediated CRPS can change to not being sympathetically mediated. Treatment options are almost endless but early recognition is crucial. For the upper extremity, involvement of a hand therapist is invaluable to maintain motion and maximize function. The drug list includes a variety of antidepressants below dosages of what is used to treat depression, anti-seizure drugs like phenytoin and gabapentin, calcium channel blockers, steroids, and surprisingly bisphosphonates. For sympathetically mediated CRPS, a stellate ganglion block can be both diagnostic and therapeutic.

Prevention is accomplished by emphasizing early motion where feasible. Awareness of the possibility of CRPS is key. For patients with distal radius fractures, 500 mg of vitamin C seems to decrease the incidence [20, 21].

13.5.2 Fibromyalgia

Fibromyalgia is one of the hardest diagnoses to make as it is a diagnosis of exclusion. In other words, the clinician has ruled out all other causes. The typical patient complains of generalized pain, headaches, fatigue, and sometimes depression or anxiety. Although having specific tender points is used to be considered diagnostic, that criteria is no longer used. Laboratory tests are normal. Treatment consists of antidepressants (starting with tricyclics), aerobic exercise, and stretching. Orthopedically, these patients may have a more difficult time recovering from surgery, so early aggressive physical therapy is appropriate. These patients are also at high risk for complex regional pain syndrome and may require more than the average amount of pain medicine postoperatively [22].

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Compartment Syndrome

14

14.1 Compartment Syndrome

Compartment syndrome is excessive swelling in one or more muscle compartments and is a surgical emergency. The patient presents after an acute injury with subsequent swelling and pain. Clues that the patient has compartment syndrome rather than just the usual pain after a fracture or injury include the fact that the pain is out of proportion to the injury and not relieved by narcotics. Other signs and symptoms include paresthesias, pallor, paralysis, pain on passive stretch (again out of proportion to injury), and pulselessness (the so-called five Ps). Importantly, the patient may never lose the pulse to the affected area. Any muscle compartment can be involved but most commonly involves those of the forearm and the leg. Other compartments include the foot, hand, upper arm, thigh, buttocks, or rarely the back.

The underlying pathology is swelling from an injury that reaches the point where venous outflow is obstructed while arterial inflow continues which causes the swelling to worsen. The consequences are muscle death, scarring, and contractures (see Volkmann's contracture). There are several factors, that may contribute to compartment syndrome and constant awareness of the possibility by the AP is important. Allowing the injured body part to be in a dependent position below the heart impedes venous outflow. Excessively tight dressings, splints, or casts do the same. Another risk factor is high-energy injuries where a high clinical suspicion of compartment syndrome needs to be present. Crush injuries may have more swelling and be at higher risk than the radiographs indicate. It may also occur after prolonged compression of a limb such as being trapped under rubble from a weather or manmade disaster. Compartment syndrome is commonly missed in foot injuries.

If compartment syndrome is suspected, the first thing to do is remove any circumferential dressings all the way to the skin. Frequent monitoring is necessary as emergent surgical treatment will be needed if the pain does not resolve with removal of the dressings, splint, or cast. The treatment is fasciotomy, i.e., release of the pressure by opening each individual muscle compartment that is involved. The skin incision is left open. After the swelling has subsided, the skin is closed by delayed

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primary closure or a split skin thickness graft. The long-term consequence of a fasciotomy, in addition to a potentially ugly scar, is a 10 to 15% strength loss of the involved muscles.

Diagnosis in obtunded or comatose patients is especially difficult, as it can be difficult to tell the difference between positioning/postsurgery swelling and compartment syndrome. Other than extremely obvious cases with gross swelling, the only way to make the diagnosis in unresponsive patients is to be suspicious and measure compartment pressures. This can be done with an arterial pressure monitor or more commonly with a small handheld device (Figs. 14.1 and 14.2). When using an arterial pressure monitor, the AP should remember to keep the monitor or at the same level as the compartment being measured. Normal intra-compartmental pressure is 0–10 mm Hg (mercury). Elevated levels after injury are typical, but the exact

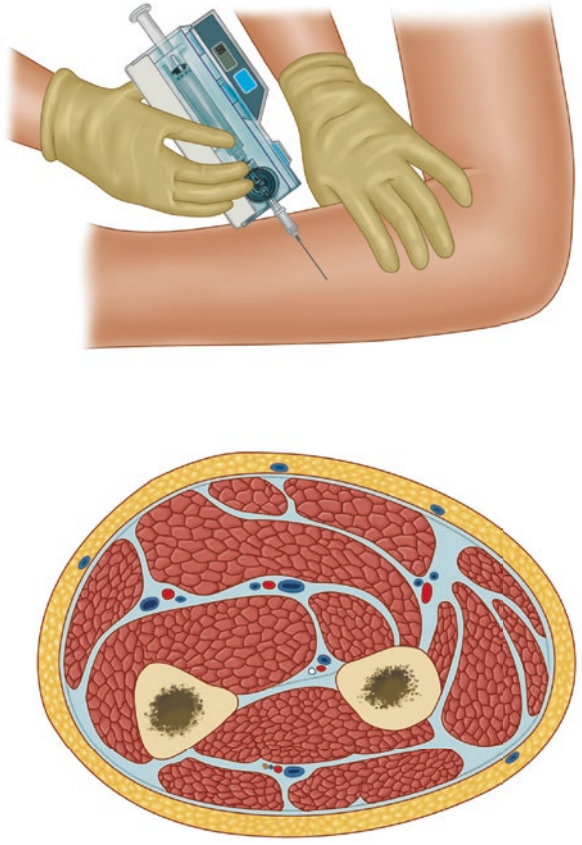

Fig. 14.1 When inserting the needle to measure the compartment pressure, the AP should remember to inject a few drops and then back the needle up slightly, so there is not an erroneous reading from the fluid being trapped against the fascia

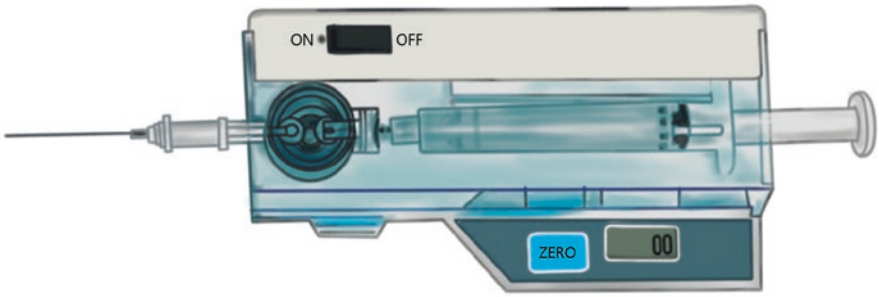

Fig. 14.2 Example of a small handheld device to measure compartment pressures. After placing the needle in the compartment, a drop or two of fluid is injected and the needle backed out fractionally to obtain an accurate reading

level where compartment syndrome begins is not absolute and depends in part on the patient's diastolic blood pressure. Although there is no solid scientific evidence as to what the absolute or relative pressure should be to diagnose compartment syndrome, most authorities agree that if the compartment pressure is within 30 mm Hg of the diastolic blood pressure, compartment syndrome is present. The key to accurate and timely diagnosis is a high index of suspicion and repeated clinical examination with compartment pressure measurements as indicated [1–4].

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