Introduction

The term congenital dislocation of the hip dates back to the time of Hippocrates. This condition, also known as hip dysplasia or developmental dysplasia of the hip (DDH), has been diagnosed and treated for several hundred years. Most notably, Ortolani, an Italian pediatrician in the early 1900s, evaluated, diagnosed, and began treating hip dysplasia. Galeazzi later reviewed more than 12,000 cases of DDH and reported the association between apparent shortening of the flexed femur and hip dislocation. Since then, significant progress has been made in the evaluation and treatment of DDH (see image below).[1,2,3,4]

Numerous radiographic measurements have been used to assist in the evaluation of developmental dysplasia of the hip (a typical radiographic evaluation is described in this image). From an anteroposterior radiograph of the hips, a horizontal line (Hilgenreiner line) is drawn between the triradiate epiphyses. Next, lines are drawn perpendicular to the Hilgenreiner line through the superolateral edge of the acetabulum (Perkin line), dividing the hip into 4 quadrants. The proximal medial femur should be in the lower medial quadrant, or the ossific nucleus of the femoral head, if present (usually observed in patients aged 4-7 mo), should be in the lower medial quadrant.

The acetabular index is the angle between the Hilgenreiner line and a line drawn from the triradiate epiphysis to the lateral edge of the acetabulum. Typically, this angle decreases with age and should measure less than 20° by the time the child is 2 years old. The Shenton line is a line drawn from the medial aspect of the femoral neck to the inferior border of the pubic rami. The line should create a smooth arc that is not disrupted. If disrupted, it indicates some degree of hip subluxation is present.
More specific terms are often used to better describe the condition; these are defined as follows:

- **Subluxation** – This is incomplete contact between the articular surfaces of the femoral head and acetabulum.
- **Dislocation** – This refers to complete loss of contact between the articular surface of the femoral head and acetabulum.
- **Instability** – This consists of the ability to subluxate or dislocate the hip with passive manipulation.
- **Teratologic dislocation** – This refers to antenatal dislocation of the hip.

**Frequency**

The overall frequency of developmental dysplasia of the hip (DDH) is usually reported as approximately 1 case per 1000 individuals, although Barlow believed that the incidence of hip instability during newborn examinations was as high as 1 case per 60 newborns. According to his study, more than 60% of hip instability became stable by age 1 week, and 88% became stable by age 2 months, leaving only 12% (of the 1 in 60 newborns, or 0.2%) with residual hip instability.

**Etiology**

The etiology of hip dysplasia is not clear, but this condition does appear to be related to a number of different factors. One such factor is racial background; among Native Americans and Laplanders, the prevalence of hip dysplasia is much higher (nearly 25-50 cases per 1000 persons) than other races, and the prevalence is very low among southern Chinese and black populations. An underlying genetic disposition also appears to exist in that a 10-fold increase in the frequency of hip dysplasia occurs in children whose parents had developmental dysplasia of the hip (DDH) compared with those whose parents did not.

Other factors possibly related to DDH include intrauterine positioning and sex, and some of these are interrelated. Female sex, being the first-born child, and breech positioning are all associated with an increased prevalence of DDH. An estimated 80% of persons with DDH are female, and the rate of breech positioning in children with DDH is approximately 20% (compared with 2-4% in the general population). The prevalence of DDH in females born in breech position has been estimated to be as high as 1 case in 15 persons in some studies.

Other musculoskeletal disorders of intrauterine malpositioning or crowding, such as metatarsus adductus and torticollis, have been reported to be associated with DDH. Oligohydramnios is also reported to be associated with an increased prevalence of DDH. The left hip is more commonly associated with DDH than the right, and this is believed to be due to the common intrauterine position of the left hip against the mother's sacrum, forcing it into an adducted position. Children in cultures in which the mother swaddles the baby, forcing the infant's hips to be adducted, also have a higher rate of hip dysplasia.

Hip dysplasia can be associated with underlying neuromuscular disorders, such as cerebral palsy, myelomeningocele, arthrogryposis, and Larsen syndrome, although these are not usually considered DDH.

**Pathophysiology**

Developmental dysplasia of the hip (DDH) involves abnormal growth of the hip. Ligamentous laxity is also believed to be associated with hip dysplasia, although this association is less clear. DDH is not part of the classic description of disorders that are associated with significant ligamentous laxity, such as Ehlers-Danlos syndrome or Marfan syndrome.

Children often have ligamentous laxity at birth, yet their hips are not usually unstable; in fact, it takes a great deal of effort to dislocate a child's hip. Therefore, more than just ligamentous laxity may be required to result in DDH. At birth, white children tend to have a shallow acetabulum; this may provide a susceptible period in which abnormal positioning or a brief period of ligamentous laxity may result in hip instability. However, this characteristic is not as true for children of black descent, who have a lower rate of DDH.

**Presentation**

Early clinical manifestations of developmental dysplasia of the hip (DDH) are identified during examination of the newborn. The classic examination finding is revealed with the Ortolani maneuver; a palpable "clunk" is present when the hip is reduced in and out of the acetabulum and over the neolimbus. A high-pitched "click" (as opposed to a clunk) in all likelihood has little association with acetabular pathology. Ortolani originally described this clunk as occurring with either subluxation or reduction of the hip (in or out of the acetabulum). More commonly, the Ortolani sign is referred to as a...
clunk, felt when the hip reduces into the acetabulum, with the hip in abduction.

To perform this maneuver correctly, the patient must be relaxed. Only one hip is examined at a time. The examiner’s thumb is placed over the patient’s inner thigh, and the index finger is gently placed over the greater trochanter. The hip is abducted, and gentle pressure is placed over the greater trochanter. In the presence of DDH, a clunk, similar to turning a light switch on or off, is felt when the hip is reduced. The Ortolani maneuver should be performed gently, such that the fingertips do not blanch.\(^2\)

Barlow described another test for DDH that is performed with the hips in an adducted position, in which slight gentle posterior pressure is applied to the hips. A clunk should be felt as the hip subluxes out of the acetabulum.\(^3\)

The clinical examination for late DDH, when the child is aged 3-6 months, is quite different. At this point, the hip, if dislocated, is often dislocated in a fixed position.\(^4\) The Galeazzi sign is a classic identifying sign for unilateral hip dislocation (see image below). This is performed with the patient lying supine and the hips and knees flexed. The examination should demonstrate that one leg appears shorter than the other. Although this finding is usually due to hip dislocation, realizing that any limb-length discrepancy results in a positive Galeazzi sign is important.

Additional physical examination findings for late dislocation include asymmetry of the gluteal thigh or labral skin folds, decreased abduction on the affected side, standing or walking with external rotation, and leg-length inequality.

Bilateral dislocation of the hip, especially at a later age, can be quite difficult to diagnose. This condition often manifests as a waddling gait with hyperlordosis. Many of the aforementioned clues for a unilateral dislocated hip are not present, such as the Galeazzi sign, asymmetrical thigh and skin folds, or asymmetrically decreased abduction. Careful examination is needed, and a high level of suspicion is important.

Note: Any limp in a child should be considered abnormal. The diagnosis can be quite variable, but an underlying etiology must always be pursued.

Of primary importance is making the diagnosis of hip dislocation or dysplasia. Once this diagnosis is made, the patient should be examined to be sure there is no underlying medical or neuromuscular disorder. Proximal femoral focal deficiency can masquerade as hip dysplasia and often manifests similarly. Because the femoral head does not ossify, the radiographic appearance also may be deceiving. Other neuromuscular disorders can manifest as dysplasia later in life, such as Charcot-Marie-Tooth disease.
Using expected-value decision analysis, Mahan et al., of Children's Hospital in Boston, found that the screening strategy associated with the highest probability of having a nonarthritic hip at the age of 60 years was to screen all neonates for hip dysplasia with a physical examination and to use ultrasonography selectively for infants who are at high risk. The expected value of a favorable hip outcome was 0.9590 for the strategy of screening all neonates with physical examination and selective use of ultrasonography, 0.9586 for screening all neonates with physical examination and ultrasonography, and 0.9578 for no screening.[25]

**Indications**

Indications for surgery are met if the results of the surgery would be better than the results of the natural progression of developmental dysplasia of the hip (DDH).[26] The natural history of hip dysplasia depends, in part, on the severity of the disease, bilaterality, and whether or not a false acetabulum is formed.[6,27,28]

Unilateral dislocations result in significant leg-length inequality, with a gait disturbance and possibly associated hip and knee pain. In addition, Hip pain commonly manifests as knee or anterior thigh pain due to the innervation of the hip joint (obturator and femoral nerve distribution). Typically, true hip pain is identified as groin pain. The development of a false acetabulum is associated with a poor outcome in approximately 75% of patients. Bilateral hip dislocation in a patient without false acetabuli has a better overall prognosis. In fact, a case was reported of a 74-year-old man with no history of hip or thigh pain whose dislocated hips were only discovered shortly before his death.[29]

Indications for treatment depend on the patient's age and the success of the previous techniques. Children younger than 6 months with instability upon examination are treated with a form of bracing, usually a Pavlik harness. If this is not effective or if the hip instability or dislocation is noted when the child is older than 6 months, closed reduction is typically recommended, often with the administration of traction before the reduction.

When the child is older than 2 years or with failure of the previous treatment, open reduction is considered. If the patient is older than 3 years, femoral shortening is performed instead of traction, with additional varus applied to the femur, if necessary. A patient with residual acetabular dysplasia who is older than 4 years should be treated with an acetabular procedure.

Treatment for DDH that is diagnosed when the patient is a young adult can be considered for residual DDH. Unfortunately, radiographic characterization of developmental dysplasia of the hip that is severe enough to lead to early osteoarthrosis is difficult. A center-edge angle less than 16º often has been used to predict early osteoarthrosis,[30] but other authors have found this measurement to be less reliable.[31,32] Subluxation, defined as a break in the Shenton line, has been demonstrated to be associated with osteoarthrosis and decreased function (see image below).[31]
Numerous radiographic measurements have been used to assist in the evaluation of developmental dysplasia of the hip (a typical radiographic evaluation is described in this image). From an anteroposterior radiograph of the hips, a horizontal line (Hilgenreiner line) is drawn between the triradiate epiphyses. Next, lines are drawn perpendicular to the Hilgenreiner line through the superolateral edge of the acetabulum (Perkin line), dividing the hip into 4 quadrants. The proximal medial femur should be in the lower medial quadrant, or the ossific nucleus of the femoral head, if present (usually observed in patients aged 4-7 mo), should be in the lower medial quadrant.

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**Relevant Anatomy**

The normal growth of the acetabulum depends on normal epiphyseal growth of the triradiate cartilage and on the 3 ossification centers located within the acetabular portion of the pubis (os acetabulum), ilium (acetabular epiphysis), and ischium. Additionally, normal growth of the acetabulum depends on normal interstitial appositional growth within the acetabulum. The presence of the spherical femoral head within the acetabulum is critical for stimulating normal development of the acetabulum.

The anatomy of the dislocated hip, especially after several months, often includes formation of a ridge called the neolimbus. Closed reduction is often unsuccessful at a later date, secondary to various obstacles to reduction. These include adductor and psoas tendon contraction, ligamentous teres, a transverse acetabular ligament, and pulvinar and capsular constriction. With long-standing dislocations, interposition of the labrum can also interfere with reduction.

**Contraindications**

Relative contraindications to surgery include older age (>8 y for a unilateral hip dislocation or >4-6 y for bilateral hip dislocation, especially if a false
acetabulum is not present). Other contraindications to surgery include a neuromuscular disorder, such as a high myelomeningocele or spinal cord injury, or cerebral palsy in a patient who has had a hip dislocation for longer than 1 year.

**Workup**

**Laboratory Studies**

- No laboratory studies are routinely ordered in the workup of DDH.

**Imaging Studies**

- Ultrasonograms have been of significant benefit in the assessment and treatment of children with hip dysplasia.\(^{[33,34,35]}\)
  - The benefit of screening all children with ultrasonography is controversial.\(^{[36,37]}\) Even with ultrasound screening, children with hip dysplasia can be diagnosed late, and one concern with the routine ultrasonographic evaluation of newborns is the overdiagnosis (increased false-positive results) of hip dysplasia.\(^{[38]}\) The use of this imaging modality for only high-risk infants has not yet been demonstrated to reduce the prevalence of late diagnosis of hip dysplasia.\(^{[39]}\) However, most authors agree that ultrasonography is an excellent tool for assessing children with suspected hip instability and is useful as an aid in the treatment of children with hip dysplasia, especially in monitoring reduction by closed methods.\(^{[40]}\)
  - An ultrasound evaluation is typically performed either by assessing the alpha and beta angles or by performing a dynamic evaluation.\(^{[33,35,41]}\) An alpha angle outlines the slope of the superior aspect of the bony acetabulum, with an angle greater than 60° considered normal. The beta angle, which is considered normal if less than 55°, depicts the cartilaginous component of the acetabulum. Many institutions now use a dynamic form of ultrasound, as heralded by Harcke.\(^{[40]}\)

- Standard radiographic views include a standing anteroposterior view of the pelvis, with the hips in neutral position, and a false profile view in which the patient is standing angled at 65° from the x-ray plate. The radiograph is then taken, profiling the anterior aspect of the acetabulum. If any evidence of hip subluxation is present, an abducted internal rotation view can help determine if the hip reduces and better determines the true neck-shaft angle of the proximal femur.

- A computed tomography (CT) scan can also be helpful in determining femoral anteversion and in determining the extent of posterior acetabular coverage.

- Three-dimensional (3-D) images are also quite popular and can be beneficial in visualizing the overall shape of the acetabulum.

- Magnetic resonance images (MRIs) can be beneficial in identifying the underlying bony and soft-tissue anatomy.

- Numerous radiographic measurements have been used in the evaluation of DDH. Radiographic evaluation is typically determined in the following manner, with the help of the image below:
Numerous radiographic measurements have been used to assist in the evaluation of developmental dysplasia of the hip (a typical radiographic evaluation is described in this image). From an anteroposterior radiograph of the hips, a horizontal line (Hilgenreiner line) is drawn between the triradiate epiphyses. Next, lines are drawn perpendicular to the Hilgenreiner line through the superolateral edge of the acetabulum (Perkin line), dividing the hip into 4 quadrants. The proximal medial femur should be in the lower medial quadrant, or the ossific nucleus of the femoral head, if present (usually observed in patients aged 4-7 mo), should be in the lower medial quadrant.

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- From an anteroposterior radiograph of the hips, a horizontal line (Hilgenreiner line) is drawn between the triradiate epiphyses.
- Next, lines perpendicular to the Hilgenreiner line are drawn through the superolateral edge of the acetabulum (Perkin lines), dividing the hip into 4 quadrants. The proximal medial femur should be in the lower medial quadrant, or the ossific nucleus of the femoral head, if present (usually observed in patients aged 4-7 mo), should be in the lower medial quadrant.
- Additionally, the acetabular indices can be measured. These refer to the angle between the Hilgenreiner line and a line drawn from the triradiate epiphysis to the lateral edge of the acetabulum. Typically, the angle decreases with age and should measure less than 20° by the time the child is 2 years old. [42,43]
- The Shenton line — a line drawn from the medial aspect of the femoral neck to the inferior border of the pubic rami — can also be evaluated. This line should create a smooth arc that is not disrupted. If the Shenton line is disrupted, it indicates the presence of some degree of hip subluxation.

**Diagnostic Procedures**
• Arthrograms are dynamic studies, performed by injecting dye into the hip joint and then examining the patient with aid of fluoroscopy, usually with the patient under anesthesia.
  o Although this procedure can be performed independently, it is routinely performed in conjunction with a closed reduction.
  o Arthrography can be helpful in determining the underlying cartilaginous profile and dynamic stability of the hip.[34] It may also be used to identify a labral tear.
  o When arthrography is performed in combination with a closed reduction, the adequacy of the reduction can be assessed. Increased medial joint space, as demonstrated by medial pooling of the dye and a rounded or interposing limbus, may be indicative of poor long-term results. After closed reduction, a limited CT scan in the transverse plane is obtained to ensure the hip is not subluxed or dislocated posteriorly.

**Treatment**

**Medical Therapy**

The treatment of hip dysplasia begins with a careful examination of the newborn. If evidence of instability is present, a Pavlik harness should be considered and, if used, fitted appropriately.[44,45,46,47] The Pavlik harness should be placed such that the chest strap is at the nipple line, with 2 fingerbreadths of space between the chest and strap. The anterior strap is at the midaxillary line and should be set such that the hips are flexed to 100-110°. Excessive hip flexion can lead to femoral nerve compression and inferior dislocations. Quadriceps function should be determined at all clinic visits.

The posterior abduction strap should be at the level of the child's scapula and adjusted to allow for comfortable abduction. This should prevent the hips from adducting to the extent that the hips dislocate. Excessive abduction should be avoided because of concern regarding the development of avascular dislocations. After the harness fits and the hips are reduced is important.

Ultrasonography is an excellent means of documenting the reduction of the hip in the Pavlik harness and should be performed early in the course of treatment.[48] If the hip is posteriorly subluxed, then the Pavlik harness therapy should be discontinued. Using the Pavlik harness for guided reduction, which occurs when the hip does not completely reduce initially but is pointed toward the triradiate cartilage, is controversial.

When the harness is used for guided reduction, the physician should obtain a radiograph after the Pavlik harness is placed to determine if the femoral heads are pointing toward the triradiate cartilage. An ultrasonogram should be obtained to determine the success, or lack thereof, of the guided reduction.

The overall duration of Pavlik harness therapy has not been universally agreed upon.[49,50] If the hip is reduced satisfactorily in the harness, then the author maintains this treatment at least until the hip is stable clinically and based on ultrasound findings with the patient out of the brace. Abduction splinting is maintained thereafter if radiographic evidence of residual dysplasia is present. The use of an abduction brace after a failure of the Pavlik harness has been suggested. In one study, 13 of 15 patients were treated successfully in this manner, and the remaining 2 patients had a successful closed reduction.[51]

When the patient is older than 6 months, the success rate with a Pavlik harness is less than 50%; therefore, this therapy should not be used in patients older than 6 months.[52] If the child is diagnosed when older than 6 months or if the Pavlik harness is determined to be unsuccessful, a closed reduction is attempted. Often, traction is performed for a 2- to 3-week period before closed reduction is attempted. Traction (usually skin traction) can be performed either at home or in the hospital. This must be monitored carefully to ensure the integrity of the skin. The overall benefit of traction is quite controversial, although most pediatric orthopedic surgeons do use skin traction.[53,54]

Closed reduction is typically performed with the aid of arthrography, which is used to determine the adequacy of the reduction. A medial dye pool and an interposing limbus are both associated with a poor prognosis. If, on the other hand, a sharp or even a blunted limbus and no medial dye pooling are present, the prognosis is good.[55] Also, the safe zone of Ramsey, which is the angle between the maximum abduction and minimum abduction in which the hip remains reduced, should be at least 25° and can be increased with release of the adductor longus.

The cone of stability—a cone that involves hip flexion, abduction, and internal and/or external rotation—has also been defined. If this cone measures greater than 30°, it is considered satisfactory.[56] A spica cast is placed, with care taken in molding over the posterior aspect of the greater trochanter of the ipsilateral limb. After this is performed, a CT scan is then obtained to ensure that no evidence of posterior subluxation is present. The cast is typically worn for 6-12 weeks, at which time the hip is reexamined, and, if found to be stable, the patient is placed in an abduction brace. If the hip remains unstable, the patient is again placed in a spica cast.

**Surgical Therapy**

Open reduction is the treatment of choice for children older than 2 years at the time of the initial diagnosis or for children in whom attempts at closed reduction have failed. In children with teratologic hips, with failure at a much younger age, open reduction can be performed through a medial approach. The medial approach has a number of advantages, as follows:

• Both hips can be reduced at the same time (in a patient with bilateral DDH).

• The obstacles to reduction (eg, psoas tendon) are easily identified.
- The adductor longus can be sectioned through the same incision.
- The hip abductor muscles are not at risk for injury, and, therefore, residual weakness is unlikely to occur.
- The iliac apophysis is not at risk for injury.
- The incision has a very good cosmetic result.

Problems with this approach include the following:

- The possibility of increased avascular necrosis
- The potential lack of familiarity of surgeons with this approach
- The inability to perform capsular placation or a pelvic procedure through this incision.

With the use of a medial approach, the cast plays a much more important role.

Most often, especially in older children, the standard anterolateral or Smith-Petersen approach is used. This can be combined with a capsule placation, if needed, and/or an acetabular procedure. In a child older than 3 years, femoral shortening is typically performed instead of traction (see image below). At that time, if proximal femoral dysplasia is present, such as that observed with significant anteversion or coxa valga, this can also be corrected. However, whether traction or femoral shortening should be performed in children aged 2-3 years is controversial.
Pelvic osteotomy may be needed for residual hip dysplasia. When this should be performed is, again, somewhat controversial. Some authors suggest pelvic osteotomy in children as young as 18-24 months, whereas others suggest waiting until the children are aged at least 4 years. If open reduction is performed in a child older than 4 years with significant hip dysplasia, an acetabular procedure should be considered at the time of open reduction. If a closed reduction is performed earlier, at least 12-18 months of acetabular remodeling should be allowed before an acetabular procedure is undertaken. At that time, if no evidence of acetabular modeling is noted, a pelvic osteotomy should be considered.

**Postoperative Details**

When open reduction is performed, the patient wears a spica cast for 6 weeks; then, the patient is placed in an abduction orthosis.

**Follow-up**

The duration that a child remains in a hip orthosis is quite controversial and depends on the treating physician’s experience and the individual patient.

**Complications**

Numerous possible complications can occur, including redislocation, stiffness of the hip, infection, blood loss, and, possibly the most devastating, necrosis of the femoral head. The rate of femoral head necrosis varies significantly; depending on the study, the rate ranges from 0% to 73%. Numerous studies demonstrate that extreme abduction, especially combined with extension and internal rotation, results in a higher rate of avascular necrosis.

**Outcome and Prognosis**

Overall, the prognosis for children treated for hip dysplasia is very good, especially if the dysplasia is managed with closed treatment. If closed treatment is unsuccessful and open reduction is needed, the outcome is less favorable, although the short-term outcome appears to be satisfactory. If secondary procedures are needed to obtain reduction, then the overall outcome is significantly worse.

**Future and Controversies**

Early diagnosis is the most crucial aspect of the treatment of children with DDH. The use of ultrasonography and other diagnostic imaging modalities and the implementation of improved educational programs will most likely decrease the number of children with DDH diagnosed late. Newer, less invasive surgical techniques (eg, endoscopic techniques, image-guided surgery) are in the process of development in an effort to decrease the morbidity of surgery and to ease recovery.

**Multimedia**
Media file 1: The Galeazzi sign is a classic identifying sign for unilateral hip dislocation. To elicit the sign, the patient lies supine and the hips and knees are flexed. The examination should demonstrate that one leg appears shorter than the other. Although this appearance is usually due to a hip dislocation, realizing that any limb-length discrepancy results in a positive Galeazzi sign is important.

Normal Hip

Dislocated Hip

Acetabular Index

Hilgenreiner Line

Perkin Line

Shenton Line (intact)

Shenton Line (broken)

Media file 2: Numerous radiographic measurements have been used to assist in the evaluation of developmental dysplasia of the hip (a typical radiographic evaluation is described in this image). From an anteroposterior radiograph of the hips, a horizontal line (Hilgenreiner line) is drawn between the triradiate epiphyses. Next, lines are drawn perpendicular to the Hilgenreiner line through the superolateral edge of the acetabulum (Perkin line), dividing the hip into 4 quadrants. The proximal medial femur should be in the lower medial quadrant, or the ossific nucleus of the femoral head, if present (usually observed in patients aged 4-7 mo), should be in the lower medial quadrant.

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Media file 3: Radiographs from a 6-year-old child who underwent open reduction with capsular placation, femoral shortening, and a pelvic (Pemberton) osteotomy.

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### Keywords

developmental dysplasia of the hip, DDH, developmental dislocation of the hip, congenital dislocation of the hip, CDH, hip dysplasia, hip subluxation, hip dislocation, teratologic hip dislocation, hip instability, displaced hip, dislocated hip, cerebral palsy, myelomeningocele, arthrogryposis, Larsen syndrome, proximal femoral focal deficiency, Charcot-Marie-Tooth disease, Ortolani maneuver, Galeazzi sign

### Contributor Information and Disclosures

**Author**

James J McCarthy, MD, FAAN, FAAP, Associate Professor, Consulting Orthopedic Surgeon, Department of Orthopedics and Rehabilitation, University of Wisconsin School of Medicine and Public Health;

James J McCarthy, MD, FAAN, FAAP is a member of the following medical societies: Alpha Omega Alpha, American Academy for Cerebral Palsy and Developmental Medicine, American Academy of Orthopaedic Surgeons, American Academy of Pediatrics, American Orthopaedic Association, Limb Lengthening and Reconstruction Society ASAMI-North America, Orthopaedics Overseas, Pediatric Orthopaedic Society of North America, Pennsylvania Medical Society, Pennsylvania Orthopaedic Society, and Philadelphia County Medical Society

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**Medical Editor**

B Sonny Bal, MD, Associate Professor, Department of Orthopedic Surgery, University of Missouri School of Medicine

B Sonny Bal, MD is a member of the following medical societies: American Academy of Orthopaedic Surgeons

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**Pharmacy Editor**

Francisco Talavera, PharmD, PhD, Senior Pharmacy Editor, eMedicine

Disclosure: eMedicine Salary Employment

**Managing Editor**

B Sonny Bal, MD, Associate Professor, Department of Orthopedic Surgery, University of Missouri School of Medicine

B Sonny Bal, MD is a member of the following medical societies: American Academy of Orthopaedic Surgeons

Disclosure: Nothing to disclose.

**CME Editor**

Dinesh Patel, MD, FACS, Associate Clinical Professor of Orthopedic Surgery, Harvard Medical School; Chief of Arthroscopic Surgery, Department of Orthopedic Surgery, Massachusetts General Hospital

Dinesh Patel, MD, FACS is a member of the following medical societies: American Academy of Orthopaedic Surgeons, American Association of Physicians of Indian Origin, American College of International Physicians, and American College of Surgeons

Disclosure: Nothing to disclose.

**Chief Editor**

William L Jaffe, MD, Clinical Professor of Orthopedic Surgery, New York University School of Medicine; Vice Chairman, Department of Orthopedic Surgery, New York University Hospital for Joint Diseases

William L Jaffe, MD is a member of the following medical societies: American Academy of Orthopaedic Surgeons, American College of Surgeons, American Orthopaedic Association, Eastern Orthopaedic Association, and New York Academy of Medicine

Disclosure: Stryker Orthopaedics Consulting fee Speaking and teaching

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