Summary
Abnormalities of the proximal femur in children range from teratologic hip dislocation and congenital coxa vara seen at birth to acquired disorders such as Legg–Calve–Perthes disease and slipped capital femoral epiphysis in later life. Left untreated, these conditions may lead to long-term morbidity in adulthood, ranging from early degenerative joint disease to complete inability to walk. However, treatment itself can be associated with significant complications such as avascular necrosis of the femoral head and chondrolysis, as well as the general risks of surgery. Optimal treatment requires careful consideration and planning and, importantly, involvement of parents in the decision-making process. Many of these conditions can be treated with a readjustment osteotomy of the proximal femur sometimes associated with a pelvic osteotomy. Prompt and timely intervention in the hands of an experienced surgeon can produce excellent results.

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Congenital dislocation of the hip (CDH)
CDH is more correctly referred to as developmental dysplasia of the hip (DDH) as few hips are truly dislocated at birth. Hip dislocations in the neonate are thought to be due to teratologic factors. The incidence of late DDH is approximately 2 per 1000 live births, compared to neonatal hip instability of 5–20 per 1000. The majority of these spontaneously stabilise. For 60% of neonates with hip instability no known risk factor(s) can be identified. In 20% of cases both hips are unstable. There are, however, well-documented risk factors such as a positive family history, female sex, firstborn children, oligohydramnios, high birth weight and breech presentation. Girls are affected more than boys at a ratio of 5:1. Breech presentation, particularly with extended knees, increases the incidence by a factor of 10. Other congenital anomalies including torticollis, metatarsus adductus, congenital talipes equinovarus (CTEV), congenital vertical talus (CVT) and calcaneovalgus (CV) are associated with DDH.

As part of routine post-natal screening, the hips are clinically examined by employing the Ortolani and Barlow tests. These tests become less appropriate in the older infants because secondary signs develop (restriction of abduction, shortening, and thigh crease asymmetry). A toddler with DDH will often be noted to have asymmetric limb lengths and will walk with a limp.

Static and dynamic ultrasonography is of value in the assessment and treatment of DDH. Management is dictated by the degree of hip instability, the mainstay of treatment being the abduction harness. Failure to respond to treatment,
or delay in presentation, results in more invasive treatment, namely an arthrogram, adductor tenotomy, with open or closed reduction of the dislocation.\textsuperscript{1}

Hip dislocation in the older child (Fig. 1) poses a greater challenge. Children presenting beyond the age of 2 years inevitably require an open reduction and are also likely to require a femoral shortening osteotomy to locate the hip without undue femoral head compression.

In the infantile hip, femoral neck anteversion and the neck shaft angle are increased. It is also well known that the dysplastic acetabulum is deficient anterosuperiorly. Surgical corrections of these alterations is important.\textsuperscript{1,2}

In the planning stage of surgical correction of the dislocated hip in the older child the parents are counselled about the need not only for an open reduction of the hip but also for a varus derotation, shortening osteotomy. This type of osteotomy is aimed at redirecting the head of the femur both medially and posteriorly, maximising its containment in an otherwise deficient acetabulum.

At the time of surgery the hip joint is approached anteriorly through a Smith–Peterson approach. A capsulotomy is performed and the true floor of the acetabulum is identified. Structures blocking reduction are addressed, notably the ligamentum teres, the pulvinar (fat pad) and the limbus. A trial reduction of the hip is then undertaken with the hip in a position of abduction and internal rotation.

A second incision is made to approach the lateral femur and a Coventry lag screw is placed in the femoral neck distal to the capital epiphysis. This gives control of the proximal fragment prior to performing subperiosteal subtrochanteric shortening osteotomy sufficient to allow femoral head reduction without tension. The degree of varus is assessed by reducing the hip and the Coventry plate contoured accordingly. The femur is then derotated to bring the foot into a normal anatomical position. The osteotomy is secured with screws through the Coventry plate (Fig. 2).

Femoral head stability is improved with a capsulorrhaphy and all wounds are closed. The osteotomy is protected with a spica cast (Fig. 3) for 6 weeks, at which point it is converted to a broomstick plaster to maintain abduction for a further 6 weeks. The broomstick plaster is exchanged for night splints for 6 weeks. The implants are removed at 4–6 months post-operatively. Residual acetabular dysplasia is addressed by a later pelvic osteotomy.

**Cerebral palsy**

Cerebral palsy is a new progressive abnormality of the central nervous system, resulting in an impairment of motor function. The neurological insult occurs before the age of 2 years but the musculoskeletal manifestations may worsen throughout later life.

The most common musculoskeletal deformity associated with cerebral palsy is equinus of the foot followed by hip displacement. Neurological subluxation or dislocation of the

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**Figure 1** Late-presenting left-hip dislocation.

**Figure 2** Intraoperative image intensifier image following varus derotation osteotomy and final placement of metalwork.

**Figure 3** Post-operative CT scan scout image demonstrating hip relocation and the one and a half spica.
A hip in cerebral palsy is more commonly associated with global body involvement such as spastic quadriplegia. Hips are usually located at birth but gradually displace under the influence of abnormal muscle balance and tone. In the normal hip, there is an interaction between the femoral capital epiphysis and the acetabulum stimulating normal development of both the proximal femur and the acetabulum. In the neurological hip, the muscle imbalance results in abnormalities of both the proximal femur and the acetabulum. Excessive femoral anteversion and valgus combine with abnormal acetabular development to produce progressive subluxation and dislocation of the hip (Fig. 4).

Treatment of the neurological hip is guided by several factors: whether the child is ambulatory, whether or not the hip is painful and if there are difficulties with sitting balance or perineal hygiene.

Managing the hip in cerebral palsy requires regular surveillance. When monitoring the neurological hip the most important radiographic parameter is the migration percentage. Since the acetabular index and centre edge angle are unreliable, the migration percentage is calculated from serial radiographs and it measures the percentage of lateral displacement of the hip. Migration of 25–30% (Normal 10%), or an increase of more than 10% in 1 year, is used as the criterion for intervention (early subluxation of 30–50%). Soft tissue procedures are used such as psoas-adductor release. For moderate subluxation of greater than 50% proximal varus derotation shortening osteotomy is recommended, combined with a pelvic osteotomy if acetabular dysplasia is severe enough. For dislocations with a migration percentage greater than 90%, reconstructive or salvage procedures should be considered.

Hip subluxation or dislocation occurs in 3–7% of ambulant children with cerebral palsy. For those with spastic quadriplegia, only 20% will walk.

**Femoral varus derotation shortening osteotomy**

The patient is placed supine on the operating table with the affected hip supported on a wedge. The proximal femur is approached via the direct lateral approach, elevating rather than splitting vastus lateralis, and exposing the bone subperiostially. The degree of varus correction is estimated from image intensifier images. If 20° of varus is required then a guidewire is passed into the femoral neck under X-ray control at 20° to the transverse plane of the femoral shaft.

**Proximal femoral osteotomy as salvage**

Chronically dislocated, painful hips can be dealt with by means of salvage osteotomies. Proximal femoral resection should be performed extraperiosteally to minimise the risk of heterotopic ossification, and this removes bone to 3 cm below the lesser trochanter.

Despite resection of the proximal femur proximal migration may still occur, resulting in a painful articulation of the resected proximal femur and acetabulum. This uncommon
complication can be overcome by a Shanz abduction osteotomy. Lateralisation of the proximal femur abolishes the painful articulation.\textsuperscript{4,5}

**Legg–calve–perthes disease (LCPD)**

The current definition of Perthes’ disease is ‘Osteonecrosis of the proximal femoral epiphysis in a growing child caused by poorly understood non-genetic factors.’ The condition is more common in boys (ratio of 4:1) with an average age of onset of 7 years and a range of 2–12. Some 10–12% are bilateral and that condition is familiar in approximately 10%. There is a predisposition in children with delayed bone age.

Symptomatic treatment involves bed rest and skin traction while the hip is irritable followed by partial weight bearing and physiotherapy.

Prolonged bed rest and immobilisation does not change the radiological course of the disease. Containment of the femoral head can be achieved by means of an osteotomy of the femur or pelvis. Both require a nearly full range of movement of the hip (no more than 10° loss of motion in any direction). Surgical containment by pelvic osteotomy or by femoral osteotomy has similar results, the latter comprising varus with or without derotation or valgus-extension to relieve hinge abduction. Salter and valgus osteotomies lengthen the leg, whereas femoral varus osteotomy shortens it and may necessitate subsequent distal femoral epiphysiodesis of the contralateral limb.

**Treatment of late disease**

A problematic late sequela of Perthes disease is hinge abduction as described by Grossbard and Catterall.\textsuperscript{6,7} They described an abnormal movement of the hip which occurs when a deformed femoral head, often with a large uncovered anterolateral segment, impinges against the lateral lip of the acetabulum (Fig. 7). This most commonly occurs in Perthes’ disease but also in other causes of avascular necrosis (AVN) of the femoral head. Physioseal arrest produces a leg length discrepancy with a short femoral neck and a high trochanter resulting in gluteal insufficiency. The valgus-extension osteotomy is designed to increase abduction and bring the more normal medial femoral head into the weight-bearing area. The pre-requisites for this form of osteotomy are (1) an arthrogram confirming hinge abduction and (2) a congruent hip in adduction with a good range of adduction.

**The Sugioka valgus osteotomy variant**

The Sugioka osteotomy is a closing wedge intertrochanteric osteotomy.\textsuperscript{6} It is performed with the patient in the lateral position. A longitudinal incision is made over the greater trochanter, which is exposed following division of the fascia lata. The flare of the femur at the base of the greater trochanter is exposed and a greater trochanteric osteotomy is performed along the line of the physis. The trochanter and its muscle attachments are reflected cephalad. A closing wedge osteotomy is then performed from the exposed surface of the greater trochanteric osteotomy in a caudal–medial direction, with the apex at the level of the lesser trochanter. The leg is then abducted to close the wedge and the osteotomy secured with two cannulated screws using image intensifier control. The osteotomised greater trochanter is then advanced caudally and secured with wire (Fig. 8).

The post-operative regimen requires 6 weeks of non-weight-bearing with crutches followed by partial weight-bearing for a further 6 weeks. Metalwork is routinely removed 6–9 months post-operatively.

**Figure 7** LCPD of the right hip.
Slipped capital femoral epiphysis (SUFE)

Slipped capital femoral epiphysis usually occurs between the age of 12 and 15 years. It is a disorder characterized by displacement of the femoral capital epiphysis from the metaphysis through the hypertrophic zone of the physis. However, in fact the metaphysis displaces in relationship to the epiphysis.

The incidence is reported to be 3/100,000 in whites and 7/100,000 in blacks. It occurs in the left hip more than the right and is bilateral in 25% of cases. Those at risk are often overweight and are undergoing a growth spurt. Endocrinopathies such as hypothyroidism, renal rickets, pituitary deficiency and treated growth hormone deficiency are known risk factors and slippage may cause slippage at a younger age.

Radiographs are pathognomonic, revealing that Klein’s line does not pass through the lateral edge of the femoral capital epiphysis on the AP and cross-table lateral radiographs of the hip. Other radiological findings include widening and irregularity of the physis and decrease in epiphyseal height.

Patients may present with a history of worsening hip or knee pain, for 3 weeks or more, in which case the slip is said to be chronic. For those with prodromal symptoms of less than 3 weeks the slip is said to be acute. The presentation can also be classified into unstable or stable according to whether the child can weight-bear with or without crutches. This distinction is important as the risk of AVN is significantly higher in acute unstable slips. SUFE is also classified depending on the degree of the slip seen on radiographs. Slips of less than 30° are mild whereas those over 60° are severe.

Treatment can be divided into three categories:

1. prevention of further slippage,
2. reduction of the degree of slippage,
3. salvage procedures.

Treatment of further slippage is achieved by in situ fixation with pins or a screw. Salvage procedures in the young principally consist of hip arthrodesis. Long-term studies confirm that the outcome following a SUFE depends on the degree of the initial slip and degenerative joint disease commonly follows moderate and severe slips.

Osteotomy of the proximal femur is restricted to severe slips (Fig. 9) as surgical intervention is not without risk, particularly avascular necrosis and chondrolysis.9,10 Intracapsular osteotomies are associated with rates of AVN as high as 35% and rates of chondrolysis of 30%. The Southwick osteotomy is extra-capsular with lower rates of complications but provides less correction.11

The Dunn osteotomy

Dunn proposed his osteotomy for severe slips in 1964.12 His primary objective was to place the epiphysis on the femoral neck without disruption of the retinacular blood supply. This was achieved through a lateral approach to the hip and a trochanteric osteotomy. The capsulotomy is formed by an incision running around the edge of the acetabulum and a vertical limb along the lateral aspect of the femoral neck to the level of the trochanteric base. The posterior ascending retinacular vessels are carefully preserved. Once the femoral neck has been exposed a trapezoidal osteotomy shortens the femoral neck, allowing the epiphysis to be placed on the cut femoral neck and held with a screw. Weight-bearing is restricted for 6 weeks and the implant removed at 1 year. A contralateral epiphysiodesis may be required.
Southwick osteotomy

Southwick proposed his osteotomy in 1967, for slips that were moderate to severe. The anterolateral aspect of the femur is approached subperiosteally and the lesser trochanter identified. The iliopsoas tendon is released. The femur is marked with a vertical line along the lateral edge. Using this orientation mark and templates a technically challenging triplane osteotomy is performed. The hip is then abducted and flexed at the level of the osteotomy achieving the desired correction. In the original description the correction was held with an external fixator but in the modern era a blade plate is used.

This osteotomy can be performed at presentation or later if the hip has initially been stabilised with pinning. The advantages of this are that the hip can be monitored for remodeling potential prior to undertaking a Southwick osteotomy, which can be reserved for hips that fail to remodel significantly.

Fish osteotomy

Fish reported his series of intracapsular osteotomies in 1984. The hip is approached anterolaterally. The capsule is opened longitudinally and transversely both proximally and distally to expose the femoral neck. The capital femoral epiphysis is then identified. A cuneiform osteotomy of the femoral neck distal to the physis is performed. All remaining physeal cartilage is removed using a curette. The epiphysis is seated on the cut femoral neck and held with pins or screws (Fig. 10).

Post-operatively the patient is kept touch weight-bearing until healing of the osteotomy is seen radiographically. The pins are removed at a later date.

Figure 10  Reduction and fixation following Fish osteotomy.

Coxa vara

Coxa vara is a retroverted deformity of the proximal femur where the angle between the neck and the shaft is reduced to less than 110°, and more typically 90° (normal 130–145°). An alternative to this measurement is the Hilgenreiner-epiphyseal angle, which is calculated by drawing a line along the physis and through the triradiate cartilages. The natural history of developmental coxa vara is variable, the greater the angle, the more propensity toward shear stress on the physis, and the less chance of spontaneous recovery.

Coxa vara has been classified by Beals as developmental, congenital, or traumatic. Infantile or developmental coxa vara is estimated to affect 1:25,000 live births and has a post-natal onset. It is bilateral in about 1/3 of cases. Clinically, there is shortening of the limb of approximately 2 cm, with weakness of the abductors and thigh atrophy. Radiographically, developmental coxa vara is characterized by a triangular metaphyseal fragment of the inferior femoral neck. Associated conditions include spondylometaphyseal dysplasia, spondyloepiphyseal dysplasia, and cleidocranial dysplasia.

Other causes of coxa vara are congenital, dysplastic, or traumatic. Congenital coxa vara is the least severe form of proximal focal femoral deficiency and is characteristic of all degrees of severity. The condition is present at birth, usually unilateral and non-progressive. A number of generalised skeletal dysplasias are characterized by dysplastic coxa vara which is often bilateral, progressive and does not remodel.

Traumatic coxa vara can obviously result from femoral neck fracture or from proximal femoral physeal arrest with resultant relative overgrowth of the greater trochanter. The latter can follow hip sepsis or avascular necrosis of the femoral head. Coxa vara resulting from relative overgrowth of the greater trochanter is treated by physeal arrest of the greater trochanter or distal transfer of the greater trochanter to improve hip mechanics.

Valgus proximal femoral osteotomy at the intertrochanteric or subtrochanteric region is the only effective intervention. Sufficient valgus must be achieved to reduce shear forces along the physis and a valgus osteotomy therefore rotates the proximal femoral physis from a vertical to horizontal position. Pauwels’ Y-shaped osteotomy and Langenskiold’s valgus producing osteotomy are examples of intertrochanteric corrective osteotomies.

Once the osteotomy has been performed it is held with a variety of internal fixation devices such as a blade plate or screw and plate combination. To minimise the risk of recurrence the Hilgenreiner-epiphyseal angle needs to be reduced to less than 40° and the neck shaft angle increased to greater than 160°. Correct treatment of coxa vara results in a painfree functional hip with a negative Trendelenborg gait. A mild leg length discrepancy may persist post-operatively which can be addressed with a contralateral epiphysiodesis. However, in the majority of cases leg length discrepancy is insignificant.
Conclusion

A wide variety of conditions affect the hip in children ranging from the newborn to the adolescent. Osteotomy of the proximal femur may be intracapsular or extracapsular, varus or valgus, and with or without a rotational element. A redirectional osteotomy in some circumstances will need to be augmented with a pelvic osteotomy. Leg length inequality can be a sequela of surgery but can be addressed with a contralateral epiphysiodesis if treated in time.

On the whole, there is consensus regarding the management of most hip conditions in the child. However, surgical intervention is far from risk-free and controversy persists around the management of some conditions.

References