Treatment of limb length discrepancy following total hip arthroplasty

ABSTRACT

Limb length discrepancy is the leading cause of patient dissatisfaction following total hip arthroplasty and the most common reason for litigation in the field of orthopaedics. This article provides a systematic, stepwise approach for identifying the aetiology of limb length discrepancy following total hip arthroplasty and provides guidance on the treatment of this complication to optimize postoperative clinical and functional outcomes. This review discusses postoperative history taking, clinical examination, radiographic assessment, conservative treatment, and surgical intervention for the management of patients with established limb length discrepancy following total hip arthroplasty. A comprehensive understanding of the multifactorial nature and methods of managing postoperative limb length discrepancy is essential for optimizing patient satisfaction, clinical outcomes and long-term function following total hip arthroplasty.

Total hip arthroplasty is a successful and highly cost-effective surgical treatment for patients with symptomatic hip osteoarthritis (Chang et al, 1996). Limb length discrepancy is a recognized complication that may lead to altered hip biomechanics, dysfunctional gait, lower back pain, sciatica, instability and early implant loosening (Bhave et al, 1999; White and Dougall, 2002). The incidence of leg length discrepancy following total hip arthroplasty ranges from 1–30% and the mean postoperative leg length inequality ranges from 3–17 mm (Ranawat and Rodriguez, 1997). Limb length discrepancy is the leading cause of patient dissatisfaction following total hip arthroplasty and the most common reason for litigation in orthopaedics (Hofmann and Skrzynski, 2000). A comprehensive understanding of the multifactorial nature and management of limb length discrepancy following total hip arthroplasty is essential to improve patient satisfaction, optimize clinical outcomes and minimize long-term complications.

This article provides a systematic, stepwise approach for the treatment of patients with leg length discrepancy following total hip arthroplasty. It discusses postoperative history taking, clinical examination, radiographic assessment, conservative treatment, and surgical intervention for the management of patients with established limb length discrepancy following total hip arthroplasty. This article follows on from the previous article by the same authors on the prevention of leg length discrepancy in total hip arthroplasty (Kayani et al, 2017). In combination, these articles provide the reader with a comprehensive understanding of the multifactorial aetiology, diagnosis, imaging and treatment strategies for leg length discrepancy in total hip arthroplasty.

Medical history

Patients often present in the early postoperative period with a 'perceived sensation' that the operated leg is longer. This is because the underlying disease process causes contractures of the soft tissues and muscles around the affected hip joint. The contractures cause inclination of the pelvis towards the diseased side. During total hip arthroplasty, these contractures are released and the pelvic inclination corrected, which makes the operated leg feel longer following surgery (Kayani et al, 2017). This perceived limb length discrepancy is poorly correlated with a structural leg length discrepancy (Rösler and Perka, 2000), and usually resolves with time and physiotherapy to stretch the affected soft tissue contractures. In a case series of 1114 patients, 30% of patients (329 total hip arthroplasties) reported a perceived leg length discrepancy but only 36% of these patients had a structural leg length discrepancy on radiographic imaging (Wylde et al, 2008). These patients should be counselled and reassured that perceived leg length inequality is poorly correlated to any long-term functional compromise and usually resolves within 6 months of surgery (Ranawat and Rodriguez, 1997).

An accurate and detailed medical history is imperative for understanding the patient's concerns and establishing an appropriate treatment algorithm. Patients with leg length discrepancy following total hip arthroplasty may present with pain, neurological disturbance, instability, abnormal gait, muscle spasms, and fatigue in the lumbar region or contralateral side. It is important to assess progress with clinical and functional outcomes as limb length discrepancy may lead to increased energy consumption and fatigue owing to altered gait mechanics, compensatory use of accessory muscles and secondary joint pain (Benedetti et al,

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2010). Artificial lengthening of a limb through the use of a 2 cm insole in patients with equal leg lengths has been shown to increase oxygen consumption during the gait cycle on treadmill analysis (Gurney et al, 2001). Reduced tolerance to limb length inequality has been reported in patients with a contralateral short limb, scoliosis, and reduced cardiac and respiratory reserve (Benedetti et al, 2010). Patients of smaller stature also tolerate proportionately smaller amounts of leg length discrepancy. Patients with these risk factors should be proactively informed about their increased risk of complications with leg length discrepancy and followed up more closely in the postoperative period.

Clinical examination

Clinical examination should include complete evaluation of the spine, hip and knee with full neurological examination of both lower limbs. Postoperative findings relating to leg length discrepancy or joint contractures should be compared to preoperative findings and clearly discussed with the patient and rehabilitation team. Examination of the gait pattern in patients with a limb length discrepancy may reveal the use of compensatory mechanisms including toe walking on the shorter side, pelvic tilt, and circumduction during the swing phase or knee flexion during the stance phase on the longer side (Ng et al, 2013). The 'flexed knee syndrome' is used to describe patients with constant knee flexion on the longer side during the gait cycle. This is often associated with over-firing of the ipsilateral quadriceps and hamstrings. Patients with functional limb length inequality secondary to a flexion–abduction contracture on the operative side have pelvic tilt towards this operated side. However, if the patient has appropriate intraoperative releases but flexion–abduction contractures on the contralateral side then he/she may have functional leg length discrepancy with pelvic tilt towards the non-operated side.

Clinical examination and measurement of leg lengths are important because plain radiographs of the pelvis will only take into account leg length inequality in the proximal femur and will disregard subtrochanteric causes. Structural leg length measurements should be recorded with the patient in the supine position (Paley, 2003). A tape measure should be used to measure and compare distances from the anterior superior iliac spines to the medial malleoli bilaterally. These should be recorded in the patient's notes. This is a reliable method for measuring structural limb length discrepancy to an accuracy of approximately 1 cm (Ng et al, 2013). Ober's test should be used to elicit any contractures of the iliotibial band or tensor fasciae lata, and Thomas test performed to record any fixed flexion deformities at the hip joints. To assess the relative contribution of the femur and tibia, further measurements of these structures using the greater trochanters, patella and medial malleoli may be performed.

Apparent leg lengths may be recorded with the patient in the supine position by measuring and comparing distances from the xiphisternum to the medial malleoli bilaterally (Kayani et al, 2017). Alternatively, apparent leg lengths may be assessed using block testing, which places graduated 5 mm raises under the shorter leg until the patient feels level and the anterior superior iliac spines feel even to the examiner. Using this technique, pelvic obliquity secondary to structural leg length discrepancy, flexible spinal deformities, and hip or knee contractures will resolve. Apparent leg lengths enable assessment of pelvic obliquity and contractures but it is important to remember that some pathology, such as rigid scoliosis or concurrent hip abduction or adduction contractures, may not improve with block testing. Examination of the spine should note any coronal or sagittal deformity with the patient standing and include Adams forward-bending test to assess for thoracolumbar scoliosis. A compensatory, flexible scoliosis may develop in patients with leg length discrepancy. A block should be placed under the shorter extremity to measure the discrepancy more accurately and assess if the coronal scoliosis is flexible or rigid.

Postoperative imaging

Postoperative anteroposterior pelvic radiographs may be used to assess implant position and changes in leg length discrepancy. Differences between the templated and final implant positions relative to bony landmarks may help to ascertain whether the acetabular cup and/or the femoral stem is responsible for any leg length discrepancy. Commonly used landmarks include the acetabular teardrop for the acetabular cup and the lesser trochanter for the femoral stem. The tip of the greater trochanter should be approximately at the same horizontal level as the centre of the femoral head. Modified cross-table lateral radiographs and computed tomography scans may be obtained if more detailed information regarding component position and orientation is required. It is also worth noting the presence of any osteoarthritis on the contralateral side, which may offer the opportunity to correct leg length inequality at a later stage with total hip arthroplasty.

There are two commonly used techniques for the radiographic measurement of leg lengths, and both techniques use pelvic and femoral reference points. The first technique uses a horizontal line transecting through the inferior aspects of the acetabular teardrops as the pelvic reference point (Woolson et al, 1999). The femoral reference point is the vertex of the lesser trochanter, which is the most prominent point on this bony landmark. Measurements are taken from these femoral reference points vertically up to the line transecting the pelvic reference points on both sides. The difference in the measurements between the two sides is the true leg length discrepancy caused by the hip and proximal femur. This technique for leg length measurement is as reliable as orthoenthenograms and reproducible with a measurement error of +/- 1 mm (Nakanowatari et al, 2013). The second technique uses a horizontal line transecting through the ischial tuberosities as the pelvic reference point (Williamson and Reckling, 1978). The vertical distance from the vertex of the lesser trochanter to this horizontal line is calculated and the difference between the two sides represents the limb length inequality. It is important to remember that these techniques assume that there is no axial rotation of the pelvis and do not consider limb length

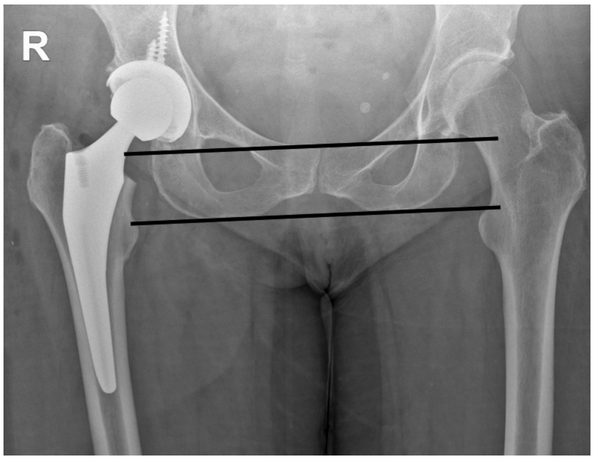

Figure 1. Anteroposterior pelvic radiograph showing the inferior aspect of the acetabular teardrops and ischial tuberosities as fixed pelvic reference points for the assessment of leg length discrepancy following total hip arthroplasty.

differences owing to anatomy below the lesser trochanters (Keršič et al, 2014) (*Figure 1*).

Conservative treatment

Leg length inequality in the early postoperative period may be the result of periarticular muscle contractures resulting in pelvic obliquity with functional leg length discrepancy (Ranawat and Rodriguez, 1997). Contractures of the abductor muscles cause the ipsilateral hemipelvis to drop down with an apparent lengthening of the leg. Conversely, contractures of the adductor muscles cause the involved hemipelvis to be raised up with an apparent shortening of the affected limb. These patients may report leg length inequality following total hip arthroplasty but on clinical and radiological examination there is no structural discrepancy.

Patient education and physiotherapy to stretch the affected soft tissue will help to release these contractures and improve or correct this functional leg length discrepancy (Ranawat and Rodriguez, 1997). The hula manoeuvre is used to stretch the hip abductor muscles and capsule by crossing the foot on the affected side over the contralateral foot while standing and leaning to the contralateral side. Anterior hip structures such as the rectus femoris muscle may be stretched by laying the patient prone and hyperextending the hips by pushing up with the arms. These procedures should initially be performed under supervision within the safe range of motion to avoid dislocation.

In a case series of 100 patients undergoing primary total hip arthroplasty, 14 patients had functional leg length inequality at 1 month following surgery but this had completely resolved in all patients by 6 months after surgery (Ranawat and Rodriguez, 1997). Functional leg length discrepancy following total hip arthroplasty may persist in 0.5–7% of patients despite physiotherapy (Ng et al, 2013). It is advisable to continue physiotherapy and soft tissue mobilization procedures but avoid introducing shoe inserts until at least 6 months after surgery (Ng et al, 2013). This will provide sufficient time for relaxation of periarticular muscles and spontaneous resolution of any functional leg length discrepancy.

The average leg length discrepancy following total hip arthroplasty is -1 to 3.5 mm (Ng et al, 2013) but there is no uniform consensus on the threshold at which leg length discrepancy is clinically relevant. Studies have shown that one-third of the general population have a leg length discrepancy of 5 mm to 2 cm which is completely asymptomatic (Hellsing, 1988) and inequalities of up to 2 cm following total hip arthroplasty do not impair the symmetry of time–distance parameters or hip kinematics during gait or stair walking (Benedetti et al, 2010). However, other studies have shown that up to 50% of patients with limb length discrepancy of 10 mm are symptomatic and 15–20% of these require shoe modification (Ranawat, 1999). In general, patients with structural limb length discrepancies up to 10 mm can usually tolerate this and do not require orthotic adjuncts. Limb length discrepancies greater than 10 mm may benefit from shoe inserts, which help to artificially reduce any limb length inequality. Shoe inserts may allow as much as 9.5 mm of additional height before additional shoe modifications are necessary (Bhave et al, 1999). Artificial correction of leg lengths using shoe insoles after total hip arthroplasty is associated with reduced pain, muscle fatigue and scoliosis, with improved posture and gait efficiency (Bhave et al, 1999).

Surgical treatment

Revision surgery for leg length discrepancy following total hip arthroplasty may be required in patients with neurological compromise, instability, pain and fatigue of the hip or lumbar spine, and/or impairment in quality of life that has not resolved within 6–12 months of surgery (Ng et al, 2013). There is no clear benchmark for the magnitude of limb lengthening that causes neurological disturbance. Studies have shown limb length inequality of 6–35 mm following total hip arthroplasty is clinically significant (Edwards et al, 1987; Bhave et al, 1999; Gurney et al, 2001), with common peroneal nerve palsy on limb lengthening by 27 mm and sciatic nerve palsy on limb lengthening by 44 mm (Edwards et al, 1987). However, other studies have shown that up to one-third of patients have a perceived limb length discrepancy (Edeen et al, 1995) following total hip arthroplasty and leg length inequalities of up to of 35 mm may be completely asymptomatic (White and Dougall, 2002).

In patients with neurological compromise following total hip arthroplasty it is prudent to consider other causes of neurological compromise other than 'stretching' of the affected nerve secondary to limb lengthening. Other causes of neurological compromise include direct trauma from retractor positioning, compression as a result of haematoma, and heat from polymethylmethacralate polymerization. Patients may require further diagnostic investigations with postoperative computed tomography, ultrasound and electromyography studies to confirm the level of injury and guide prognosis. Peroneal nerve palsy in patients with limb length discrepancy of less than 6 mm may resolve spontaneously within 6–24 months (Woolson et al, 1999).

During this time, persistent foot drop should be managed with ankle foot orthosis and passive physiotherapy to prevent contractures and flexion deformities.

Revision surgery for limb lengthening with neurological compromise following total hip arthroplasty has a variable success rate. In a series of 17 patients with severe neurological deficit and persistent paraesthesia with limb lengthening (range 1.3–4.1 cm) following total hip arthroplasty, revision surgery with limb shortening was undertaken (Pritchett, 2004). This included two acetabular revisions, five modular head exchanges and 10 femoral component revisions. The mean shortening with revision surgery was 1.5 cm (range 0.5–3.6 cm). Nine of these patients had excellent outcomes, which was defined as the elimination of their paraesthesia. Seven of the 11 patients with motor compromise had improvement in strength with three of these patients making a full recovery. Two patients had partial improvement in symptoms and six patients had no improvement in symptoms. Although some centres report full resolution of pain, paraesthesia and improved hip instability with revision surgery to correct a lengthened limb with neurological disturbance (Parvizi et al, 2003), the outcomes and prognosis following revision surgery are highly variable. This must be discussed clearly with patients before embarking on revision surgery for leg length discrepancy with neurological compromise. Intraoperative assessment of soft tissue contractures should also be performed and releases performed appropriately as per routine total hip arthroplasty to minimize any functional limb length discrepancy (Kayani et al, 2017).

In patients with femoral and acetabular implants that are well positioned and aligned, the simplest option is modular component exchange. Revising the head size, adjusting the neck length and changing the acetabular liner are the simplest solutions. These procedures may be combined with excision of soft tissues and bone causing impingement to improve hip stability and correct leg length (Toomey et al, 2001). However, modular component exchange may increase risk of liner dissociation and impingement, instability and femoral head dislodgment from the stem trunnion (Barrack et al, 1993). Patients undergoing revision surgery with modular component exchange for leg length inequality will require more scrupulous clinical and radiological follow up for these complications.

Plain imaging or computed tomography may reveal suboptimal implant position and/or orientation leading to leg length discrepancy and/or instability. Intraoperative malposition of the acetabular cup in the primary total hip arthroplasty may lead the surgeon to overlengthen the femur to improve stability. In such cases, revision of the cup and conversion to a modular head may help to correct the leg length without compromising stability further. Overstretching the adjacent soft tissues may create laxity that may be addressed with increasing the diameter of the femoral head, inserting lateralized acetabular liners, high-offset femoral components and/or trochanteric advancement (Berend et al, 2010).

Careful preoperative imaging and intraoperative assessment must be undertaken to assess the relative contribution of both the femoral and acetabular components to any leg length discrepancy and instability. Primary suboptimal positioning and orientation of the femoral (Konyves and Bannister, 2005) or acetabular component (Parvizi et al, 2003) may be responsible for leg length inequality. In a study of 21 patients with symptomatic leg length discrepancy, revision surgery was undertaken by a single surgeon at 8 months (range 6 days to 6 years) following primary total hip arthroplasty (Parvizi et al, 2003). The study included 11 patients with hip and/or back pain, eight patients with hip instability, one patient with hip pain and paraesthesia, and one patient with hip pain and ipsilateral foot drop. The mean leg length discrepancy was 4 cm (range 2–7 cm). Of these patients, 15 patients underwent revision of the acetabular cup, three patients underwent revision of the acetabular cup and femoral component, and three patients underwent revision of the femoral component. The study showed equalization of leg lengths in 15 patients, discrepancy reduced to less than 1 cm in the remaining six patients, and an overall improvement in the Harris Hip score. Two patients were not satisfied with the outcome of surgery because of ongoing back or hip pain and hip subluxation.

The authors emphasized the importance of evaluating the components to be revised by distinguishing between two types of excessive limb lengthening. The first category includes component malposition that leads directly to limb lengthening. For example, the acetabular cup is placed inferior to the teardrop or the femoral component is not appropriately seated into the proximal femur. The second category includes component malposition with compensatory changes to the other component to maintain stability. For example, excessive acetabular component retroversion leading to intraoperative instability, which causes the surgeon to tighten the soft tissues by increasing the femoral neck length or offset of the femoral stem. These may improve hip stability but lead to excessive leg lengthening. Meticulous review of preoperative imaging and careful intraoperative assessment of both femoral and acetabular components should be undertaken to restore leg length equality while preserving stability and function.

The use of distraction osteogenesis to increase leg length on the contralateral shorter limb following total hip arthroplasty was described in a series of three patients (Thakral et al, 2014). In this study, two methods were used to correct leg length discrepancies of 2 cm after total hip arthroplasty: lengthening with an external fixator over a femoral nail and lengthening with an intramedullary kinetic skeletal distractor. The authors reported equal leg lengths in less than 4 weeks, healed distraction gap at 4 months, and no postoperative complications. This study had a small size with no long-term follow up and limited data on clinical and functional outcomes. More recently, evolution in computer-guided and robotic-assisted total hip arthroplasty has enabled on-table assessment and correction of leg lengths with more accurate implant positioning and preservation of hip stability and femoral offset.

Conclusions

Limb length discrepancy following total hip arthroplasty is multifactorial. A comprehensive medical history, clinical examination and radiographic assessment will help to quantify the leg length inequality, establish the underlying aetiology and guide further treatment. Functional leg length discrepancy following total hip arthroplasty often arises secondary to hip contractures causing pelvic obliquity. This may be effectively treated with physiotherapy to stretch the soft tissue contractures and strengthen periarticular musculature. Residual symptomatic functional and structural leg length discrepancy may require insoles and shoe modification to artificially correct leg length. Surgical intervention may include soft tissue releases, modular component exchange, and revision of malpositioned femoral and acetabular implants but both clinicians and patients should understand that outcomes of revision surgery for leg length discrepancy are highly variable. **BJHM**

Conflict of interest: none.

KEY POINTS

- Limb length inequality following total hip arthroplasty may lead to altered hip biomechanics, dysfunctional gait, lower back pain, sciatica, instability and increased risk of dislocation.
- Postoperative history taking must ascertain any pain, instability, fatigue and neurological symptoms associated with limb length discrepancy.
- Clinical examination should identify any structural and/or functional limb length discrepancy following total hip arthroplasty.
- Functional limb length inequality in the early postoperative period is often the result of muscle contractures, which resolve with time and physiotherapy.
- Implant positioning on postoperative plain radiographs should be compared to preoperative templates using osseous landmarks to identify the relative contribution of the acetabular cup and femoral stem to any leg length discrepancy.
- Shoe insoles may be used to artificially correct leg length but should not be prescribed until 6 months after surgery to allow sufficient time for soft tissue contractures to resolve.
- Surgical intervention for leg length discrepancy following total hip arthroplasty may include soft tissue release, modular implant exchange, and change of femoral and/or acetabular implants but outcomes of revision surgery are highly variable.

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