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Review article

Nerve injuries associated with total hip arthroplasty

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ABSTRACT

Nerve injury is a relatively rare, yet potentially devastating complication of total hip arthroplasty (THA). Incidence of this ranges from 0.6 to 3.7%, and is highest in patients with developmental hip dysplasia and previous hip surgery. Apart from patient and surgeon dissatisfaction, this complication can have medico-legal consequences. Therefore, the purpose of this study was to review the risk factors, etiology, diagnostic options, management strategies, prognosis, and prevention measures of nerve injuries associated with THA. We specifically evaluated the: 1) sciatic nerve; 2) femoral nerve; 3) obturator nerve; 4) superior gluteal nerve; and 5) the lateral femoral cutaneous nerve.

1. Background

Nerve injury is a relatively rare, yet potentially devastating complication of total hip arthroplasty (THA). The reported incidence of nerve injuries associated with THA ranges from 0.6 to 3.7%, with a higher risk found in patients receiving revision THAs (7.6%).[1–8] Apart from patient and surgeon dissatisfaction, this complication may result in medico-legal consequences for the surgeon; therefore, proper assessment of risk factors, knowledge of commonly implicated anatomical structures and etiologies, and application of preventive measures is important.

2. Etiology

Nerve injuries can occur during THA due to compression, traction, ischemia, and/or transection.[9–13] Neural compression affects not only the nerve structure, but also its vascular supply.[10] It can occur perioperatively with patient positioning and draping, improper retractor placement, procedural hip dislocation, or in the setting of a developing hematoma.[9,12] With respect to patient positioning, special attention should be paid to the lateral aspect of the knee, as the common peroneal nerve is particularly susceptible to injury since it courses superficially in this region. Traction, or stretch injuries often occur with intraoperative manipulation, such as during dislocation and reduction of the hip, or with limb lengthening or lateralization as a result of THA.[12] The amount of traction required to cause injury is nerve-specific; unlike freely mobile nerves, nerves that are more fixed are at the highest risk.[10] For example, Edwards et al.[8] demonstrated that isolated palsy of the common peroneal nerve, which is relatively more fixed distally at the fibular head compared to that of the tibial nerve, which courses freely through the popliteal fossa, was associated with lengthening of less than 3.8 cm; whereas, involvement of the tibial division of the sciatic nerve did not occur until lengthening of greater than 4 cm. Furthermore, Dehart et al.[10] used rabbit models to quantify an association between limb-lengthening and nerve conduction failure, reporting that sciatic nerve dysfunction occurred at 25% lengthening, though histologic changes were seen earlier at 4 to 11% lengthening. Ischemic nerve injuries, previously described in Lundborg's experiments,[14] may occur secondary to compression, which has been shown to lead to earlier development of nerve injury, evidenced by endoneurial edema in as little as 2 to 4 h.[10] Compression causing ischemia may occur as a result of patient positioning. Direct neural transection or laceration commonly occurs from direct trauma by the scalpel, electrocautery, reaming, screws, or other implant or procedural equipment, including sutures.[10,12] Risk for transection is highest in nerves that have tightly packed fascicles, such as the common peroneal nerve, whereas multifasicular nerves with abundant connective tissue are

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less vulnerable.[10] Lastly, bone cement may also cause neural injury as a result of compressive and/or thermal damage, and therefore, leaked bone cement should be removed.[13] Despite awareness of these common etiologies, in 50% of cases where nerve injury is suspected, no underlying cause has been identified.[2,13]

3. Risk factors

Proper identification of perioperative risk factors associated with nerve injuries in THA may allow surgeons to avoid such complications. Some of the important risk factors have been listed in Table 1. The surgical approach chosen for THA may place certain nerves at an increased risk of injury and this has been listed in Table 2.

4. Prognosis

The prognosis of nerve injuries associated with THA can be related to various factors; however, the main prognostic factors are dependent on the initial neural insult, specifically, whether it was a complete or incomplete injury, traction injury and certain patient factors, especially body mass index (BMI).[5,15–17] Persistent dysesthesias have been a predictor of poorer outcomes in nerve injury cases and have been reported to occur 28% of the time.[5] Edwards et al.[8] and Park et al.[17] reported a worse prognosis associated with traction injuries and increasing BMI, respectively. With respect to BMI, the mechanism underlying the association with poorer outcomes currently remains unclear. Isolated sensory neuropathies have shown better recovery compared to those involving motor branches, and incomplete palsies have shown to have a more favorable outcome than complete nerve palsies.[17] Also, patients with early neurologic improvements tend to recover more completely.[2] Most patients achieve maximum recovery of neurologic function by seven months; however, recovery may continue for up to 12 to 18 months following the injury.[6] Unfortunately, complete neural recovery is not likely to occur, with one study reporting only 36% of complete nerve palsies, mostly sciatic or its divisions, fully recovered[9] and another showing full recovery occurring in 56% of patients with incomplete nerve palsies.[17]

5. Diagnosis and work-Up

Nerve injuries are diagnosed clinically in most cases; therefore, the most important diagnostic tool is a well-documented preoperative and postoperative physical exam. However, Weale et al.[18] reported that certain nerves may present with subclinical findings in approximately 70% of patients, thereby leading to an underestimation of injuries.[1] In such instances, more objective measures can be obtained through use of electromyography (EMG), somatosensory evoked potentials (SSEP), and measurement of nerve conduction velocities (NCV).[19–21]

Guidelines for postoperative use of EMG for diagnosis and management of nerve injuries has not been well established, but some studies have recommended routine electrodiagnostic testing in high-risk patients[8,22] and other have recommended the use of EMG when suspecting injury to nerves known to have obscure presentations, such as the obturator nerve.[12] On the other hand, Farrell et al.[9] obtained EMGs eight to twelve weeks after nerve injury in patients who were failing to recover, in order to gather information pertaining to the level of nerve injury and prognosis. The American Association of Neuromuscular & Electrodiagnostic Medicine (AANEM) issued a policy for electrodiagnostic medicine in 2010 after reporting that its use was poorly understood by many in the medical community, leading to overutilization in inappropriate settings.[23] The AANEM reported that physicians may benefit most when utilizing the combination of EMG and NCV several weeks after injury. However, with nerve transections, NCVs are useful more acutely, since delayed use may prevent the precise identification of the injured region, which could delay treatment.

Table 1
Major Risk Factors of Nerve Palsy in THA.

Risk Factor	Literature	Etiology of Injury
Preoperative Diagnosis of Developmental Dysplasia of the Hip (DDH) or Post-Traumatic Arthritis	Farrell et al.[9] found that patients with DDH had a 4.06 higher odd of nerve injury ($p = 0.00004$), and those with post-traumatic arthritis had a 3.42 high odd of nerve injury ($p = 0.01$) when compared to those receiving a THA with only a diagnosis of osteoarthritis. Other studies in the literature agree that these risk factors increase patient susceptibility to nerve injury.[10,12]	Nerve injury has been attributed to the technical difficulty of the THA in such patients. Previously, nerve injury in these patients was believed to be due to limb lengthening, but the literature has since dismissed this idea.[1,15,51,52]
Revision THA/Previous Hip Surgery	Patients receiving revision THA or those with a history of previous hip surgery are at increased risk of nerve injury. This is thought to be due to nerve embedment in scar tissue which alters nerve blood supply and increases vulnerability to traction injury.[8,10,21]	Ischemia and Traction injury
Female Gender	Numerous studies have shown females to be nearly twice as likely to experience nerve injury during THA [2,5,8,10] with one study demonstrating an increased ratio of 80:20.[4] However, a more recent study spanning over 30 years failed to show a significant increase in nerve injury trend in female patients ($OR = 1.39$; $p = 0.27$).[9]	1) Unknown, but two hypotheses exist. 2) Females tend to have lower soft tissue mass, increasing their susceptibility to nerve injury.[1] 3) Females have higher rates of DDH.[53]
Limb Lengthening	There is consensus that increasing limb length beyond a certain length is associated with increased risk of nerve injury.[5,11] Edwards et al.[8] showed a 28% increased risk of nerve injury in patients with greater than 4 cm lengthening following THA.	Traction
Cementless Surgical Technique	Despite cement being an etiology of nerve injury itself by its ability to cause compression and thermal injuries, THAs that involve cementless fixation of the implant are in fact associated with a higher risk of nerve palsy.[9,17]	Cementless fixation: Farrell et al.[9] hypothesized that due to the requirement of an inference fit with the cementless prosthesis, surgeons tend to ream and fixate the prosthesis with more force, thus increasing the likelihood of more transection nerve injuries.
Spinal Issues w/Pre-Existing Nerve Injury	Note: Controversial in the literature	"Double crush syndrome": Nerves become less tolerant of compression at the same or second locus if they have pre-existing compression, such in the case of spinal disc herniation disease.

Table 2
Nerve injuries associated with surgical approach.

Approach	Anterior	Lateral or Anterolateral	Posterior
Nerves At Risk	Lateral cutaneous femoral nerve (81% incidence[a])[44] and femoral nerve (0.8%)[35]	Superior gluteal nerve (77%[b])[40]	Sciatic, with the common peroneal branch being more common (0.3% to 2.1%)[17]

[a] Based off patient questionnaire at 1 month follow-up; repeat questionnaire at 6 months reveals only 6% with palsy.
[b] Subclinical palsy identified on EMG testing.

They also reported that earlier EMG application has value in diagnosing pre-existing conditions, and identifying the time of nerve injury and baseline nerve function. Yet, the AANEM does not offer precise timely recommendations for testing.

Other than objectively quantifying the degree of motor compromise in nerve injuries, EMG allows for better localization of the lesion than clinical exam.[24] One potential disadvantage to the use of EMGs, however, is that an abnormal finding may be due to muscle rather than nerve injuries; thus, NCVs are usually performed concurrently with EMG.[25] In addition, EMGs are unable to determine chronicity, potentially allowing for false positive findings in patients with previously acquired nerve damage.

Another neurophysiologic monitor that has been suggested, particularly in those with developmental dysplasia of the hip (DDH), is the somatosensory evoked potential (SSEP).[21] Used intraoperatively, SSEPs can identify when a nerve has been compromised. One study that utilized this technique while performing revision THAs found that 32% of patients experienced nerve compromise during acetabulum exposure that was related to traction[26]; however, another study determined that intra-operative SSEP use for non-high risk cases was less effective in preventing nerve palsy.[27]

Imaging studies also hold value in the diagnosis of nerve injuries. Compression injury due to a hematoma is largely a clinical diagnosis and requires prompt decompression[21]; however, if the diagnosis is not clear ultrasound or computerized tomography (CT) imaging may help confirm the diagnosis.[13] In a case report involving a leaking pseudoaneurysm, the source of bleeding and hematoma was identified by using CT angiography.[28] In addition, the use of magnetic resonance imaging, especially for delayed-onset nerve palsy, has enabled clinicians to visualize the peripheral nervous system from the nerve root distally through the peripheral nerves with an enhanced diagnostic accuracy.[29]

6. Major nerve-Specific injuries

6.1. Sciatic nerve

Sciatic nerve palsy is the most commonly encountered nerve injury associated with THA, accounting for over 90% of all reported nerve injuries.[2] The sciatic nerve exits the pelvis via the greater sciatic notch, anterior to the piriformis muscle, and then branches into its common peroneal and tibial divisions. In 1937, Beaton et al.[30] described six course variations of the sciatic nerve in relation to the piriformis muscle. After dissection of 1510 cadavers, Bergman et al.[31] determined that the most common course of the sciatic nerve was it exiting below the piriformis, which was seen in 88% of cadaveric models. The most common variant, seen in 11% of cadaveric models, involved the common peroneal nerve branching more proximally and exiting through the piriformis muscle. The common peroneal nerve is at an increased risk for injury compared to the tibial nerve as a result of this anatomical variation and its superficial course more distally. Also, the common peroneal nerve consists of tightly packed fascicles, rather than the abundance of connective tissue that comprises the tibial nerve; thus, it is more vulnerable to transection and compression.[10,16,32] The relationship between the extent of limb lengthening and nerve damage has been debatable, but Edwards et al.[8] were able to quantify a correlation between the amount of lengthening and the distribution of nerve injury as previously mentioned in this article. Patients with sciatic nerve palsy may present with foot drop, buttock pain radiating down the posterior thigh, and/or paresthesias in the sciatic nerve distribution.

The incidence of sciatic nerve palsy following THA has been reported to be 1.5%,[1,2] which could increase to 3% to 8% in revision THA and 5.8% in those with preexisting DDH.[2] The etiology of injury remains unknown in 50% of cases.[10,12] Edwards et al.[8] evaluated post-THA nerve injuries in 10 patients who had 11 sciatic nerve injuries, finding limb lengthening greater than 4 cm in four cases, and despite reporting poor recovery in all cases, sciatic nerve injuries due to direct trauma had better recovery than those due to traction. Farrell et al.[9] reviewed 47 cases of nerve injuries following THA, of which 93% of cases involved the sciatic nerve or the common peroneal nerve, with complete palsies in 62% of cases. They reported more desirable recovery results, with 36% achieving complete and 39% achieving partial recovery. More recently, Park et al.[17] evaluated 30 patients with common peroneal nerve palsies following THA and reported a 50% complete recovery rate, noting the only significant factor to have influenced prognosis was BMI. On the contrary, Schmalzried et al.[2] concluded that prognosis was dependent on the severity of the initial injury, stating that a worse prognosis would be seen in patients with complete nerve palsies, severe dysesthesias, and failure to retain motor function or improve in the immediate postoperative period.

The posterior/posterolateral approach to the hip is most commonly used for THA, but places the sciatic nerve at the highest risk of injury.[18] However, overall occurrence of sciatic nerve injury is relatively low; except in cases of revision surgery or DDH. Prognosis is less than desirable, with even the best results in any given study demonstrating full recovery in only 50% of nerve injury cases. Management is variable for sciatic nerve injury with acute surgical intervention being considered in cases where a compressing structure, such as hematoma, has been identified and in cases of acute palsy with limb lengthening. Regev et al.[33] reported on 12 patients who underwent neurolysis in the setting of chronic sciatic nerve palsy that had failed to improve with non-operative management, finding that the mean common peroneal and tibial nerve scores more than doubled after the procedure, and all but one patient reported improvement in their pain.

6.2. Femoral nerve

Femoral nerve palsy is the second most common nerve injury associated with THA, accounting for 2.3% of all nerve injuries.[34] Reports of 0.04% to 0.8% of THA patients will present with a femoral nerve injury; however, unlike the sciatic nerve, patients tend to complain of medial pelvic or anterior thigh paresthesias, and may have difficulty managing stairs secondary to quadriceps weakness.[1,2,12,34] The femoral nerve travels distally from the abdomen into the pelvis, anterior to the iliopsoas muscle, and inside the femoral triangle, an area that lacks elasticity, making the femoral nerve particularly vulnerable to prolonged hyperextension.[10,13] Other mechanisms of femoral nerve injury include iliacus hematomas especially in patients on anticoagulation, and more commonly the use of anterior acetabular retractors, during anterior and anterolateral THA approaches,[10,13] with the anterior approach shown to be associated with the higher risk.[35] Furthermore, there is a potential for compression injuries to both the femoral and obturator nerves when hip positioners are used without adequate positioning and cushioning.[36]

Simmons et al.[34] reported on 10 patients with femoral nerve palsies following THA, all related to the use of anterior acetabular retractors during an anterolateral approach, but all of the patients fully recovered without any prolonged disability. Weber et al.[1] concluded that prolonged femoral nerve disability is likely to be due to entrapment by cement rather than by compression injury with retractor use. Other studies agree that recovery from femoral nerve palsies follows a more predictable and less disabling course[12,37] compared to sciatic nerve palsies. Also, prognosis tends to be more favorable than sciatic nerve injuries. Currently, no definitive treatment protocol exists for the management of femoral nerve palsy, except in the case of an acute iliacus hematoma which requires prompt decompression.[35]

6.3. Obturator nerve

Obturator nerve palsy is an extremely rare complication of THA. The obturator nerve descends through the pelvis, transects the psoas major muscle, and then passes medially into the pelvic brim before exiting through the obturator foramen. Obturator nerve injuries typically present as medial thigh paresthesias, groin pain, and/or adductor weakness. Diagnosis can be difficult given its low prevalence and lack of serious functional disability.[10,13] Siliski et al.[38] reported on four cases of intra-pelvic extrusion of cement leading to obturator nerve palsy after THA. Three patients underwent revision surgery with cement excision and nerve exploration, which led to full improvement in nerve function. Similarly, Weber et al.[1] found that one case out of more than 2000 cases was complicated by obturator nerve injury, which was also due to extruded cement. Given this seemingly recurrent etiology, the use of a bone graft or barrier device was recommended by Weber et al.[1] when using a cemented acetabular component in the setting of a medial acetabular defect. Other risk factors for obturator nerve palsies include violation of the anterior quadrant or floor of the acetabulum.[21]

Similar to femoral nerve palsy, prevention of known associated risk factors can prevent obturator nerve injuries. Unless an identifiable cause of compression has been identified, a protocol for surgical intervention is not clearly established in the literature.

6.4. Superior gluteal nerve

The superior gluteal nerve exits the pelvis through the greater sciatic notch, exits proximal to the piriformis muscle, and then branches into superior and inferior divisions before innervating the hip abductors. Injury to the superior gluteal nerve may occur if the gluteus medius is dissected 5 cm proximal to the greater trochanter,[39] and would present with abductor weaknesses and Trendelenburg gait.[10] Violation of this critical area is most common during a direct lateral or anterolateral approach.[40] Also, through experimental cadaveric dissections, Grob et al.[41] proposed that ligation of the ascending branch of the lateral circumflex femoral artery was a potential source of superior gluteal nerve injury. Picado et al.[42] evaluated 40 patients who underwent THA with the direct lateral approach and all had EMGs 4-weeks postoperatively, revealing superior gluteal nerve injuries in 17 patients; however, only 3 of these patients continued to demonstrate injury patterns 6-months postoperatively and at 1-year postoperatively only 1 patient had a positive Trendelenburg sign. This suggested that superior gluteal nerve injuries found on early EMGs can resolve spontaneously.

Lateral and anterolateral approaches pose the greatest risk for superior gluteal nerve injury.[10] Prognosis is better than that seen in sciatic nerve injuries. In addition, no protocol is in place to indicate the need for urgent surgical exploration, except in the setting of a compressing force, where surgery helps achieve decompression.

6.5. Lateral femoral cutaneous nerve

After originating from the posterior divisions of the anterior rami of the L2 and L3 nerve roots, the lateral femoral cutaneous nerve (LFCN) runs on the anterior surface of the iliacus muscle within the iliac fascia, eventually entering the thigh medial to the anterior superior iliac spine and then passing over the sartorius muscle before branching.[43,44] Three branching patterns have been described with evaluation of cadaveric specimens, with each variation appearing in approximately a third of the specimens.[43] The LFCN is a sensory nerve, and injury does not typically lead to functional limitations. Injury is a known complication of the anterior THA approach; however, the incidence of injury has been reported to range from 15% to 81%.[44–46] Another risk factor identified with LFCN palsy is hip resurfacing,[44] and this has been attributed to a larger incision required for the procedure.

Based on patient surveys, Homma et al.[46] reported that patients with LFCN palsy had a decreased quality of life, albeit hip function was unaffected. The prognosis of LFCN palsy has been controversial, where Bhargava et al.,[45] reported greater than 80% of their patients fully recovered from sensory deficits, but Goulding et al.[44] reported that only 5.7% of their patients fully recovered. The designs of these two studies varied significantly, which could have accounted for the differing results.

There is a paucity of literature regarding incidence, prognosis and management of this condition, and of the literature that does exist, there is considerable discrepancy. For certain, LFCN palsies do not pose functional limitations for the patient; however, for management purposes, it remains important to address quality of life issues.

7. Prevention

Primary prevention is the key to avoiding neural injuries and its potentially catastrophic consequences. This begins with establishing a strong foundation in anatomical knowledge, which should include the ability to recognize anatomical variants.[13] Moving chronologically in regards to prevention, patients should be screened preoperatively for risk factors, especially for DDH and previous hip surgery.[10] Surgeons should use caution and avoid improper positioning, excessive traction, improper instrumentation, and bone cement leakage.[13] Also, in high-risk patients, it may be beneficial to use intraoperative SSEP to identify any neural compromise that occurs during the procedure.[21] In the immediate postoperative period, radiographs are helpful in identifying cement extrusion, prosthesis positioning and inadvertent acetabular penetration, all of which may lead to nerve injuries.[21] Delayed nerve injuries can occur in the setting of scar formation or hematoma development leading to compression injury; therefore, in the postoperative period, careful evaluation and patient education is important to ensure rapid identification of these potential complications.[13]

8. Medico-legal issues

Medico-legal issues may result from nerve injuries associated with THA. No etiology is found in nearly 50% of cases, which may be of use to surgeons that find themselves in such a situations.[2,5,21]

Uwin et al.[21] reported that rather than the complication itself, medico-legal cases resulted more so from the failure to diagnose and properly manage nerve palsies, specifically in regards to the identifying the level of the lesion, which may be considered negligent.

9. Management

Unwin et al.[21] believed pain to be the most important diagnostic feature of nerve injuries, as it indicates continual insult to the nerve, and thus, it was suggested that urgent surgical exploration should be considered in cases of nerve palsies associated with severe pain. Other indications for urgent surgical exploration include any findings that suggest a hematoma, which may present as a delayed nerve palsy and would require prompt decompression.[9,21] Also, limb lengthening in combination with acute sciatic nerve palsy identified as a patient recovers from anesthesia is an indication for immediate revision surgery.[9] The timing of nerve exploration must also be considered. Acute intervention with primary repair clearly has advantages in nerve injuries where there is complete transection; however, when nerves are bluntly divided, delayed exploration by a few weeks offers better outcomes for the reason that the nerve stumps can be sectioned back to healthy neural tissue.[47] In a more recent experimental study by Jonsson et al.,[48] delayed nerve exploration was conducted in rats with sciatic nerve transections, and it was determined that delay beyond 3 months had poorer regeneration outcomes.

Management becomes less clear when pain is absent. In these instances, the risk of reoperation must be weighed against the potential benefit of exploration. Also, the suspected etiology of nerve injuries must be accounted for. However, not all etiologies have good results with surgical management. Pritchett et al.[11] identified 19 patients who had THAs that were complicated by traction nerve injury due to limb lengthening, and 17 of the patients underwent limb-shortening revisions. They reported that 9 patients had pain relief, and out of 11 patients who had motor symptoms, 7 patients improved.

Non-operative treatment generally includes physiotherapy with joint mobilization, extended bracing, and expectant waiting for functional return. During this period, diagnostic testing may be sought in order to provide the patient with more accurate information regarding injury extent and prognosis. When these methods are exhausted, there is an option for tendon transfer, which has shown promising results. Tendon transfers are not time-sensitive, and are typically performed after 18 months, allowing maximal nerve recovery and tissue equilibrium to develop beforehand. If tendon transfer is performed earlier, an end-to-side approach should be undergone so as to allow the nerve to continue its recovery after the procedure.[49] In a review of 12 patients with common peroneal nerve palsies who were treated with tendon transfers, all patients had improved function.[50] The study further compared those who underwent combined tendon transfers with nerve repair to those who underwent tendon transfers alone, and found that 57% of patients with combined therapy were able to return to higher physical activity levels compared to 20% who only had tendon transfers.[50]

10. Conclusion

Nerve palsies associated with THA are relatively rare, yet the potentially devastating nature of the injury makes it a topic of interest. Although many possible risk factors for nerve injuries have been suggested, previous hip surgery and DDH are the most commonly reported. Rather than negligence and poor technique, nerve injuries in these cases appear to be associated with the difficulty of the procedure due to anatomical changes. As the field of orthopaedic surgery advances, more patients with these conditions will become surgical candidates for THA, thus, surgeons should be aware of the inherent surgical risks. As such, it is important for surgeons to evaluate patients for perioperative risk factors.

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