Wake-up Test in Total Hip Arthroplasty With High-riding Developmental Dysplasia

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Abstract

Total hip arthroplasty (THA) for patients with Crowe type IV developmental dysplasia of the hip is technically challenging. This group of patients has a higher incidence of nerve injury during THA. Although neurophysiologic intraoperative monitoring has been developed to provide nerve monitoring, it is not always available. The wake-up test has been used for intraoperative spinal cord monitoring during major spinal surgery, but no study has reported the use of the wake-up test for neurologic monitoring during THA in patients with severe developmental dysplasia of the hip. The authors retrospectively reviewed 22 THA procedures in 20 patients with Crowe type IV developmental dysplasia of the hip who underwent the wake-up test during THA. In the current study, 1 patient could not dorsiflex her foot during the wake-up test. Therefore, the authors immediately reduced the length of limb lengthening by 1 cm. Postoperative drop foot and numbness occurred but resolved completely 2 months later. None of the patients who showed no deficits in motion of the feet during the intraoperative wake-up test had signs of postoperative nerve injury. In the current study, there was no false-positive or false-negative finding. The authors concluded that the wake-up test, which is simple, safe, and reliable, is a useful technique and a possible alternative to neurophysiologic intraoperative monitoring in checking nerve function during THA in patients with severe developmental dysplasia of the hip.

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The Crowe classification, a widely accepted system used to assess the severity of developmental dysplasia of the hip, has been used to group hip dysplasia into 4 types. Crowe type IV developmental dysplasia of the hip is severe, with more than 100% proximal displacement of the femoral head.1 Total hip arthroplasty (THA) in adults with developmental dysplasia of the hip is a challenging task because of the complicated anatomic complexity of the hip joint.

Nerve palsy after THA is an infrequent but severe complication. The incidence of nerve palsy after THA has been reported to range from 0.3% to 3.7% in patients undergoing primary THA and from 1.8% to 7.6% in patients undergoing revision THA.2,3 Farrell et al4 reported that developmental dysplasia of the hip was an important risk factor in sustaining motor nerve palsy after THA. Schmalzried et al5 reported that the incidence of nerve injury after primary THA was 5.2% in patients with developmental dysplasia of the hip. Although there is no consensus about the differences in the incidence of nerve palsy among types of developmental dysplasia of the hip, the incidence of nerve palsy may be higher in more severe hip dysplasia (eg, Crowe type IV).6 Therefore, neurologic evaluation is important for early recognition and prevention of nerve palsy in patients with developmental dysplasia of the hip who are undergoing THA.

Electrophysiologic monitoring and the wake-up test have been used either alone or in combination for intraoperative neurologic monitoring. Electrophysiologic monitoring techniques, including somatosensory-evoked potentials, motor-evoked potentials, and electromyography, are more sophisticated techniques. However, artifacts may be a problem in the operating room, and false-positive or false-negative findings can occur.7 In addition, electrophysiologic monitoring requires expensive equipment and well-trained technicians. Furthermore, the equipment is not always available. Although somatosensory-evoked potentials have been used to detect nerve injury during THA, the results were not satisfactory.8,9

The wake-up test, performed by a skilled anesthesiologist without special neurophysiologic monitors, has been developed to assess intraoperative spinal cord function during major spinal surgery to avert neurologic complications and optimize the surgical outcome. It involves temporarily lightening the anesthetic depth to the point where patients are able to follow verbal commands during surgery. After active movement of the patient’s arms and legs has been demonstrated as a positive response, the anesthetic depth is increased to the routine anesthetic level and surgery is continued.10 Routine use of the wake-up test in patients undergoing spinal surgery involving distraction or instrumentation and various procedures has been advocated. However, there has been no study of the use of the wake-up test for neurologic monitoring during THA in patients with severe developmental dysplasia of the hip.

The goal of the current study was to investigate the use of the wake-up test to check intraoperative nerve function in patients with high-riding developmental dysplasia of the hip who were undergoing THA.

**Materials and Methods**

Surgery and anesthesia records were reviewed for all patients with high-riding developmental dysplasia of the hip who underwent THA and received the intraoperative wake-up test at Taipei Veterans General Hospital from January 2007 through December 2012. A total of 22 hips in 20 consecutive patients with Crowe type IV developmental dysplasia of the hip who underwent the wake-up test during THA were analyzed. This study received approval from the institutional review board of Taipei Veterans General Hospital.

Patients who were scheduled for elective surgery were instructed during the preoperative anesthetic visit about awakening during surgery (wake-up test) to check voluntary motor function of the lower limbs. The patients were informed that the anesthesiologist would first ask them to squeeze the anesthesiologist’s hand with their fingers, wiggle their toes, and then dorsiflex their ankles. They were reassured that they would feel no pain and would fall asleep again quickly after completion of the wake-up test. Providing a complete explanation of the technique, stressing the importance of checking motor function intraoperatively, made the patients comfortable with the surgery. After the patient agreed to the wake-up test, the whole procedure was recorded with a video camera.

All of the THA procedures were performed by a single surgeon with a similar surgical technique. During surgery, before the wake-up test, a limb shortening procedure, such as subtrochanteric osteotomy, extended trochanteric osteotomy, or no osteotomy, was performed, depending on the soft tissue tension based on the surgeon’s experience. The limb shortening procedure was selected according to the anatomic character of the patient’s proximal femur. If the trochanteric area of the femur was well developed, subtrochanteric osteotomy was used.11 In patients with a poorly developed trochanter, extended trochanteric osteotomy was performed.12 General anesthesia was induced with atropine 0.01 mg/kg, fentanyl 3 μg/kg, propofol 2 to 3 mg/kg, and cisatracurium 0.15 to 0.2 mg/kg to facilitate endotracheal intubation and maintained with either inhalation anesthesia or total intravenous anesthesia. On one hand, patients who were given inhalation anesthetics (desflurane) were ventilated to keep the end-tidal concentration of desflurane at approximately 0.7 to 1 minimal alveolar concentration and intravenously infused with fentanyl (1 μg/kg/h). Patients who received total intravenous anesthesia were given target-controlled infusion of propofol (3-5 μg/
mL at the brain effect site) and fentanyl (1 μg/kg/h). The lungs were ventilated with 50% inspired oxygen to maintain end-tidal CO₂ concentration at approximately 35 to 40 mm Hg during surgery. One hour before and during the wake-up test, no additional muscle relaxants were given. After the hips were reduced with a trial component, awakening was accomplished by withdrawing desflurane, propofol, and fentanyl 10 minutes before the test. The patient was then called by first name and asked to move the hands and dorsiflex the feet. Once the integrity of sciatic nerve function had been checked, the anesthetic depth was increased with either an intravenous bolus of propofol (2 mg/kg) and diazepam (0.1 mg/kg) or reintroduction of desflurane. Supplemental doses of muscle relaxant were given until the end of surgery. If the wake-up test showed a motor function deficit, a further shortening procedure was performed immediately until the surgeon considered the peripheral soft tissue adequately loosened.

The amount of limb lengthening was calculated by comparing the distance from the umbilicus to the medial malleolus before and after surgery with the patient placed on a bed. Motor and sensory aspects of nerve function were examined. The authors checked motor function by asking the patient to actively perform flexion and extension of the hip, knee, and ankle joints. Sensory function was examined by performing a pinprick test to the L2-S1 dermatome. Patients with abnormal findings on nerve examination preoperatively were excluded from the study. Nerve function was checked 1 day before surgery, immediately after emergence from anesthesia in the postoperative room, every day during hospitalization, and then 2, 4, and 8 weeks after surgery in the outpatient department.

**RESULTS**

Study participants included 18 women and 2 men with a mean age of 34.1 years (range, 18-56). Mean weight was 57.5 kg (range, 43-75), and mean height was 160.2 cm (range, 156-171).

Mean operative time was 157 minutes (range, 125-196). Of 22 THA procedures in the current study, extended trochanteric osteotomy was performed in both hips of 1 patient (Figure 1), subtrochanteric osteotomy (Figure 2) was performed in 11 hips, and 9 hips did not receive osteotomy (Figure 3). In 2 patients, although the limb was lengthened more than the distance (4 cm) associated with a high risk of nerve injury according to the literature, osteotomy was not performed because of normal findings on the wake-up test.

The limbs were lengthened a mean of 4.3 cm (range, 3.8-6.2). One of the 20 patients could not dorsiflex the foot during the wake-up test. Initially, no osteotomy was performed because of the surgeon’s experience with soft tissue tension before reduction of the hip with a trial component. However, during the wake-up test, the authors found that the patient could dorsiflex the right ankle after the hip was reduced. Therefore, because of the
positive finding on the wake-up test, the authors immediately shortened the length of limb lengthening via subtrochanteric osteotomy an additional 1 cm. After the subtrochanteric osteotomy was performed, the authors explored and identified the sciatic nerve to check the tension of this nerve. The sciatic nerve did not appear overstretched during hip flexion. Thus, no further shortening procedure was performed. Postoperative right drop foot and numbness over the L5 dermatome occurred in this patient but resolved completely 8 weeks later. The final leg lengthening for the patient was 4.4 cm. None of the other 19 patients who showed no deficits in motion of the feet during the intraoperative wake-up test had signs of nerve injury in the postoperative room. During hospitalization and 2, 4, and 8 weeks after surgery, no motor or sensory deficit was noted in these patients.

**DISCUSSION**

For patients with unilateral Crowe type IV developmental dysplasia of the hip, leg length discrepancy is a major problem in terms of appearance and ambulation. Thus, making the affected leg nearly equal in length to the normal leg after THA is the expectation of both patients and surgeons. Although leg lengthening is not necessary in this group of patients for pain, improving the leg length discrepancy improves the clinical outcome.

Simple palpation of the sciatic nerve with checking of tension is 1 method to prevent nerve injury during THA. However, the results are subjective and dependent on the surgeon’s experience. During surgery, nerve injury may occur as a result of stretching. The surgeon may feel normal nerve tension after stretching, even if the nerve was already injured. Therefore, more objective and scientific methods, such as the wake-up test and neurophysiologic monitoring, are used.

Somatosensory-evoked potentials, motor-evoked potentials, and electromyography have been used to monitor the status of the sciatic or peroneal nerves during primary and revision THA. Clinical studies based on these techniques originally showed that the nerves can be monitored continuously and intraoperative conductive change can be detected.

Stone et al were the first to use intraoperative somatosensory-evoked potential monitoring during THA. However, the results with somatosensory-evoked potentials in THA were not superior to those of the wake-up test. Black et al performed somatosensory-evoked potentials to detect intraoperative sciatic nerve compromise during THA in 100 consecutive patients. Two patients had loss of amplitude of the tracings at the time of closure, and both of these patients had postoperative sciatic nerve palsy. The incidence of nerve injury in the somatosensory-evoked potential group was 2%. There were no false-negative results. In the control group, matched for age, weight, surgical approach, and leg lengthening, the incidence of nerve injury was 2.6% (15 of 574 cases). The
authors did not endorse the routine use of somatosensory-evoked potentials in THA.9

Another study was reported by Rasmussen et al.8 There were 8 cases of sciatic nerve palsy among the 290 patients (2.8%) in the somatosensory-evoked potential group, and 13 cases of sciatic nerve palsy occurred in 485 consecutive patients (2.7%) in the control group. In addition, 2 monitored patients (0.7%) had no intraoperative evidence of sciatic nerve palsy but had sciatic nerve palsy after surgery (false-negative findings). The incidence of sciatic nerve palsy in 2 groups seemed to be no different. The authors concluded that somatosensory-evoked potential monitoring was neither effective in predicting sciatic nerve palsy nor helpful in preventing it.8 In addition, somatosensory-evoked potentials were focused on monitoring dorsal column function but did not detect corticospinal pathway damage. For most patients, motor function is the most important function. For this reason, the wake-up test has replaced somatosensory-evoked potentials in spine surgery as the gold standard for assessing motor tract integrity.17,18 Considering the accuracy of somatosensory-evoked potentials in detecting nerve injury and the additional costs incurred from the staff and instrumentation required for intraoperative monitoring, the question is whether the use of somatosensory-evoked potentials in THA is cost-effective.

Electromyography monitors a given segment of nerve but not the entire nerve conduction route.16 Sutherland et al19 reported its use in 44 consecutive revision and complex THA procedures. Five patients showed sustained electromyographic activity during surgery that subsided after retractors were removed, with the limb brought into an anatomic position. None of the 5 patients showed evidence of nerve injury after surgery. One patient had no sustained electromyographic activity during surgery but had causalgia finally without motor dysfunction.

Motor-evoked potentials in combination with electromyography were used to identify specific intraoperative maneuvers that may increase the risk of sciatic nerve injury during revision THA.16 There have been no reports of the accuracy of this approach in monitoring sciatic nerve palsy during THA.

Recently, a study described the use of multimodal intraoperative monitoring in averting nerve injury during complex hip surgery.20 The modalities used during surgery included continuous electromyography, motor-evoked potentials, and somatosensory-evoked potentials. Of 69 patients who underwent complex hip surgery with multimodal intraoperative monitoring, in 24 (35%) procedures the surgeon was warned about possible sciatic or femoral injury. There was only 1 true-positive case of postoperative nerve injury. There were no false-positive or false-negative results.20 The improvement and the combination of various monitoring modalities increased the accuracy of intraoperative neurophysiologic monitoring. However, these expensive and sophisticated modalities are not available in most hospitals, nor are well-trained technicians.

The wake-up test, also known as the Stagnara test,21 monitors voluntary motor function of the lower limbs when at risk for nerve injury. The wake-up test requires an anesthetic regimen that provides fast recovery and fast return of cognition to allow immediate neurologic evaluation.7 Advantages of the wake-up test are that it is simple to perform and it does not require sophisticated equipment.22 The wake-up test has been considered effective in spinal monitoring.7 However, the disadvantages of the wake-up test are that it can miss the onset of injury or ischemia and it does not identify isolated nerve or subtotal change.7 Contraindications to the test are mental retardation, psychological problems, and preexisting neurologic impairment.23

This is the first report of the use of the wake-up test to monitor the sciatic nerve during THA. In the current preliminary study, the wake-up test was used to examine nerve function during THA in patients with Crowe type IV developmental dysplasia of the hip. This study had no false-negative or false-positive results, similar to the finding of multimodal intraoperative monitoring.20 One patient had a motor deficit shown on the test and had temporary drop foot and numbness after surgery, even though a limb shortening procedure was performed and appropriate nerve tension was achieved. The limitation of the wake-up test in the current study was lack of continued nerve condition monitoring. Therefore, anatomic adjustments by the surgeon could not be rechecked. Nerve injury as a result of dislocation, reduction, or retraction may happen after a normal finding on the wake-up test. Further study is needed to evaluate the percentage of inevitable false-negative results. However, through the warning of the wake-up test, the authors noticed the possibility of nerve injury and then identified the sciatic nerve as the source of the problem to make sure that sciatic nerve tension was loosened enough after the proximal femur shortening procedure. This procedure was not done as a routine part of THA. If nerve function was not checked by the wake-up test and the femur was not shortened, the risk of permanent nerve injury was higher. All of the other patients without intraoperative motor deficit had satisfactory results. The findings of the current study meant that the surgeon would be reassured about nerve function if the results of the wake-up test were normal.

From the authors’ perspective, no matter what method was used, when the nerve monitoring methods showed abnormal findings, such as an abnormal wake-up test finding or a signal change on electrophysiologic monitoring, variable degrees of nerve damage had already occurred. During surgery, the surgeon may not know if damage was caused by stretching or direct nerve injury. All that the surgeon can do is eliminate possible causes of in-
jury. Tension of the nerve is a major cause that can be addressed. Thus, the authors performed shortening osteotomy for the patient and rechecked the nerve tension. However, there was no evidence as to what definitely caused the nerve recovery.

The study results support the idea that the wake-up test can be used to check nerve injury during THA. It can be used to assess motor nerve function directly and has no associated problems, such as hypersensitivity, high cost, or the need for equipment. In addition, if a motor deficit is observed on the wake-up test, a limb shortening procedure can be performed immediately without concern about a false-positive finding. The limb shortening procedure, in combination with the wake-up test, can help to prevent nerve injury.

Intraoperative neurophysiologic monitoring is improving, but it is not always available in most hospitals. In this situation, the wake-up test may be an alternative method for intraoperative nerve monitoring. After the authors’ 6 years of experience with the wake-up test in THA for high-riding developmental dysplasia of the hip, it was concluded that the wake-up test, which is simple, reliable, and inexpensive, is a feasible technique to detect nerve injury in THA for patients with severe developmental dysplasia of the hip.

REFERENCES