Clin Orthop Relat Res (2012) 470:2209–2219
DOI 10.1007/s11999-012-2409-1

Clinical Orthopaedics and Related Research®
A Publication of The Association of Bone and Joint Surgeons®

CLINICAL RESEARCH

# Prevention of Nerve Injury After Periacetabular Osteotomy

**Rafael J. Sierra MD, Paul Beaule MD, Ira Zaltz MD,
Michael B. Millis MD, John C. Clohisy MD,
Robert T. Trousdale MD, for the ANCHOR group**

Received: 8 July 2011 / Accepted: 16 May 2012 / Published online: 9 June 2012


## Abstract

*Background* The Bernese periacetabular osteotomy (PAO) is the preferred pelvic osteotomy in many centers treating symptomatic acetabular dysplasia in the young adult. Major nerve injury has been reported as a complication that can occur with this complex procedure, but the incidence and circumstances associated with such injury are not well known.

*Questions/Purposes* We asked: (1) What is the incidence of sciatic and femoral nerve injury after PAO; (2) what are the risk factors associated with such injury; and (3) what are the consequences of such injury including the degree of neurologic recovery?

*Patients and Methods* We identified 1760 PAOs that were performed between 1991 and 2008 at five institutions. A major nerve injury was defined as a postoperative motor nerve palsy or sensory deficit present after surgery in the distribution of the femoral or sciatic nerves. Risk factors associated with nerve injury and the treatment and degree of neurologic recovery were reviewed from medical records.

*Results* Thirty-six of the 1760 patients (2.1%) had a major nerve deficit of the sciatic or femoral nerve develop. We identified no patient or surgical risk factor associated with the occurrence of nerve injury. Seventeen of the 36 patients had complete recovery. The median time to recovery or plateau was 5.5 months (range, 2 days to 24 months).

*Conclusions* The incidence of sciatic and femoral nerve injury during PAO is less than previously reported. Full recovery can be expected in only ½ of the patients and more commonly with injuries of the femoral nerve. If direct nerve injury is suspected, we believe exploration may be warranted.

In addition to the authors, Perry Schoenecker MD and Young Jo-Kim MD comprise the ANCHOR group.
One of the authors (RJS) certifies that he has or may receive payments or benefits, in any one year, an amount in excess of $10,000 from Biomet Inc (Warsaw, IN). One of the authors (JCC) certifies he has or may receive payments or benefits, in any one year, an amount of less than $10,000 from Biomet Inc. One of the authors (RTT) certifies he has or may receive payments or benefits, in any one year, an amount in excess of $100,000 from DePuy, Warsaw, IN, USA, and less than $10,000 from MAKO Surgical Corp., Ft. Lauderdale, FL, USA, and Wright Medical, Arlington, TN, USA.
All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research* editors and board members are on file with the publication and can be viewed on request.
Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
This work was performed at the Mayo Clinic, Rochester, MN, USA.

R. J. Sierra (✉), R. T. Trousdale
Mayo Clinic, Orthopedic Surgery,
200 First Street SW, Rochester,
MN 55905, USA
e-mail: sierra.rafael@mayo.edu

P. Beaule
Division of Orthopedic Surgery, Adult Reconstruction
Service, Ottawa General Hospital, Ottawa, Canada

I. Zaltz
William Beaumont Hospital,
Detroit, MI, USA

M. B. Millis
Department of Orthopaedic Surgery, Boston
Children's Hospital, Boston, MA, USA

J. C. Clohisy
Department of Orthopedic Surgery, Washington University
School of Medicine, St Louis, MO, USA

*Level of Evidence* Level II, prognostic study. See the Guidelines for Authors for a complete description of levels of evidence.

## Introduction

The Bernese periacetabular osteotomy (PAO) as described by Ganz et al. [7] has become the preferred pelvic osteotomy in many centers for the treatment of symptomatic acetabular dysplasia in the young adult [2, 3, 5, 16, 18, 20–22]. Correcting the structural deformity improves pain and function for these patients, with greater than 90% of patients having substantial pain relief and improved function [2, 3, 5, 16, 18, 21, 22] However, the operation has been criticized by some because of its complexity and its lengthy learning curve [1, 6, 16].

One of the major potential complications associated with the procedure is nerve injury. In the first report on the PAO, Ganz et al. [7] reviewed 75 cases and reported one femoral neurapraxia with no injuries to the sciatic nerve. Davey and Santore [6] noted four sciatic or peroneal nerve palsies in their first 70 patients and discussed the lengthy learning curve associated with the procedure. Subsequent studies of the osteotomy using a modern abductor-sparing approach also had femoral and sciatic nerve palsies at rates ranging from 0% to 15% [4, 8, 13, 16, 17]. The varying rates of nerve injury reported in the literature and the lack of understanding regarding what risk factors are associated with such injury prompted this review.

We used a large multicenter cohort of patients who had PAO for varying forms of acetabular dysplasia to answer the following questions: What is the incidence of sciatic and femoral nerve injury after PAO; (2) what are the risk factors associated with such injury, and (3) what are the consequences of such injury including the degree of neurologic recovery?

## Patients and Methods

We obtained Institutional Review Board approval from all participating institutions.

We retrospectively reviewed 1760 PAOs performed between 1991 and 2008 at five institutions (Mayo Clinic, Washington University, Ottawa University, Boston Children's Hospital, William Beaumont Hospital). The surgeries were performed by eight surgeons (RJS, RTT, PB, JC, MM,YJK, IZ, PS) who specialized in treatment of the young hip. Because 93 charts at one institution had been discarded and were not available for review, the final cohort consisted of 1677 PAOs that included 1322 performed in females (79%) and 352 performed in males (21%). The average age of the patients was 26 years (range, 12–60 years). The minimum followup for this large cohort is unknown, however no patients with nerve injury were lost to followup. No patients were recalled specifically for this study; all data were obtained from medical records and radiographs.

The PAO is performed with the patient supine on a radiolucent table if intraoperative fluoroscopy is used. For this cohort, all surgeons perform the osteotomies using fluoroscopic guidance. Electromyographic monitoring was used in 599 cases and only at two of the five institutions. An abductor-sparing approach to the hip using a modified Smith-Petersen approach was used. Intraoperative measures to reduce nerve injury include: (1) at the time of the ischial osteotomy, care is taken to abduct the leg so as to move the sciatic nerve away from the plane of the osteotome in case the osteotome exits through the ischium; (2) at the time of the posterior column osteotomy, care is taken not to exit laterally and posteriorly as the sciatic nerve may lie close to the posterior column; (3) during exposure of the inner pelvis, care is taken to maintain adequate placement of the retractors under the periosteum, especially retractors inside the sciatic notch; (4) at the time of the pubic osteotomy, the leg is flexed to relieve tension of the psoas as the femoral nerve is in close proximity; and (5) after completion of the osteotomy and fragment repositioning, the surgeon should note whether there is tension on the femoral nerve and inguinal ligament by the repositioned fragment, especially if a reverse PAO is performed.

The charts of the 1677 patients who had PAOs were reviewed to address pertinent risk factors associated with the injury. These included gender, age at surgery, BMI, previous surgery, underlying diagnosis, concomitant procedures, and the use of EMG at the time of surgery. For the 36 nerve injuries additional data were obtained from retrospective chart review at each of the surgeons' centers and by review of in-house databases and surgeon's summary of cases. A standardized form then was completed with specific questions regarding the nerve injury (Appendix 1). The operative reports of these 36 patients and the use of the EMG were recorded in addition to the details regarding the occurrence of the nerve injury at the time of the surgery. Specifically, any occurrences at the time of surgery that could have led to the suspicion of a nerve injury were recorded, such as the leg contracting at the time of an osteotomy or EMG firing during the case, among others. The clinical histories of all 36 patients were reviewed to assess the treatment of the nerve injury and the degree of neurologic recovery. Motor muscle strength was evaluated using a 0 to 5 scale as described by the Medical Research Council [13].

We defined a major nerve injury as a postoperative motor nerve palsy or sensory deficit present after surgery in the distribution of the femoral or sciatic nerves regardless of its severity or duration. All patients were examined postoperatively by the treating surgeon and the injury was diagnosed then. The centers did not follow a standardized protocol regarding how to diagnose, treat, or follow the patients with nerve injuries. However, it is common practice to examine patients in the immediate postoperative period and document nerve function. Because of the unreliability of diagnosing and the ambiguity of reporting minor nerve deficits, especially sensory, only major nerve deficits reported in the immediate postoperative period were included. Specifically, we chose to exclude lateral femoral cutaneous nerve injuries because of the lack of specificity in the charts regarding what corresponded to an injury and because many were not diagnosed in the immediate postoperative period. We decided to report only objective nerve dysfunctions that led to change in practice and followup. Nevertheless, lateral femoral nerve dysfunction is common after the PAO.

Based on the severity of the injury, the decision was made by the surgeon regarding treatment of the injury and postoperative followup. Because the nerve injuries were not thought to be related to malpositioned hardware no additional testing was performed in the form of CT or MRI. EMG was performed in 11 cases. Patients with nerve injuries would be seen at 6 weeks to 3 months after surgery, and per surgeon discretion, the patient was seen again at either 3 months or 1 year. We identified a range of EMG findings (Table 1).

All data are summarized as mean (standard deviation) for continuous data and count (percentage) for discrete data, unless otherwise specified. The analysis focused on the outcome of postoperative nerve palsy, as described above. The association of patient demographics and other potential risk factors was evaluated using logistic regression; odds ratios are reported with 95% confidence intervals. All statistical tests were two-sided. All analyses were conducted using SAS version 9.2 (SAS Institute Inc, Cary, NC, USA).

## Results

Thirty-six patients (36 hips) of the 1677 who had PAOs (2.1%) had a major nerve deficit postoperatively. Twenty-nine of these patients were females and eight were males with an average age of 24 years (range, 13–51 years) at the time of surgery. The diagnosis leading to the PAO was classic dysplasia in 30, postPerthes deformity in three, neuromuscular hip dysplasia in three, and retroversion of the acetabulum in one. Classic hip dysplasia was considered by the treating surgeon to be a lack of coverage of the femoral head by the acetabulum identified by a lateral center-edge angle less than 20$^o$ and a roof angle greater than 10$^o$. Eight patients had previous surgery. These included a proximal femoral osteotomy in three, previous pelvic osteotomies in two, iliac bone grafting in one, and hip arthroscopy in one, and one patient had multiple previous operations that were unknown. Eighteen patients had a concomitant procedure at the time of the PAO and included nine diagnostic arthrotomies, one arthrotomy with osteochondroplasty of the femoral head-neck junction, two arthrotomies and labral debridement, five proximal femoral osteotomies, and one proximal femoral osteotomy and open arthrotomy. The average surgical time was 309 minutes (range, 150–625 minutes) for patients for whom it was known.

Twenty-eight patients had a postoperative deficit of either the sciatic or the peroneal nerve or tibial division of the sciatic nerve. Eight patients had a deficit of the femoral nerve, and one patient had a combined sciatic-femoral nerve deficit. In these groups, two of the 28 sciatic or peroneal nerve deficits were pure motor, nine were sensory only, and 17 were combined motor and sensory deficits. In the eight femoral deficits, two were pure sensory and six were combined motor and sensory deficits. The combined sciatic and femoral injury was a combined motor and sensory deficit. The etiology of the injury was not known for 21 patients.

For the 1677 patients having PAOs, the average BMI was 25 with 54% of patients having a BMI less than 18, 27% had a BMI between 25 and 30, and 14% had a BMI greater than 30. The diagnosis leading to the majority of PAOs was classic hip dysplasia (89%). In 32 hips the PAO was performed for Perthes (2%), in 28 hips for retroversion (1.9%), in 74 (4.5%) for neuromuscular hip dysplasia, and in 43 (2.6%) for other diagnoses. Other procedures were performed in 1028 hips (61%) and included a proximal femoral osteotomy in 135 (8.1%), open arthrotomy for treatment of intraarticular disease in 850 (50.7%), adductor tenotomy in 16 (1%), and trochanteric advancement in 28 (1.7%). No association was found between any of the demographic and surgical variables and the occurrence of nerve injury. None of the surgical or demographic risk factors examined was associated with an increased risk of nerve injury. Of the patients who had an arthrotomy, 1.4% (12/850) had nerve palsy compared with 2.9% (24/827) of the patients who did not have an arthrotomy (odds ratio [OR] = 2.1). The difference in the incidence of nerve injury in patients who had undergone arthrotomy or not was not significant after adjusting for age and BMI (OR = 1.7, 95% CI = 0.82, 3.73), p = 0.152).

Nonoperative treatment was chosen for 32 of the 36 patients with major nerve deficits. Exploration and neurolysis were performed in four patients. The decision to explore the nerve was surgeon-dependent and involved other specialists. In one case of a sciatic deficit, the peroneal nerve was decompressed at the fibular head because it was believed that excessive lengthening (> 2 cm) of the extremity had occurred after a concomitant femoral osteotomy. In another patient with a direct injury to the sciatic

**Table 1.** Patients with nerve injuries after PAO

| Number | Age (years) | Gender | Diagnosis | Number of previous surgeries | Concomitant procedures | EMG at PAO | Nerve involved | Type of injury | EMG findings | Time to clinical improvement | Treatment | Final deficit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 19 | F | Classic dysplasia | 0 | No | Yes | Peroneal | Motor | Not done | Permanent | Observation | 0/5 |
| 2 | 17 | F | Perthes | 3 | Yes | Yes | Peroneal | Both | Sciatic neurapraxia | 18 months | Neurolysis at knee | None |
| 3 | 20 | M | Neuromuscular | 0 | No | Yes | Sciatic, femoral | Both | Not done | 48 hours | Observation | None |
| 4 | 15 | F | Retroversion | 0 | Yes | Yes | Femoral | Both | Not done | 5 months | Exploration | None |
| 5 | 18 | M | Perthes | 2 | Yes | Yes | Peroneal | Both | Incomplete neuropathy | 11 months | Observation | None |
| 6 | 42 | F | Classic dysplasia | 0 | No | Yes | Sciatic | Sensory | Done | Permanent | Observation | 5/5, permanent dysesthesia |
| 7 | 10 | F | Classic dysplasia | 3 | No | Yes | Femoral | Both | Not done | 12 months | Observation | None |
| | 27 | F | Classic dysplasia | 0 | No | Yes | Femoral | Both | Not Available | 6 months | Observation | None |
| 9 | 30 | F | Classic dysplasia | 0 | No | Yes | Femoral | Both | Not done | 16 months | Observation | 5/5, dysesthesia medial thigh |
| 10 | 53 | F | Classic dysplasia | 5 | No | Yes | Femoral | Both | Neurapraxia, femoral nerve | 4.5 months | Exploration and neurolysis | None |
| 11 | 27 | F | Classic dysplasia | 0 | No | Yes | Sciatic | Sensory | Sciatic nerve irritation | 2 months | Observation | None |
| 12 | 29 | F | Classic dysplasia | 0 | No | Yes | Sciatic | Sensory | Normal | 48 months | Blocks, gabapentin | None |
| 13 | 38 | F | Classic dysplasia | 0 | No | Yes | Peroneal | Sensory | Not done | 2 Months | Gabapentin | None |
| 14 | 14 | F | Classic dysplasia | 0 | No | Yes | Sciatic | Sensory | Not done | 12 months | Amitriptyline | None |
| 15 | 13 | F | Classic dysplasia | 0 | No | Yes | sciatic | Motor | Not done | 7 months | Observation | 4/5 |
| 16 | 22 | F | Classic dysplasia | 0 | No | Yes | Sciatic | Both | Severe peroneal, complete involvement | Permanent | Observation | 0/5 |
| 17 | 16 | F | Classic dysplasia | 0 | No | Yes | Femoral | Both | Acute almost complete femoral neuropathy | 5 months | Observation | None |
| 18 | 30 | F | Classic dysplasia | 0 | No | Yes | Peroneal | Both | Not done | Permanent | Observation | 3/5 |
| 19 | 37 | F | Classic dysplasia | 0 | No | No | Femoral | Sensory | Direct injury, denervation | 6 months | Observation | Cold intolerance |

**Table 1.** continued

| Number | Age (years) | Gender | Diagnosis | Number of previous surgeries | Concomitant procedures | EMG at PAO | Nerve involved | Type of injury | EMG findings | Time to clinical improvement | Treatment | Final deficit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 13 | M | Perthes | 1 | No | No | Sciatic | Both | Not done | Permanent | Neurolysis, repair of partial laceration | 2/5 |
| 21 | 15 | F | Classic dysplasia | 0 | No | No | Peroneal | Both | Not done | Permanent | Observation | 3/5 |
| 22 | Unknown | Unknown | Neuromuscular | 0 | No | No | Peroneal | Both | Not done | 9 months | Observation | None |
| 23 | 13 | M | Neuromuscular | 0 | Yes | No | Femoral | Both | Not done | 3 months | Observation | None |
| 24 | 17 | F | Classic dysplasia | 1 | No | No | Peroneal | Sensory | Not done | 6.5 months | Observation | None |
| 25 | 16 | F | Classic dysplasia | 3 | No | No | Peroneal | Both | Not done | 6.5 months | Observation | 4/5 |
| 26 | 22 | F | Classic dysplasia | 0 | No | No | Peroneal | Both | Not done | Permanent | Observation | 4/5, no brace required |
| 27 | 28 | M | Classic dysplasia | 0 | No | No | Peroneal | Both | Recovering function tibial nerve more than peroneal | Permanent | Observation | 4/5, no brace required |
| 28 | 21 | F | Classic dysplasia | 2 | No | No | Sciatic | Both | Not done | Permanent | Observation | 2/5 |
| 29 | 13 | M | Classic dysplasia | 0 | Yes | No | Sciatic | Both | Not done | Permanent | Observation | 4/5 EHL weakness |
| 30 | 15 | F | Classic dysplasia | 0 | No | No | Peroneal | Both | Not done | 6 months | Observation | 4/5 EHL weakness, dorsum tingling |
| 31 | 16 | M | Classic dysplasia | 0 | Yes | No | Peroneal | Both | Not done | 12 months | Observation | None |
| 32 | 35 | F | Classic dysplasia | 0 | No | No | Peroneal | Sensory | Not done | 6 Months | Observation | None |
| 33 | 27 | F | Classic dysplasia | 0 | No | No | Sciatic, tibial | Sensory | Not done | 6 months | Observation | None |
| 34 | 45 | F | Classic dysplasia | 0 | No | No | Sciatic | Sensory | Not done | Permanent | Observation | Numbness on sole |
| 35 | 40 | F | Classic dysplasia | 0 | Yes | No | Sciatic, peroneal | Both | Neurapraxia to sciatic nerve | 9 months | Observation | 4/5, motor deficit in eversion |
| 36 | 43 | F | Classic dysplasia | 0 | No | No | Peroneal | Both | Neurapraxia | 16 weeks | Observation | None |

EMG = electromyography; PAO = periacetabular osteotomy; EHL = extensor hallucis longus.

nerve at the time of the ischial osteotomy, exploration and neurolysis of the nerve were performed and the patient had partial recovery of the deficit. Two other patients underwent exploration of the femoral nerve. One of these patients had a PAO for pure acetabular retroversion, and it was believed that the excessively anteverted fragment was compressing the nerve between the pelvic floor and inguinal ligament. This patient underwent release of the ligament and removal of impinging bone. The second patient with a femoral nerve palsy had nerve conduction studies consistent with neurapraxia at the level of the ilioinguinal ligament, but at the time of exploration had no signs of trauma to the nerve and neurolysis was not performed. Both patients had full recovery of femoral nerve function.

Seventeen of the 36 patients had complete recovery and 19 had only partial recovery. All six patients with femoral nerve motor injury achieved full recovery. Six of eight patients with femoral nerve sensory injury recovered fully. Of the 20 patients with sciatic nerve motor dysfunction, only nine recovered their preoperative function. Fourteen of 17 patients with sciatic sensory deficits recovered. Of the 11 patients with sciatic injuries who recovered fully, one underwent exploration and neurolysis of the nerve at the level of the knee and the other 10 recovered their preoperative function without exploration. However, 12 patients with sciatic or peroneal palsies who were treated nonoperatively continued to have some motor deficit at final followup (Table 2). The average time to recovery of function or detection of no noticeable clinical improvement of the deficit was 8 months (range, 2 days to 24 months).

## Discussion

Sciatic and femoral nerve injuries have been described in patients undergoing PAO [1, 6, 8, 16, 17]. However, the incidence and circumstances associated with such injury are not well known. We therefore addressed the following questions: What is the incidence of sciatic and femoral nerve injury after PAO; (2) what are the risk factors associated with such injury, and (3) what are the consequences of such injury including the degree of neurologic recovery?

This study has certain limitations. First, because the study is retrospective, we relied on the physical examinations and notes obtained from medical charts from treating surgeons. We had no set protocol for identifying these injuries. The actual severity of the injury could be overestimated or underestimated in the patients' charts, and minor injuries that led to some disability could have been missed. In addition, unless there was a profound femoral nerve injury that was accounted for immediately after the operation, there could be instances where the femoral nerve deficit could be inadvertently missed and only noted until a few weeks after the operation, also underestimating the number of injuries. Second, this study represents potentially a best case scenario as the operation has been performed by surgeons who specialize in this procedure and the results may not be applicable to the community surgeon. Third, the number of injuries may be too small to ascertain any statistical correlation between the type of injury and patient demographic or surgical factors that potentially could predispose to the development of the injury, however the large number of cases did allow us to make relatively good correlations. Finally, there was variation regarding the diagnosis and management of the nerve injury per center and the aggressiveness of treatment could account for the differences in neurologic recovery.

The incidence of major nerve injury after PAO in this multicenter study was 2.1%, consistent with what has been reported in other studies. Published studies have reported an incidence of femoral and sciatic nerve injuries ranging from 0% to 15% after PAO (Table 3). The incidences of sciatic and femoral nerve injuries were 1.6% and 0.5%, respectively, in this series. Ganz et al. reported only one femoral neurapraxia in 75 cases and no injuries to the sciatic nerve in their initial study [7]. After 1993, a less invasive approach to PAO with preservation of abductor musculature and indirect osteotomies might account for a greater incidence of nerve injuries compared with the number reported by Ganz et al. [7]. The lower rate of sciatic nerve injury reported after rotational osteotomy supports the hypothesis that wider exposure and direct observation may decrease the risk of nerve injury. The benefits of abductor sparing approaches such as those currently used for the PAO must be weighed with the risk of nerve injury and individualized to the patient [9, 15].

We found no surgical or demographic variables that could indicate which patients are at risk for such complications. However, care must be taken with all patients undergoing PAO and the surgeon should be familiar with certain intraoperative maneuvers that could be used to decrease the risk of nerve injuries.

Pring et al. [17] specifically studied nerve injuries after PAO at one institution and reported an incidence of 5%, of which 0.7% of injuries were permanent. They recommended the use of intraoperative EMG to decrease the risk of nerve injury and as a prognostic tool in cases when injury had occurred [17]. Its use during PAO, however, has been debatable and is currently surgeon-dependent. Its drawbacks include cost and the fact that it requires specialized personnel present for its interpretation during the case. It also has certain limitations because it cannot identify all nerve irritation or trauma. A sharp laceration of the nerve, for example, may not produce neurotonic

**Table 2.** Odds ratio estimate, 95% confidence interval, and adjusted p values for each of the risk factors

| Variable | Number of hips | Events | Events/cases | Subgroup stratification | Odds ratio estimate | 95% CI for odds ratio | p value |
|---|---|---|---|---|---|---|---|
| Age, 10-year increase | 1677 | 36 | N/A | N/A | 0.746 | (0.527, 1.056) | 0.0989 |
| Gender | 1674 | 36 | 25/1322 = 1.9% | Female | | | |
| | | | 11/352 = 3.1% | Male | 1.674 | (0.815, 3.435) | 0.1605 |
| BMI, five-unit increase | 1247 | 30 | N/A | N/A | 0.711 | (0.456, 1.107) | 0.1312 |
| BMI, categorized | 1247 | 30 | 21/680 = 3.1% | $18.5 \leq BMI < 25$ | | | |
| | | | 5/339 = 1.5% | $25 \leq BMI < 30$ | 0.47 | (0.176, 1.257) | 0.1324 |
| | | | 2/182 = 1.1% | $30 \leq BMI$ | 0.349 | (0.081, 1.501) | 0.1572 |
| | | | 2/46 = 4.3% | $BMI < 18.5$ | 1.426 | (0.324, 6.280) | 0.6386 |
| Diagnosis group | 1650 | 35 | 31/1478 = 2.1% | Developmental hip and developmental hip dysplasia with retroverted socket | | | |
| | | | 1/74 = 1.4% | Neuromuscular | 0.639 | (0.086, 4.749) | 0.662 |
| | | | 3/98 = 3.1% | Perthes, slipped capital epiphysis, retroverted socket, posttraumatic, other | 1.474 | (0.443, 4.909) | 0.5273 |
| Other procedures | 1677 | 36 | 17/1028 = 1.7% | Yes | | | |
| | | | 19/649 = 2.9% | No | 1.794 | (0.925, 3.477) | 0.0836 |
| Arthrotomy | 1677 | 36 | 12/850 = 1.4% | Yes | | | |
| | | | 24/827 = 2.9% | No | 2.087 | (1.037, 4.202) | 0.0393 |
| Proximal femoral osteotomy | 1677 | 36 | 30/1542 = 1.9% | No | | | |
| | | | 6/135 = 4.4% | Yes | 2.344 | (0.958, 5.736) | 0.062 |
| Previous surgery | 1537 | 36 | 6/264 = 2.3% | Yes | | | |
| | | | 30/1273 = 2.4% | No | 1.038 | (0.428, 2.519) | 0.9346 |
| EMG monitoring | 1677 | 36 | 19/1078 = 1.8% | No | | | |
| | | | 17/599 = 2.8% | Yes | 1.628 | (0.840, 3.157) | 0.1491 |

EMG = electromyography; N/A = not available.

**Table 3.** Clinical results of PAO in the literature and reported nerve injury

| Study | Number of hips | Mean age at time of PAO (years) | Mean followup (years) | Nerve injury |
|---|---|---|---|---|
| Trousdale et al. [21] | 32 isolated PAO (76%)<br>10 combined ITO and PAO (24%) | 37 | 4 | 1 hip with LFCN requiring neurolysis |
| Cockarell et al. [5] | 21 isolated PAO (79%)<br>4 combined ITO and PAO (21%) | 21 | 3.2 | 3 peroneal nerve dysfunction |
| Matta et al. [12] | 56 isolated PAO (85%)<br>10 combined ITO and PAO (15%) | 34 | 4 | None described |
| Trumble et al. [22] | 90 isolated PAO (73%)<br>33 combined ITO and PAO (27%) | 33 | 4.3 | None described |
| Siebenrock et al. [18] | 59 isolated PAO (79%)<br>16 combined ITO and PAO (21%) | 29 | 11.3 | 1 femoral nerve dysfunction |
| Clohisy et al. [2] | 10 isolated PAO (62%)<br>6 combined ITO and PAO (38%) | 17.6 | 4.3 | 1 femoral nerve and 1 peroneal nerve dysfunction |
| Kralj et al. [10] | 26 hips | 34 | 12 | None described |
| Peters et al. [16] | 69 (83%) isolated PAO<br>13 (16%) combined ITO and PAO | 28 | 3.8 | 3 femoral nerve and 1 sciatic nerve dyfunction<br>1 (1%) LFCN |
| Steppacher et al. [19] | 59 isolated PAO (79%)<br>16 ITO (21%) | 29 | 20.4 | 1 femoral nerve dysfunction |
| Biedermann et al. [1] | 33 isolated PAO<br>17 combined ITO and PAO | 27 | 7.4 | 1 sciatic and 5 peroneal nerve dysfunction |
| Millis et al. [14] | 87 hips | 44 | 4.9 | 1 sciatic sensory neurapraxia |
| Matheney et al. [11] | 110 isolated PAO<br>25 combined ITO and PAO | 27 | 9 | 9 transient peroneal nerve palsy |
| Thawrani et al. [20] | 78 isolated PAO<br>5 combined ITO and PAO | 15 | 2 | 4 LFCN dysfunction |

PAO = periacetabular osteotomy; ITO = intertrochanteric osteotomy; FNL = relative femoral neck lengthening; LFCN = lateral femorocutaneous nerve.

discharges and may not be recorded. The presence of EMG could potentially provide the surgeon a false sense of safety that could lead to inadvertent injury to the nerve. It may be useful in surgery, however, because it may identify situations in which the nerve is at risk, such as during placement of retractors in inappropriate locations and it may identify overlengthening of the extremity. It also could help the surgeon in determining whether exploration of the nerve may be warranted, such as in cases when the EMG fires during a specific maneuver that may injure the nerve.

In the current study, the prognosis of the nerve injury depended on what nerve was injured and the severity of the insult. Motor sciatic injuries recovered fully only in ½ of the patients and were thought to occur most likely because of direct trauma or stretch associated with overlengthening of the extremity. The femoral nerve motor function recovered in all patients and this injury was believed to be related to excessive traction on the structure. The literature supports that the majority of femoral nerve injuries will resolve with time and nonoperative treatment would be the preferred treatment [1, 2, 4–6, 10, 12, 18, 21, 22]. In contrast, our study and previous studies show that some sciatic nerve injuries may lead to permanent disability, and therefore detailed study of the events occurring at the time of surgery that prompted the injury is warranted and a decision regarding surgical management should be made.

We found an incidence of major nerve injury after PAO of 2.1% in more than 1700 PAOs performed in five centers. We were unable to determine which patients are at increased risk of nerve injury at the time of PAO. Femoral nerve injuries have a good prognosis whereas the degree of neurologic recovery of sciatic nerve injuries depends on the cause and severity of the damage. We believe exploration may be warranted if direct nerve trauma is suspected.

**Acknowledgments** We thank Perry Schoenecker MD and Young Jo-Kim MD for contributing cases for this study.

## Appendix 1. Nerve Injury after PAO Data Collection Sheet

Institution: ________________________________

PAO Time Period _______ to _______

Total Number of PAOs Performed during Time Period ________

Case Number ______

Identifier Code

Patient Gender F M

Patient Age at Surgery ________ DOB: ___________________

Patient Date of Surgery_____________________

Wt ______ lbs Height ________

BMI ___________

Preoperative Diagnosis
- O Classic DDH
- O Perthes-like
- O Postraumatic
- O Retroversion
- O Neuromuscular Hip
- O High DDH Crowe ___

Underlying Medical Comorbidity
- O Diabetes
- O Neuromuscular
- O Radiculopathy
- O Other Neurologic

_____________________________

Previous Surgery # ______ Describe:
- O Previous Pelvic Osteotomy
- O Open Reduction
- O PFO
- O Multiple Describe above

Duration of Surgery ____________ minutes

Other Procedures in addition to PAO, same setting or staged? O Y O N

O PFO O Surgical Hip Dislocation

Other______________

EMG monitoring Used O Yes O No

Nerve Injury O Yes O No

O Sciatic O Peroneal Division O Tibial Division O Femoral

Mark all that apply

O Motor O Sensory O Both

Duration of Injury

Detailed Description of Initial Deficit
__________________________________________________________________

__________________________________________________________________

Treatment

O Observation
O Exploration

O Neurolysis

EMG Findings Postoperative

Was an EMG performed? Y N

EMG results ________________________________________

O Transitory

Time to Plateau _______ weeks

Time to Full Recovery _______ weeks

O Permanent

Describe Final Deficit
______________________________________________________________________________
______________________________________________________________________________
________________________________________

When Does Surgeon Believe Injury Could Have Occurred?

Did Leg Contract (Jump). Did Monitor Fire: Y N

When _________________________________

Medical Legal Problems?

Radiographic Review

1. Was Large Correction Performed
2. Posterior Column Disruption
3. Ischial Bone Spike?
4. Through Ischial Osteotomy?
5. Other ____________________________

Followup __________________Months

PAO = periacetabular osteotomy; PFO = proximal femoral osteotomy ; DDH = developmental dysplasia of the hip;

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