INTRODUCTION

Most peroneal nerve injuries resulting in foot drop are secondary to trauma or iatrogenic. Kretschmer et al. reported iatrogenic nerve lesions with an incidence rate as high as 17.4%. Iatrogenic causes include mainly the lower back spine, hip, and knee surgeries. Lumbosacral plexopathy can cause peroneal or tibial nerve pathology, weakening or loss of the foot and ankle dorsiflexors resulting in foot deformity, and functional gait impairment.
with characteristic foot slap during the heel strike and a steppage gait.\cite{18,20} Lumbar spinal nerve root damage and peroneal nerve injury are the most frequent causes of foot drop.\cite{4} Bakhsh \textit{et al.}\cite{2} reported that the long-term outcome of lumbar disk surgery was unsatisfactory, and new neurological deficits caused foot drop postoperatively in 8.8% of their patients. Failed back surgery syndrome due to postspinal surgical injury also causes foot drop.\cite{18,21} Dellon\cite{5} found that 58% of their postarthroplasty palsy patients had peroneal neuropathy and indicated surgical neurolysis of the common peroneal nerve.

Neurological deficit in the postsurgical period is under-recognized. Electrophysiological studies help diagnose the type and level of nerve injury.

Our study focuses on the surgical outcomes of iatrogenic foot drop resulting from potential complications of previous surgeries (lower back spine, hip, and knee surgeries) in other institutions before presenting to our clinic.

\section*{MATERIALS AND METHODS}

We have reviewed our foot drop patients’ data who consulted us over 17 years (07–2004 to current) to determine the iatrogenic causes and incidence of foot drop. EMG and NCS results were used for diagnosing nerve injuries in addition to clinical examinations of the involved foot. We successfully managed foot drop by neurolysis of the peroneal nerve and the nerve transfer\cite{7} procedures described below.\cite{14}

\subsection*{Surgical procedure}

The involved leg was prepared and draped in a sterile fashion. A vertical midline incision was created in the distal posterior thigh, extended laterally along the posterior knee crease at the popliteal fossa, and then curved inferiorly along the course of the peroneal nerve over the fibular neck. The sciatic nerve was identified in the upper incision, which extended 6–8 cm above the popliteal fossa, and the terminal bifurcation of the nerve was traced. The superficial and deep peroneal nerve components were stimulated to identify or confirm conduction through the lateral and anterior muscle compartments. In those patients where the superficial peroneal nerve showed reasonable function, it was selected as the donor for the deep peroneal nerve. A partial transfer of one-third to the motor branch of the peroneal was feasible without clinical loss of eversion, as the superficial peroneal nerve is physically larger than the motor branch to the anterior tibialis muscle by about 3 times.

The motor branch to the anterior tibialis muscle was dissected several centimeters proximally within the common peroneal nerve so that coaptation was easily done without tension. If the lesion affected both superficial and deep branches, the tibial nerve was selected as a donor to the deep peroneal component of the common peroneal nerve or the deep peroneal nerve directly, if possible, by anatomy or by intraneural dissection. The incision created at the posterior knee and thigh allowed visualization of the sciatic bifurcation and dissection of the peroneal component to a distal level as possible to reduce regeneration time. The proximal tibial nerve was gently dissected intraneural to separate component fascicle groups. Typically, two large fascicle groups were then dissected out as suitable in diameter to fill the volume of the anterior and lateral part of the common peroneal nerve constituting the eventual deep peroneal motor branch. If intraneural dissection within the common peroneal nerve to isolate the deep peroneal nerve was feasible, then the tibial fascicle groups were coapted directly to the deep peroneal nerve fibers. Dissection was performed as distally as possible to reduce the length of regeneration to the anterior tibialis muscle. The deep peroneal nerve was sectioned with microsurgical technique and transposed to the area of the tibial nerve. The selected tibial nerve fascicles were then transected and placed in opposition to the peroneal nerve 2–4 cm distal to the bifurcation of the sciatic nerve and proximal to the popliteal crease area. Approximately 25–30% of the overall volume of the tibial nerve was transferred. Neither the severed distal fascicles of the donor’s nerve nor the transected proximal fibers of the recipient’s deep peroneal nerve were managed specifically after being cut. The transfer site was secured with 9–0 nylon epineural stitches placed in a circumferential fashion around the peroneal-tibial or superficial peroneal-deep peroneal interface. The leg was then placed into a full range of motion to ascertain no tension at the repair site even with the knee was fully extended.

\section*{RESULTS}

Before the onset of foot drop, all except one (27 of 28) patient have had surgeries in other clinics before presenting to our institution. Foot drop in one patient was due to infection and hip wound after he was intubated and stayed in ICU for weeks. Thirteen of the 28 patients have had lumbosacral (L3-4, L4-L5, and L5-S1) fusion or laminectomy, eight have had hip surgery, and five have had knee surgery. One patient had a fasciotomy due to compartment syndrome, and another patient had two previous surgeries for posterior tibial entrapment and tarsal tunnel syndrome at other institutions. NCS/EMG results showed that all except one patient had reduced peroneal nerve conduction velocity and amplitudes, and an absence or low sensory response of sural nerves. One patient had a femoral nerve injury and scarring and two patients also had tibial nerve injury.

Preoperatively, 10 patients had severe foot drop with muscle weakness and a functional grade of 0/5; 16 patients had grades ranging from 1 to 2/5; and two patients had 3/5 [Table 1] and [Videos 1A and 1B]. Overall, 23 of the 28 patients (83%) had
Table 1: Surgical improvements of foot drop in patients with iatrogenic nerve injury.

| #  | Gender/Age | Preoperative history | Type of injury | NCS/EMG Results | Preoperative | Postoperative | Ankle dorsiflexion | Follow-up months | Surgical outcomes |
|----|------------|----------------------|----------------|----------------|--------------|--------------|-------------------|-----------------|------------------|
| 1  | F/59       | L3-L5 laminectomy    |                | Abnormality was noted in both deep peroneal motor responses showing a significant axonal dropout and slowing in conduction velocities. Amplitude loss was present, but the sural sensory response was normal. EMG showed no recruitment and no voluntary motor units in the right tibialis anterior | Preoperative | Postoperative | 1                | 2+              | 15               | Improvement in ankle dorsiflexion and extension |
| 2  | M/21       | Fell at home, knocked himself out, mild strokes, infection, intubated in ICU for weeks, hip wound |                | There was no palpable and no electric responses in the left peroneal nerves | Preoperative | Postoperative | 32               |                | Some improvements, still steppage gait present |
| 3  | F/69       | Retroperitoneal hematoma, femoral palsy. Hip replacement |                | Femoral innervated muscles on the right demonstrated active denervation. F-waves, latencies, velocities, and conduction were normal in the right tibial, peroneal, and sural nerves. Femoral nerve palsy/scarring had microneurolysis of femoral nerve. | Preoperative | Postoperative | 3                | 4+/5            | 9                | Gained 4+/5 MRC grade No steppage gait |
| 4  | F/53       | Knee replacement: slow steps used a cane |                | The abnormal electrodiagnostic study report of the left lower extremity consistent with left peroneal neuropathy at or proximal to the fibular head, evidence of tibial neuropathy. Diffused sensorimotor polyneuropathy. | Preoperative | Postoperative | 0                | 2+              | 20               | Significant improvement; was able to walk without a cane |
| 5  | F/39       | Had tarsal tunnel and tibial nerve entrapment surgeries |                | The left peroneal motor nerve showed reduced amplitude (0.8mA). The left superficial peroneal sensory nerve showed no response. | Preoperative | Postoperative | 2                | 4+              | 2                | Excellent outcome Achieved 4+ grade No steppage gait |
| 6  | M/60       | Had fasciotomy due to compartment syndrome |                | Significant denervation to the left peroneus and longus anterior muscle. | Preoperative | Postoperative | 2 -R             | 3+ -R           | 15               | Improvement in the right foot Developed left FD later due to compartment syndrome Recommended for tendon transfer |
| 7  | F/48       | Bilateral knee replacement; left FD |                | Acute denervation to the left peroneus and longus anterior muscle. | Preoperative | Postoperative | 17               |                |                  | (Contd...) |
Table 1: (Continued).

| #  | Gender/ Age | Preoperative history | NCS/EMG Results | Preoperative Ankle dorsi-flexion | Follow-up months | Surgical outcomes |
|----|-------------|----------------------|-----------------|---------------------------------|------------------|------------------|
| 8  | M/48        | Lumbar spine surgery | Denervation changes were seen bilaterally, left worse than the right. | Preoperative Postoperative | 21 | Not significant improvement |
| 9  | F/15        | Had prior ligament reconstruction in the right knee | No nerve action potentials were recorded with the direct nerve to nerve stimulation of the peroneal nerve. cAMPS was recorded with stimulation of anterior tibialis and peroneus longus muscle with stimulus intensities 1.0 mA | Preoperative Postoperative | 18 | Great improvement No steppage gait |
| 10 | F/56        | Lumbar spine surgery | Abnormal needle examination with severe denervation noted in the L5 innervated right leg muscles | Preoperative Postoperative | 10 | Improved significantly |
| 11 | F/44        | Hip replacement | Peroneal innervated muscles shared acute denervation changes and absent recruitment of MUP, indicating axonal disruptions. Continued acute denervation with no evidence of regenerating motor units in the common PN distribution | Preoperative Postoperative | 8 | Excellent results: the patient sent us a photo wearing and able to walk in high heel |
| 12 | F/18        | Femoral palsy; prior surgery for foot drop | Severe left sciatic neuropathy with more significant involvement of the PN division of the sciatic nerve | Preoperative Postoperative | 13 | No steppage gait |
| 13 | M/59        | Laminectomy | Abnormal findings of left tibialis anterior and posterior, also, gastrocnemius, axonal sensory polyneuropathy. | Preoperative Postoperative | 10 | Some improvement in dorsiflexion but not yet achieved anti-gravity |
| 14 | F/64        | Hip replacement | Peroneal neuropathy manifested by low motor CMAP amplitudes and slowing of conduction velocity of the peroneal around the fibular head | Preoperative Postoperative | 17 | Excellent surgical outcome Patient was able to walk normally |
| 15 | M/69        | Laminectomy | Preneurolysis; peroneal to tib, anterior – no response at 10 mA | Preoperative Postoperative | 1 | Improvement in gait |

(Contd...)
Table 1: (Continued).

| #  | Gender/Age | Preoperative history | NCS/EMG Results | Preoperative Postoperative | Ankle dorsiflexion | Follow-up months | Surgical outcomes |
|----|------------|----------------------|-----------------|----------------------------|-------------------|------------------|-------------------|
| 16 | F/60       | Hip replacement      | superficial peroneal to lateral compartment – no response at 10 mA |                            | 0                 | 4                | 16                | Significant improvement, no steppage gait |
| 17 | F/39       | Laminectomy          | L5 radiculopathy; evidence of acute and chronic muscle denervation changes | Preoperative Postoperative | 0                 | 2                | 9                 | Some improvement in eversion and planter flexion. Gait present. |
| 18 | M/59       | L5-S1 microdiscectomy| Diffused diminished amplitudes throughout the left lower extremity | Preoperative Postoperative | 1                 | 3+               | 7                 | Excellent results of nerve transfer. Improvement in ankle dorsiflexion and eversion; stable ankle movements |
| 19 | F/59       | Lumbar nerve injury  | The right tibial and peroneal motor conduction studies revealed prolonged and markedly reduced CMAP amplitude and NCV | Preoperative Postoperative | 0                 | 3                | 30                | An ongoing stable, excellent function of both ankles. No steppage gait |
| 20 | F/46       | Lower Back surgery   | L5 radiculopathy; superimposed peroneal neuropathy. The right peroneal motor nerve CMAP amplitude was diminished | Preoperative Postoperative | 1                 | 3+               | 18                | No notable functional improvement |
| 21 | F/44       | L5 transforaminal epidural steroid injection, and surgery | NCSs of the lower left extremity revealed an absence of motor responses. Absent peroneal sensory response and low sural sensory response | Preoperative Postoperative | 0                 | 2                | 10                | Steppage gait reduced |
| 22 | F/54       | L5-S1 lumbar fusion  | The right peroneal nerve CMAP was absent from the extensor digitorum brevis; the right peroneal F-waves were absent | Preoperative Postoperative | AG                | 4+               | 5                 | Continued improvement in dorsiflexion after nerve transfer. Excellent result of surgery. Steppage gait much reduced |

(Contd...)
| #  | Gender/Age | Preoperative history | NCS/EMG Results | Preoperative Postoperative | Ankle dorsiflexion | Follow-up months | Surgical outcomes |
|----|------------|----------------------|-----------------|---------------------------|-------------------|-----------------|------------------|
| 23 | F/41       | Hip replacement      | There was no elicitable response of peroneal motor nerve by stimulating the extensor digitorum brevis or tibialis anterior, left tibial motor nerve showed decreased amplitude with slow conduction. No elicitable response by stimulating the left peroneal sensory nerve; the left sural sensory nerve showed mild prolongation of the distal latency. | Preoperative Postoperative | 2                  | 3               | 7                | Improved gait    |
| 24 | F/49       | Hip replacement      | Left peroneal distal latency and amplitude were absent, normal in the right, altered sensation in the left peroneal nerve distribution. Motor study: the left peroneal over EDB unobtainable. Left peroneus longus revealed absent motor unit activity. | Preoperative Postoperative | 14                 |                 | No improvement yet |                 |
| 25 | F/76       | L4-5 spinal fusion, laminectomy | Distal peroneal and tibial latency was prolonged with markedly reduced amplitude. Sensory NCV was absent in peroneal and sural nerves | Preoperative Postoperative | 0                  | 2+              | 6                | Improvement in ankle dorsiflexion Almost AG |
| 26 | M/23       | Knee surgery         | The right peroneal nerve conduction velocity was slowed; NCV slowing of conduction over fibular head. A conduction block was reported. No right F-wave response could be elicited—no activation of motor unit potential in the right peroneal innervated muscles. | Preoperative Postoperative | 0                  | 4+              | 6                | Excellent result of surgery Patient back to work |
| 27 | F/64       | Hip replacement      | The left peroneal motor (ankle) and sural sensory nerves (calf) showed no response. | Preoperative Postoperative | 2                  | 3+              | 8                | Gait improved    |
| 28 | F/50       | three prior surgeries for herniated disk L3-L4, L4-L5, and L5-S1 | | Preoperative Postoperative | 1                  | 9               | The wound healed, no improvement yet | |
improvement in their ankle dorsiflexion with anti-gravity and gained a healthier gait after neurolysis and decompression of the peroneal nerve and transfer of functional fascicles of either the superficial peroneal or the tibial nerve to the deep peroneal nerve [Table 1] and [Videos 2A, 2B, and 2C]. The severity of the foot drop and the surgical improvements were not related to the type of patients’ previous surgery. The severity of the foot drop and the surgical improvements were not related to the type of patients’ previous surgery.

**DISCUSSION**

Iatrogenic nerve injuries can occur during any surgical procedure. Kretschmer et al. found 17.4% iatrogenic nerve injuries among 722 of their surgically treated cases of peripheral nerve trauma patients. Ghobrial et al. reported an average of 9% postoperative neurologic complications (range 0.46–24%) in 2783 patients from 12 studies. About 18% of 1022 patients with foot complications who consulted our institution since 07–2004 had lower back/lumbosacral spine or hip or knee surgeries in other clinics before presenting to us. However, not all 18% of the patients have had foot drop.

In addition to peroneal nerve injury, sciatic nerve injuries and major arterial injuries during spine and acetabular surgical reconstruction were presented with symptoms ranging from radiculopathy to foot drop. Bohrer et al. found 1.8% postoperative neuropathy and foot drop in 14 (11 patients) of their 616 female patients who underwent elective gynecologic/pelvic surgery. Compression stretching of the superficial peroneal nerve causing numbness of the lower extremity, foot drop, and gait instability was reported after the laparoscopic gynecologic/pelvic surgery.

Complete familiarity with the region’s anatomy can significantly reduce the risk of nerve damage. Issack and Helfet recommended keeping the patient’s hip extended and knee flexed during these surgeries to prevent the injury. About 82% of our patients improved dorsiflexion of the foot and ankle by direct nerve transfer rather than nerve grafting, as nerve grafts were shown to prevent neural regeneration. Prasad et al. further demonstrated that this is due to the stretch/traction injury zone extending into the myoneural junction. None of our 28 patients in this study reported postoperative complications or iatrogenic injury.

**CONCLUSION**

Twenty-three of the 28 (83%) iatrogenic foot drop patients in this report gained a healthier gait with improved ankle dorsiflexion and anti-gravity after neurolysis of the peroneal nerve and transfer of functional fascicles of either the superficial peroneal or the tibial nerve to the deep peroneal nerve at our clinic.

**Acknowledgments**

We thank the patients and their families who participated in this study.

**Declaration of patient consent**

The authors certify that they have obtained all appropriate patient consent.
Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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How to cite this article: Nath RK, Somasundaram C. Iatrogenic nerve injury and foot drop: Surgical results in 28 patients. Surg Neurol Int 2022;13:274.