



Grand Rounds from HSS

MANAGEMENT OF COMPLEX CASES

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Each author certifies that Hospital for Special Surgery has approved the reporting of this case and that all investigations were conducted in conformity with ethical principles of research.

FROM THE EDITOR



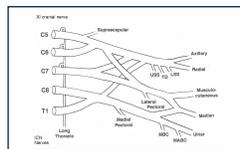
This volume of *Grand Rounds from Hospital for Special Surgery* begins with the successful management of a tremendous challenge to orthopaedic surgeons, a case of brachial plexus injury, presented by Scott Wolfe. In the past 20 years Scott has treated over 200 plexus cases, from single level to complete, and published many important advances in managing these devastating injuries. Dr. Wolfe is Director of the HSS Center for Brachial Plexus and Complex Nerve Injury, leading a multispecialty team offering new hope to patients with these once hopeless injuries. For more information, please visit www.hss.edu/brachialplexuscenter.

The cases that follow represent no less challenging conditions and demonstrate current sound principles in other areas of orthopaedic care. Mathias Bostrom overcomes the challenge of severe acetabular bone loss in a 62-year-old male after three revision total hip arthroplasties and deep implant infection, with a custom triflange acetabular component. In the next case, Jonathan Deland demonstrates his evidence-based, innovative approach in managing posterior tibial tendon rupture and severe, progressive flatfoot deformity in a 62-year-old male. In the final case, Mark Figgie enables an 18-year-old female with severe skeletal dysplasia to walk without an assistive device using bilateral custom hip implants. We hope you find these cases to be of interest and the principles presented informative. Comments are always welcome at complexcases@hss.edu.

Edward C. Jones

— Edward C. Jones, MD, MA, Assistant Attending Orthopaedic Surgeon

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Adult Traumatic Brachial Plexus Injury

Case presented by Scott W. Wolfe, MD, and Kieran O'Shea, MB, FRCSI

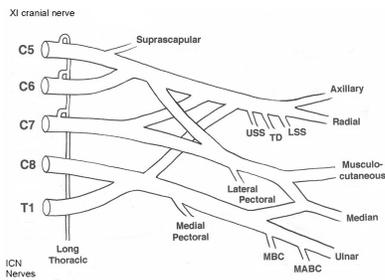


Figure 1: Schematic illustration of the brachial plexus. USS = upper subscapular. LSS = lower subscapular. TD = thoracodorsal. MBC = medial brachial cutaneous nerve. MABC = medial antebrachial cutaneous nerve.

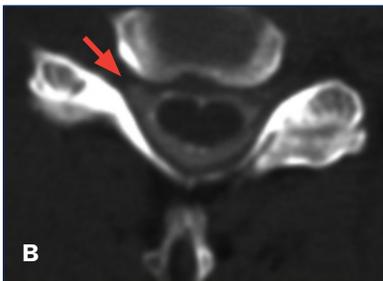


Figure 2: (2A) Frontal view during myelogram demonstrates pseudomeningocele formation at the left C6 and C7 nerve roots (arrows) and (2B) CT myelogram at the C6/7 level showing intact ventral and dorsal nerve roots at the spinal cord level on the right hand side (arrow) and no root on the left side indicating avulsion.

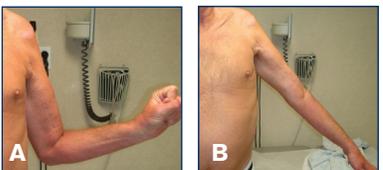


Figure 3: (3A) Clinical photograph, at 8 months post first surgery, demonstrating active elbow flexion and external rotation with the shoulder in a neutral position. Good biceps muscle bulk is evident and (3B) clinical photograph, at 15 months post injury, demonstrating active abduction against gravity at the shoulder with visible deltoid muscle contraction.

CASE REPORT: A 57-year-old right-hand dominant gentleman presented to Hospital for Special Surgery for evaluation two months following a closed head injury, left clavicle fracture and left-sided brachial plexus injury sustained during a motorcycle accident in Bermuda.

Initial assessment demonstrated complete paralysis of the patient's shoulder and elbow; with loss of function of the deltoid, supraspinatus, infraspinatus, pectoralis major, biceps and triceps muscles, consistent with a supraclavicular brachial plexus injury affecting the upper and middle trunks (Figure 1). Electrodiagnostic evaluation suggested pre-ganglionic injuries to the C6 and C7 nerve roots. As the rhomboids and serratus had incomplete denervation and retained clinical function, a high extra-foraminal C5 injury was suspected. CT myelography confirmed the suspected avulsions of the left C6 and C7 roots from the spinal cord. (Figures 2A, 2B). Elevation of the left hemi-diaphragm was evident on chest radiography indicative of a phrenic nerve injury.

At surgery three months post injury, somatosensory evoked potentials (SSEP) were absent on stimulation of the C5 nerve root. Histological frozen section analysis of the C5 root, taken just distal to the exit of the spinal root from its foramen, showed complete denervation with absent fascicular pattern, indicating intraforaminal traction injury. A microsurgical reconstruction of the brachial plexus was performed, including multiple nerve transfers: spinal accessory nerve to suprascapular nerve; fourth, fifth and sixth intercostal nerves to the axillary nerve; dual nerve transfer for elbow flexion (coaptation of a fascicle of the ulnar nerve to the biceps motor branch and a fascicle of the median nerve to the brachialis motor branch).

At follow-up examination eight months post-operatively, anti-gravity elbow flexion had been restored. There was active external rotation at the shoulder with the arm in the neutral position (Figure 3A). There was no evidence of functional return of the deltoid muscle although compression of the posterior deltoid elicited chest wall paraesthesias, consistent with an intact neural pathway. Electrodiagnostic evaluation demonstrated re-innervation of the biceps, supraspinatus and infraspinatus muscles but persistent complete deltoid denervation. In the interim following surgery, spontaneous triceps muscle function had returned both clinically and by electrodiagnostic criteria.

At 11 months post injury, using a "reverse" end-to-side coaptation technique, a transfer of the medial head of the triceps branch of the radial nerve, through an epineurial window, into the

anterior motor branch of the axillary nerve, was performed.

15 months following injury, anti-gravity active elevation at the shoulder was restored with obvious deltoid muscle contraction (Figure 3B). Active external rotation at the shoulder in 90 degrees of abduction was also possible, indicative of a functioning teres minor muscle. Electrodiagnostic testing confirmed reinnervation of the deltoid and teres minor. Elbow flexion against light resistance was possible (Grade 4 power).

DISCUSSION: This case illustrates the management of a complex traumatic brachial plexus injury. A multidisciplinary approach was adopted with therapeutic decisions based on clinical examination findings as well as pre-operative specialized imaging, intra-operative histological analysis of the nerve and pre-, intra- and post-operative electrodiagnostic evaluation.

The functional treatment priorities are to restore elbow flexion, shoulder abduction and external rotation. Reconstructive options include neurolysis, nerve repair, nerve grafting and nerve transfer procedures (1). Because of its critical importance to arm function, a dual nerve transfer was done to restore elbow flexion.

Absent intra-operative SSEP's and the frozen section histological findings ruled out the possibility of using a cabled sural nerve graft from the C5 nerve root to reinnervate the axillary nerve. A dual transfer to restore shoulder function was therefore performed. The spinal accessory nerve was transferred to the suprascapular nerve. Transfer options to the axillary nerve are either a triceps muscle branch of the radial nerve, the medial pectoral nerve or thoracodorsal nerves. Unfortunately, all potential donor nerves showed clinical and electrical evidence of injury and could not be utilized (2). Though reliable in 70 percent of cases, intercostal nerve transfers carry the potential morbidity of harvesting, especially in the face of ipsilateral phrenic nerve palsy. They also have a comparatively low axonal count and require a greater recovery time (3).

A therapeutic dilemma arose in how to proceed at between 8 and 11 months postoperatively, given that there was evidence of functional return of the elbow flexors as well as the supra- and infraspinatus, but no deltoid recovery as yet. Because triceps muscle strength had spontaneously improved, an opportunity to transfer a branch of the radial nerve from the medial head of the triceps to the axillary

Article, references and online CME course information continued on back page.

A Custom Triflange Acetabular Component for Management of Severe Acetabular Bone Loss

Case presented by Mathias P.G. Bostrom, MD, and Michael B. Cross, MD



Figure 1: AP pelvis and frog lateral radiographs showing the cement spacer, significant (20 cm) leg length inequality, and heterotopic bone surrounding the proximal femur.



Figure 2A



Figure 2B

Figure 2: (2A) AP Pelvis and (2B) AP and frog lateral radiographs of the right hip taken at the 1.5 year follow-up visit showing the custom triflange acetabular component with a constrained liner and the cemented proximal femoral replacement.

AUTHOR DISCLOSURES:

Dr. Mathias P.G. Bostrom is a paid consultant for Smith and Nephew, receives research support from Smith and Nephew, Bone Support and the NIH, is on the editorial board of the *HSS Journal*, and is a board member of the Orthopaedic Research Society and International Society for Fracture Repair.

Dr. Michael B. Cross does not have a financial interest or relationship with the manufacturers of products or services.

CASE REPORT: Management of severe acetabular bone loss can be challenging. As described by Paprosky (4), traditional treatment options for Type III acetabular defects include an oversized (“jumbo”) hemispherical acetabular shell with or without an allograft, metal augments and screws, or an acetabular cage, depending on the degree and location of the bone loss. Custom triflange acetabular components have been recently used at Hospital for Special Surgery and other institutions in place of cage constructs with success (1).

Limb length inequality can also be challenging to manage during revision total hip arthroplasty. Inadequate restoration of limb length and soft tissue tension can lead to instability, while over-lengthening can increase the risk of sciatic nerve palsy (2). We present a case of severe acetabular bone loss, heterotopic ossification and a 20 cm limb-length inequality following a deep implant infection that was managed with a custom, triflange acetabular shell and a cemented, proximal femoral replacement with excision of the heterotopic ossification.

GL is a 62-year-old male who underwent a primary total hip arthroplasty (THA) in 1994 for post-traumatic arthritis, which developed after a motor vehicle accident in 1993. He subsequently underwent three revisions after his index THA, with the third revision complicated by a deep implant infection. To manage his infection, both the femoral and acetabular components were removed at an outside institution, leaving the patient with a cement spacer and profound bone loss of the acetabulum and proximal femur. In addition to persistent pain, he presented with a 20 cm leg length inequality and loss of motion of his hip; however, he was able to ambulate in his household using a walker.

Radiographs performed on presentation to the senior author’s office (MPGB) revealed a large cement spacer in the pelvis and significant heterotopic bone formation around the remaining proximal femur (Figure 1). Work up for residual infection, which included hip aspiration and blood work, was negative. Due to the significant acetabular bone loss, a custom triflange acetabular component was designed and manufactured using a preoperative computed tomography (CT) scan with three-dimensional reconstructions. Utilizing a posterolateral approach, the custom triflange acetabular component was implanted with a constrained liner and the heterotopic ossification surrounding the proximal femur was resected. A cemented, proximal femoral replacement was also used, which restored the limb length to within 7 cm

of the contralateral limb. Intraoperative cultures were taken but were all negative. After an uneventful postoperative course, the patient was discharged from the hospital. At his one year follow-up visit, the patient was now able to ambulate in the community using a cane and was free of pain. Radiographs taken at the one-and-a-half year follow-up visit showed that both components were well fixed (Figures 2A, 2B).

DISCUSSION: For severe acetabular bone loss, custom tri-flange acetabular cups provide initial stability, potential long-term implant stability and pain relief (1). During design of these implants, a model of the implant and pelvis are first made using CT scans with three-dimensional reconstructions. Following collaboration with the attending surgeon, screw locations on the implant are determined and modifications are made; thus, an obvious disadvantage of using custom triflange components is that they require significant time to manufacture and are expensive. Still, in select cases with the appropriate resources, they offer the surgeon a safe and effective alternative to acetabular anti-protrusion cage constructs, which have variable reported success rates (1,5).

When approaching a patient with a prior infection, it remains essential to rule out any residual infection prior to implantation of expensive, revision implants. This can be done by obtaining a hip aspiration (i.e. synovial fluid analysis) prior to surgery, as well as serum laboratory bloodwork including a C-Reactive Protein (CRP) and Erythrocyte Sedimentation Rate (ESR) (3). Further, intraoperative cultures can be obtained. All of these were negative for infection in our patient. As a secondary effect to prolonged infection, however, our patient developed significant heterotopic ossification, which required excision. Excision of heterotopic bone should be performed after the bone has matured, as was the case in our patient.

Finally, determining intraoperative leg length can be very difficult, especially using a posterolateral approach. Careful preoperative planning and templating can assist the surgeon in restoring limb length to the contralateral limb (2). However, in this patient, given the chronic nature of his limb length inequality, he developed shortening and scarring of the soft tissues, which prevented complete restoration of length. Thus, the goal in this particular case was to restore adequate soft tissue tension to enhance stability while being careful not to over lengthen the limb, in order to minimize the chance of a post-operative sciatic nerve palsy.

References continued on back page.

Management of Posterior Tibial Tendon Rupture and Severe Flatfoot Deformity

Case presented by Jonathan T. Deland, MD, and Elizabeth Young

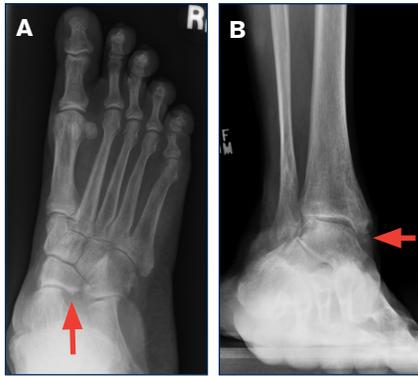


Figure 1: (1A) Standing AP of the foot pre-operatively. Note near dislocation of the talonavicular joint and (1B) Pre-operative standing AP view of the ankle demonstrates valgus talar and hindfoot alignment with talar tilt.



Figure 2: (2A) Standing AP of the foot post-operatively. The talonavicular joint is reduced and (2B) Standing AP of the ankle post-operatively. The ankle joint is reduced.

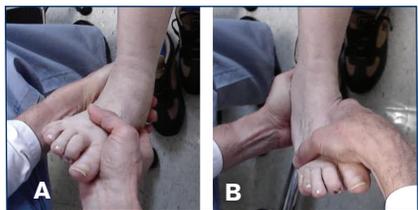


Figure 3: (3A) Eversion motion of the foot and (3B) Inversion motion of the foot.

AUTHOR DISCLOSURES:

Dr. Jonathan T. Deland does not have a financial interest or relationship with the manufacturers of products or services.

Elizabeth Young does not have a financial interest or relationship with the manufacturers of products or services.

CASE REPORT: A 64-year-old male presented with severe, progressive bilateral flatfoot deformity. The patient noted increasing difficulty walking, worse on the right foot. He used braces for ankle and arch supports but the deformity and pain progressed.

Physical exam showed severe heel valgus bilaterally, greater on the right. He was unable to single stance heel rise, and there was 60 percent of normal triple joint motion (inversion/eversion). There was an Achilles' contracture, which resolved with the knee bent. There was no significant inversion strength. His X-ray showed a severely incongruent talonavicular joint on the AP view with most of the talar head uncovered (Figure 1A). There was valgus tilting of the talus within the ankle mortise (Figure 1B).

Due to the increasing deformity, pain and difficulty with walking, it was decided to intervene surgically. Options and risks were discussed. A standard reconstruction for a flatfoot with severe collapse would include calcaneal osteotomies, possible first metatarsal-tarsal fusion and reconstruction of the posterior tibial tendon. However, with the severe deformity at the talonavicular joint on the AP view, it was very questionable whether the standard reconstruction even with an anterior calcaneal lateral column lengthening would resolve this deformity. Fusion of the talonavicular joint, part of a triple arthrodesis, was offered as the common treatment for very severe talonavicular deformity not treatable by a standard reconstruction. The other option discussed was reconstruction with anterior and posterior calcaneal osteotomies and spring ligament reconstruction with allograft tendon. Reconstruction of the deltoid was also discussed. These procedures were in addition to reconstruction of the posterior tibial tendon with a flexor digitorum tendon transfer and stabilization of the first ray with a first metatarsal-tarsal fusion. The patient was told of the possibility of needing to convert the foot to a triple arthrodesis if the spring ligament reconstruction failed. The patient decided upon a spring ligament reconstruction and not a triple arthrodesis.

At the time of the procedure, an anterior calcaneal osteotomy with tricortical bone graft wedge (lateral column lengthening) failed to reduce the deformity at the talonavicular joint. The spring ligament reconstruction using allograft Achilles tendon was therefore done along with the other procedures. The Achilles allograft was passed from the navicular to the medial malleolus, reconstructing both the superomedial portion of the spring ligament and the anterior deltoid which blends in with this portion of the

spring ligament. Intra-operatively this corrected the deformity while the bony procedures did not by themselves give sufficient correction. Post-operatively, the patient healed with good reduction of both the ankle and the talonavicular joints (Figure 2A and 2B). He maintained triple joint motion, was able to perform a single stance heel rise and demonstrated eversion and inversion of his heel (Figure 3A and 3B).

DISCUSSION: Adult-acquired flatfoot deformity (AAFD) is a progressive condition caused by posterior tibial tendon insufficiency, as well as failure of the ligaments that support the arch (1). Collapse of the medial longitudinal arch and heel valgus occurs in addition to midfoot abduction and forefoot supination, depending upon the amount of deformity.

A classification system was originally developed by Johnson and Strom and described three unique stages depending on deformity and motion in the foot (3). This was subsequently modified to include the involvement of the deltoid ligament in Stage IV (4).

Surgical treatment most often requires a combination of soft tissue and bony procedures. Reconstruction of the posterior tibial tendon is common, and is done with the correction of heel valgus (posterior calcaneal osteotomy). Late stage AAFD (stage IV) is defined by the talar tilt in the ankle (failure of the deltoid ligament), as occurred in this case, and presents a most challenging problem. There has not been much literature published on the treatment and outcomes of stage IV AAFD. The first series of patients successfully treated for the deltoid insufficiency with correction of deformity was published in 2010 from HSS (2). The spring ligament reconstruction was also published in 2010 (6). These procedures are not routine but have been developed when standard procedures fail to gain adequate correction. Successful results with these reconstructions have been demonstrated. In the case of the spring ligament reconstruction, it allows patients who have motion but severe deformity to retain triple joint motion (inversion/eversion) and avoid a triple arthrodesis. In the case of the deltoid ligament reconstruction, which can be done separately from the spring ligament reconstruction or with it, reduction of the ankle joint should prolong the life of the joint and minimize lateral compartment arthritis. These procedures have helped patients prolong the lifetime of their joints and achieve better function.

This patient was able to maintain flexibility and function of his foot and ankle despite the severe

Article and references continued on back page.

Bilateral Custom Femoral Stems in a Patient with Skeletal Dysplasia

Case presented by Mark P. Figgie, MD, and Seth A. Jerabek, MD



Figure 1A and 1B: AP pelvis with crests with hips in neutral (A) and frog leg lateral (B) demonstrate severe shallow acetabuli with congruent deformities of the proximal femoral heads, bilaterally.

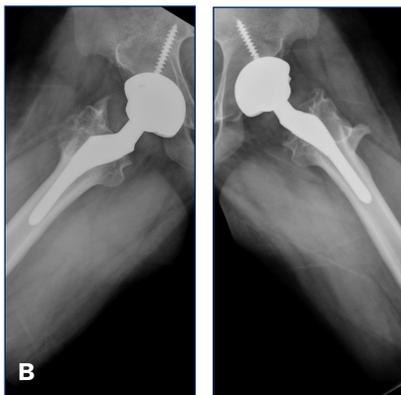
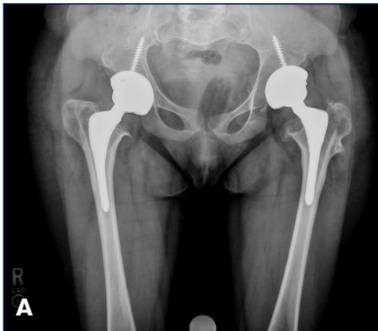


Figure 2: Frontal (A) and frog leg lateral views of both hips (B) eight weeks post-op demonstrates bilateral total hip prosthesis in anatomic alignment.

CASE REPORT: The patient is an 18-year-old female with spondyloepiphyseal dysplasia congenita (SED) who presented to HSS with bilateral hip pain. She had bilateral femoral osteotomies and trochanteric advancement at an outside institution five years prior. She did well for four years, but then developed increasing bilateral groin pain and declining function. Upon presentation she was limited to walking two blocks with a walker and failed conservative treatment with physical therapy and NSAIDs.

Plain radiographs showed bilateral hip dysplasia with shallow acetabuli and deformities of the femoral heads (Figures 1A and 1B). A CT scan of her pelvis revealed 18 degrees of femoral anteversion on the right and 15 degrees on the left. Her acetabular anteversion was 15 degrees bilaterally.

It was decided to proceed with bilateral total hip arthroplasties. Given the shape and small size of her femurs, custom femoral implants were manufactured. She had adequate acetabular bone stock for standard acetabular components. The posterolateral approach was utilized. A 44 mm trabecular metal shell with a single screw was placed with a highly cross-linked polyethylene insert. A Charnley awl was used to establish the femoral canal, which was reamed to 8 mm. The custom-made broach demonstrated excellent fit and fill of the proximal femoral metaphysis. The custom implant was seated and a 28 mm + 0mm cobalt chrome head was placed. A standard posterior repair was performed through drill holes in the greater trochanter.

She was made weight bearing as tolerated with posterior dislocation precautions. Her hospital course was uncomplicated and she was discharged on POD 6. She returned for her 8-week follow-up and was doing well. She was walking without an assistive device and had minimal pain. Her follow-up X-rays show the components in excellent position (Figures 2A and 2B).

DISCUSSION: SED is a rare skeletal dysplasia caused by a defect in type II collagen. Patients with this disorder typically have a short trunk with rhizomelic shortening of the limbs. Tubular bones are short with epiphyseal fragmentation and metaphyseal irregularities (1). The femurs are small and the proximal femur often has excessive anteversion, coxa vara, a relatively wide metaphysis and a narrow diaphysis. Commercially available implants are often too large for the femur or don't come in the correct shape to appropriately fill the metaphysis, restore the offset, or adjust the anteversion.

In 1993, Huo published a case series of 14 patients (19 THAs) with hip deformities from skeletal dysplasia reconstructed with custom-

designed, cemented THAs. Eighteen had excellent results and one had a good result at an average of 4.8 years follow-up (2). However, patients with skeletal dysplasia are relatively young, thus cemented implants may lead to reconstructive challenges in the future. Others have advocated for modular, cementless implants, as they are versatile. The surgeon can adjust the length, offset and anteversion. The survival of these small-sized, modular, femoral components is unknown. Additionally, off-the-shelf modular devices may not fit a dysplastic femur.

Recently, there has been increasing interest in custom, cementless, non-modular femoral stems for patients with skeletal dysplasia. This, in part, is due to advances in imaging and manufacturing technology. The data from thin-cut CT scans can be used by engineers to accurately design and manufacture femoral stems that will provide excellent fit while restoring length, offset and anteversion. Sewell et al. reported a case series of 25 patients with skeletal dysplasia for a total of 40 custom, cementless THAs and found 93 percent femoral component survival at a mean of 10.1 years.

In this case, we considered alternative bearing surfaces. The size of her acetabular shell did not allow for a ceramic liner and the custom stem trunion was not machined to accommodate a ceramic head. Given she is young and of child-bearing age, we excluded metal-on-metal as an option. Thus, a cobalt chrome head on highly cross-linked polyethylene was used.

This case illustrates the challenges of treating patients with skeletal dysplasia. Preoperative planning is paramount. In this case, a cementless, custom implant was the best choice for femoral fixation as it can achieve a predictable fit, as well as restore length, offset and anteversion without the possible complications of cement or modularity. However, the long-term outcomes and economic viability of cementless custom femoral components are yet to be determined.

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AUTHOR DISCLOSURES:

Dr. Mark P. Figgie does not have a financial interest or relationship with the manufacturers of products or services.

Dr. Seth Jerabek does not have a financial interest or relationship with the manufacturers of products or services.



Grand Rounds from HSS MANAGEMENT OF COMPLEX CASES

CASE 1 CONTINUED

nerve arose, with the intention of “super-charging” the reinnervation of the deltoid and teres minor muscles (4). A reverse end-to-side transfer (rather than end-to-end) coaptation was performed in order to retain the ongoing potential for the intercostal nerve grafts to reach their targets, while harnessing additional reinnervation strength from the triceps donor nerve (5). At most recent follow-up, encouraging signs of deltoid and teres minor recovery were evident.

EARN CME CREDIT ONLINE

The Anatomy and Physical Exam of the Adult Brachial Plexus Online CME Activity is available at www.hss.edu/cme-online.

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Additional references for Case 1 appear online at www.hss.edu/complexcases.

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CASE 2 CONTINUED

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Additional references for Case 2 appear online at www.hss.edu/complexcases.

CASE 3 CONTINUED

deformity he presented with. To quote the patient:

“A couple of days ago, I went to a cabin in the woods, was able to carry my bags to the cabin from the car on uneven ground and help load the wood into the wood box. In addition, I was able to climb a ladder to get upstairs to the sleeping loft.”

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Additional references for Case 3 appear online at www.hss.edu/complexcases.

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