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3D-Printed Model in Preoperative Planning of Sciatic Nerve Decompression Because of Heterotopic Ossification

A Case Report

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Abstract

Case: A 31-year-old patient presented with an encapsulated sciatic nerve secondary to extensive hip heterotopic ossification (HO), which prevented visualization of a safe osteotomy site to avoid nerve damage. The 3D-printed model demonstrated an easily identifiable osseous reference point along the inferior aspect of the heterotopic mass, allowing for a vertical osteotomy to be safely performed.

Conclusion: HO is associated with loss of normal anatomic topography. The current case report illustrates the use of a 3D-printed model to identify pertinent anatomic landmarks required for safe decompression of an encapsulated sciatic nerve within the anatomic region of the hip.

Heterotopic ossification (HO) of the hip is a complication associated with trauma, particularly in the setting of traumatic brain injuries. HO after acetabular fracture, with an incidence rate of 22 to 51%, can dramatically hinder long-term function and quality of life[1-6]. Surgical removal has been shown to improve outcomes, but is inevitably associated with complications[2,4,7,8]. Traditional radiographs are sufficient for initial diagnosis; however, computed tomography (CT) is the gold standard for diagnosing ankylosis and is useful for preoperative planning [3,4]. In the case of sciatic nerve involvement, intraoperative neuromonitoring has been reported with success by Cole et al.; however, neuromonitoring leads to considerable expense[4,9,10]. Requiring only a CT scan and basic computer-aided design software, stereolithographic (SLA) 3D-printed models present a viable, cost-effective method to augment preoperative planning and operative execution through identification of subtle anatomic landmarks, particularly when critical osseous or neurovascular structures are at risk. Stereolithography (also known as vat photopolymerization) represents 1 type of 3D printing technology, where photochemical processes occur in a layered fashion to cure liquid resin into a solid model. There have been many reports of the utilization of 3D printing for orthopaedic preoperative planning, ranging from mass excision and complex reconstruction to the creation of patient specific implants and cutting guides.[11-22] This case report demonstrates the use and efficacy of a 3D-printed model for preoperative planning and surgical decompression of the sciatic nerve secondary to HO encasement.

Informed consent was obtained directly from the patient in reference to the publication of this case report and details included within.

Case Report

A 31-year-old male patient presented with complaints of right leg pain, hip stiffness, and equinas contracture of the ankle, concerning for partial sciatic nerve palsy. Two years earlier, the patient underwent open reduction internal fixation (ORIF) of a right posterior wall acetabular fracture at another institution after a motor vehicle accident. The patient's initial Glasgow Coma Score on presentation was 10/15. At the time of the accident, the patient additionally sustained fractures to the right calcaneus, ribs 4 through 9, nasal bone, and L2 transverse process. ORIF of the posterior wall was performed on day 4 after injury using a posterior approach.

At 8 months postop, the patient presented to our office with poor range of motion and unexplainable pain of the right lower extremity. Initial X-rays and CT demonstrated Brooker IV HO with bridging ossification, extending from the greater sciatic notch to the greater trochanter, resulting in encasement of the sciatic nerve (Figs. 1 and 2). The hip joint was fixed at 20° of

Disclosure: The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJSCC/C298).

Keywords 3D printing; Heterotopic ossification; Preoperative planning; Intraoperative reference

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flexion with 0° of motion in any plane. Physical examination of the foot demonstrated equinas contracture at 20° plantarflexion with no passive dorsiflexion or improvement with Silfverskiold

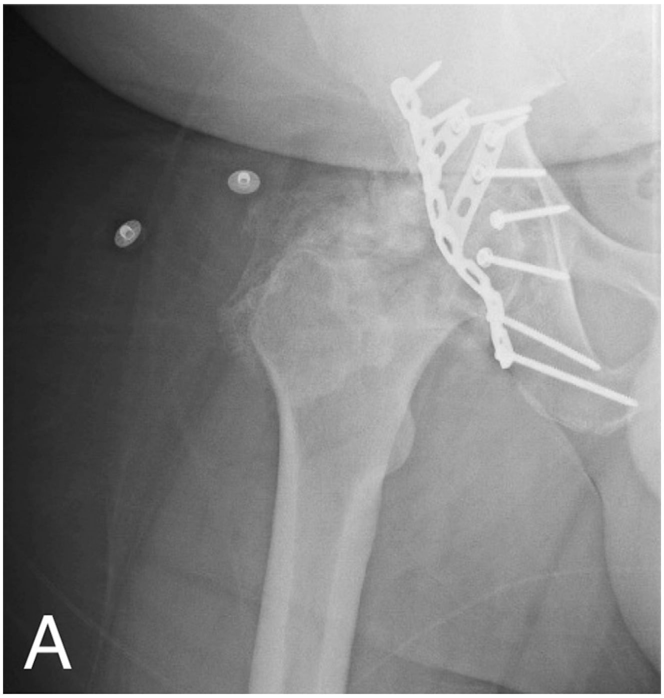

Fig. 1-A

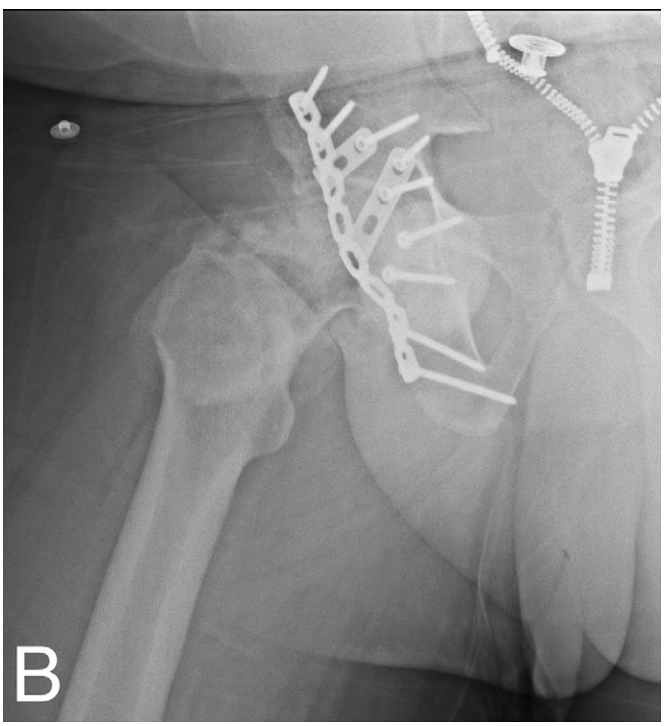

Fig. 1-B

Anteroposterior (**Fig. 1-A**) and lateral (**Fig. 1-B**) of the right hip demonstrating bridging ossification, extending from the greater sciatic notch to the greater trochanter.

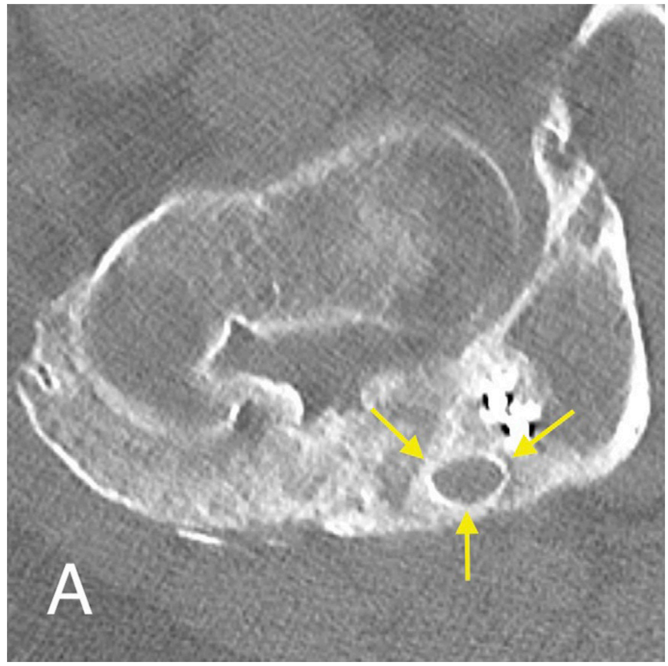

Fig. 2-A

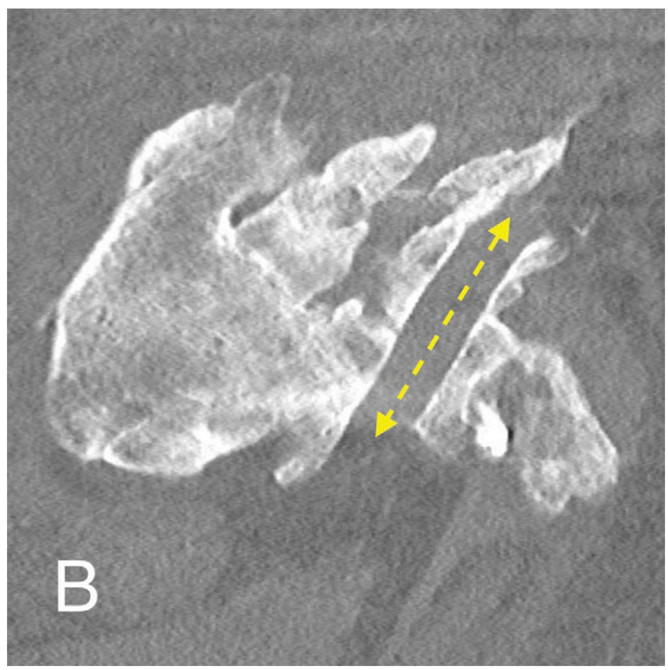

Fig. 2-B

Axial (**Fig. 2-A**) and coronal (**Fig. 2-B**) slices of a computed tomography scan of the right hip. Complete ankylosis is visualized in both slices. The yellow arrows (**Fig. 2-A**) denote the inferior opening of the bony canal through which the sciatic nerve exits the heterotopic mass on axial slice. The yellow line (**Fig. 2-B**) tracts along the course of the sciatic nerve because it tunnels through the heterotopic bone on coronal view. Because of the 2D orientation of the viewing platform, the osteotomy landmarks are more difficult to appreciate than on the 3D-printed model.

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test with knee in flexion. Strength was 1/5 and 2/5 for dorsiflexion and plantarflexion, respectively, compared with 5/5 in both ipsilateral knee flexion and extension. The patient demonstrated decreased sensation to light touch in the distribution of the common peroneal and sural nerves. Electromyography (EMG) demonstrated absent responses in the right peroneal sensory and motor, tibial motor, and sural sensory distributions, consisted with partial sciatic nerve palsy in the distribution of the branch to the long head of the biceps femoris. The patient was unable to ambulate without the assistance of crutches. Because of concerns for hypercoagulability in the setting of recent deep vein thrombosis and lupus, the patient was initially treated conservatively. After 2.5 years of serial examinations and repeat EMG demonstrating no neurological improvement, surgery was indicated as the best course of action.

The treatment goal was to decompress the sciatic nerve, while increasing hip range of motion, through removal of the HO mass. Because of the complexity of structures involved in the patient's heterotopic bone, careful planning was required to minimize iatrogenic risk to the encased sciatic nerve medially and femoral neck laterally. Given the important structures at risk in the setting of challenging aberrant anatomy, a custom 3D-printed SLA model was created preoperatively to better elucidate anatomical features and provide reference points that could be used intraoperatively to safely remove the heterotopic growth without iatrogenic injury.

A CT scan was obtained of the patient's right hip (Fig. 2). The Digital Imaging and Communications in Medicine images were loaded into the free source software, 3D Slicer. The voxel depth was set to match the CT resolution of 0.5 mm, and each image slice was manually segmented through thresholding the voxel intensity (Hounsfield unit range). The errors generated during this process were manually erased, ensuring accuracy of each image's region of interest (ROI). The ROI of each segment included the encased sciatic nerve and surrounding bone for use in orientation and landmark identification. With ROI dimensions kept constant, the segmented volume was processed using the 3D Slicer Model Maker algorithm. The resulting stereolithography (STL) file was imported into Preform (Formlabs) then printed in clear resin at a resolution of 50 μm using the Form 2 SLA 3D printer (Formlabs) (Fig. 3-A).

Fig. 3-A

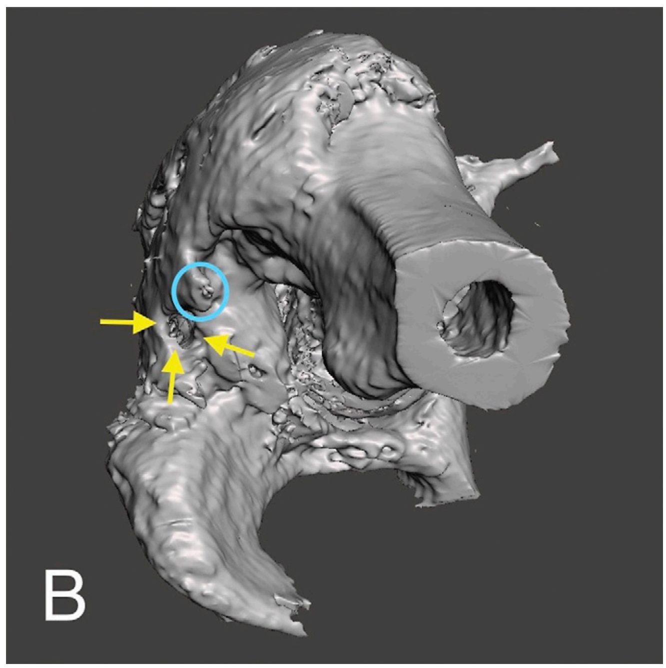

Fig. 3-B

SLA (**Fig. 3-A**) and digital (**Fig. 3-B**) 3D models of the right hip. The probe in Figure A tracks along the canal where the sciatic nerve runs through the heterotopic bone. The opening of said canal is denoted by the yellow arrows in **Fig. 3-B**. The blue circle (**Fig. 3-A and Fig. 3-B**) surrounds the tubercle, which served as a landmark for osteotomy orientation during surgical decompression. SLA, stereolithographic.

3D-Printed Model—Application

On close examination, the 3D-printed model demonstrated a unique tuberosity along the inferior aspect of the heterotopic bone. Located lateral to the sciatic nerve and medial to the native proximal femur, this tuberosity served as an important anatomic reference point where a vertical osteotomy could be safely performed to avoid nerve injury (Fig. 3-B). This anatomic reference point, although visible in 2 dimensions on the CT scan, was not fully appreciated until physical inspection of the 3D model. This model was additionally referenced during the surgery to aid in orientation.

Operative Surgical Procedure

The patient's previous posterior incision was used for surgical exposure. The sciatic nerve was identified exiting inferiorly from the HO mass. The tuberosity identified preoperatively was located and provided a critical intraoperative reference point from which a vertical osteotomy was created, permitting access for sciatic nerve decompression. The entire regional distribution of the sciatic nerve was visualized through extensive neurolysis. The nerve was subsequently freed from its fibrous and osseous encasement using burrs, Kerrison rongeurs, and osteotomes. Major deterioration of the overall quality of the nerve was observed both visually and

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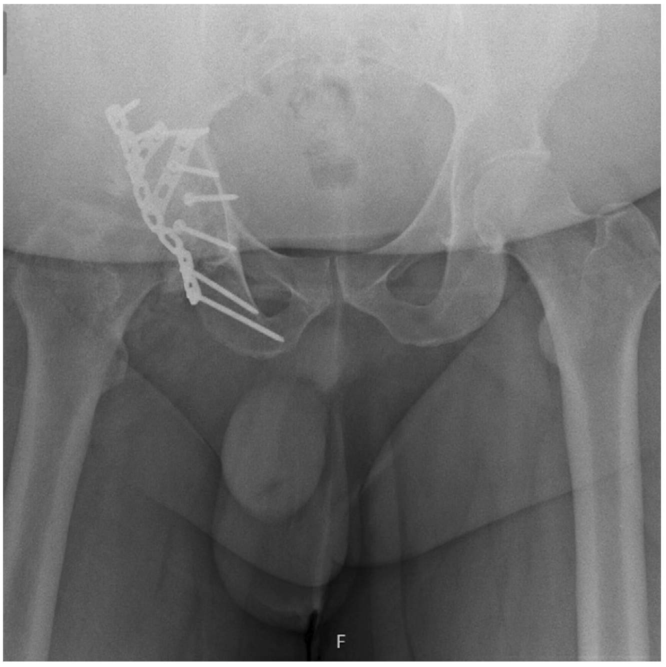

Fig. 4

Postoperative anteroposterior radiograph of the pelvis demonstrating reduction of heterotopic mass and no femoral neck fracture.

texturally, particularly in an area of stricture passing through the HO mass. Careful debulking was performed from within and around the hip joint. Direct visualization, palpation, and fluoroscopy confirmed no iatrogenic injury to the femoral neck.

At the conclusion of the case, the patient's intraoperative range of motion was 60° in forward flexion, full extension, and approximately 20° external rotation, in contrast to 0° in all planes preoperatively. Concomitant tendo-Achilles lengthening allowed foot to be brought to neutral, with a passive range of motion from 0° dorsiflexion to 20° plantarflexion. The patient was treated with a single 700 centigray fraction on postop day 2 for HO prophylaxis. Postoperative films demonstrated significant reduction in size of the heterotopic mass without fracture of the femoral neck (Fig. 4).

The patient completed 24 physical therapy visits. Examination at final 6-month follow-up demonstrated flexion, extension, internal rotation, and external rotation to be 80, 10, 5, and 45°, respectively, compared with fixed contracture at 20° preoperatively. Ankle range of motion improved to 40° dorsiflexion to 40° plantarflexion from fixed contracture at 20° plantarflexion preoperatively. Strength in hip flexion and extension increased to 4+/5 and 5/5 from 2−/5 and 4+/5, respectively. Ankle strength improved to 4/5 and 4/5, in dorsiflexion and plantarflexion, from 1/5 and 2/5, respectively. Sensation to light touch improved in all distributions of the sciatic nerve, demonstrating successful sciatic nerve recovery. The patient was importantly able to ambulate with the assistance of an ankle-foot orthosis, compared with crutches preoperatively. The patient was satisfied with their functional improvement and is anticipating a total hip arthroplasty to address residual pain associated with underlying post-traumatic arthritis.

Discussion

In regard to HO, specifically, 3D printing has been described for preoperative planning of HO resection after femoral neck, elbow, and acetabular fractures, but has not yet been reported with respect to sciatic nerve decompression of the hip[11-14]. Nóbrega et al.[23] augmented sciatic nerve decompression using an electronic 3D model generated by imaging software; however, such models are often limited in axes of rotation and demonstrate all structures simultaneously, thus, potentially impeding full visualization of specific segments of aberrant anatomy. By contrast, 3D-printed SLA models allow for specific anatomy to be selected, allowing for visualization of structures that may otherwise be obscured on radiographic imaging. 3D-printed models provide the added tactile benefit of allowing surgeons to directly trial surgical instruments and operative approaches. Thus, 3D SLA models are of utility to both preoperative planning, intraoperative verification of anatomic structures, as well as general orthopaedic resident education.

The current case report documents the use and efficacy of a 3D-printed model for safe nerve decompression in the setting of post-traumatic HO. In a clinical case with significant neurovascular involvement and complex resection planes, the model was integral to defining the operative approach and obtaining successful clinical outcomes. ■

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