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Endoscopic resection of S1 butterfly vertebra-associated lumboradiculopathy: a case report in a high-performance athlete

Resección endoscópica de lumbarradiculopatía asociada a vértebra en mariposa S1: reporte de un caso en un atleta de alto rendimiento

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Palabras clave:
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ABSTRACT

Introduction: lumbosacral radiculopathy secondary to a congenital S1 butterfly vertebra is an exceptionally rare spinal anomaly that poses diagnostic and therapeutic challenges. Conventional decompressive surgeries often fail to comprehensively address both the intricate bone malformation and the accompanying foraminal narrowing while preserving motion. This report details the successful application of a highly specialized, minimally invasive endoscopic technique combined with neuronavigation in a high-performance athlete. **Case presentation:** we present the case of a 23-year-old male triathlete with six weeks of refractory low back pain, radiating into his left leg with numbness and progressive weakness. Imaging confirmed S1 spina bifida with a characteristic butterfly configuration, congenital L5-S1 fusion, and marked L5-S1 foraminal stenosis. His preoperative Oswestry disability index (ODI) score of 64% indicated severe disability. He underwent endoscopic resection of the symptomatic S1 butterfly fragment, precisely guided by O-arm neuronavigation and continuous neuromonitoring. **Results:** postoperatively, the patient experienced an immediate and significant reduction in pain (VAS: 8/10 to 4/10). By six weeks, pain was negligible (0-1/10), his left L4 motor strength recovered fully (5/5), and his ODI dramatically improved to 8%, reflecting minimal disability. Crucially, he resumed full triathlon training by six weeks post-procedure without complications. **Conclusions:** endoscopic resection of an S1 butterfly vertebra, particularly when assisted by neuronavigation, represents a safe, highly effective, and motion-preserving treatment for refractory lumboradiculopathy in specialized cases. This approach is demonstrably well-suited for high-demand individuals who rely on a rapid and complete return to athletic activity.

RESUMEN

Introducción: *la radiculopatía lumbosacra secundaria a una vértebra en mariposa S1 congénita es una anomalía espinal excepcionalmente rara que plantea desafíos diagnósticos y terapéuticos. Las cirugías descompresivas convencionales a menudo no abordan de manera integral tanto la compleja malformación ósea como el estrechamiento foraminal asociado, a la vez que preservan*

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el movimiento. Este informe detalla la aplicación exitosa de una técnica endoscópica mínimamente invasiva altamente especializada, combinada con neuronavegación, en un atleta de alto rendimiento. ***Presentación del caso:*** *presentamos el caso de un triatleta varón de 23 años con seis semanas de dolor lumbar refractario, que se irradiaba a la pierna izquierda con entumecimiento y debilidad progresiva. Las imágenes confirmaron espina bífida S1 con una configuración característica de vértebra en mariposa, fusión congénita L5-S1 y marcada estenosis foraminal L5-S1. Su puntuación preoperatoria en el índice de discapacidad de Oswestry (ODI) de 64% indicaba discapacidad grave. Se sometió a una resección endoscópica del fragmento sintomático de la vértebra en mariposa S1, guiada con precisión mediante neuronavegación O-arm y monitorización neurofisiológica continua.* ***Resultados:*** *en el postoperatorio, el paciente experimentó una reducción inmediata y significativa del dolor (EVA: 8/10 a 4/10). A las seis semanas, el dolor era insignificante (0-1/10), su fuerza motora L4 izquierda se recuperó completamente (5/5) y su ODI mejoró drásticamente a 8%, reflejando una discapacidad mínima. Crucialmente, reanudó el entrenamiento completo de triatlón a las seis semanas del procedimiento sin complicaciones.* ***Conclusiones:*** *la resección endoscópica de una vértebra en mariposa S1, particularmente cuando es asistida por neuronavegación, representa un tratamiento seguro, altamente efectivo y que preserva el movimiento para la radiculopatía lumbar refractaria en casos especializados. Este enfoque es demostrablemente adecuado para individuos de alta demanda que dependen de un regreso rápido y completo a la actividad atlética.*

Abbreviations:

CT = computed tomography
ESS = endoscopic spine surgery
MRI = magnetic resonance imaging
ODI = Oswestry disability index

INTRODUCTION

The butterfly vertebra is a rare congenital anomaly resulting from incomplete chondrification of the vertebral body, most commonly observed in the thoracolumbar regions. Its occurrence at the S1 segment is particularly uncommon, with an estimated prevalence of 0.5-1.5% in the general population.[1,2] This malformation results in a sagittal cleft within the vertebral body, which can predispose the segment to instability, foraminal stenosis, and persistent lumboradiculopathy that is often refractory to conservative management.[3,4] While many individuals remain asymptomatic, young, physically active adults, especially high-performance athletes, are susceptible to developing symptoms due to the effects of repetitive microtrauma and increased biomechanical loading.[5,6]

Conventional open surgical approaches, such as wide laminectomy or instrumented fusion, can effectively relieve nerve root compression but typically involve greater tissue morbidity, prolonged recovery times, and the obligatory loss of segmental motion.[7] These drawbacks are particularly detrimental to athletes whose careers and quality of life depend on maintaining spinal flexibility and achieving a rapid return to high-impact activities.[8] Endoscopic spine surgery (ESS) has emerged as a preferred minimally invasive alternative for certain pathologies, offering precise bone removal with minimal soft tissue disruption, leading to faster rehabilitation and shorter hospital stays.[9,10]

This case report details the presentation, complex diagnosis, and successful endoscopic management of lumboradiculopathy induced by an S1 butterfly vertebra in a triathlete. We highlight the critical role of advanced intraoperative imaging and neuronavigation in executing a precise and safe decompression in this distinctly rare congenital anomaly.[11]

CASE PRESENTATION

Patient information and clinical findings

A 23-year-old male triathlete, otherwise systemically healthy individual, reported six weeks of severe, constant low back pain exacerbated by training. The discomfort radiated into his left leg and was accompanied by progressive numbness and weakness. His initial functional assessment yielded an ODI score of 64%, signifying severe disability, which dramatically impacted his athletic performance. The neurological examination revealed left L4 motor weakness (4/5, foot dorsiflexion), with brisk deep tendon reflexes (++/++++), and intact distal sensation.

Diagnostic assessment

Initial plain radiographs suggested S1 spina bifida. Computed tomography (CT) definitively confirmed the presence of an S1 butterfly vertebra with a central sagittal cleft, congenital L5-S1 fusion, and marked L5-S1 foraminal stenosis. Magnetic resonance imaging

(MRI) confirmed severe compression of the left L5 nerve root. The final diagnosis was left L5 lumboradiculopathy secondary to foraminal stenosis, compounded by a congenital S1 butterfly vertebra and L5-S1 fusion.[12,13]

Therapeutic intervention

Following comprehensive counseling and informed consent, the patient underwent endoscopic resection of the symptomatic bone fragment under general anesthesia with continuous neurophysiological monitoring.

A precise 10-mm paramedian incision was made at the L5-S1 level. A fiducial array was securely affixed to the L3 spinous process, facilitating the initialization of the O-arm neuronavigation system (Medtronic, Dublin, Ireland) *(Figure 1)*. The resection of the butterfly fragment was performed using high-speed diamond burrs guided by real-time neuronavigation *(Figure 2)*. This advanced guidance was essential for meticulous bone removal while safeguarding the adjacent neural structures, which were partially obscured by the congenital deformity *(Figure 3)*.[14] The technique allowed for minimal blood loss and maximized safety. Post-resection, an intraoperative O-arm scan was performed to immediately verify complete decompression and confirmed full removal of the anomalous bone. Endoscopic hemostasis was achieved, and the incision was closed in layers with absorbable sutures.

Follow-up and outcomes

The patient reported an immediate, gratifying reduction in radicular pain, with the postoperative VAS score dropping from 8/10 to 4/10. Pain continued to improve, registering 2/10 at two weeks and 0-1/10 at the six-week mark. Left L4 motor strength made a complete recovery to 5/5 within six weeks, and the ODI score plummeted from 64% preoperatively to 8%, indicating minimal functional disability.[15] Crucially for the athlete, he successfully resumed full, high-intensity triathlon training by six weeks, having experienced no complications.

DISCUSSION

The successful outcome in this high-performance athlete demonstrates that endoscopic resection is a viable, motion-preserving strategy for managing refractory lumbosacral radiculopathy caused by rare congenital anomalies like the S1 butterfly vertebra.[16] The patient's dramatic functional improvement (ODI from 64 to 8%) and expedited return to high-demand activities by six weeks stand as key outcomes that highlight the unique advantage of the endoscopic approach in this demographic.[17]

The surgical challenge presented by an S1 butterfly vertebra, especially when co-occurring with congenital L5-S1 fusion, is twofold: the inherent difficulty in precisely identifying and resecting the anomalous bone through a minimal exposure, and the risk of instability if too much posterior element is removed.[18] In contrast, conventional open decompressive surgeries (laminectomy/foraminotomy) often require wider dissections and carry a higher risk of muscle damage, postoperative pain, and longer rehabilitation periods, drawbacks

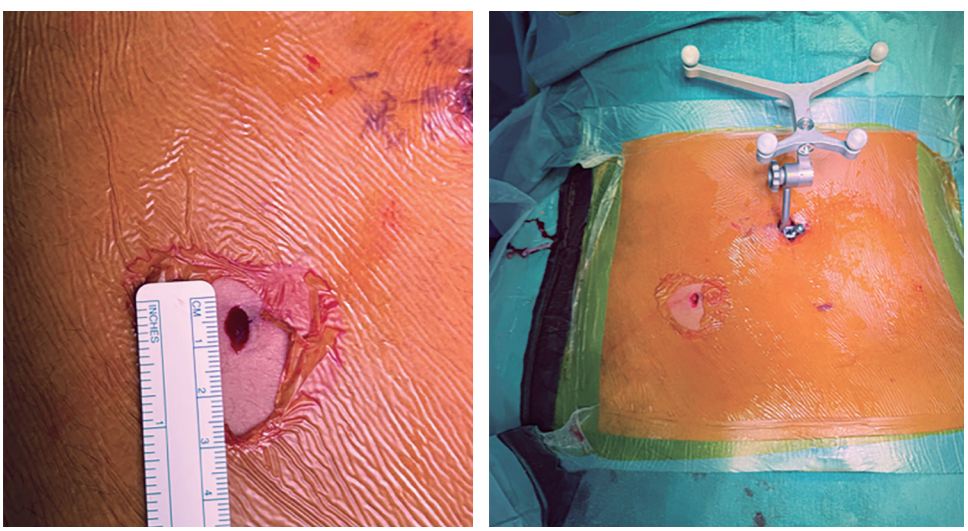

Figure 1:

Neuronavigation star colocation in L3 spinous process and 10-mm paramedial incision at L5-S1.

particularly unacceptable for an elite athlete.[7,19] Furthermore, while fusion procedures (PLIF, TLIF) reliably treat instability and compression, they permanently eliminate motion at the L5-S1 segment, which is highly undesirable for an athlete focused on peak spinal flexibility and performance.

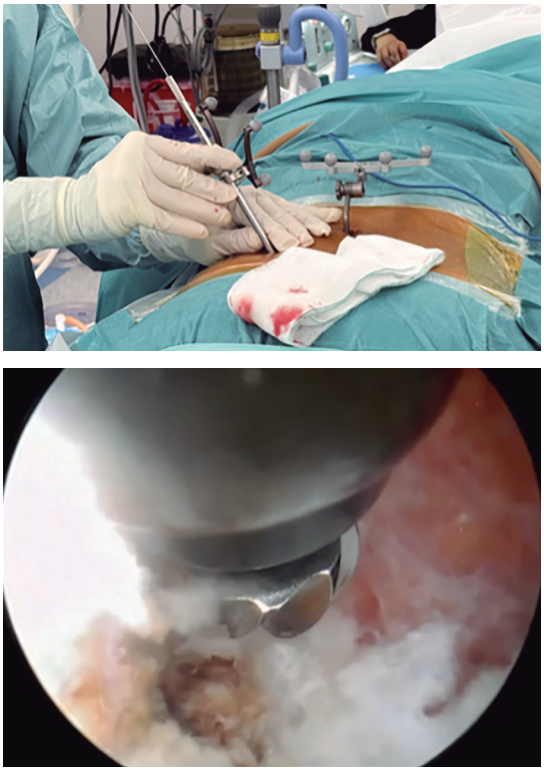

Figure 2: High-speed diamond burrs were carefully employed to meticulously resect the S1 butterfly segment guided by neuronavigation.

The integration of O-arm imaging and neuronavigation was not merely supplementary but pivotal to the successful execution of this case. Standard endoscopic techniques, which rely heavily on fluoroscopy and direct vision, may be adequate for routine disc herniations, but they carry significant risk when applied to complex, congenitally distorted bone anatomy.[20] Studies on spinal navigation, particularly in complex deformities, have consistently demonstrated placement accuracy rates exceeding 95%.[13] In our case, navigation enabled the surgeon to accurately map the boundaries of the butterfly fragment and guide the high-speed burr trajectory through the minimal incision, mitigating the risk of inadvertent neural injury to the traversing L5 and S1 roots in an anatomically treacherous area.[14]

However, a critical perspective on this approach reveals necessary trade-offs and limitations. While navigation drastically increases precision, it inherently introduces the cost of specialized equipment, additional time for setup and registration, and a potentially higher cumulative patient radiation exposure from the intraoperative 3D spin.[12] Furthermore, the technique itself requires a significant institutional commitment and a substantial learning curve for the surgical team.[16] As a Level IV single case report, we cannot provide comparative data regarding the safety or long-term recurrence rates against a standard open approach; we can only assert that the successful result, coupled with the minimal morbidity, suggests that this precise, image-guided, motion-preserving

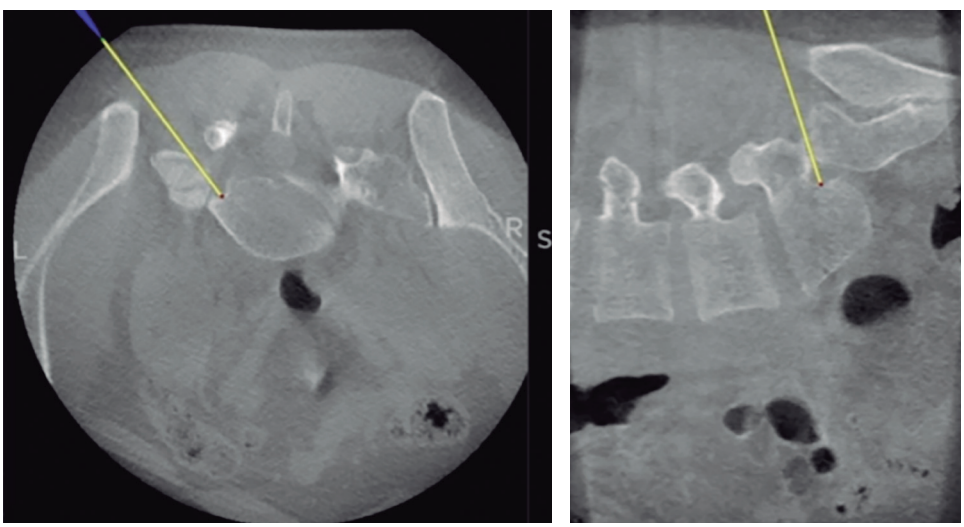

Figure 3:

Bone removal was then performed under real-time navigational guidance.

method *may be a feasible and preferable alternative in highly selected patients* with similar complex congenital anomalies.[21]

CONCLUSIONS

The outstanding clinical outcome, marked by the patient's rapid functional recovery and return to elite athletic training by six weeks, strongly supports the conclusion that *navigated endoscopic resection is a safe and highly effective treatment strategy for lumboradiculopathy associated with rare S1 butterfly vertebrae in high-demand patients*.[22]

The functional results reported here, characterized by a rapid reduction in the ODI score from severe to minimal disability, appear superior in terms of recovery speed when compared to typical outcomes reported for open surgical decompression or fusion procedures in similar complex congenital spinal cases, which often necessitate extended rehabilitation protocols.[7,19]

Our experience underscores the critical necessity of advanced image guidance when adapting minimally invasive techniques to complex congenital pathology. Navigation provides an objective, real-time mechanism for ensuring complete resection of anomalous bone in anatomically distorted segments, effectively bridging the gap between the minimal trauma of the endoscopic approach and the high precision demanded by the pathology.[14]

The primary strength of this report is its documentation of a successful treatment of a rare, technically demanding congenital anomaly using a motion-preserving, minimally invasive technique in a patient where rapid recovery was essential. However, the study's limitations are inherent to its Level IV status: it is confined to a single patient, the follow-up is limited to six months, and the results are not statistically generalizable.

Future research should prioritize the formation of multicenter prospective patient registries or comparative cohorts with long-term follow-up to rigorously evaluate the long-term recurrence rates, stability, and cost-effectiveness of navigated endoscopic resection compared to traditional open fusion for this uncommon pathology. Our recommendation for clinical practice is that *O-arm neuronavigation should be considered an essential adjunct when performing endoscopic resection of complex congenital vertebral anomalies*, allowing surgeons to maximize patient-reported benefits while ensuring surgical precision and safety.

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