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TECHNICAL NOTE

The role of flexible hollow core carbon dioxide lasers in resection of lumbar intraspinal lipomas

Sohum Kiran Desai · David Paulson · Bobbye Jo Thompson · Joel Patterson · Aaron Mohanty

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Abstract
Purpose The authors assess the role of flexible hollow core CO_2 laser system (Omniguide system) in resection of intraspinal lipomas.
Methods Eight patients with intraspinal lipomas were operated using an Omniguide laser system over a 22-month period. The age range varied between 6 months and 16 years. All of them had lipoma of the conus medullaris associated with lumbar subcutaneous lipoma. Two of these had previous surgery with resection of the subcutaneous part of the lipoma; in one of them, a partial resection of the conus medullaris lipoma had also been performed. In six, there were no obvious motor or sensory deficits whereas two had gross neurologic deficits, with the deficits occurring in one after the previous decompression. Resection of the conus lipoma, untethering of the spinal cord, and reconstruction of the decompressed conus was performed in all aided with Omniguide laser system. The power settings of the laser system ranged from 4 to 8 W.
Results Subtotal to near-total resection was achieved in all. None of the patients developed any new motor or sensory deficits. Three had postoperative CSF leaks which initially required reoperation with graft resuturing and subsequently placement of lumboperitoneal shunt. One child with preexisting neurologic deficits improved in power over the next 12 months.
Conclusion Flexible CO_2 laser system was precise and convenient in decompressing the conus lipomas and untethering of the cord in lumbar spinal lipomas.

Keywords CO_2 laser · Laser · Lipomyelomeningocele · Lumbar lipoma · Omniguide laser

S. K. Desai · D. Paulson · B. J. Thompson · J. Patterson · A. Mohanty (✉)
Division of Neurosurgery,
University of Texas Medical Branch at Galveston,
301 University Boulevard, Rt. 0517,
Galveston, TX 77555-0517, USA
e-mail: aarmohanty@yahoo.com

Introduction

Although CO_2 laser has been available for neurosurgical usage over the past five decades, its bulky design and poor ergonomics have made it difficult in the past to be accommodated during the surgery with the existing microsurgical instrumentation [6]. With the discovery of the ability to transmit the CO_2 laser energy through flexible hollow core fiber system (Omniguide, Omniguide Inc., Cambridge, MA), the CO_2 laser system has become considerably more user friendly. The authors report their initial experience in using the Omniguide system in resection of intraspinal lumbar lipomas.

Materials and methods

Eight children with lumbar lipomyelomeningocele with intraspinal lipoma were operated between February 2010 and November 2011 using the Omniguide Laser system. The locations of the lipoma, its extent, the degree of tethering, and associated abnormalities were determined with a preoperative magnetic resonance imaging (MRI). During the surgery, a resection of the lipoma was considered with leaving behind a layer of the lipoma on the spinal cord. A flexible CO_2 laser system (Omniguide Inc) was used to decompress the lipoma, untether the cord, and resect of the filum terminale. During the surgery, the system was used at a low laser power output (between 4 and 8 W continuous wave) with the tip being closer (2–4 mm) to the lipomatous mass for cutting action while it was kept at a distance of 10–15 mm for the coagulation action. The lipomatous mass away was resected initially in piecemeal with microscopic dissection and with the laser. Subsequently, while in close proximity to the neural structure, the lipoma was gently vaporized with lower power setting in the laser (4 W continuous wave). Often, a layer of lipomatous tissue was left behind close to the neural tissue to prevent injury to the underlying spinal cord. All patients underwent intraoperative electromyographic monitoring of the lower limb muscles during the procedure. After the resection, the exposed margins of the conus were reapposed with 6–0 interrupted pial sutures to reconstruct the spinal cord. The dural defect was closed with a dural graft (cadaver dura allograft or a synthetic dural substitute). A watertight closure was performed wherever was possible. The paraspinal muscles and fascial layer were closed as a single layer to have a close approximation. A portion of the lumbar subcutaneous lipoma was resected before approximation of the skin.

In the postoperative period, the patients were nursed preferably in a prone position to prevent development of a pseudomeningocele. If a pseudomeningocele was evident, it was initially tapped few times and if it recurred, the patients were considered for a reexploration and resuturing the dural defect site. A lumboperitoneal shunt was placed if there was a persistent collection or a leak. An initial follow-up MRI was obtained between 6 weeks and 3 months to assess for the extent of excision. The extent of resection was classified as partial resection (50–80 %), subtotal resection (80–90 %), and a near-total resection (>90 %) basing on the postoperative MRI imaging.

Results

The demographics and the clinical picture are described in Table 1. The age range varied between 6 months and 16 years with most of the patients being less than 2 years. Two patients who were 8 and 16 years of age had previously been operated by resection of the subcutaneous lipoma and partial decompression of the residual intraspinal lipoma early in their childhood. These two had symptoms of tethering and were considered for reexploration and excision of the lipoma and release of the tethered cord. Two patients had preoperative neurological deficits; it was evident in one at birth with deformed feet and limitation of movements in both ankles and toes. The other had developed bilateral complete ankle and foot weakness after a previous surgery where the lipoma was decompressed. The MRI showed a lipoma in the conus medullaris in all patients (Figs. 1a, b and 2a, b) with extension of the lipoma to the subcutaneous compartment. One patient has a terminal syrinx in the distal spinal cord just superior to the lipoma. At surgery, five had a transitional variety of conus lipoma while it was caudal in two and dorsal in the remaining one patient. A partial resection (50–80 %) was performed in two, subtotal resection (80–90 %) was carried out in four and a near-total resection (>90 %) was performed in the rest 2 (Figs. 1c, d and 2c, d). The filum terminale was identified and resected in all thus detethering the cord. After resection, the edges of the spinal cord were reapposed in all to reconstruct the conus. The dura was closed with a cadaver dural allograft in five and a synthetic porcine intestine dural substitute in three.

In the postoperative period, three patients developed progressive pseudomeningocele. As these did not subside after initial percutaneous aspirations, required reexploration and resuturing of the dura. Two of these had a porcine intestinal graft which was removed and replaced with autologus fascial graft. All three subsequently required placement of lumboperitoneal shunt for adequate control of the pseudomeningocele.

The follow-up period varied between 10 and 30 months. There were no new motor or sensory neurological deficits noticed in any of the patients in the follow-up period. Four patients developed transient bladder dysfunction which require intermittent catheterization and improved during the follow-up at 3–6 months. The child who was born with ankle and foot weaknesses was found to have motor functions partially regained at follow-up.

Discussion

Of the several varieties of lumbar intraspinal lipoma, the lipoma of the conus medullaris is technically the most challenging for the pediatric neurosurgeon. The role of surgery in the lumbar spinal lipomas has been reduction of the lipomatous mass and detethering of the spinal cord. The spinal cord is tethered by three factors: by the lipomatous mass which most often is continuous with the subcutaneous lipoma, a thickened short filum terminale, and short transversely exiting nerve roots. Excision of the lipoma is complicated by intimate adhesion of the lipoma to the terminal spinal cord and its proximity to the exiting nerve roots. Evidence of traversing nerve roots through the lipomatous mass is often encountered. A near-total or subtotal resection of the lipoma without causing additional neural injury, untethering the cord by resection of the filum, and detachment of the lipomatous mass from its attachment with the spinal cord

Table 1 Clinical data: lipomas of the conus medullaris

Sl no.	Age/sex	Clinical presentation	Type of lipoma	Postoperative complications	Follow-up (months)	Outcome	Comments
1	8 years/male	Tingling, numbness in the lower limbs, and previous surgery for subcutaneous lipoma	Transitional	Pseudomeningocele and LP shunt	26	Symptoms improved	
2	10 months/male	Lumbosacral lipoma	Transitional	None	14	Asymptomatic	Terminal syrinx
3	18 months/female	Lumbosacral lipoma	Transitional	Pseudomeningocele and LP shunt Bladder dysfunction	24	Asymptomatic	
4	5 years/male	Lumbosacral lipoma	Transitional	Pseudomeningocele and LP shunt Bladder dysfunction	12	Asymptomatic	
5	6 months/male	Lumbosacral lipoma Weakness in the feet	Dorsal	Bladder dysfunction	30	Weakness partially improved	
6	16 years/female	Low back pain, bilateral ankle and toes weakness and previous surgery for partial resection of spinal lipoma	Transitional	None	18	Symptoms improved	
7	6 months/female	Lumbar cutaneous hemangioma and lumbar lipoma	Caudal	Bladder dysfunction	12	Asymptomatic	Terminal syrinx
8	20 months/female	Lumbosacral lipoma	Caudal	None	10	Asymptomatic	

and reconstruction of the terminal spinal cord have been the goals of the surgery [2, 9, 11].

Lasers in spinal lipoma Apart from the usage of microscopic dissection, the most effective tool aiding in decompression of the lipomas has been the CO_2 laser [4, 7, 9]. The CO_2 laser can be used both as a cutting tool and a vaporizing tool depending on the power setting. Its high absorption in water and its predominantly superficial effect makes it an ideal tool for usage in adjacent to critical areas like the brain and the spinal cord. In intraspinal lipoma resection, the CO_2 laser has been reported to be advantageous in debulking the lipoma by vaporization while sealing small vessels during the resection [9]. Debulking the lipoma by vaporization reduces adjacent neural trauma by reducing tissue manipulation as the lipoma is decompressed layer by layer with the laser beam. Simultaneous sealing of the small blood vessels reduces blood loss which is of considerable importance in infants. Additionally, the laser dissection does not interfere with intraoperative monitoring which is commonly used during the procedure. Pang et al. favor microscopic dissection of the lipomatous tissue than a laser decompression to better identify the plane of demarcation by tactile feeling during the excision process [10].

After the initial enthusiasm, neurosurgeons were quick to realize that the cumbersome design and tiring ergonomics of CO_2 lasers limited their ability to use the system in confined spaces resulting it to be disfavored by many neurosurgeons [6, 12]. However, the recent development of hollow core photonic band gap optical fibers for CO_2 lasers have transformed the nonergonomic overhead delivery system to flexible user friendly hand pieces that can be used like any other microsurgical tool.

The Omniguide laser system The Omniguide laser system uses flexible hollow core fiber system to transmit CO_2 laser energy. The hollow core fiber is lined with dielectric mirrors which guide the CO_2 energy along the fiber by efficiently reflecting it along the walls. Medical grade helium is directed through the core to reduce the heat production on the surrounding tissue as well as the remove the smokes produced at the tip and also ensures its patency. A detailed discussion about this system has been published before [1, 5].

The CO_2 laser energy can be guided through the tip to achieve either the cutting or coagulating effect. A convergent beam with a spot size of 320 μm can be used as a dissecting tool whereas by retracting the dissection tip away from the target tissue achieves a coagulation effect. The power of the laser beam can be adjusted between 4 and 10 W to precisely direct the beam to the desired depth of the tissue penetration.

The principal advantage of the system is its light weight and flexibility which improves the ergonomics and considerably reduces surgical fatigue. Another advantage is the low profile tip which can be precisely positioned to focus

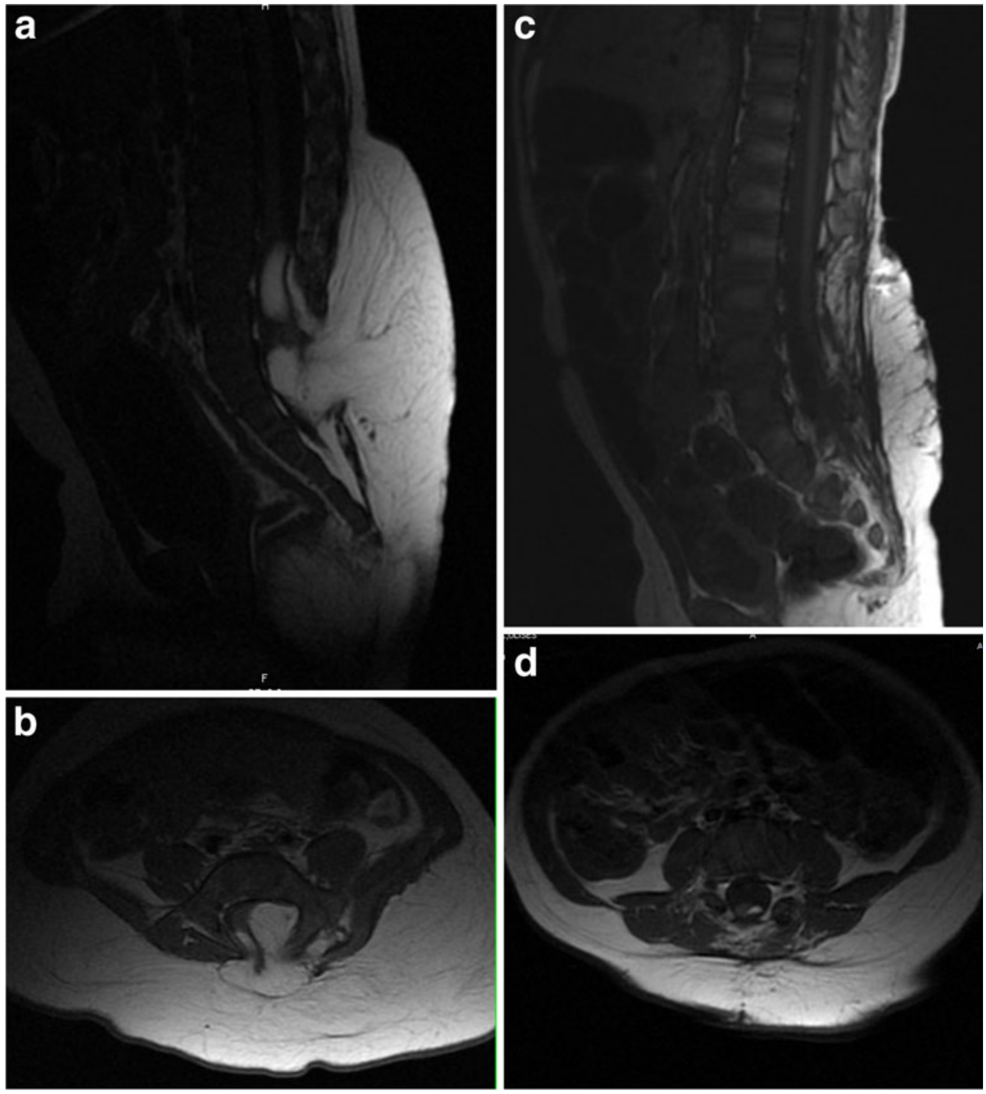

Fig. 1 **a** Preoperative sagittal T1-weighted MRI demonstrating a large intraspinal lipoma with subcutaneous extension. **b** Preoperative axial T1-weighted MRI demonstrating the intraspinal lipoma with subcutaneous extension. Note the neural tissue surrounded by the lipoma on both sides. **c** Postoperative sagittal T1-weighted MRI demonstrating a small residual lipoma. **d** Postoperative axial T1-weighted MRI revealing a small residual lipoma with reconstruction of the conus

the CO_2 laser energy during the dissection of the lipoma from the conus and the displaced nerve roots which are in close proximity. Varying the distance from the tissue surface to either coagulate or dissect and vaporize the tissue has often been considered to be useful during the different stages of the surgery. The ability of the constant flowing helium to clear the field from the smoke, blood products, and debris helps in reducing direct suctioning of the operative field.

Omniguide system in neurosurgery There have been few recent reports regarding the usage of Omniguide CO_2 laser system in neurosurgical procedures [1, 3, 5, 8]. Killory in 2010 reported 45 neurosurgical procedures where the Omniguide system was used. The authors reported that He laser was most useful in debulking fibrous tumors too tough for ultrasonic aspirators and lesions adherent to delicate neurovascular structures [5]. They did not encounter any advantage with highly vascular tumors. One of their cases was filum lipoma with tethered cord. Malone et al. excised a calcified choroid plexus papilloma which was vascular using the system. The CO_2 laser was helpful in vaporizing the neoplastic cellular material and simultaneously cauterizing the microvascular structures [8]. Another report cited its usefulness in 23 patients with cavernous malformations [3].

Browd reported the usage of the Omniguide system in three patients of pediatric intraspinal surgeries. One of their cases was an intraspinal conus lipoma. The CO_2 laser was found to be useful during the initial vaporization and subsequent dissection from the nerve roots. The authors did find the CO_2 laser effects to be restricted to the operative target and did not injure the nerve roots deeper to the plane as evidenced by normal electromyographic response [1].

In the present series, we have used the flexible CO_2 hollow core laser system in eight patients with intraspinal lipomas. To the best of our knowledge, this is the first report

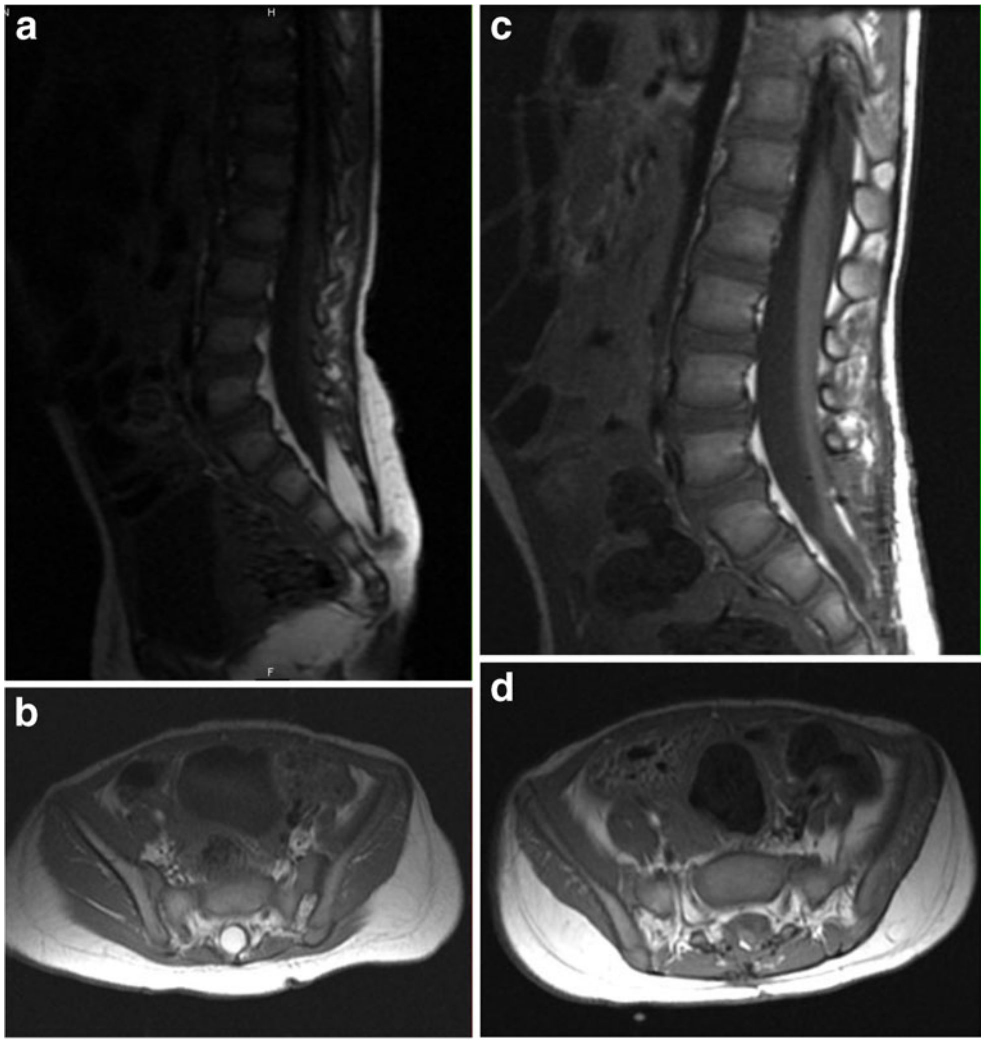

Fig. 2 **a** Preoperative sagittal T1-weighted MRl demonstrating a caudal intraspinal lipoma in the sacral region. **b** Preoperative axial T1-weighted MRl demonstrating the intraspinal lipoma with subcutaneous extension. Note the neural tissue capping the lipoma on the left side. **c** Postoperative sagittal T1-weighted MRl demonstrating a small residual lipoma on the dorsal surface. **d** Postoperative axial T1-weighted MRl revealing a small residual lipoma on the dorsal surface

with a consecutive series of eight patients with spinal lipomas in whom Omniguide laser has been used for resection. We had no difficulty in incorporating the system with the other microsurgical instruments and performed most of our dissection microscopically. We have used it for both vaporization and for cutting functions by altering the power of the system and the distance of the tip from the target. During the initial part of the decompression, the lipoma can be quickly debulked by resecting part of the lipoma extruding out from the spinal cord with the laser used as a cutting tool by keeping the beam parallel to the spinal cord surface. The vaporization function can be used when the decompression is performed close to the neural structures (Fig. 3).

We did not encounter of worsening of any new postoperative motor or sensory deficits in all of our children. A short lasting bladder dysfunction was seen in four children but improved in all. The only patient with preoperative neurological deficits improved in the motor power in the follow-up period. Though the small case cohort in the present series precludes any derivation of useful conclusion regarding the efficacy of the system in reducing the postoperative neurological deficits, we believe that as the flexible laser system could be well incorporated with other microinstruments and microsurgical techniques it certainly plays a role in the overall outcome of these patients.

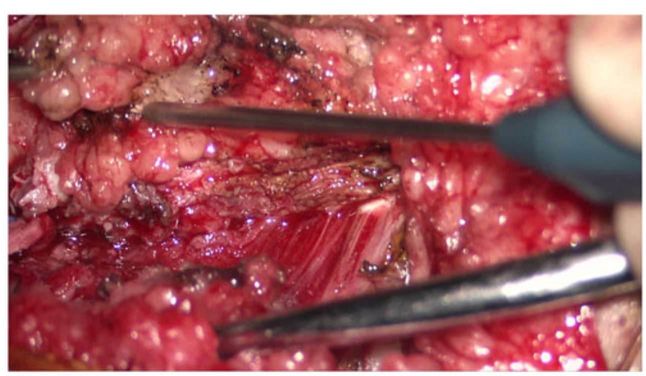

Fig. 3 Intraoperative photograph demonstrating the thin profile of the Omniguide handpiece decompressing the intraspinal part of the lipoma by vaporization

Disclosure The authors report no conflict in interest concerning the materials or methods used in this study or the findings specified in this paper.

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