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Dorsal Column Mapping via Phase Reversal Method: The Refined Technique and Clinical Applications

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BACKGROUND: Safe resection of intramedullary spinal cord tumors can be challenging, because they often alter the cord anatomy. Identification of neurophysiologically viable dorsal columns (DCs) and of neurophysiologically inert tissue, eg, median raphe (MR), as a safe incision site is crucial for avoiding postoperative neurological deficits. We present our experience with and improvements made to our previously described technique of DC mapping, successfully applied in a series of 12 cases.

OBJECTIVE: To describe a new, safe, and reliable technique for intraoperative DC mapping.

METHODS: The right and left DCs were stimulated by using a bipolar electric stimulator and the triggered somatosensory evoked potentials recorded from the scalp. Phase reversal and amplitude changes of somatosensory evoked potentials were used to neurophysiologically identify the laterality of DCs, the inert MR, as well as other safe incision sites.

RESULTS: The MR location was neurophysiologically confirmed in all patients in whom this structure was first visually identified as well as in those in whom it was not, with 1 exception. DCs were identified in all patients, regardless of whether they could be visually identified. In 3 cases, negative mapping with the use of this method enabled the surgeon to reliably identify additional inert tissue for incision. None of the patients had postoperative worsening of the DC function.

CONCLUSION: Our revised technique is safe and reliable, and it can be easily incorporated into routine intramedullary spinal cord tumor resection. It provides crucial information to the neurosurgeon to prevent postoperative neurological deficits.

KEY WORDS: Dorsal column mapping, Phase reversal, Somatosensory evoked potentials

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Intramedullary spinal cord tumors are difficult to resect because they usually cause significant alteration in the architecture of the spinal cord, compressing, engulfing, or displacing the neural structures. Thus, surgical treatment carries a high risk of postoperative neurological deficits. The approach to resection usually involves an incision (ie, myelotomy) made in the dorsal median raphe (MR). This physiologically inert structure separates the left and right dorsal columns (DCs) of the spinal cord, which harbor the large fiber sensory system conveying vibration and conscious proprioception senses from the upper and lower limbs, via cuneate and gracilis tracts, respectively. Any error in localizing the MR can irreversibly damage the neighboring DCs, especially the gracilis tracts, which are located most medially (closest to the MR), leading to severe postoperative neurological compromise. With normal anatomy, the MR can be easily identified by visual inspection, and its trajectory can be tracked over the span of several spine levels. However, with intramedullary tumors that significantly distort the spinal cord anatomy, this may not be reliably achieved.

It is in these cases that intraoperative neurophysiologic dorsal column mapping (DCM) can make a difference by accurately identifying the physiological midline and guiding the

ABBREVIATIONS: DC, dorsal column; **DCM,** dorsal column mapping; **MR,** median raphe; **SSEP,** somatosensory evoked potential

myelotomy. The use of such mapping techniques has been shown to decrease postoperative neurological deficit by as much as 40%.[1] Currently, there are 2 established techniques used for DCM.[2-5]

We have previously described a new method based on the phase-reversal of cortical somatosensory evoked potentials (SSEPs) triggered by direct electrical stimulation of the gracilis tracts.[6] At that stage, our experience was limited to 1 successful mapping case. In this article, we outline the improvements we have since made to the technique and review a series of cases where its reliability has been tested.

PATIENTS AND METHODS

The method is based on changes in laterality of the positive scalp field of the somatosensory cortex with alternating stimulation of the right or left large fiber sensory system (ie, right/left posterior tibial nerves, or right/left DCs). In our previous work,[6] we stimulated the DC by using an 8-contact minielectrode (consisting of 2-mm exposed 40-gauge stainless steel wires, with 1-mm contact spacing), placed perpendicular to the spine. Repetitive electrical pulses at 3.17 Hz, 0.2 mA, and 0.3-ms pulse width were applied directly to the DC via 2 adjacent contacts of this minielectrode, in succession from left to right, to stimulate the left and right gracilis tracts, respectively. SSEPs were recorded after each stimulation, via scalp electrodes. The midline raphe was identified by locating the 2 adjacent contacts of the electrode, which when stimulated resulted in a phase reversal of cortical SSEPs.

Improvements to the previously published methodology, including replacement of the minielectrode with a bipolar handheld stimulator, are detailed in the Discussion section, and Figures 1 and 2 illustrate our refined technique.

RESULTS

We have successfully implemented our improved method for DCM in 12 patients who underwent spinal cord tumor resection.

Demographic and Clinical Data

The mean age was 45.8 years (range, 19-78). There were 6 men and 6 women. Mapping was done at the cervical and thoracic levels of the spinal cord. Preoperatively, 4 patients presented with sensory concerns suggestive of DC deficits (patients 1, 6, 11, and 12). In 1 patient, DC function was not specified (patient 7). Neurological examinations performed postoperatively, at 4 weeks or later, showed no changes from the preoperative baseline in 10 patients and improvement in 2 patients (patients 1 and 12).

Table 1 summarizes patient demographics and clinical data (pathology, spine level, preoperative and postoperative somatosensory deficit related to DC dysfunction).

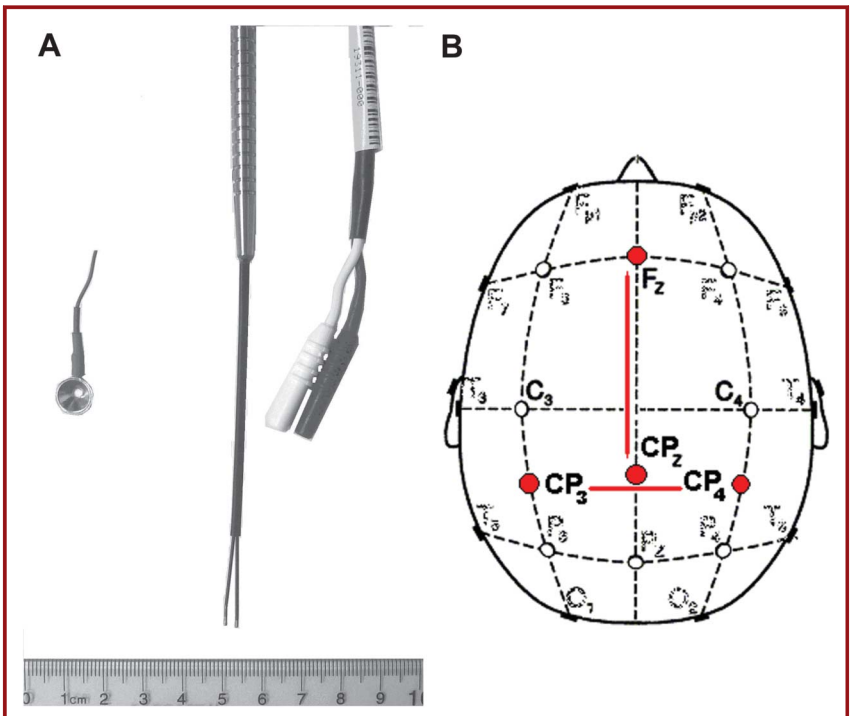

FIGURE 1. *Technical setup.* **A**, *handheld bipolar stimulator (Viasys) used for direct spinal cord mapping and 10-mm gold-plated disc reusable electrodes (Natus) for scalp recordings.* **B**, *location of scalp recording electrodes: axial view in 10 to 20 International Electrode System.*

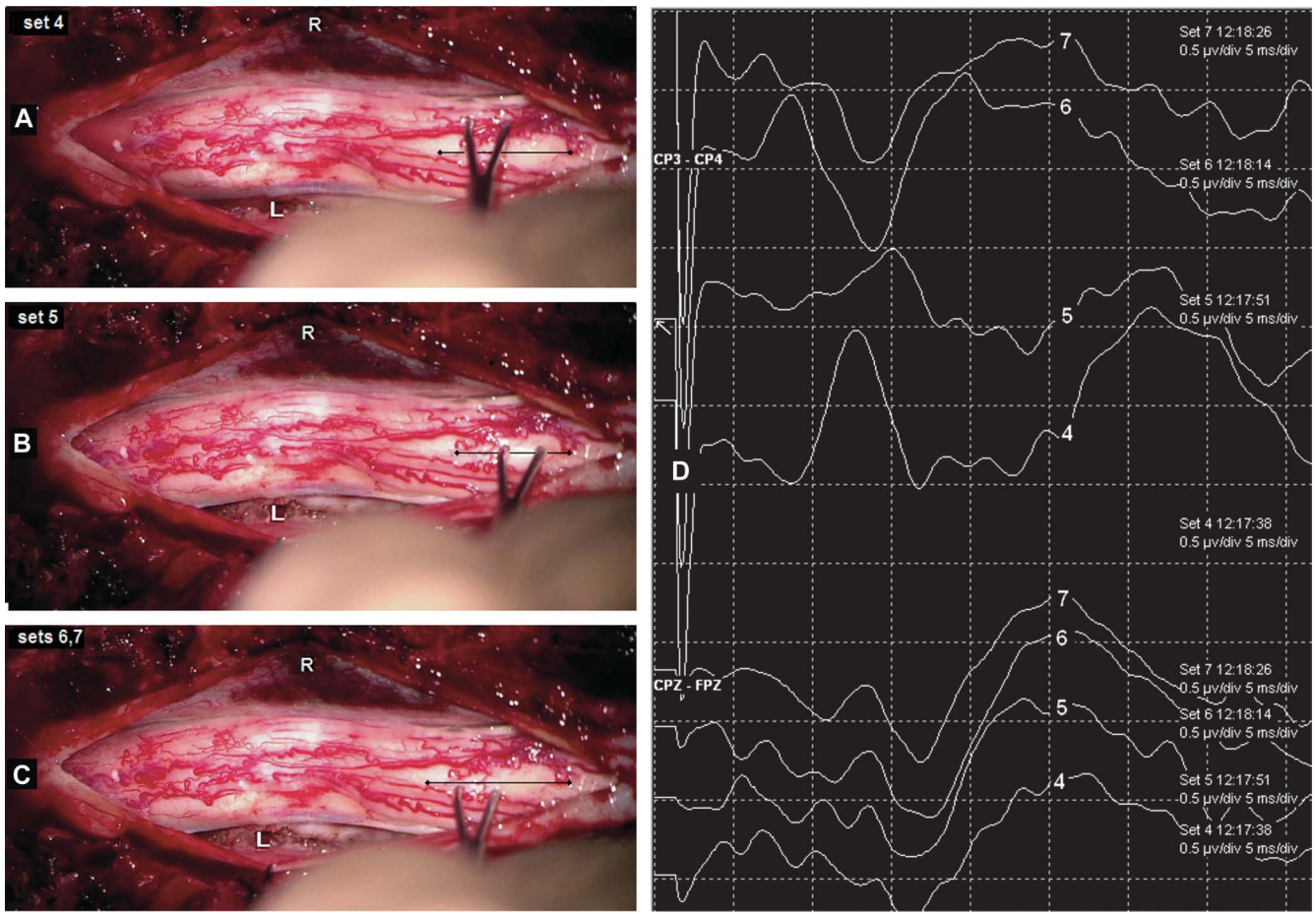

FIGURE 2. *Illustration of the methodology applied for DCM in patient 9. Direct stimulation of the dorsal cord at T3 level is performed with the stimulator oriented with the prongs parallel to the longitudinal axis of the cord. Stimulation of the right DC (**A**) results in a negative upward peak in CP3-CP4 channel and a positive downward peak in CPz-Fz channel (set 4, **D**). Next, the surgeon performs stimulation closer to the midline, yet still right sided and slightly more distally (**B**), resulting in a smaller negative peak in CP3-CP4 channel and a positive peak in CPz-Fz channel (set 5). **C** shows stimulation of the left DC, which triggers positive deflections in both channels (sets 6 and 7). The line drawn between right and left DC depicts the location of the MR. Notice the small lag between the SSEPs recorded in CPz-Fz (17 ms latency) vs CP3-CP4 channel (13.4 ms latency). This correlates with the lag present in the baseline posterior tibial SSEPs, best seen when using the same time base (5 ms/div). A small arrow indicates the start of the stimulus. DC, dorsal column; DCM, dorsal column mapping; MR, median raphe; SSEP, somatosensory evoked potential.*

Identification of the MR and DC

The MR location was visually identified in 7 patients, reliably in 2 (patients 7 and 9), and presumably in 5 (patients 2, 5, 10, 11, and 12). In all 7 cases, the MR location was confirmed with the use of our neurophysiologic mapping technique. Additionally, MR was neurophysiologically identified in 4 other patients (patients 3, 4, 6, and 8). MR could not be localized in 1 patient (patient 1). However, in this patient, the right DC was identified and myelotomy was safely performed in nervous tissue that did not trigger recordable SSEPs when stimulated (see Discussion, Negative mapping technique).

Three of the 11 MRs identified neurophysiologically were not located at the anatomic midline of the dorsal cord, but they were pushed to the right by the lesion (patients 4, 6, and 8). In these 3 cases, MR could not be visually identified.

Among the 11 patients in whom the MR was neurophysiologically identified, myelotomy was done at the MR location in 8 patients (patients 2, 3, 5, 6, 7, 10, 11, and 12); in 2 cases (patients 4 and 8), a safe path of entry other than the MR was chosen, where the tumor was closest to the spinal cord surface (see Discussion, Negative mapping technique). Of note, in 1 case (patient 12), incision was made at midline, where MR was presumably located; however, at this location the cystic lesion was also quite superficial

TABLE 1. Demographics and Clinical Data[a]

ID	Age, y	Sex	Pathology	Lesion Level	Preoperative DC Sensory Deficits	Postoperative DC Sensory Deficits at >1 mo
1	48	M	Ependymoma grd III/IV	C1-3	Impaired vibration sense (all limbs)	Improved
2	19	F	Ependymoma grd II/IV	C1-4	No	No
3	48	M	Ependymoma	C1-6	No	No
4	64	F	Hemangioblastoma grd I/IV	C2-3	No	No
5	40	M	Ependymoma grd II/IV	C3-4	No	No
6	25	F	Ependymoma grd II/IV	C5-C6	Impaired vibration sense (upper limbs)	No change
7	26	M	Syrinx	C7	NS	NS
8	29	F	Diffuse infiltrating astrocytoma grd II/IV	T2-4	No	No
9	78	F	Meningioma	T3-4	No	No
10	41	M	Syrinx	T5-7	No	No
11	68	F	Low-grade infiltrating glioma suggestive of ependymoma	T9	No vibration sense (feet)	No change
12	64	M	Dermoid cyst	T9	No vibration and joint position sense (feet)	Improved

[a]DC, dorsal column; Grd, World Health Organization grading system of gliomas; NS, not specified.

(see Discussion, Negative mapping technique). In 1 patient (patient 9), no myelotomy was necessary.

Whether the DC could be identified visually or not matched that of the MR, with the exception of patient 4, in whom the left DC was presumably identified by visual inspection, without reasonable visual identification of the MR.

Both right and left DCs were neurophysiologically identified in 11 patients. The results accurately matched the visual inspection. Only the right DC could be identified in patient 1.

Neurophysiologic Monitoring

Bilateral reproducible baseline posterior tibial SSEPs were obtained in 10 patients, and only right posterior tibial SSEPs were obtained in 2 patients (patients 1 and 12). After the myelotomy site was chosen based on the DCM results, the posterior tibial SSEPs were closely monitored for changes during myelotomy (Figure 3B).

In all cases, there were no significant changes from the baseline posterior tibial SSEPs at the end of the surgery. However, during myelotomy, 1 patient (patient 10) had transient deterioration of the posterior tibial SSEPs. The surgeon was promptly informed and myelotomy was halted. He performed irrigation with warm saline and the systemic blood pressure was increased. The SSEPs gradually recovered, and, by the end of the surgery, they returned to the premyelotomy baselines.

Table 2 summarizes the results of the neurophysiologic and visual identification of the DC and MR, the site where the myelotomy was performed, postmyelotomy changes in posterior tibial SSEPs, and postoperative changes in the sensory DC examination.

DISCUSSION

The advantages of our technique, such as a decreased mapping time and risk for error in measurements as well as increased signal-to-noise ratio in the recordings, were previously detailed.[6]

Since our initial description, we have made several changes to our technique. Some of these developments resulted from following up on suggestions made by the reviewers of the previous article. Others evolved from practical observations encountered in our clinical practice.

Stimulation via a Bipolar Stimulator

In our previous description of the technique, in an attempt to minimize the current spread, we used an 8-contact minielectrode placed directly over the spinal cord for stimulation of the DCs. Unfortunately, in our experience, the use of the minielectrode has been a relatively delicate and potentially time-consuming procedure, regardless of whether it is used for recording[2-4] or stimulation.[6] This is because sustained good contact with the pulsatile dorsal cord of the 8-contact minielectrode usually requires several readjustments of the position, irrigation, and sometimes even replacement of the electrode owing to defective contacts.[6] More so, the presence of prominent vasculature of the dorsal cord may be an additional obstacle in easy and safe placement of the recording electrode. Last, but not least, the minielectrode is prohibitively expensive, without being reusable. Thus, we considered it was worthwhile to revisit and

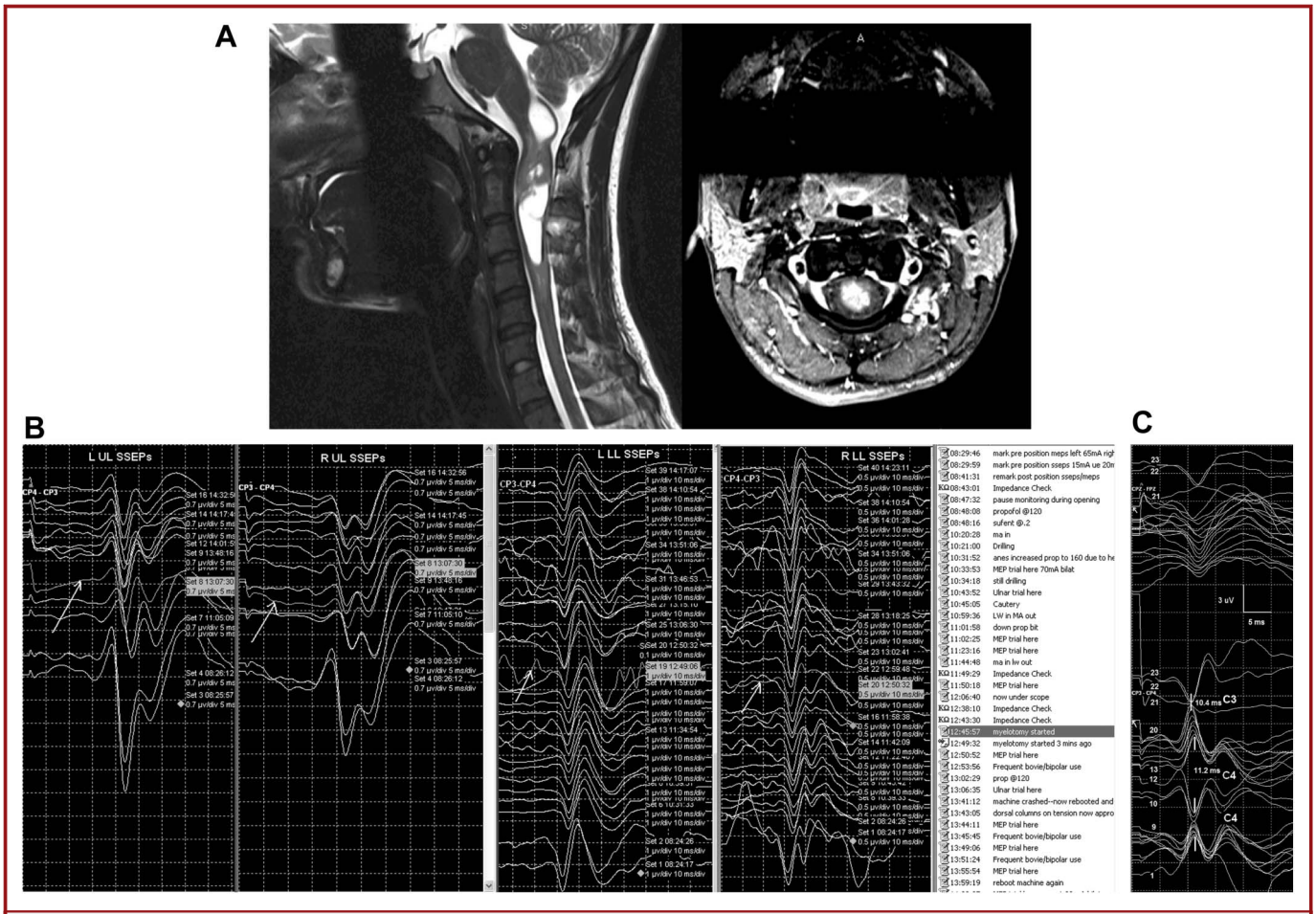

FIGURE 3. *Intraoperative neurophysiologic testing in patient 2 during resection of cervical ependymoma.* **A**, *MRI sagittal and axial images showing hyperintense cervical lesion at C1-C4.* **B**, *continuous upper limb (ulnar nerves) and lower limb (posterior tibial nerves) SSEP monitoring. No significant changes from baseline are seen during and after myelotomy and throughout the resection. In each window, the first 2 traces (bottom of the stack) show preposition baseline SSEPs. As a direct result of the effect of anesthetics during the opening time, all SSEPs recorded after the opening have overall lower amplitudes than the preposition baselines. The arrows point to the first SSEP recordings (highlighted) after the beginning of myelotomy (see also notes in the recording's log).* **C**, *DCM in the same patient.* Channel CP3-CP4*: Stimulation from right to left at C4 level triggers negative deflections with absolute latency of 11.2 ms (trials 1 through 9) due to depolarization of the right gracilis tract, followed by positive deflections with same latencies (trials 10 through 12) triggered by stimulation of the left gracilis tract. The phase reversal between trials 9 and 10 points toward the location of the MR. The midline is crossed once again (phase reversal between trials 12 and 13) from left to right (trial 13 shows a negative deflection triggered by stimulation of the right gracilis tract). Next, the surgeon performs successive stimulation of the right DC, tracking its trajectory proximally, from C4 toward C3 level. Notice the progressive shortening of the absolute latencies from trial 13 (11.2 ms) to trial 20 (10.4 ms). Once again, the stimulation is performed from right to left, this time at the C3 level. Stimulation of the MR results in a relatively isoelectric line (trial 21) recorded in both CP3-CP4 as well as CPz-Fz channels. Stimulation of the left gracilis tract results in positive deflections (trials 22, 23).* Channel CPz-Fz*: Stimulation of either right or left gracilis tracts results in positive deflections. A small arrow indicates the start of the stimulus. DC, dorsal column; MR, median raphe; SSEP, somatosensory evoked potential.*

fine-tune the stimulation of the dorsal cord with a handheld bipolar stimulator (Figures 1A and 2), understanding that the main risk remains current spread, as it may be when used to antidromically elicit SSEPs.[5] However, the stimulus amplitude used to antidromically elicit SSEPs is 2 to 8 mA, whereas we use a current as low as 0.3 mA. In order to avoid current spread, we gradually increase the stimulus intensity until we obtain reliable and reproducible SSEPs. The maximum stimulus amplitude we used in our series of cases was 0.5 mA. In order to detect the possibility of current spread, we have introduced an additional recording channel (ie, CPz-Fz, see Additional recording channel, below). The use of a handheld stimulator also allows for a more versatile mapping at multiple spinal levels (see Reconstructing the trajectory of the MR).

TABLE 2. Intraoperative Findings and Neurophysiologic-Neuroanatomic Correlation During DCM[a]

ID	Lesion Level	Visual Identification of the DCs	Neurophysiologic Identification of DCs	Visual Identification of MR	Neurophysiologic Identification of MR	Location MR
1	C1-3	No	Yes-only Rt DC	No	No	Not localized
2	C1-4	Yes-presumed (cord symmetrically swollen)	Yes-confirmed	Yes-presumed	Yes-confirmed	Midline
3	C1-6	No	Yes	No	Yes	Midline
4	C2-3	Yes-presumed (Lt DC bordering the medial margin of the tumor)	Yes-confirmed	No	Yes	Right to midline
5	C3-4	Yes-presumed	Yes-confirmed	Yes-presumed	Yes-confirmed	Midline
6	C5-C6	No	Yes-Rt > Lt DC	No	Yes	Right to midline
7	C7	Yes	Yes-correlated[d]	Yes	Yes-correlated	Midline
8	T2-4	No	Yes	No	Yes	Right to midline
9	T3-4	Yes	Yes	Yes	Yes-correlated	Midline
10	T5-7	Yes-presumed	Yes-confirmed	Yes-presumed	Yes-confirmed	Midline
11	T9	Yes-presumed	Yes-confirmed	Yes-presumed	Yes-confirmed	Midline
12	T9	Yes-presumed	Yes-confirmed	Yes-presumed	Yes-presumed	Midline

ID	Myelotomy Site	Reproducible Baseline Posterior Tibial SSEPs	Posterior Tibial SSEP Changes at Myelotomy	Averaged Absolute Latency[b] Lt and Rt Posterior Tibial Nerve SSEPs	Averaged Absolute Latency[c] of Gracilis SSEP and Corresponding Spinal Level
1	Near Lt dorsal root entry zone (cystic part of the tumor)	Yes-Rt, No-Lt	No	44.8	9.9-C2, 10.6-C3
2	MR	Yes	No	35.6	10.4-C3, 11.2-C4
3	MR	Yes	No	38.2	10.0-C3, 11.1-C4, 12.0-C5
4	Lateral to the Lt DC (tumor)	Yes	No	40	8.0-C1
5	MR	Yes	No	41.3	10.3-C3
6	MR	Yes	No	42.2	11.3-C5
7	MR	Yes	No	34.4	9.5-C7
8	Lateral to Lt DC (tumor)	Yes	No	39.7	12.2-T2
9	NA	Yes	NA	41	13.4-T3
10	MR	Yes	Yes, with recovery at end of monitoring	43.8	15.3-T7
11	MR	Yes (poor)	No	48.2	15.6-T8, 16.6-T10
12	Midline (MR/cyst)	Yes-Rt (poor), No-Lt	No	51.8	18.4-T8, 19.7-T9

[a]DC, dorsal column; DCM, dorsal column mapping; MR, median raphe; NA, no myelotomy performed; SSEP, somatosensory evoked potential; Lt, left; Rt, right.
[b]Averaged absolute latency in milliseconds, measured in CP3-CP4 channel, during the last trial before the initiation of the DC.
[c]Averaged absolute latency in milliseconds, measured in CP3-CP4 channel, for a certain spine level.
[d]Correlated = neurophysiologic identification agreed with visual identification.

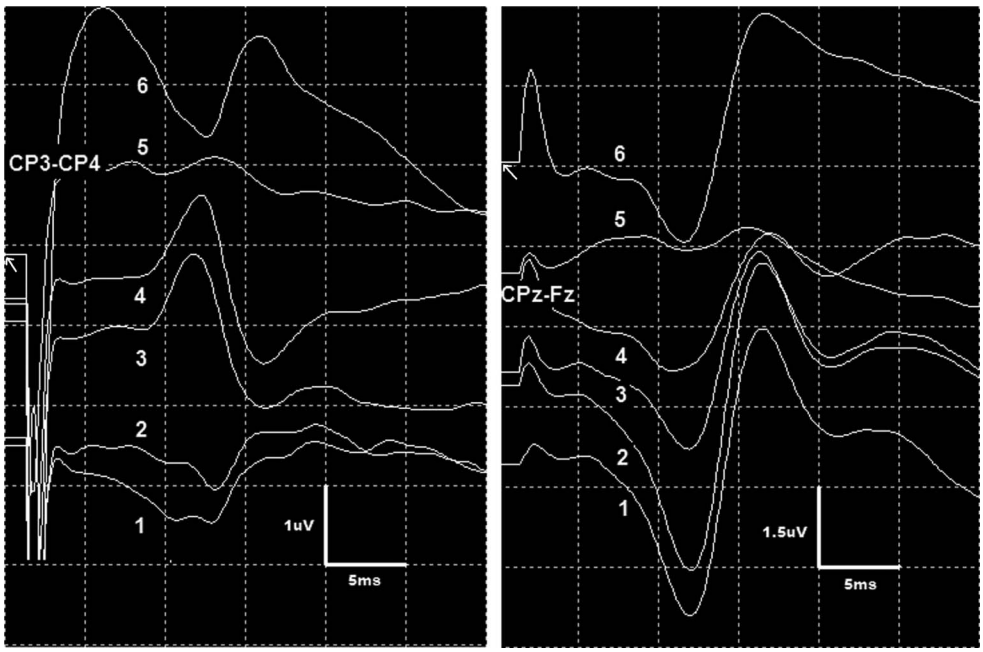

FIGURE 4. *The importance of the CPz-Fz channel. DCM is performed at T2 level in patient 8. Trials 1 and 2 show high-amplitude, robust SSEPs in the CPz-Fz channel, whereas CP3-CP4 recordings show small amplitudes, relatively poor morphology positive deflections. These results suggest simultaneous stimulation of left > right gracilis tracts (the relative polarity in the CP3-CP4 channel is positive), likely due to current spread. Next, stimulations were performed at lower current intensity (dropped from 0.6 to 0.3 mA), of right gracilis tract (sets 3, 4), close to MR (set 5) and left gracilis tract (set 6). When stimulating close to MR, both recording channels showed unreliable SSEPs (set 5). A small arrow indicates the start of the stimulus. DCM, dorsal column mapping; MR, median raphe; SSEP, somatosensory evoked potential.*

Progressive Stimulation From Lateral to Medial and Over the Midline

This approach allows recording changes in the SSEPs, with a consistent decrease in their amplitudes as the stimulation approaches the neurophysiologic midline (Figure 2).

Additional Recording Channel

The additional CPz-Fz channel helps identify concomitant stimulation of both right and left gracilis tracts, and thus current spread. In such instances, one should observe the attenuation to disappearance of evoked potentials in CP3-CP4/CP4-CP3 channels (owing to the cancellation of the polarities), whereas CPz-Fz will show a robust positivity, equivalent to the P37. On the other hand, stimulation of neurophysiologically inert tissue results in minimal to no evoked responses in all channels (Figure 4).

Reconstructing the Trajectory of the MR

Distorted anatomy of the dorsal cord may hinder visual identification of the MR and of its trajectory from 1 spinal level to the next. While repeated positioning at different spinal cord levels of the stimulating minielectrode is cumbersome, the use of a handheld stimulator significantly expedites the process. Using the handheld stimulator, we started mapping routinely at several spine levels in an attempt to reconstruct the trajectory of the MR (Figures 3C and 5).

Latencies of Evoked Responses: Normative Data

A challenging factor in interpreting the results is the variability of the expected SSEPs' latencies, based on the spinal level of stimulation and other factors (eg, height).

Table 2 details individual measurements of the averaged absolute latencies of the cortical SSEPs after both peripheral posterior tibial nerve stimulation and direct spinal cord stimulation. Measurements are done in the CP3-CP4 channel. A small lag may exist between SSEPs recorded simultaneously in CP3-CP4 and CPz-Fz channels (Figure 2).

Negative Mapping Technique

Similar to negative cortical mapping techniques,[7,8] negative mapping of the DC allows accurate delineation of the tumor

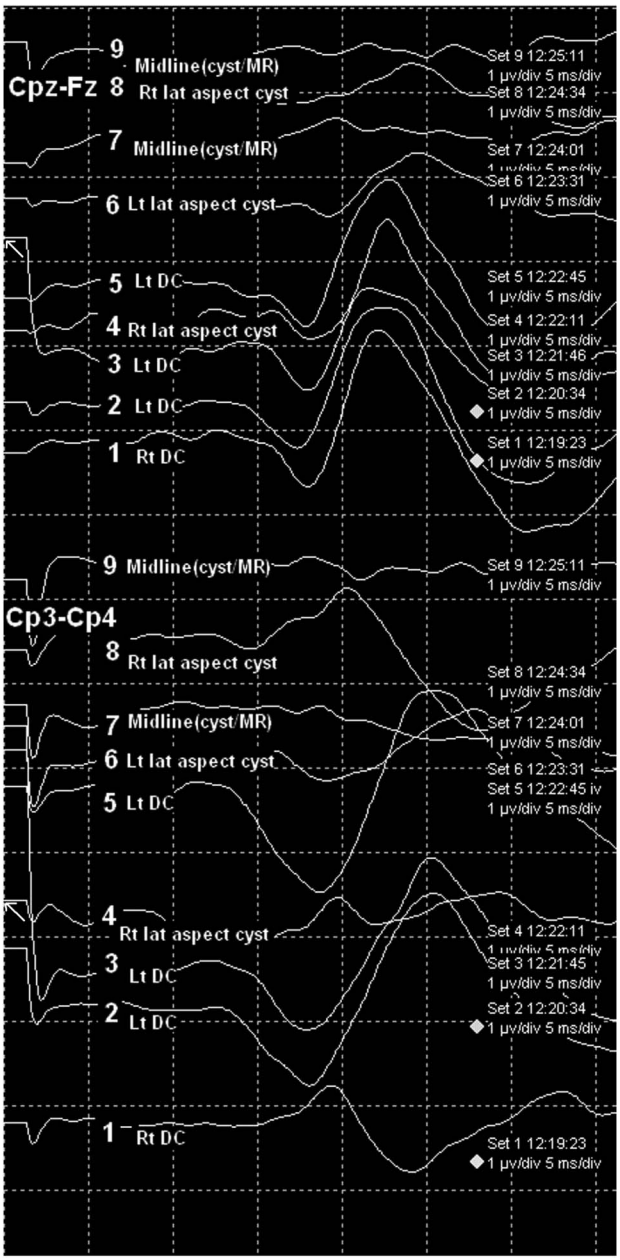

FIGURE 5. *Negative mapping in patient 12. Stimulation of left DC at the T8 level triggers reproducible, robust positive deflections in the CP3-CP4 channel (sets 2, 3, and 5; latency 18.4 ms); stimulation at T9 level (latency 19.7 ms) of Basketed fibers over the right and left aspects of the cyst triggers smaller negative and positive responses, respectively (sets 4, 8, right-sided fibers, and set 6, left-sided fibers). The incision is done at the midline portion of the cyst, situated in between right and left basketed fibers, and likely coinciding with the location of the MR. Stimulation in this region triggers no SSEPs (sets 7 and 9). A small arrow indicates the start of the stimulus. DC, dorsal column; MR, median raphe.*

margins.[1] In 3 of our 12 DCM cases, myelotomy was not performed at the neurophysiologically inert MR, even when the latter was reliably identified (patients 4 and 8). Instead, the incision was made in an area that offered a more "generous" path of entry, where the tumor was closest to the pial surface. This approach was also necessary in patient 1, because the MR could not be identified. Before making the incision for myelotomy, the region was "cleared" by stimulating the area and confirming the absence of SSEPs. Similarly, in patient 12, the surgeon stimulated different areas on the surface of the cystic lesion, including "basketed" fibers visualized on its lateral aspect that were ultimately preserved. Incision was made at midline, in a neurophysiologically inert region, also presumed to be the location of the MR (Figure 5).

These examples show that, despite identifying the MR as a safe site for myelotomy, the surgeon may choose to place the incision at a different location as revealed by negative mapping, especially in cases where the tumor tissue is present superficially.

Neurophysiologic Lateralization

In the absence of MR localization, polarity-specific recordings result in lateralization (left or right) of gracilis tract fibers and of their trajectory. This, together with differences in the amplitudes and morphologies of right vs left gracilis SSEPs, can provide a better understanding of the distorted local topography and increase the chances for choosing the best anatomic plan for resection (Figure 6).

Limitations

We realize that our measurements of absolute latencies did not take into account factors such as height, spinal cord, and/or peripheral nerve pathology that could significantly impact these parameters. While this shortcoming may not be so important for the purpose of DCM or for intraindividual comparisons (ie, posterior tibial SSEPs and gracilis SSEPs), it certainly may explain unexpected interindividual latency measurement differences of gracilis SSEPs (eg, patients 1 and 7).

We were not able to compare our DCM method against the more established ones.[2-5] This is primarily because the surgeons were satisfied with the feedback provided, which concurred with their clinical assessment, and did not consider it necessary to repeat the mapping procedure using the other techniques.

In contrast with other methods,[4] we did not achieve or attempt mapping of the Cuneate tracts. Because we were mostly concentrated on localizing the physiologic midline, and in the interest of time, we stopped after identification of the Gracilis tracts. However, we acknowledge the fact that, at the cervical levels of the spinal cord, a complete mapping of the DCs should also include localization of the Cuneate tracts.

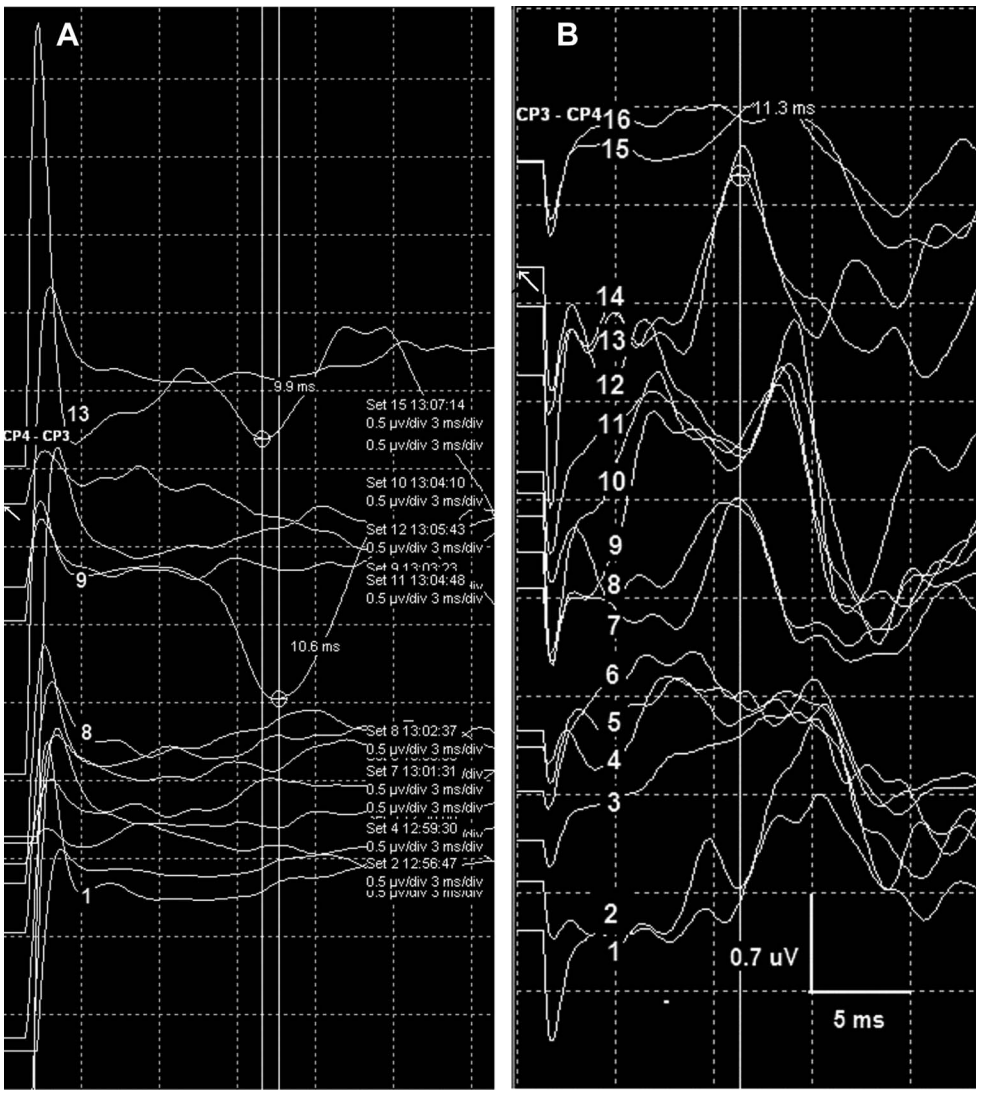

FIGURE 6. *Neurophysiologic lateralization.* **A**, *DCM in patient 1. Only the right DC can be identified, by triggering right gracilis SSEPs first at the C3 level (set 9, latency 10.6 ms) and afterward at the C2 level (set 13, latency 9.9 ms). The incision is done in an area that triggered no responses (ie, sets 1-8).* **B**, *DCM in patient 6 at C5 level. Stimulation of the right DC consistently results in robust, high-amplitude right gracilis SSEPs (upward negative deflections in CP3-CP4 channel-sets 7, 8 and 13, 14), whereas stimulation of the left DC triggers smaller amplitude, less well formed left gracilis SSEPs (positive deflections in CP3-CP4 channel-sets 1,2 and 9-12). Stimulation in between the left and right DC does not trigger reproducible SSEPs (sets 3-6 and 15, 16). A small arrow indicates the start of the stimulus. DC, dorsal column; DCM, dorsal column mapping; SSEP, somatosensory evoked potential.*

Our observational results and clinical experience with DCM call for a prospective study with the goal of a more systematic approach that will help address the above-mentioned shortcomings.

CONCLUSION

We present our experience with a new DCM method. We have found this technique to be safe, fast, and reliable, and it provides invaluable real-time feedback to the surgeon for successful resection of intramedullary tumors, thus decreasing the occurrence of postoperative deficits.

Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

The authors' technique depends upon good, localized stimulation at the spinal cord and easily identifiable and separated positive evoked potential peaks at the scalp. The stimulation will need to be at the lowest effective stimulus intensity. The site will need to be kept away from CSF to avoid current spread to the contralateral dorsal column. Occasional patient's scalp evoked potential sites will occur at or near the midline rather than laterally. That is a common physiological variant. In those patients, electrodes placed closer to the midline may be useful, eg, at scalp sites CP1 and CP2. Another fact to keep in mind is that the lower extremity somatosensory evoked potential localizes paradoxically to the "incorrect" scalp, ie, the scalp contralateral to the hemisphere generating the potential. That fact will be useful in interpreting occasional difficult cases.

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The method of lower extremity SEP phase reversal is a quick and reliable method for detection of median raphe; it may be more useful when the surgeon needs to extend myelotomy. The withdrawal of the method does not give information about upper extremity dorsal columns when it is necessary.

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