Spinal Cord Stimulators: Typical Positioning and Postsurgical Complications

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OBJECTIVE. Implantation of a spinal cord stimulator (SCS) is one option for pain control in individuals with chronic lumbosacral radicular or axial lumbar pain. The expected positioning of SCSs based on the location of pain, the types of electrodes (percutaneous vs surgical paddle), and the types of electrode arrays and the potential complications have not been described to date in the radiology literature.

MATERIALS AND METHODS. A 5-year retrospective review of the radiology information system at our institution revealed 24 patients with images of 36 SCSs. Those images were reviewed to identify the location and type of electrodes as well as the location of the lead within the spinal canal. Not all implantable pulse generators were within the radiologic field of view. Complications identified by reviewing medical records were correlated with imaging findings.

RESULTS. Fourteen different types of electrodes were identified. Most were placed in the thoracic spine only, but six thoracolumbar and two cervical spine electrodes were also present. We measured the position of the electrodes within the spinal canal on 26 CT studies of the 24 patients. On 22 of 26 CT studies, the electrodes were placed in the epidural space in the posterior one third of the spinal canal. Complications included misplaced, retained, and broken leads; puncture of the thecal sac; infection; and hematoma.

CONCLUSION. Radiologists should be familiar with the different types of electrodes and typical spinal locations of electrodes, leads, and implantable pulse generators. Improper placement of electrodes may lead to ineffective pain relief or to other complications.

Keywords: CT, CT myelography, epidural positioning, postsurgical complication, spinal cord stimulator

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Pain is described by the International Association for the Study of Pain as "an unpleasant sensory and emotional experience associated with actual or perceived tissue damage" [1]. However, pain that persists 3–6 months after an injury—that is, beyond the acute phase—or that persists after the expected healing period is considered chronic pain [2].

The spine is the primary site for most cases of chronic pain [3]. The prevalence of spinal pain at some point in one's life has been reported to be between 54% and 80% in the general population [4]. One year or more after the inciting event, chronic, persistent low back and neck pain is seen in 25–75% of patients [4]. Spinal pain is associated with significant economic, social, and health-related burdens.

Surgery often is the preferred treatment only after medical therapies, physiotherapy, and noninvasive treatments have been exhausted [5]. In fact, there is little scientific evidence about the effectiveness for surgical decompression (laminotomy, laminectomy) or fusion for the treatment of degenerative disk disease (degenerative lumbar spondylosis) compared with conservative therapies, placebo, or natural history [6].

Implantation of a spinal cord stimulator (SCS) is a well-established treatment of neuropathic spinal pain [7]. SCSs are placed in the thoracic region more frequently than in the cervical region or lumbar region and are used predominantly to treat low back and lower extremity radicular pain. SCS placement is indicated for the treatment of chronic intractable pain of the trunk or limbs including unilateral pain and bilateral pain.

The aim of our study was to show the most common locations and types of SCS electrodes. We defined the appropriate distance of the electrode from the posterior margin of the central spinal canal and identified postsurgical complications.

Materials and Methods

Institutional review board approval was obtained for this study. Informed consent was waived by the institutional review board and the study was compliant with HIPAA.

We conducted an electronic search of the radiology information system for the records of patients treated between 2004 and 2009 using the search terms "epidural stimulator," "epidural electrode," "epidural wire," and "stimulator"; we then cross-referenced the records yielded by the search to spinal studies (CT, myelography, and radiography) performed by the radiology department during the study period. This search identified 24 patients who had 26 CT studies, three of which were studies performed after myelography, and 20 radiographic examinations. However, several patients had more than one implantation or trial, which increased the number of available SCS devices to 36. One third of the patients were male (8/24) and two thirds were female (16/24). The mean age of the patients was 47 years (range, 17–81 years). The time of implantation ranged between the years of 1991 and 2009.

The indications for the CT studies included investigation of persistent or recurrent pain in 16 of the 24 patients, identification of the location of SCS hardware for explantation or reimplantation in four patients, evaluation for infection suspected because of fever ($n = 2$) or visible periimplant cellulitis ($n = 1$) in three patients, and assessment of new weakness after new diagnosis of breast cancer in one patient.

The various causes of pain recorded from the electronic medical records (EMRs) are listed in Table 1. The levels at which the leads entered the spinal canal and the levels of the implanted SCS electrodes were also recorded (Table 2). Each type of electrode and lead and the sites of the implantable pulse generators were also identified (Table 3) if available through review of the EMRs and through consultation with the neurosurgeon and pain management specialist who performed SCS implantations. Each patient's chart was retrospectively evaluated with respect to subjective pain as scored on a pain scale by the patient to correlate SCS implantation with the degree of pain relief.

Using electronic calipers, we measured the distance between the posterior wall of the bony spinal canal and the anterior wall (posterior margin of the vertebral body) to determine canal diameter. We then measured the distance from the posterior wall to the anterior margin of the electrode element. Bone window settings were manipulated to reduce artifact and optimize measurement. The CT images were also displayed and analyzed in the 3D mode to show the SCSs and electrodes to best advantage (Fig. 1C) and to investigate the location of the electrode within the bony spinal canal. In three patients, images previously obtained at myelography enabled us to see the relationship between the electrode and the dural surface of the thecal sac (Fig. 2).

TABLE 1: Causes of Pain

Causes of Pain	No. of Patients ($n = 24$)
Injury[a] or complex regional pain syndrome	6
Postlaminectomy syndrome	5
Failed back surgery syndrome	4
Chronic intractable pain as a consequence of degenerative disk disease	4
Poststroke	2
Neuromuscular scoliosis	1
Degenerative scoliosis	1
Bilateral thoracic outlet syndrome	1

[a]Injury from sports, fall in bathtub, crush, motor vehicle crash, heavy lifting.

TABLE 2: Level of Electrodes and Lead Entries According to 36 CT and Radiographic Images

SCS Electrode Implantation Level	No. of SCSs Implanted at That Level (Total, $n = 36$)	Lead Entry Level	No. of Leads Inserted at That Level (Total, $n = 36$)
Cervical	2		1
C3-4	1	C3-4	1
C5-7	1		
Thoracic	28		30
T4-5	1	T1-2	1
T6-7	2	T2-3	1
T7-8	2	T5-6	1
T8-9	5	T6-7	1
T9-10	6	T7-8	2
T9-11	3	T8-9	1
T10-11	5	T9-10	3
T10-12	1	T10-11	7
T11-12	3	T11-12	3
		T12-L1	10
Thoracolumbar and lumbar	6	Lumbar	5
T11-L1	1	L1-2	3
T12-L1	4	L2-3	2
L2	1		

Note—SCS = spinal cord stimulator.

Results

Among our study population, the most common indications for SCS implantation were complex regional pain syndrome and chronic intractable back pain after spinal surgery (Table 1). Only one patient underwent cervical implantation; in that patient, pain was due to ulnar neuropathy as a consequence of bilateral thoracic outlet syndrome.

Electrode and Lead Placement

According to the CT and radiographic images, electrode placement varied between C3 and L2 with the most common placement extending from T8 through T11 (20/36 cases, 55.6%) (Table 2). In many cases, the electrode array spanned more than one vertebral segment in the superior-inferior direction, particularly with eight-contact paddle electrodes (Fig. 2). Insertion levels of the leads into the spinal canal varied between T1 and L3 with the exception of one case with a cervical entry level at C3-4 (Fig. 2). However, the most common level of entry into the spinal canal was

TABLE 3: Contact Configurations and Electrode Placement

Case No.	Implanted Spinal Cord Stimulator			Location[a] (%)	Type of Surgical Approach
	Brand Name or Model No.	Manufacturer	No. of Contacts (Configuration)		
1	3587A	Medtronic	4	22.7	L
2	Exclaim	St. Jude Medical	6	< 33[b]	L
3	Eon	St. Jude Medical	4	13.3	Pc
4	Exclaim	St. Jude Medical	6	12	L
5	Axxess	St. Jude Medical	4	10	Pc
6	NA	Boston Scientific (Advanced Bionics)	8	16.7	L
7	3186	St. Jude Medical	8	17.3	Pc
8	NA	Medtronic	8	< 33[b]	Pc
9	Tripole	St. Jude Medical	16 (5-6-5)	48	L
10	Axxess	St. Jude Medical	4	< 33[b]	Pc
11	Exclaim	St. Jude Medical	6	< 33[b]	L
12	NA	NA	16 (8 × 2)	27.6	L
13	NA	Medtronic	8	< 33[b]	Pc
14	NA	Medtronic	16 (5-6-5)	46.3	L
15	NA	St. Jude Medical	4	31.7	Pc
16	NA	St. Jude Medical	4	31	Pc
17	Octrode	St. Jude Medical	8	< 33[b]	Pc
18	NA	NA	4	< 33[b]	Pc
19	NA	NA	8 (4 × 2)	24.1	L
20	NA	Medtronic	16 (5-6-5)	20	L
21	Artisan paddle	Boston Scientific (Advanced Bionics)	16 (8 × 2)	26.8	L
22	NA	NA	16 (8 × 2)	35.5	L
23	3587 A	Medtronic	4	40.7	L
24	NA	St. Jude Medical	16 (8 × 2)	22.2	L
25	NA	Medtronic	8 (4 × 2)	< 33[b]	L
26	NA	NA	8 (4 × 2)	18.5	Pc
27	Specify	Medtronic	8 (4 × 2)	< 33[b]	L
28	NA	Medtronic	16 (5-6-5)	< 33[b]	L
29	Specify	Medtronic	8 (4 × 2)	12.3	L
30	Exclaim	St. Jude Medical	6	33.3	L
31	NA	NA	4	12	L
32	NA	NA	16 (8 × 2)	19.8	L
33	NA	St. Jude Medical	8 (4 × 2)	19.1	Pc
34	Octrode	St. Jude Medical	16 (8 × 2)	19.5	L
35	NA	Medtronic or St. Jude Medical	4	11.3	L
36	NA	St. Jude Medical	8	17.1	L

Note—Pc = percutaneous, L = laminectomy or laminotomy, NA = not available (i.e., manufacturer could not be determined from review of either the medical records or the radiographic images).

[a]Location within the spinal canal was measured from posterior bony edge of the spinal canal / anteroposterior diameter of spinal canal.

[b]The location of the SCS devices was evaluated on radiographs. All were located within the posterior 33% of the spinal canal.

T9-L1 (23/36, 63.9%) (Table 2). Only two of the 24 patients had devices implanted at the cervical spinal level (Fig. 2).

The distance between the electrodes and the posterior bony central canal ranged from 1.3 to 10.4 mm (mean, 4 mm; SD, 2.054). All electrodes except four (11.1% [4/36]) (Figs. 3 and 4) were placed in the posterior one third of the spinal canal within the posterior epidural space (Fig. 2).

According to the CT images and clinical data, electrode placement was temporary in nine of 36 cases (25.0%) and permanent in 25 cases (69.4%); if the electrode placement was temporary or permanent was unknown

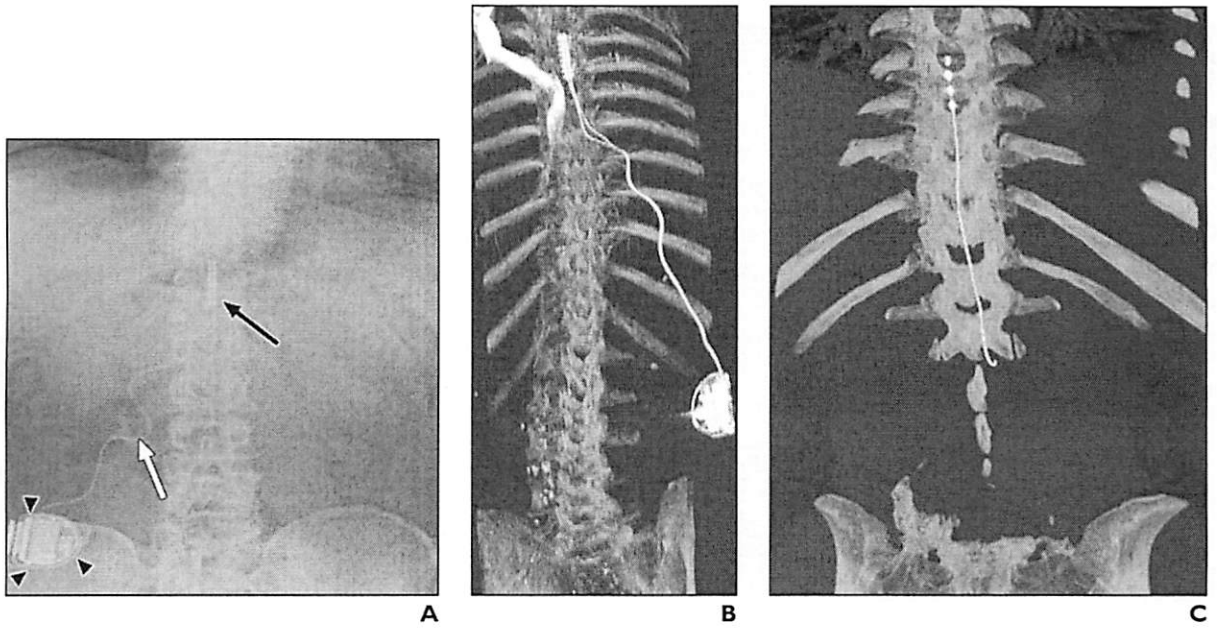

Fig. 1—Spinal cord stimulator (SCS) and its components.
A, 54-year-old man with complex regional pain syndrome due to crush injury. Anteroposterior radiograph shows 16-contact paddle electrode with 8 × 2 configuration. Components of SCS are shown: lead (*white arrow*), implantable pulse generator (*arrowheads*), and paddle electrode (*black arrow*).
B, 67-year-old man with chronic intractable pain as consequence of degenerative disk disease. Three-dimensional coronal CT bone window image shows 16-contact paddle electrode with 8 × 2 configuration.
C, 36-year-old woman with failed back surgery syndrome. Four-contact paddle electrode is shown in 3D reformatted image with its lead entering spinal canal at lumbar level but with its electrode at T8-9. Pulse generator is located out of field of view.

in the two remaining cases (5.6%) because neither the CT images nor clinical data included that information.

Implantable Pulse Generator Placement

The images showed that 15 of the 36 implantable pulse generators (41.7%) were positioned in the flank or upper buttock: Eight of 36 were implanted subcutaneously on the right side and seven of 36 on the left side (Fig. 1). The implantable pulse generators were placed in the abdomen, left paraspinal region, or out of the view of the images in 15 cases. In the six patients with temporary electrode placement, the leads were seen traveling from the epidural space to the skin and no implantable pulse generators were identified.

Electrode Configurations

Both surgical paddle electrodes and percutaneous electrodes are available for trials and implantations. In our study group, the lead most commonly used, seen in 12 of 36 cases (33.3%), contained an eight-contact paddle electrode; all were permanently implanted. The configurations of the paddle electrodes varied as single, dual (4 × 2, 8 × 2), or triple 5-6-5 parallel columns of contacts. Ten of the leads (27.8%) had a four-contact paddle (Figs. 1 and 2): Five were considered temporary and five, permanent. Four of the leads

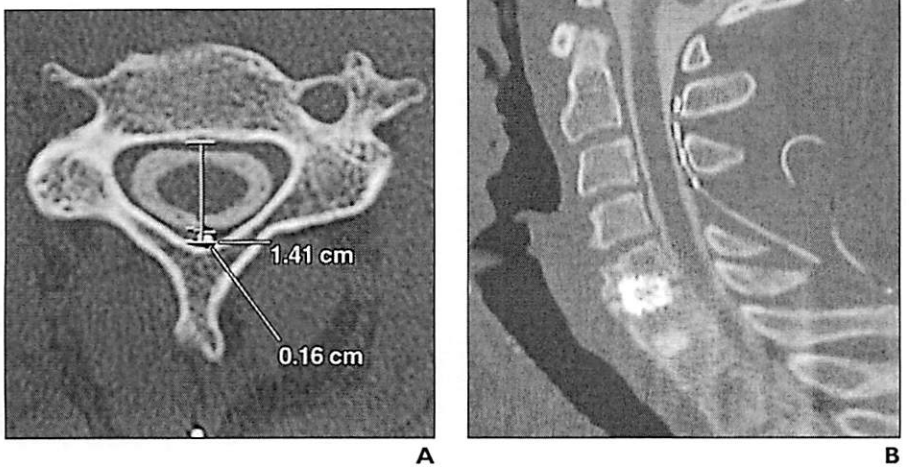

Fig. 2—73-year-old woman who injured cervical spine while lifting.
A, Posterior epidural location of this eight-contact paddle electrode is ideal, shown best on this postmyelogram CT. Overall canal diameter is 1.41 cm and electrode is located 0.16 cm from posterior margin of (bony) spinal canal.
B, Sagittal CT myelography image shows four-contact paddle electrode of spinal cord stimulator entering spinal canal via laminectomy at level of C3-4. Note prior anterior fusion of C5-7 levels.

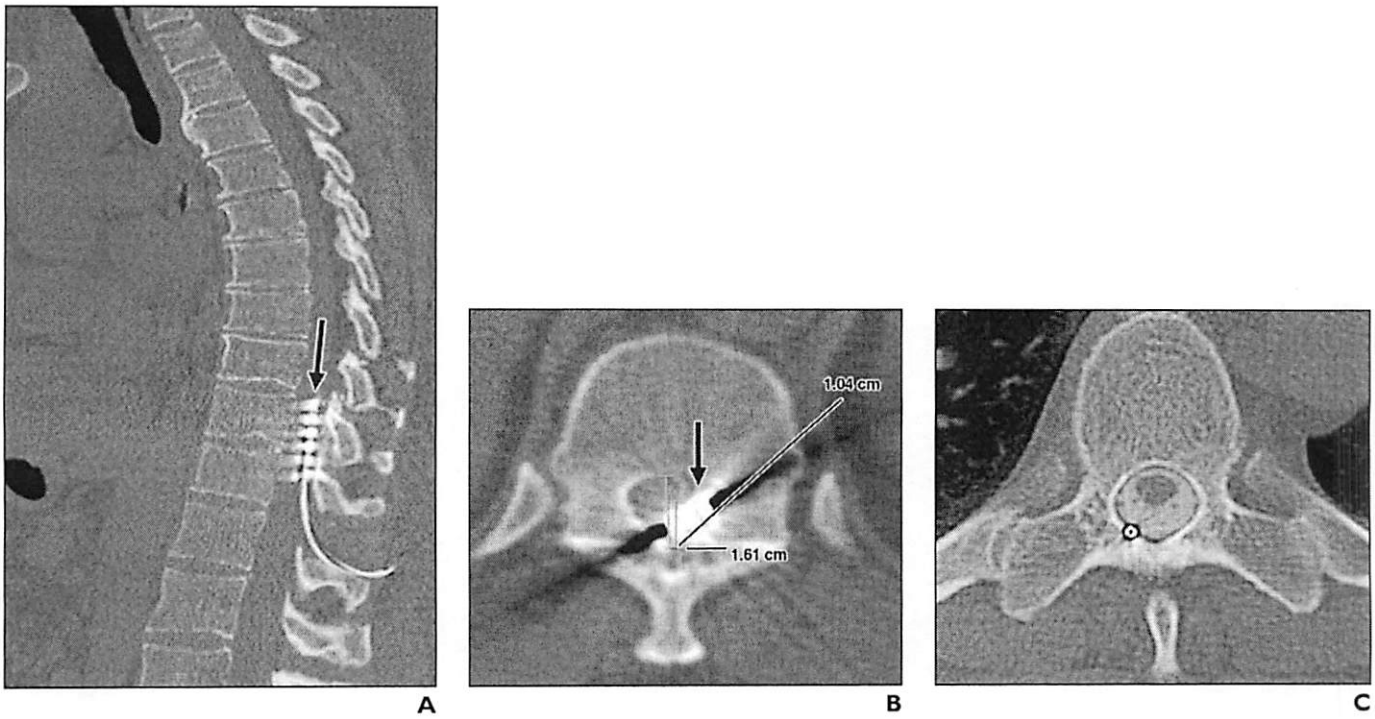

Fig. 3—Examples of improperly placed spinal cord stimulators.
A and **B**, 52-year-old woman with spinal injury due to fall in bathtub. Sagittal 2D reformatted (**A**) and axial (**B**) images show electrode (*arrow*) is placed to left of midline and is placed too far anteriorly. Potential for cord compromise may exist and should be correlated with clinical data.
C, 81-year-old woman with chronic intractable pain as consequence of degenerative disk disease. Single electrode is placed to right of midline. In patients who have unilateral or predominantly ipsilateral symptoms, this may be necessary to avoid bilateral paresthesia. Patient's clinical history and operative notes must be reviewed to confirm adequacy of placement.

(11.1%) had a six-contact paddle, all of which were permanent. All 10 of the leads with a 16-contact paddle (27.8%) (Fig. 1) were permanent. They were configured as either two columns of eight parallel contacts or three columns of 5-6-5 parallel contacts. One CT scan was excluded from the study because electrode identification was incomplete and only retained leads within the spinal canal could be seen (Fig. 5).

The manufacturers of each neuromodulation system could be determined from both the images and the operative notes in 29 of the 36 cases. Sixteen systems were manufactured by St. Jude Medical (St. Paul, MN); 11, Medtronic (Minneapolis, MN); and two, Boston Scientific (Natick, MA).

Outcomes and Complications

Review of the EMRs revealed that 17 of the 24 patients (70.8%) who underwent either a trial or a permanent implantation experienced partial pain relief (15 permanent implantations and two SCS trials) and that four (16.7%) experienced complete pain relief (three permanent implantations). One patient experienced no benefit at all from trial implantation (1/24, 4.2%). In two patients, clinical data were not available to determine analgesic benefit.

Among the four patients who were initially pain free, one developed infection at the operative site with very slow wound healing, one required bilateral T6-9 facet block for pain management, and one required replacement of an SCS 3 years after the initial permanent placement due to battery failure.

Technical complications were the most frequent type of complication (Table 4 and Fig. 4). Three of 36 electrodes (8.3%) were displaced significantly off midline to the right or left (Fig. 3B). Of these, two were permanently implanted and one was temporarily placed for a trial. The initial pain might have been lateralized to the left or right, but we were unable to clinically correlate from the EMRs whether these lateralized electrodes were implanted off midline intentionally or accidentally. Four of 36 electrodes (11.1%) were not placed in the typical posterior one third of the spinal canal (Figs. 3 and 4).

In two of the 36 studies (5.6%), a lead appeared to be curled within the thecal sac: one at the thoracic level and the other in the lumbar region. Both of these patients continued to report pain. In one of these patients, imaging did not detect paddle or percutaneous electrodes or an implantable pulse generator (Fig. 5). The other patient's lead was coiled within the spinal canal and had no associated electrode. The patient's implantable pulse generator was placed, however, in the right flank.

Seven of the 24 patients (29.2%) experienced lead migration or breakage (two fractures of the electrode and five lead migrations) (Fig. 5). During clinical follow-up, four of the 24 patients (16.7%) needed to undergo reimplantation of the SCS electrodes.

An implantable pulse generator was displaced in one patient (4.2%) and failed in two patients (8.3%). In three of the 24 patients (12.5%), the battery failed. After implantation, revision or reprogramming of the implantable pulse generator was required in six of 24 patients (25%).

After implantation, seven of 24 patients (29.2%) developed inflammatory or infectious complications. Three patients (12.5%) had inflammation or cellulitis at the implantation site. Two patients (8.3%) developed arachnoiditis or arachnoidal adhesions. Two

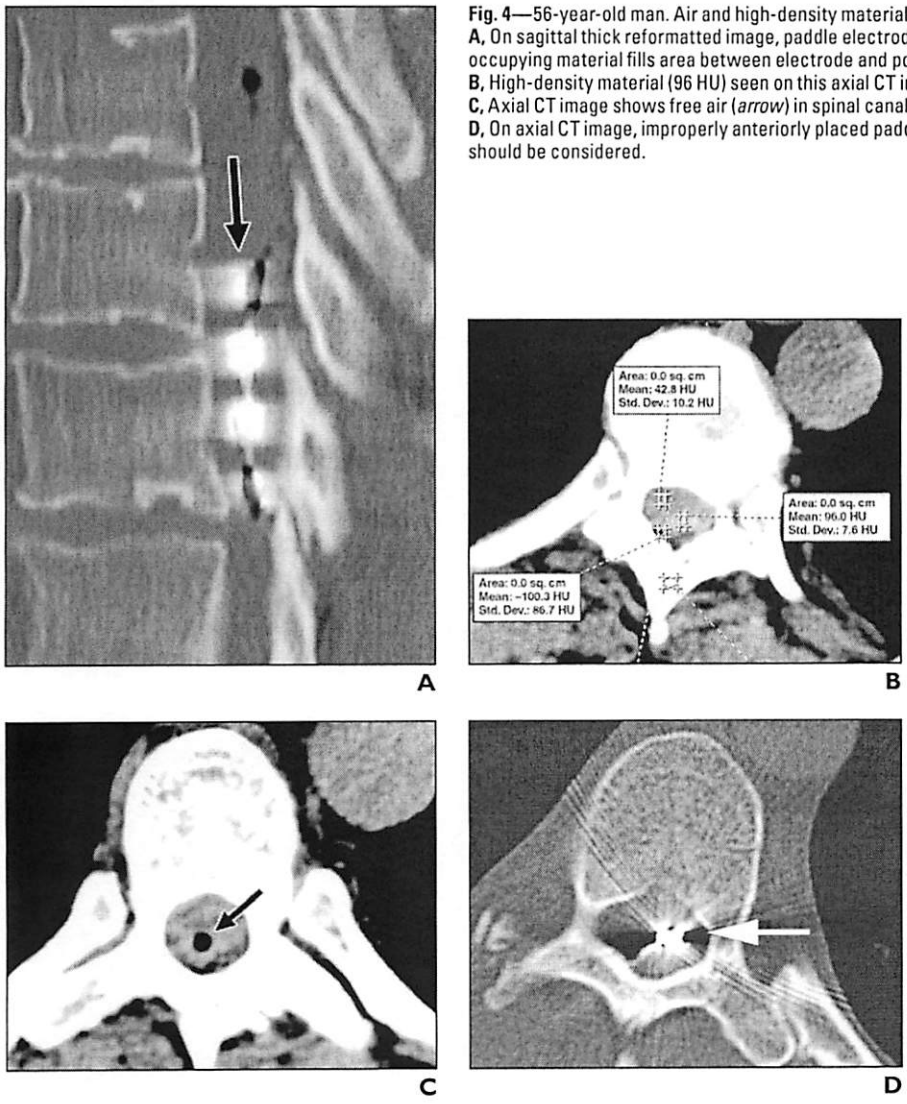

Fig. 4—56-year-old man. Air and high-density material are seen in spinal canal.
A, On sagittal thick reformatted image, paddle electrode (*arrow*) is displaced anteriorly because space-occupying material fills area between electrode and posterior epidural space.
B, High-density material (96 HU) seen on this axial CT image is compatible with hematoma.
C, Axial CT image shows free air (*arrow*) in spinal canal.
D, On axial CT image, improperly anteriorly placed paddle electrode (*arrow*) is seen. Potential cord compromise should be considered.

patients (8.3%) had fever of unknown origin after the surgery that resolved on antibiotics.

CSF leakage and failure of wound healing were the other complications seen in two of 24 patients (8.3%). Two patients (8.3%) experienced irritation and discomfort at the implantable pulse generator site after implantation that resulted in readmission to the hospital. One patient (4.2%) reported long-term incisional pain. Another patient (4.2%) experienced a local epidural hematoma immediately after implantation that subsequently required explanation (Fig. 4).

Discussion

The management of spinal pain is a significant burden on the economy because of a reported prevalence of 54–80% in the general population. Approximately 300,000 lumbar surgeries are performed in the United States per year to treat chronic lumbar pain with failure rates as high as 40% [5]. The success rate decreases significantly with each subsequent back surgery. Failed back surgery syndrome (FBSS) refers to the persistence of pain with functional limitations in patients who have undergone corrective lumbosacral spine surgery for pain relief [8, 9].

Indications for Spinal Cord Stimulator Placement and Mechanism of Action

Implantation of an SCS is not generally a first-line treatment of spinal pain. Before SCS placement is introduced as a therapeutic option, patients are typically treated with systemic medications, nerve blocks, epidural corticosteroid injections, spinal surgery, physical therapy, and even complementary or alternative therapies. Hence, clinicians reserve spinal cord stimulation for the treatment of patients with chronic, intractable pain.

An SCS device is composed of a lead (wire and its insulation between contacts), an electrode (an assembly of electrically conductive contacts and wires with insulating spacers and backing material, often referred to as the "business end" of the lead where the contacts reside to deliver current to tissue), contacts (an electrically conductive surface from which current passes into tissue), and an implantable pulse generator that connects to the lead and supplies power to the electrodes (Fig. 1). Either percutaneous electrodes or paddle electrodes may be implanted, although the latter require either a laminotomy or laminectomy for placement in the spinal canal. A "paddle" electrode refers to a flat insulated electrode.

Electrical stimulation of the posterior columns of the spinal cord underlies the basic mechanism of analgesia [10]. The mechanism highlights the well-known gate theory for segmental pain suppression. Activation of the large, coarse afferent fibers of the dorsal column inhibits transmission of nociceptive information from the targeted segmental level and most effectively suppresses neuropathic pain. Further, stimulation causes a conduction block in spinothalamic fibers. In conditions involving neuropathic pain such as sympathetically maintained complex regional pain syndrome, stimulation affects autonomic function in a way that may also contribute to the alleviation of the pain [11–15]. There is some evidence that stimulation may augment the release of substance P (increase in the extracellular level) and γ-aminobutyric acid (GABA), thereby altering neurotransmission [16, 17].

Process of Spinal Cord Stimulator Implantation

Patients undergo a trial of stimulation before permanent surgical implantation of the lead and implantable pulse generator. The trial typically consists of positioning a tempo-

TABLE 4: Complications of Spinal Cord Stimulator Implantation

Complication	% (No. With Complication / Total No.)
Technical	
Based on 36 images	
Displaced electrode significantly off midline	8.3 (3/36)
Atypical positioning of electrode[a]	11.1 (4/36)
Electrode fracture or retained material	5.6 (2/36)
Lead migration	13.9 (5/36)
Total	38.8 (14/36)
Technical	
Based on 24 EMRs	
IPG displacement	4.2 (1/24)
IPG failure	8.3 (2/24)
IPG reprogramming or revision	25 (6/24)
Battery failure	12.5 (3/24)
Total	50 (12/24)
Infectious	
Based on 24 EMRs	
Inflammation or cellulitis at implantation site	12.5 (3/24)
Arachnoditis or arachnoid adhesions	8.3 (2/24)
Fever of unknown origin	8.3 (2/24)
Total	29.1 (7/24)
Other	
Based on 24 EMRs	
CSF leakage and failure of healing	8.3 (2/24)
Irritation and discomfort at implantation site	8.3 (2/24)
Local epidural hematoma immediately after implantation	4.2 (1/24)
Long-term incisional pain	4.2 (1/24)
Total	25 (6/24)

Note—EMR = electronic medical record, IPG = implantable pulse generator.
[a]Out of posterior one third of the spinal canal.

rary percutaneous lead in the posterior epidural space adjacent to the dorsal aspect of the spinal cord at the appropriate nerve root levels (dermatomes). Zones of paresthesia are generated in the patient's painful areas from the electrical current transferred by the electrode. The evoked paresthesia can be adjusted in intensity and location to obtain the best coverage. A trial neurostimulator system includes a lead with an electrode at its distal margin, screening cable, external neurostimulator, patient programmer, and software application. Preliminary percutaneous stimulation serves as a useful diagnostic tool to aid in predicting the outcome of a permanently implanted system. In particular, the percutaneous trial is very useful in eliminating patients who would not otherwise tolerate a permanent device [18].

Clinicians generally consider at least 50% reduction in pain without intolerable side effects to represent a successful trial and to merit permanent implantation. The actual result after implantation is often less pain reduction than the trial but improved quality of life [19].

For effective treatment, proper coverage of the painful areas with stimulating zones of paresthesia is critical. However, zones of paresthesia may fail to overlap the target area because of electrode migration, growth of connective tissue encapsulating the electrode after surgery, or a change in the topography of the pain [19]. Hence, pain reduction produced by an SCS may change over time.

A permanent SCS consists of an implantable pulse generator placed subcutaneously at the level of the flank, abdomen, or upper buttock with a lead connecting the implantable pulse generator to the intraspinal electrode and contacts via laminectomy or laminotomy for surgical paddles or via percutaneous (needle) insertion for percutaneous electrode placement. Electrodes of various contact combinations may be introduced within the epidural space: paddle electrodes or percutaneous electrodes. The procedure to implant the neurostimulation system involves an incision over the spine with placement of the paddle electrode or percutaneous electrode under fluoroscopy. The lead is tunneled under the skin and connected to the implantable pulse generator. A subcutaneous pocket is formed in the abdominal-flank area or the upper buttock for implantation of the implantable pulse generator. Both midline and pocket incisions are then closed surgically. Current is supplied by the implantable pulse generator that is attached to the leads. Parameters such as pulse width, frequency, and amplitude can be adjusted in response to changes in a patient's pain or to optimize pain relief.

Complications of Spinal Cord Stimulation

Complications related to spinal cord stimulation may be technical or biologic. The literature reveals that the most frequent complications are technical and are caused by lead migration, electrode dislocation or breakage, and implantable pulse generator failure, all of which necessitate revision and reprogramming [20]. Biologic complications most frequently reported include infection, CSF leakage, and pain at the incision or electrode site, local implantable pulse generator site discomfort, inflammation, and fever of unknown origin [21]. The latter complication often leads to spinal tap to rule out meningitis. Paralysis is an infrequent (0.03%) but possible complication [21].

Electrode placement varies according to the level targeted from the superior-to-inferior direction, but the electrode should reside in the posterior one third of the spinal canal in the epidural space to achieve the most effective pain relief. If the electrode is substantially anterior to this demarcation, there may be encroachment on the spinal cord and subsequent complications. Anterior electrode displacement may be secondary to a hematoma located posteriorly or to inadvertent misplacement at the time of insertion.

A paramedian approach may be intentional if the patient's symptoms are unilateral,

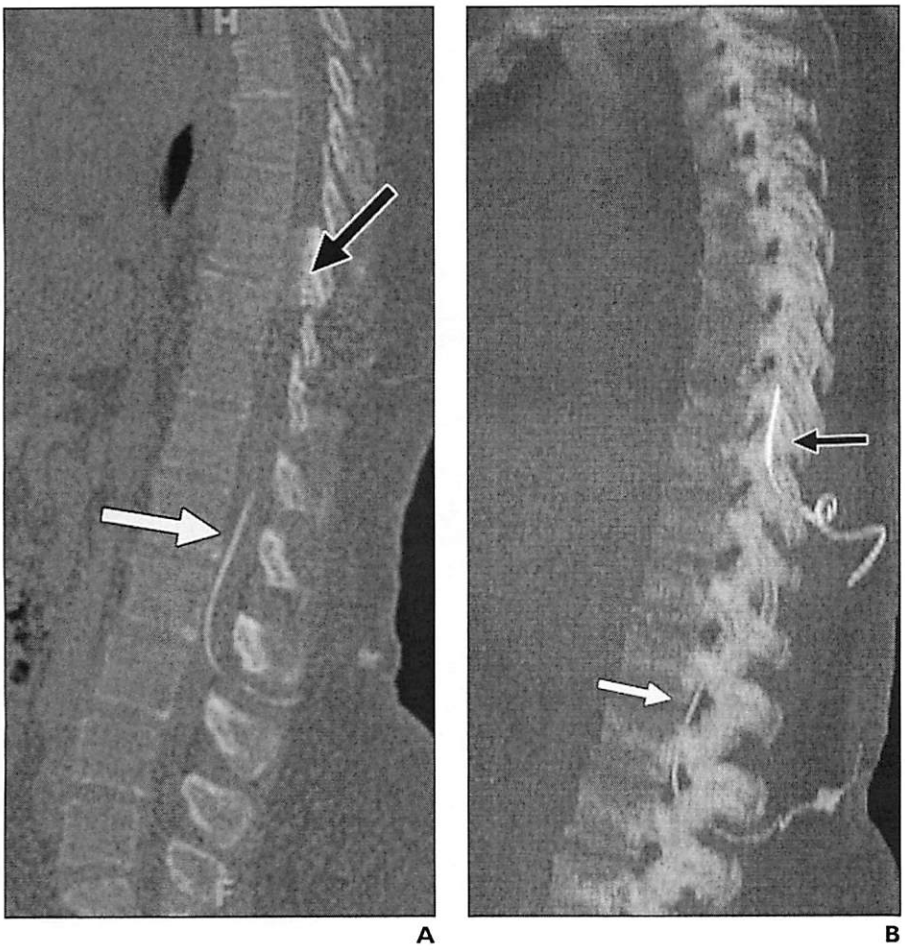

Fig. 5—Broken paddles and leads in 45-year-old woman with complex regional pain syndrome due to motor vehicle crash.
A and **B**, Sagittal reformatted (**A**) and sagittal 3D reformatted (**B**) CT images show retained and broken lead (*white arrow*) at T12-L2 level. Paddle electrode was subsequently inserted via laminectomy at T10-11 level (*black arrow*). Note two separate leads shown in **B**.

but this approach should be correlated with the clinical data and discussed with the physician implanting the device.

Broken or misplaced leads may be better detected on radiography than CT because the leads course in and out of the CT scan plane; even with 2D multiplanar reconstructed images, the leads can be difficult to detect (Fig. 5). Three-dimensional reconstructed CT images may help for this indication. For the evaluation of the electrode location, both CT and radiography have value. For instance, CT is ideally suited to identify complications such as hematomas (Fig. 4), abscesses (with IV contrast administration), impingement on the thecal sac or spinal cord, and CSF leakage (with intrathecal contrast administration). If CT is used, 3D postprocessing and multiplanar imaging are very helpful for more accurate localization and depiction of the lead, electrode, or implantable pulse generator (Fig. 1). CT myelography is indispensable for assessing the precise epidural location of the lead and electrode as well as concomitant disk abnormalities (Fig. 6).

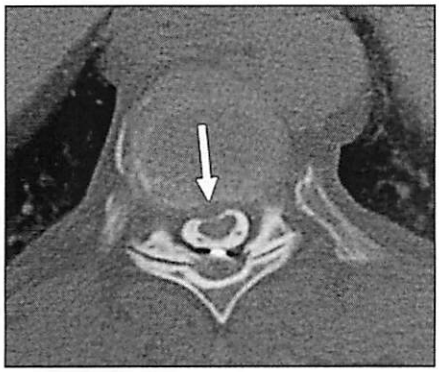

Fig. 6—72-year-old woman with postlaminectomy syndrome. Pain relief was not achieved. Please note small right paracentral disk protrusion (*arrow*) compressing thecal sac.

The high rates of complications in this study may not be representative of SCS implantations in general because of selection bias; incomplete medical records; and inadequate follow-up outside our institution, given the retrospective nature of this study. Our results were biased due to the search criteria within the radiology archive. One normally does not perform imaging if an SCS device is performing appropriately. The purpose of this study was to enlighten readers as to the various types of electrodes and leads and their typical positioning within the epidural space, not to provide incidences of complications.

Physicians who implant SCS devices typically consider spinal radiographs to verify lead–electrode position after implantation if patients report a loss of pain relief or paresthesia overlap in the affected region (e.g., suspected lead migration); the development of pain in a new location that is not covered by paresthesia; posturally induced alterations in stimulator coverage; unrelieved pain at the spinal implantation site not due to infection; and possible equipment malfunction at the spinal or generator battery site due to fracture, corrosion, insulation failure, or lead or extension conductor dislocation.

In conclusion, implantation of an SCS offers pain reduction to selected patients for whom previous methods of treating their discomfort have failed. There are many varieties of electrode–lead–implantable pulse generator combinations. The typical location of the electrode and the possible complications of SCS therapy should be familiar to radiologists who work in practice settings where this option is afforded to patients.

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