Accumulating evidence exists for a dorsomedially located pathway for pain in the human spinal cord that is separate from the spinothalamic tract and whose destruction results in visceral pain relief far beyond that predicted from midline interruption of decussating spinothalamic axons. Historically, several investigators have proposed, based on animal studies, that sensory information from viscera is conveyed by the dorsal columns to higher centers, but it has been unclear if the visceral information signaled pain. In recent experiments the authors have documented that a major pelvic visceral pain pathway ascends in the midline of the posterior columns. By using retrograde and anterograde tracer labeling, as well as electrophysiological recordings obtained from neurons in the thalamus, dorsal column nuclei, and the central visceral processing region of the spinal cord, the authors of these studies have shown that segmental primary visceral afferents activate neurons in the spinal gray matter around the central canal whose axons ascend ipsilaterally in the dorsal column. The axons from neurons in sacral segments cluster near the midline before terminating in the nucleus gracilis. Nociceptive input is then transmitted to viscerceptive neurons of the contralateral ventral posterolateral thalamus by way of the medial lemniscus.

Surgical case studies of humans in whom pain relief following limited midline myelotomy has been successful have provided corroborative evidence for the existence of a newly recognized midline posterior column pathway that mediates the perception of visceral pelvic and abdominal pain. Preliminary data indicate that significant pain relief can be obtained following PMM with minimal neurological morbidity and suggest that the procedure may provide an alternative treatment modality for cancer-related pain in patients in whom adequate pain control with narcotics cannot be achieved or narcotic side effects cannot be tolerated.

Key Words • myelotomy • cancer pain • posterior columns • pain pathway • visceral pain

Object. This study offers clinical support for the concept that neurosurgical interruption of a midline posterior column pathway by performing a punctate midline myelotomy (PMM) provides significant pain relief without causing adverse neurological sequelae in cancer patients with visceral pain refractory to other therapies.

Methods. A PMM of the posterior columns was performed in six cancer patients in whom visceral pain had been refractory to other therapies. The cause of the visceral pain was related to residual, progressive, or recurrent local cancer or postirradiation effects. Clinical efficacy of the procedure was examined by comparing patient pain ratings and narcotic usage pre- and post-PMM. Follow-up periods ranged from 3 to 31 months. Examination of the results indicates a significant reduction in pain ratings as well as a significant reduction in daily narcotic use. No adverse neurological effects were observed. One spinal cord has been recovered for postmortem examination.

Conclusions. These findings provide corroborating clinical evidence for the existence of a newly recognized midline posterior column pathway that mediates the perception of visceral pelvic and abdominal pain. Preliminary data indicate that significant pain relief can be obtained following PMM with minimal neurological morbidity and suggest that the procedure may provide an alternative treatment modality for cancer-related pain in patients in whom adequate pain control with narcotics cannot be achieved or narcotic side effects cannot be tolerated.

Abbreviations used in this paper: BPI = Brief Pain Inventory; PMM = punctate midline myelotomy.
findings have prompted a revision in our understanding of pain pathways and our approach to the management of visceral cancer pain.

This study presents clinical results obtained in six consecutive cancer patients in whom PMM was performed for the treatment of refractory visceral pain. Since our initial case report, the current series provides additional patient experience with the procedure, describes a refinement of the initial surgical technique, and provides follow-up analysis of the cases. The findings provide additional clinical evidence that ablation of the posterior column visceral pain pathway in the spinal cord offers an alternative approach for the management of visceral pelvic and lower abdominal pain.

Clinical Material and Methods

Patient Characteristics

Six adult cancer patients ranging in age from 34 to 52 years with intractable abdominal visceral pain were referred by the oncology service for neurosurgical intervention. Appropriate surgical candidates were individuals whose pain was refractory to pain relief otherwise provided by aggressive narcotic therapy or poor pain control due to intolerable narcotic side effects. In all patients there was an estimated life expectancy of greater than 3 months, a Karnofsky performance score of 40 or more, and a stable medical status suitable for surgery. The patients had diverse primary cancers, including cervical in two cases, vulvar in one, rectal in one, lung carcinoma in one, and presacral sarcoma in one case. Visceral involvement was confirmed by laparotomy or by abdominal and pelvic imaging studies. The cause of the visceral pain was related to residual, progressive, or recurrent local cancer or to postirradiation effects.

Preoperative Evaluation

The preoperative evaluation consisted of a comprehensive neurological examination, history of pain management, and current analgesic use. Patients completed a standardized battery of pain and symptom measures for baseline purposes. Ratings of pain severity (on a scale from 0–10, with 0 = no pain and 10 = pain as bad as you can imagine) were obtained using the BPI. This scale has widespread empirical support, with documented reliability and validity in the evaluation of pain in patients with cancer. The protocol was approved by the Institutional Review Board for Human Subjects and patient consent was obtained.

Postoperative Evaluation

Table 1 provides a summary of clinical characteristics, lesion site, and pain ratings. Postoperative pain ratings were obtained after narcotic use had been appropriately tapered. Subsequent monitoring of pain status was conducted by the oncology/anesthesia service as part of each patient’s routine clinic visits. Follow-up periods ranged from 3 to 31 months. In five of the six cases, patients were followed until death; the remaining patient continues to be monitored. One spinal cord was recovered for postmortem examination. The spinal cord was dissected, removed from the vertebral column, placed in buffered aldehydes for 3 weeks, and paraffin embedded. Tissue sections were cut, mounted on glass slides, and stained with Luxol fast blue and hematoxylin and eosin. Spinal cord sections and the demyelinated region in the dorsal column resulting from the PMM were drawn with the aid of a camera lucida attachment of a Zeiss microscope under low magnification.

Statistical Analyses

Statistical analyses were conducted using StatXact-3 for Windows. Wilcoxon’s signed-rank tests were performed to evaluate changes in patient ratings of pain and daily narcotic usage.

Surgical Procedure

After induction of general endotracheal anesthesia, the patient was placed prone on a radiolucent arch frame to avoid abdominal compression. A localization x-ray film was obtained to confirm the intended thoracic level (Table 1), and a laminectomy was performed at that level as well as parts of the lamina above and below. With the aid of an operating microscope (× 10–15), the dura was opened longitudinally in the midline. The arachnoid and septum posticum were incised, the midline posterior vein was identified, and posterior root entry zones were visualized bilaterally. The exact midline of the spinal cord was determined by measuring midway between the two root entry zones, because the midline posterior vein and the pial attachment of the septum posticum are known often to meander from side to side across the midline.

At the suggestion of Dr. Hirshberg, we introduced a modification to the procedure performed in the initial case report of the PMM. Specifically, in the first case we performed the procedure by using a sharp midline transverse cut made by a 16-gauge needle inserted to a depth of 5 mm. In subsequent cases, the midline tissue, extending 1 mm to each side, was crushed between the blades of fine forceps inserted to a depth of 5 mm (Fig. 1). The new approach was designed to minimize the risk of causing
bleeding within the spinal cord. Great care was taken to avoid any off-midline angulation by making certain that the patient was positioned perfectly prone and that the view angle of the operating microscope was kept parallel to the midline.

Results

Two primary outcome variables were examined: patient ratings of their worst pain as recorded on the BPI \(^9\) and daily narcotic usage. \(^1\) Baseline BPI ratings were obtained within 1 week before surgery and postoperatively after narcotic tapering. Results indicated a significant reduction in patients’ ratings of their worst pain (p = 0.03). All patients experienced a significant reduction in daily narcotic use (p = 0.03) as illustrated in Fig. 2. No adverse procedure-related neurological changes were observed. There was no evidence of sensory deficit, motor weakness, gait disturbance, or permanent sphincter dysfunction as a result of the procedure. Specific clinical features of each case are described below.

Report of Cases

Case 1

The first patient in this series, a 38-year-old woman in whom a diagnosis of cervical cancer had been made, underwent surgery and radiotherapy, but she developed severe complications of radiation enteritis. She underwent PMM for lower abdominal visceral pain \(^27\) and was followed for 31 months post-PMM. During this time, she continued to report an absence of pain in the lower abdomen, despite complications of a sacral decubitus ulcer and a fistula located between the colon and bladder that necessitated a bilateral nephrostomy and a colostomy. She described pain of the body wall (associated with the decubitus ulcer, nephrostomies, and colostomy) and later developed peritonitis, with symptoms of upper abdominal pain but none below the umbilicus. She died of sepsis.

Case 2

This patient was a 51-year-old woman with hypertension and adult-onset diabetes, in whom a diagnosis of colorectal adenocarcinoma had been made 3 years before having undergone PMM. Initial treatment consisted of radiotherapy, abdominoperineal resection, and chemotherapy for lymphangitic spread. Studies revealing extension of the disease to the pelvic wall and vagina prompted additional treatment: palliative external-beam radiation, chemotherapy, and placement of interstitial implants. She developed increasingly severe perirectal midline pain, which was poorly controlled despite high doses of oral narcotics and the use of a patient-controlled analgesia pump. In her preoperative neurological workup, baseline abnormalities included slight pinprick hypesthesia and reduced bilateral lower-extremity sensation to light touch in stocking and perirectal areas. Two days following the PMM, use of the patient-controlled analgesia pump was discontinued. Transient urinary retention was reported postoperatively; cystometric studies indicated neurogenic bladder with overflow incontinence. The patient reported satisfactory-to-excellent results at her 1-month follow-up visit, having discontinued all Schedule II narcotics and obtained adequate pain control with Vicodin. Her neurological deficits were unchanged. In the ensuing weeks, she experienced a recurrence of vulvar perineal pain associated with invasion of the disease through the superficial tissues and skin. Her 2-month postoperative neurological examination demonstrated progression with reduced vibratory sensation in both feet, decreased pinprick sensation in the posterior right leg and thigh, mild weakness of the hamstrings/foot extensors, and loss of the right Achilles tendon reflex, all presumably due to plexus involvement of her cancer. She died 9 months after having undergone PMM.

Case 3

This patient, a 49-year-old man, presented with a history of poor-to-moderately differentiated left lung adenocarcinoma 2 years before undergoing PMM. He was treated with left-sided pneumonectomy, but he developed right-sided rib pain postoperatively, which was consistent with

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metastasis, and thus he underwent palliative external-beam radiotherapy. Two months later, he noted symptoms of dizziness, ataxia, and right-sided hearing loss. Imaging studies revealed a mass in the cerebellar pontine angle. A right retromastoid craniectomy and excision of the metastasis was performed, followed by radiotherapy. Several months later, a right 10th and 11th rib metastasis was revealed, and the patient underwent additional external-beam radiotherapy. Five months later, he developed severe perianal and coccygeal pain that worsened with defecation and urination, which was inadequately controlled using massive doses of narcotic analgesics. Bone and computerized tomography scans and MR images obtained of the abdominal, pelvic, and spinal regions failed to reveal a source for the pain. A PMM was performed with continuous intraoperative somatosensory evoked potential monitoring. No adverse changes occurred, although pressure on the spinal cord at the time of the myelotomy produced a transient decrease in amplitude of the lower-extremity somatosensory evoked potentials, which returned to baseline after 30 seconds. Following PMM, his BPI scores were reduced initially, but fluctuating pain levels at discharge prompted reintroduction of a fentanyl patch, oral doses of MS Contin, and morphine elixir for breakthrough pain. The patient was placed in hospice care and died 8 months post-PMM. At autopsy, the spinal cord from this patient was removed to study the lesion site. After staining, the demyelinated region of the dorsal column resulting from the PMM was clearly evident. A composite drawing of the demyelinated portion of the dorsal column at the cervical spinal cord level rostral to the lesion site is shown in Fig. 3. The demyelinated region of the spinal cord in this patient overlaps the region where ascending axons that transmit information about visceral nociception are situated in animal studies.

Case 4

This patient, a 52-year-old woman with a history of poorly differentiated squamous cell carcinoma of probable cervical or rectal origin with metastasis, underwent subtotal resection, colostomy, and multiple courses of chemotherapy and radiotherapy. A bilateral ureteral stent was placed for the treatment of obstructive hydronephrosis. With spread of the disease, she developed chronic visceral pelvic pain, intolerable side effects, and could obtain only incomplete pain control with narcotics. A PMM was performed, which effectively relieved her pain initially, but her condition eventually worsened with increased tumor growth. She was placed in hospice care and died 5 months post-PMM.

Case 5

This patient remains the only survivor in the current series and, at 21-months post-PMM, continues to report dramatic relief of previously unbearable caudal pain. This 49-year-old man with hypertension and Type II diabetes was initially diagnosed at an outside hospital as having presacral small cell carcinoma and underwent multiple courses of chemotherapy and subsequent radiotherapy, with minimal shrinkage of the presacral mass. He developed increasingly severe rectal pain, which worsened with defecation and was resistant to medical management despite the administration of high doses of narcotic analgesics. A magnetic resonance image demonstrated an increase in the size of the presacral mass to 5 × 3 × 3 cm, but the patient was unable to undergo additional radiotherapy because of previous irradiation of the lesion. A PMM was performed, narcotic use was tapered, and the pain subsequently abated. He was able to obtain complete pain control and, for 11 months post-PMM, was without any need for narcotic medications; at this time, however, he noted a recurrence of pain. A magnetic resonance image revealed an increase in the size of the presacral mass, measuring 4 × 5 × 5 cm, located in the presacral fat and extending into the sacral canal at S-4 and through the right S-4 foramen. The patient underwent an S3–5 resection of the sacrum and coccyx, with epidural dissection of caudal nerve roots and diverting colostomy. Pathological examination of the tumor specimen revealed sarcoma invading the sacral bone with extensive necrosis. Postoperatively the patient’s recovery was complicated by bacteremia, left upper-extremity deep venous thrombosis, and a sacral wound infection. He underwent surgical debridement and local flap closure 4 months after the initial resection, and his surgical repair-related pain was managed with narcotic agents.

Case 6

This patient, a 34-year-old woman, was diagnosed as having Stage III vulvar and Stage I cervical squamous cell carcinoma, and she underwent radiotherapy, chemotherapy, and surgical resection. She developed severe, unabated lower abdominal pain, resulting in hospitalization for significant emaciation and failure of narcotic pain control. At 1-month post-PMM, she reported resolution of pain, and narcotic analgesics were discontinued. At 2-months...
Punctate midline myelotomy

![Image](image.png)

**Fig. 3.** Drawing of a formalin-fixed, paraffin-embedded spinal cord tissue section obtained postmortem from the cervical cord of the patient in Case 3. The degenerated ascending fibers above the punctate midline myelotomy site placed at T-7 were stained with Luxol fast blue, H & E, and are indicated in the drawing by the black wedge-shaped region in the dorsal column. The bar represents 1 mm.

post surgery, she was able to obtain good pain control with Ativan and required only occasional doses of Dilaudid. Progression of the disease resulted in partial bowel obstruction (ileal stricture), urinary tract infection, significant malnutrition, ascites, and death at 3 months post surgery. Her family reported that the original pain that had been refractory to narcotics had not recurred.

**Discussion**

The results of this study confirm that PMM at the level of the midthoracic spinal cord can provide significant relief of visceral pain and a reduction in the requirements for narcotic analgesic drugs in patients with cancer of visceral organs in the pelvis and lower abdomen. This procedure was based on previous observations that making a midline stereotactic lesion at the C-1 level could provide visceral pain relief over an unexpectedly wide region of the body. Placement of the lesion at the thoracic level under direct visual control was chosen in this series because the procedure was better defined and raised fewer concerns about potential respiratory or upper limb complications. A midline lesion would interrupt the visceral pain pathway that ascends from the sacral spinal cord, and any rostrocaudal level above the level of entering pain fibers should be effective. Our study was limited to pelvic and lower abdominal pain, largely because we could define the midline accurately and, hence, could target the ascending pain fibers from these regions. Studies conducted in animals have indicated that to treat visceral pain originating from more rostral organs innervated by primary afferents entering the midthoracic spinal cord, the lesion must be placed more laterally along the dorsal intermediate septi of the posterior columns.

Presumably, the lesions placed with stereotactic guidance at the C-1 level by Hitchcock interrupted the same posterior column visceral pain pathway as the commissural myelotomies performed at other levels. This would be consistent with the course of the axons mapped in anatomical studies. Both of these procedures resulted in much more widespread pain relief than could be predicted by interruption of the decussating axons of the spinthalamic tract at the level of the surgically created lesion. In this series, we avoided cases in which visceral pain originated from more rostral organs because of the unknown effectiveness and risks associated with lesion placement in the more lateral dorsal columns.

Clinically, it is axiomatic that accurate evaluation of pain recurrence is feasible only in patients with medical conditions in which relative remission or stabilization of the primary disease has been achieved. However, in our series of patients, the assessment of recurrent pain is confounded by the progressive, unrelenting nature of the disease course. The six patients in this report survived between 3 and 31 months following PMM. The original pain that was relieved by the surgical procedure did not recur within this time frame, although in some patients new or different pains developed from other sources or from progression of the original source, resulting in involvement of somatic sources and lumbosacral plexus. The posterior column lesion did not produce any persistent changes in sensation or somatic motor or autonomic function, although one patient experienced transient sensory signs and urinary retention. This observation is consistent with a previous report in which it was found that presumably incomplete surgically placed lesions of the posterior column in human subjects result in remarkably little neurological deficit.

Appropriate indications for this midline myelotomy procedure are individuals with predominantly visceral pain who are otherwise in good condition, manifest a relatively stabilized disease state, and could benefit from pain relief as a result of inadequate response to, or intolerance of, opiates. In this context, PMM has limited routine clinical applicability, but, in appropriate cases, the procedure can provide a major improvement in the patient’s remaining life.

**Conclusions**

Experience with midline myelotomy in this series of patients supports the notion that there is a posterior column sensory pathway that mediates visceral pain in humans. Further, interruption of the pathway by PMM offers an alternative for the treatment of intractable cancer pain of the pelvic region and the abdomen that is not satisfactorily relieved by opiate medication. Provided that the underlying disease is stable, visceral pain can be reduced and the analgesic medication dose lowered for up to 31 months after surgery without sensory, motor, or autonomic complications.

**References**


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