Early diagnosis and treatment of spinal epidural metastasis in breast cancer: a prospective study

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Abstract

This prospective study evaluated the usefulness of myelography in breast cancer patients who present with radiculopathy or myelopathy. A total of 124 consecutive myelograms were performed in 100 patients. Epidural metastasis (EM) was diagnosed in 67 myelograms (54%). Multiple epidural metastases were diagnosed in 15 (22%) of those, resulting in a total of 87 epidural lesions. A complete block was found in 13 EM (15%) and an incomplete block in 14 EM (16%). Clinical data could not predict the site of EM in 29 cases (33%). Fifteen asymptomatic EM were detected in myelograms with multiple EM. Plain radiographs were of no value in determining the site of EM in 29 cases (33%), including 13 cases (15%) without vertebral metastasis at the site of EM. Treatment consisted of radiotherapy (RT) with or without systemic treatment in 52 cases (80%), systemic treatment alone in 11 cases (17%) and surgery in two patients (3%). Clinical improvement was noticed in 72%, no change in 13%, and deterioration in 15%. No difference in response was noticed between RT and systemic therapy. Before treatment 21% and after treatment 15% of the patients could not walk. The one year survival was 42%. The ambulatory status at presentation was the most important prognostic factor. Examination of the spinal fluid, obtained at myelography, disclosed meningeal carcinomatosis in 9% of the patients. Imaging of the whole spinal canal with cytological examination of the spinal fluid is recommended in breast cancer patients suspected of epidural tumour with features of radiculopathy or myelopathy, irrespective of further clinical data and plain spinal radiographs.

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Spinal epidural metastases (EM) develop in approximately 5% of patients with systemic cancer.¹ These epidural lesions are a common cause of serious morbidity: at diagnosis about half of the patients have already lost the ability to walk because of compression of the spinal cord or the cauda equina and this proportion does not usually change significantly after treatment.²⁻⁶ Epidural carcinomas are usually direct extensions of vertebral metastases. Vertebral metastases occur in as much as 60% of

patients with breast cancer.^{7,8}

Since the neurological outcome and results of treatment depend primarily on the neurological status at the time of diagnosis, an early and accurate identification of epidural tumour is of major importance. This study was designed to analyse prospectively the benefit of performing myelography in any breast cancer patient who presents with symptoms or signs of radiculopathy or myelopathy irrespective of the severity of the clinical signs and the radiographic findings.

Patients and methods

This prospective study contains the myelograms, performed in breast cancer patients who presented with symptoms or signs of radiculopathy or myelopathy from December 1984 to February 1989. Plain spinal radiographs were performed before myelography. Bone scans were not performed routinely but recent bone scans were available in about half of the patients.

Myelography was performed via lumbar puncture with a 20 gauge spinal needle.⁹ We attempted to image the whole lumbosacral and thoracic, and, when possible, cervical spinal canal to determine the occurrence of additional asymptomatic EM. In the case of a complete spinal epidural block the upper border was visualized following an additional cisternal puncture. Dexamethasone was administered to a maximum of an intravenous bolus of 16 mg, followed by 4 mg four times per day. Radiotherapy (RT) ports included two vertebrae above and below the epidural tumour.

The clinical findings and the results of plain spinal radiographs were compared with the results of myelography and considered of adequate diagnostic value when they predicted the epidural lesion correctly within a margin of two vertebral bodies. Survival was analysed using the Kaplan Meier method. Survival curves were compared with the logrank test.

Results

Myelography

A total of 124 consecutive myelograms were performed in 100 patients. Myelograms were repeated because of suspected recurrent EM in 14 patients. These showed recurrent EM in six cases and EM at a new site in two cases. One hundred and eight myelograms (87%) included at least the lumbosacral and the whole thoracic spinal canal (table 1), demonstrating EM in 63

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Table 1 Spinal segments visualised by myelography

Spinal Segment	Number of myelograms	Percentage
Lumbar	7	6
Lumbar + Thoracic	91	73
Lumbar + Thoracic + Cervical	17	14
Cervical	8	6
Cervical + Thoracic	1	1
Total	124	100

instances, including 15 myelograms showing multiple EM. Sixty seven myelograms (54%) of the entire series of 124 consecutive myelograms were found positive for EM. These 67 myelograms were performed in 55 of the 100 patients, and showed a total of 87 EM. A complete or nearly complete epidural block was noticed in about one third of the myelograms showing tumours and in about the same percentage the epidural tumour extended over more than 2 vertebrae (table 2). The majority of asymptomatic EM was found in the thoracic area (fig 1). Cytological examination of the

Table 2 Characteristics of 87 epidural metastases on myelography

	Number of epidural lesions	Percentage
Complete block	13	18
Incomplete block	14	16
Extent of epidural tumour		
1 vertebra	46	53
2 vertebrae	17	20
3 vertebrae	14	16
4 vertebrae	9	10
6 vertebrae	1	1

Figure 1 Distribution of 87 asymptomatic and symptomatic spinal epidural metastases. Level L4 is involved most frequently.

CSF from cases with EM demonstrated intradural metastases as well in 3 cases. Complications related to myelography did not occur; particularly no neurological deterioration was observed after a spinal tap below an epidural block.

Characteristics of cases with and without epidural metastasis

The patient characteristics are summarised in table 3. Only four patients with EM had no evidence of bone metastases. The presenting symptoms and signs are outlined in table 4. Pain was a presenting symptom in all cases with EM. As a result of our study design almost all patients had radicular pain; we did not routinely examine breast cancer patients with back pain only. Weakness and sensory loss were present in about a half of the patients and were usually segmental as a result of radiculopathy. Bladder dysfunction was rather uncommon but in all instances caused by metastatic disease: it occurred in four patients with EM and in one patient with meningeal carcinomatosis. No significant difference was seen in presenting symptoms or signs between patients with single and those with multiple EM. There was no particular symptom or sign that convincingly predicted the presence or absence of EM.

Clinical data, plain radiographs and epidural tumour characteristics

Clinical findings predicted the site of EM correctly (within a margin of 2 vertebrae) in 58 (67%) of the 87 EM. Fifteen of the 29 EM that were not correctly anticipated were asymptomatic and occurred in twelve myelograms with multiple EM. Epidural tumour at the level of the conus medullaris (vertebra Th12) appeared to cause false localising symptoms and signs rather frequently; it caused sciatica as the only symptom in five patients mimicking an epidural lesion at the lumbosacral level. Extension of the epidural tumour beyond two vertebrae of the predicted level and psoas paresis with EM at Th10 or L5 were other causes of incorrectly predicted EM. The non-ambulatory status in patients with EM was not exclusively caused by epidural compression: two patients with EM could not walk because of serious osteolysis in the hip. Thus 12 (18%) of the 67 cases with EM were non-ambulatory due to epidural compression.

Plain spinal radiographs were of no additional localising value in 29 (33%) of the 87 epidural lesions. Spinal radiographs were normal in four cases, and showed only one metastatic lesion (however, not at the level of EM) in four other cases. Spinal radiographs showed several vertebral metastases, but not at the level of EM in five cases. Sixteen cases of clinically incorrectly predicted EM, showed diffuse vertebral metastasis. A recently performed bone scan was available in 35 of the 67 tumour positive cases. It showed abnormalities in all instances. However, in 4 cases (11%) this was not within a margin of 2 vertebrae of the EM. Usually a bone scan showed diffuse vertebral lesions.

Table 3 Patient characteristics in tumour-positive and tumour-negative myelograms

	Single Epidural Metastasis	Multiple Epidural Metastasis	No Epidural Metastasis
Number of myelograms	52	15	57
Age, median (year)	55	59	52
range	37-73	35-84	32-77
Interval primary tumour-myelogram, median (months)	52	54	60
range	5-240	30-126	3-183
Bone metastases	48	15	29
Other systemic metastases	16	7	24
No systemic metastasis	1	—	13

Treatment and outcome

Treatment was instituted in 65 of the 67 cases with EM. Treatment was not given in two seriously ill patients because of coexistent brain metastases and meningeal carcinomatosis and because of recurrence of multiple EM. The majority of the patients were treated with RT (table 5). Systemic treatment, that is, chemotherapy and/or hormonal therapy, was instituted in 11 patients as a primary and sole treatment of EM. Surgical anterior decompression of the EM with vertebral body resection and stabilisation was performed in two patients for recurrent EM after RT.

All patients who were able to walk at diagnosis were ambulatory after treatment. Four out of 14 patients became ambulatory after treatment. One of these patients became ambulatory after RT for osteolysis in the hip,

given simultaneously with treatment of the EM.

Given the small size of the various treatment groups no clear difference in efficacy was found between the various treatment modalities. Outcome was not related to the duration of neurological symptoms. Outcome was also not related to the extent of the epidural lesion or to the number of EM (fig 2). Median duration of neurological improvement or survival in patients with a complete block was 6 months (range 2-22 months) and in those with an incomplete block 4 months (range 2 weeks-31 months). Outcome was significantly affected by the pretreatment ambulatory status (fig 3): median survival of the patients who could not walk at diagnosis was 1 month versus 7 months for the ambulatory patients ($p < 0.001$). Median survival of those who remained non-ambulatory was 2 months (range 2 weeks-12 months). The four patients who became ambulatory all died in one month. Six patients got a relapse of EM; one of these patients suffered two relapses and two patients three relapses. The duration of the response to treatment of recurrent EM was not significantly different from the response to the first treatment. Two patients developed a new EM.

The majority of the patients with EM died of progressive systemic disease, whilst in a neurologically stable or improved condition. Moreover, most patients who did not respond to

Table 4 Neurological symptoms and signs in cases with and without epidural metastasis

	Single Epidural Metastasis (n = 52)		Multiple Epidural Metastasis (n = 15)		No Epidural Metastasis (n = 57)	
	Number	%	Number	%	Number	%
Pain						
Radicular pain	48	92	15	100	51	89
Back pain only	4	8	—	—	2	4
No pain	—	—	—	—	4	7
Symptoms, but no signs	5	10	3	20	14	25
Sensory loss	31	60	5	33	24	42
Weakness	22	42	6	40	27	47
Bladder dysfunction	3	6	1	7	1	2
Reflex changes	36	69	10	67	30	53
Signs of radiculopathy	47	90	14	93	54	95
Signs of myelopathy	8	15	2	13	3	5
Status at myelography						
ambulatory	41	79	12	80	52	91
not ambulatory	11	21	3	20	5	9
Duration of symptoms						
median (months)	1.5		1		1	
range	1 day-10 months		1 wk-8 months		2 days-30 months	

Table 5 Results of treatment of epidural metastasis

Mode of treatment	Improved Number	%	No change Number	%	Worse Number	%	Duration of improvement (or survival)* median (month)	Range (month)
RT alone (n = 28)	21	75	2	7	5	18	3	0.5-20
RT + chemotherapy (n = 13)	8	62	2	15	3	23	3	0.5-23
RT + hormonal therapy (n = 8)	8	100	—	—	—	—	16	1-44
RT + chemotherapy + hormone therapy (n = 3)	3	100	—	—	—	—	12	4-31
Chemotherapy alone (n = 8)	4	50	4	50	—	—	6	2-22
Hormonal therapy alone (n = 2)	1	50	1	50	—	—	13	
Chemotherapy + hormone therapy (n = 1)	1	100	—	—	—	—	18†	
Surgery (n = 2)	2	100	—	—	—	—	16†	11-22†
No treatment (n = 2)	—	—	—	—	—	—	2	
Total 67	48	72	9	13	10	15	7	0.5-44

* In case of sustained improvement until death

† Still alive

Figure 2 Survival curves of patients with single epidural metastasis (---) and with multiple epidural metastases (—).

Figure 3 Survival curves of patients who could walk (---) and of patients who could not walk before treatment (—).

treatment for their epidural tumour, died of systemic disease (table 6). As expected, patients with EM and visceral metastases had a worse outcome than those with only bone metastases (table 6). Overall median survival was 7 months and the one year survival 42%. The median time of follow up in the 13 patients who were still alive or lost to follow up was 15 months (range 3.5–31 months).

Findings in cases without epidural metastasis

Fifty seven myelograms were negative for EM. They were performed in 53 patients. Eight of these 53 patients had more than one myelography. Intervertebral disc disease was diagnosed most frequently. Meningeal carcinomatosis was diagnosed in 8 cases (14%). The median survival of the 45 patients without EM was 5 months (range 1 week–39 months).

Discussion

In this study we analysed the usefulness of myelography with CSF examination in breast cancer patients who present with radiculopathy or myelopathy. Following this approach a non-ambulatory status at diagnosis of EM was found in only 21% of the patients, which compares favourably to the figure of 40–60% mentioned in large retrospective studies.^{2–4 10} This difference, however, should be interpreted cautiously because the other studies included more aggressive primary tumours than breast cancer. Sphincter dysfunction, usually occurring later in the course of epidural compression and indicative of a poor prognosis, was noticed less often than reported by others.^{2 10–13} The possibly early diagnosis of EM in our patients is also suggested by the extent of the epidural lesions. In a retrospective study of breast cancer patients with EM,¹³ 50% of the patients with EM showed a complete block, versus 15% in this study. The site of EM in our patients may have contributed to the relatively good neurological condition at diagnosis. The lumbar area was frequently involved by epidural tumour whereas in other reports the majority of EM involve the thoracic area.^{1–3 10} Lesions below the conus medullaris may become symptomatic earlier, in comparison with lesions at the thoracic level. In a certain sense this is also suggested by our finding that asymptomatic EM was found predominantly at the thoracic level.

Two other prospective studies have been performed that analysed the relevance of myelography in relation to clinical findings and spinal radiography for early identification of EM.

Rodichok *et al* evaluated in two complementary studies^{14 15} cancer patients with back pain and vertebral metastases on plain films and also those with features of radiculopathy or myelopathy regardless of the findings on plain films. The study concerned patients with various primary tumours, including 24% with breast cancer. Epidural tumour was found in 59% of the myelograms. Similar to our findings, about 75% of the patients with myelopathy and 60% of those with radiculopathy had EM. As many as 63% of the patients with back pain and vertebral metastases but without abnormalities on neurological examination appeared to have EM. This group of patients, however, also included patients with neurological symptoms, but without signs. In our study, 36% of the patients with neurological symptoms but without signs had EM. Asymptomatic lesions were less frequently diagnosed in the study of Rodichok *et al*, that is, in 7% of their tumour-positive myelograms versus 18% in our study. The difference in myelographic procedures explains this clinically important difference: almost all our myelograms encompassed the lumbar and whole thoracic segment. As recently reported, asymptomatic EM are common and easily missed when myelography or MRI is confined to the symptomatic area.^{16 17}

Ruff and Lanska¹⁸ evaluated prospectively

Table 6 Survival and cause of death related to the systemic disease status at diagnosis* and to the neurological response to treatment in 55 patients with epidural metastasis

Survival and cause of death	Bone metastasis only (n = 41)	Bone and visceral metastasis† (n = 13)	Neurological response Improved (n = 40)	No change (n = 8)	Worse (n = 7)
Survival (months)					
median	7 months	3 months	12 months	3 months	1 month
range	0.5-44	0.5-20	0.5-44	1.5-12	0.5-13
Cause of death					
systemic disease (n = 26)	19/41	7/13	18/40	4/8	4/7
neurological‡ disease (n = 12)	8/41	4/13	7/40	2/8	3/7
complication of treatm. (n = 3)	2/41	1/13	2/40	1/8	
intercurrent disease (n = 1)	1/41			1/8	
alive (n = 10) or lost to f-up (n = 3)	11/41	1/13	13/40		

* One patient only regional lymph node metastasis.

† 12/13 bone and visceral metastasis; 1/13 only visceral metastasis.

‡ Including brain metastasis and meningeal carcinomatosis.

95 male veterans with cancer and back pain by spinal radiograms and myelograms with imaging of the entire spinal canal for the presence of epidural tumour. Most of those patients had lung cancer or prostate cancer. About 75% of the patients with myelopathy and 50% of those with radiculopathy had EM, while none of the 29 patients with only back pain had EM. Similar to our approach, myelography encompassed the entire spinal canal; 12% of EM were asymptomatic. As much as 68% of the patients with EM had a complete or nearly complete block and 51% of the patients were not ambulatory at the diagnosis of EM. These differences with our study probably reflect differences in patient populations: particularly in lung cancer epidural tumour may progress rapidly.

It is questionable whether our diagnostic approach for early detection of EM in breast cancer patients can be improved in a practical way. Evaluation by spinal CT scanning with intrathecal contrast administration or myelography has been advocated in patients with back pain only and even in asymptomatic patients with a suspect bone scan.^{19,20} This would, however, imply that invasive techniques should be performed and possibly repeated in more than a half of all breast cancer patients with metastatic disease, with the profit of diagnosing EM at an earlier stage in only a small additional number of patients. In view of this, it is noted that in a retrospective analysis of breast cancer patients who had myelography for suspected epidural tumour 54%, that is, 42 of the 78 myelograms showed EM,¹³ similar to the 54%, that is, 67 of the 127 myelograms in our prospective study.

With the introduction of MRI, however, a highly sensitive technique has become available which can visualise the entire spinal canal, the vertebrae and the paravertebral space without the use of intrathecal contrast. However, MRI has some limitations, particularly in patients with metastatic epidural disease. With the present MRI scanners imaging of the entire spinal canal can take too long for a patient with pain to remain still, resulting in an inadequate investigation.¹⁸ In areas of scoliosis, for instance due to vertebral metastasis, MRI may be unable to image an epidural lesion accu-

rately. In addition, it has as yet not been demonstrated convincingly that MRI is superior to myelography in identifying epidural lesions; particularly small EM may be better detected by myelography.²¹ However, technological advances and increasing use of paramagnetic contrast media will undoubtedly improve the usefulness of MRI in the near future. The major disadvantage of myelography is the discomfort and possibly hazardous lumbar or cervical puncture. Lumbar puncture might carry a major risk of acute neurological deterioration when performed below an epidural block.²² Myelography was well tolerated in all our patients and without subsequent deterioration. Rodichok^{14,15} and Ruff¹⁸ reported the same experience, which means that no deterioration was observed by lumbar puncture in a total of 86 prospectively evaluated myelograms with a complete or nearly complete epidural block. Also, in large retrospective studies^{2,3,13,23} no neurological deterioration was documented following lumbar puncture below an epidural lesion. It indicates that a lumbar puncture below a spinal block carries at most only a small chance of neurological deterioration.

Obtaining spinal fluid for cytological examination seems an important factor in favour of myelography, at least in breast cancer patients. Meningeal carcinomatosis is a frequent complication, particularly in breast cancer,²⁴ and has important implications for further management. In this study spinal fluid cytology was tumour positive in 11 of the 124 samples.

Whatever technique is being used to visualise EM, as much of the spinal canal as possible should be examined because of the high proportion of asymptomatic EM that might be the cause, if left unrecognised, of neurological deterioration.^{17,25} Moreover, symptomatic lesions can show false localising signs.

The outcome of patients with EM is mainly dependent on the degree of deficit before treatment and on the nature of the primary tumour.^{2,6,26} Apparently, both factors contributed to the comparatively favourable outcome of our patients. In contrast with other studies we found no relation between outcome and presence of an epidural block.²⁶ This finding, however, should be interpreted carefully

because of the presence of a complete block in only 13 of our patients.

There are two established modes of treatment for EM, namely, RT and surgery. During the last decade a number of retrospective studies reported that RT is as effective as surgery combined with RT.²⁻¹³ Comparison of treatment results, however, is difficult because of variations in the distribution of radio-sensitive and radioresistant primary tumours, differences in diagnostic methods and in prognostic factors like ambulatory status and systemic disease status. The only randomised prospective study comparing RT with surgery plus RT²⁷ did not show significant difference in outcome, but the small number of patients and the heterogeneity of the primary tumours in that study do not allow firm conclusions. Furthermore, in those comparative reports the surgical approach was a decompressive laminectomy. Since the majority (85%) of EM arise from the vertebral body and invade the epidural space anteriorly, the more recently developed anterior decompression²⁸⁻³⁰ has become the surgical method of choice, though only feasible in a selected group of patients; laminectomy as surgical treatment is usually only considered in case of posterior cord compression.³¹ Although there is by far no consensus about the mode of primary treatment in epidural tumour, it is generally agreed that EM from radiosensitive tumours like myeloma and also breast carcinoma should be treated primarily with RT, unless there is bony compression of the spinal cord. The results of RT in this study are comparable with those reported by others in breast cancer patients.^{2-10, 26}

Diagnosing EM when the patient was not in an emergency status clinically, allowed us to develop new treatment strategies: a number of patients were successfully treated with systemic therapy as the sole treatment even in the case of a complete epidural block.³² The response to systemic therapy in our study was comparable with the response to RT, whereas systemic therapy was often given for recurrent EM after RT.

In conclusion, imaging of the whole spinal canal in breast cancer patients, presenting with symptoms or signs of radiculopathy or myelopathy, irrespective of the severity of the clinical signs and the results of plain spinal radiographs, reveals EM in more than 50% of the patients and also asymptomatic EM in a substantial number of patients. Spinal fluid examination disclosed meningeal carcinomatosis in 9% of our patients.

Finally, systemic therapy appears a valuable new mode of treatment for EM from breast cancer and can be important particularly in recurrence after RT.

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- Barron KD, Hirano A, Araki S, Terry RD. Experiences with metastatic neoplasms involving the spinal cord. *Neurology* 1959;9:91-106.
- Gilbert RW, Kim JH, Posner JB. Epidural spinal cord compression from metastatic tumor: Diagnosis and treatment. *Ann Neurol* 1978;3:40-51.
- Livingston KE, Perrin RC. The neurosurgical cord and cauda equina compression. *J Neurosurg* 1978;49:839-43.
- Constans JP, De Divitiis E, Donzelli R, Spaziant R, Meder JF, Haye C. Spinal metastases with neurological manifestations. Review of 600 cases. *J Neurosurg* 1983;59:111-118.
- Dunn RC, Kelly WA, Wohns RNW, Howe JF. Spinal epidural neoplasia. A 15 year review of the results of surgical therapy. *J Neurosurg* 1980;52:47-51.
- Sorensen PS, Borgesen SE, Rohde K, et al. Metastatic epidural spinal cord compression: Results of treatment and survival. *Cancer* 1990;65:1502-8.
- Fornasier VL, Horne JG. Metastases to the vertebral column. *Cancer* 1975;36:590-4.
- Viadana E, Bross LDJ, Pickren JW. An autopsy study of some routes of dissemination of cancer of the breast. *Br J Cancer* 1973;27:336-40.
- Kelly WM, Badami P, Dillon W. Epidural block: myelographic evaluation with a single-puncture technique using metrizamide. *Radiology* 1984;151:417-419.
- Stark RJ, Henson RA, Evans JW. Spinal metastases a retrospective survey from a general hospital. *Brain* 1982;105:189-213.
- Black P. Spinal metastasis: Current status and recommended guidelines for management. *Neurosurgery* 1979;5:726-46.
- Greenberg HS, Kim JH, Posner JB. Epidural spinal cord compression from metastatic tumor: Results with a new treatment protocol. *Ann Neurol* 1980;8:361-6.
- Harrison KM, Muss HB, Ball MR, McWhorter M, Case M. Spinal cord compression in breast cancer. *Cancer* 1985;55:2839-44.
- Rodichok LD, Harper GR, Ruckdeschel JC, et al. Early diagnosis of spinal epidural metastases. *Am J Med* 1981;70:1181-8.
- Rodichok LD, Ruckdeschel JC, Harper GR, et al. Early detection and treatment of spinal metastases the role of myelography. *Ann Neurol* 1986;20:696-702.
- Van der Sande JJ, Kröger R, Boogerd W. Multiple spinal epidural metastases; an unexpectedly frequent finding. *J Neurol Neurosurg Psychiatry* 1990;53:1001-3.
- Bonner JA, Lichter AS. A caution about the use of MRI to diagnose spinal cord compression. *N Engl J Med* 1990;322:556-7.
- Ruff RL, Lanska DJ. Epidural metastases in prospectively evaluated veterans with cancer and back pain. *Cancer* 1989;63:2234-41.
- O'Rourke T, George CB, Redmond J, et al. Spinal computed tomography and computed tomographic metrizamide myelography in the early diagnosis of metastatic disease. *J Clin Oncol* 1986;4:576-83.
- Redmond J, Friedl K, Cornett P, Stone M, O'Rourke T, George CB. Clinical usefulness of an algorithm for early diagnosis of spinal metastatic disease. *J Clin Oncol* 1988;6:154-7.
- Hagenau C, Grosh W, Currie M, Wiley KRG. Comparison of spinal magnetic resonance imaging and myelography in cancer patients. *J Clin Oncol* 1987;5:1663-9.
- Hollis P, Malis LI, Zappulla RA. Neurological deterioration after lumbar puncture below complete spinal subarachnoid block. *J Neurosurg* 1986;64:253-6.
- Bernat JL, Greenberg ER, Barrett J. Suspected epidural compression of the spinal cord and cauda equina by metastatic carcinoma: Clinical diagnosis and survival. *Cancer* 1983;51:1953-7.
- Yap HY, Yap BS, Tashima CK, Distefano A, Blumenschein GR. Meningeal carcinomatosis in breast cancer. *Cancer* 1978;42:283-6.
- Loeffler JS, Glicksman AS, Tefft M, Gelch M. Treatment of spinal cord compression: a retrospective study. *Med Pediatr Oncol* 1983;11:347-51.
- Maranzano E, Latini P, Checcaglini F, et al. Radiation therapy in metastatic spinal cord compression. *Cancer* 1991;67:1311-17.
- Young RF, Post EM, King GA. Treatment of spinal epidural metastasis. Randomized prospective comparison of laminectomy and radiotherapy. *J Neurosurg* 1980;53:741-8.
- Harrington KD. Anterior cord decompression and spinal stabilization for patients with metastatic lesions of the spine. *J Neurosurg* 1984;61:107-117.
- Sundaresan N, Galicich JH, Bains MS, et al. Vertebral body resection in the treatment of cancer involving the spine. *Cancer* 1984;53:1393-6.
- Fidler MW. Anterior decompression and stabilisation of metastatic spinal fractures. *J Bone Joint Surg* 1986;68:83-90.
- Siegel T, Siegel T. Surgical decompression of anterior and posterior malignant epidural tumors compressing the spinal cord: a prospective study. *Neurosurgery* 1985;17:424-31.
- Boogerd W, Van der Sande JJ, Kröger R, Bruning PF, Somers R. Effective systemic therapy for spinal epidural metastases from breast carcinoma. *Eur J Canc Clin Oncol* 1989;25:149-53.