

# The Correspondence Between Magnetic Resonance Images and the Clinical and Intraoperative Status of Patients with Spinal Tumors

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**Abstract: Introduction:** Surgical treatment of tumors, particularly metastases to the spine, has become increasingly common owing to the progress in anesthesiology and spinal surgery and greater detectability. The patients qualified for surgeries are those with mechanical pain, fracture or at risk of vertebral fracture or neurological complications. The basis for qualification for different types of surgeries is clinical and imaging examination, particularly MRI and CT. Qualification should always be multidisciplinary and requires understanding and knowledge of its most essential aspects. When carrying out imaging examinations, it is necessary to assess the size and the type of the tumor, taking into account of differential diagnosis. One should also consider the factors indicating spinal instability or the onset of neurological deficits. The criteria developed by Kostiuk-Weinstain and Taneichi are used for that purpose.

The aim of the present study was to evaluate the correspondence between the most essential elements of clinical and MRI examination of the spine and the intraoperative status of patients with spinal tumors.

**Materials and Methods:** We carried out prospective examination assessing the correspondence between the clinical status and MR images and the intraoperative spine. We introduced algorithm to describe the morphology of neoplastic lesions within the spine.

**Results:** The information obtained from the clinical examination and the intraoperative status of the spine corresponded with the MRI examination with the exception of the assessment of neoplastic infiltration to soft tissues, dura mater and nerve roots. It was also found that there are no clear-cut MRI features allowing differentiation of metastatic lesions from primary tumors and osteitis. Furthermore, MRI examination does not allow for the assessment of the quality of bone tissue in the vicinity of the tumor.

**Keywords:** Magnetic resonance, qualification for spinal surgery, spinal metastases, spine tumors, surgical treatment of the spine.

## BACKGROUND

Primary bone tumors are rare, accounting for approximately 4,2% of all the spinal tumors. Osteomas, cartilaginous exostoses, eosinophilic granuloma and chondromas are most frequent. Amongst primary malignant bone, osteosarcomas, chondrosarcomas and chordomas are most often identified [1, 2].

Spinal metastases occur much more frequently. They account for approximately 96% of all the spinal tumors and it is estimated that they occur in nearly 30% of patients with malignant neoplasms. 60% of all the bone metastases are localized in the spine [3, 4].

The increasing detection of tumors, spinal metastases in particular, result from the increase in the number of people coming down with neoplastic diseases. More and more successful methods of oncological treatment result in the prolonged survival of patients, but on the other hand, they carry

the risk of developing complications such as bone metastases, particularly spinal metastases. The most common site of metastases is the thoracic and lumbar spine, less commonly - cervical spine. The occurrence of metastases is particularly frequent in patients with myeloma, breast cancer, lung cancer, prostate cancer and kidney cancer. Usually, they are multifocal; in 6-32% of cases they are the first symptom of neoplastic disease and in such instance they should be differentiated from primary bone tumors, metabolic and infectious diseases and osteoporosis [5-7].

The treatment should prevent the risk of possible neurological complications, reduce pain and improve the quality of life [8].

Radiotherapy proves successful in fighting somatic pain but fails in the patients with mechanical pain caused by fractures and spinal instability. It does not prevent nervous structures compression and neurological complications in patients [1, 2].

All the patients with spinal instability, vertebral fracture or those at risk of vertebral fracture and developing or worsening neurological complications should be qualified for surgery [9, 10].

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Progress in spinal surgery is possible because of the development of anesthesiology, orthopedics, and diagnostic imaging. The problem of early detection of spinal tumors and differential diagnosis is therefore becoming more and more present-day. It is crucial for the diagnosticians and clinicians to closely co-operate, also when planning the treatment, and share experience [11, 12].

Multidisciplinary, case-by-case approach allows for most reasonable decisions concerning therapy and good treatment outcome. Standard radiograms are not sufficient for the precise assessment of the stage of neoplastic disease, the size of the tumor and its form. Approximately 50% of trabecular bone must be lost for a vertebral lesion to be evident on a plain radiograph. Often, clear visualizing of the passageway between the skull and neck and of the lower cervical vertebrae, upper thoracic vertebrae and sacral bone is not possible. Complex anatomy of the spine does not allow for sufficient visualizing of articular processes, vertebral arch and vertebral canal. Minor fractures may also not be visible [1, 2, 13, 14].

Computed tomography enables the assessment of bone quality, occurrence of fractures, periostenic reactions and the width of the vertebral canal. It is an aid in differentiating benign lesions from malignant lesions and in differentiating primary sarcomas from metastatic lesions [15, 16].

Magnetic resonance makes it easier to evaluate tumor extension and infiltration in the adherent tissues, particularly vessels and nerves. It allows to assess the radicality of the treatment, to monitor the patient and to early detect local recurrences [17, 18].

## MATERIALS AND METHODS

Our objective was the prospective examination of the correspondence between the clinical status of patients and the MR images of spinal metastases and the intraoperative status.

Between 2012 and 2014, at the Department of Orthopaedic Oncology in Brzozów, a total of 382 patients with spinal tumors were treated, of whom 325 underwent surgery.

We analyzed the medical records, results of orthopaedic and neurological examinations and MRI scans. The analysis also covered the records of surgical procedures with account being taken of the information on the morphology of metastasis, the condition of bone tissue, spinal stability, the size of the tumor, its localization in relation to paraspinal structures and infiltration to soft tissues.

At the time of diagnosis and treatment planning, all the patients had computer tomography and magnetic resonance. In 75% of cases, the examinations were conducted in the Radiology Department in Brzozów. The remaining 25% of examinations carried out outside our hospital were re-analyzed by radiologists. Together with orthopedists, radiologists introduced algorithm for MRI interpretation, considering information crucial for the process of treatment and assessed in the examination (MRI imaging algorithm).

MRI examinations were performed on 3.0-T MRI machines (Philips Medical Systems). The assessment of the tumors was made using the following sequences: SE spin-echo, IR inversion recovery, STIR short time inversion recovery, GRE gradient echo and T1 – weighted and T2 – weighted with fat-suppression.

The described above examination did not include the assessment of spinal axis disorders, the size of the lesions in the vertebrae and the morphology of the spinal cord. Spinal stability evaluation was made on the basis of a modified Kostiuk-Weinstain scale and the criteria of Taneichi *et al.* [10]. The original Kostiuk-Weinstain scale is based on the lateral radiogram of the spine and CT transverse cross-section. The same criteria of stability were applied for MRI. The vertebra was divided into 6 zones, 4 of which covered the vertebral body and the remaining 2 - posterior elements with inter-process joints. Involvement of two or more zones

## MR IMAGING ALGORITHM

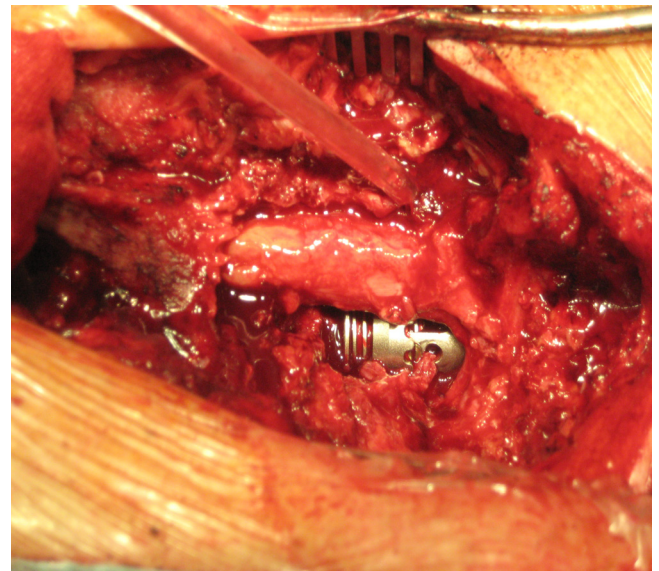
1. Localization and number of lesions in the spine.
2. Spinal axis disorder.
3. Size and localization of lesions in vertebra (body, arches and posterior elements)
4. Character of bone deterioration (lytic, sclerotic, mixed).
5. Infiltration into paraspinal soft tissues (vertebral canal, meninges, spinal cord, nerve roots, tissues, and organs of neck, mediastinum and retroperitoneal space).
6. Width of spinal canal, liguid reserve, stenosis
7. Morphology of spinal cord (demyelination, oedema, ischemia, mechanical damage).
8. Spinal stability (according to the criteria of Taneichi and Kostiuk-Weinstain).
9. Occurrence of vertebral fractures.
10. Elements of differential diagnosis (contrast intensification, specific features of some tumors and lesions).
11. Quality of bone tissue in the adjacent vertebrae.

**Table 1. Etiology of spinal tumors in non-diagnosed patients (38) based on MRI and histopathological examination.**

	MRI	HISTOPATHOLOGICAL EXAMINATION
Metastasis	29	30
Bacterial inflammation	7	-
Tuberculous inflammation	2	-
Osteoid osteoma	-	2
Angiomas	-	3
Aneurysmal cysts	-	2
Eosinophilic granuloma	-	1



**Fig. (1).** Sagittal cross-section through a tumor of second thoracic vertebra on MRI. The tumor is seen destroying the entire vertebral body and infiltrating dura mater.



**Fig. (2).** A photograph of the vertebral body prosthesis after its placement at the site of the removed tumor and vertebral body of Th2. Intraoperative image not confirmed infiltrating dura mater.

gives an indication of instability, as in the case of wedging greater than 20 degrees in a lateral projection.

According to Taneichi et al, in the thoracic spine (Th1-10), the involvement of 50-60% of the vertebral body with no other damage or the involvement of 25-30% of the vertebral body together with costotransverse joint indicate instability of the segment. In the lower thoracic and lumbar section (Th11-L5), the involvement of 35-40% of the vertebral body or of 20-25% of the body together with the posterior elements of the spine is indicative enough to diagnose spinal instability [19].

Statistical researches were conducted by comparing the differences between the two structural indicators using one-tailed and two-tailed tests. STATISTICA 10.0. program was used for the calculations.

**RESULTS**

The majority of the treated patients were women (202), representing 62% of patients. The mean age was 63 for women, and 68 for men.

In a cohort of 325 operated patients, the majority were patients with metastases from diagnosed and treated malignant neoplasms (287) 88%. Amongst neoplasms, breast cancer dominated-94 cases (29%), followed by prostate cancer -26 cases (8%), multiple myeloma- 39 cases (12%); lung cancer- 29 cases (9%); kidney cancer- 9 cases (6%); lymphoma- 10 cases (3%), thyroid cancer- 10 cases (3%); cancer of unknown primary site- 38 cases (12%), other uncommon neoplasms- 55 cases (17%).

Non- diagnosed patients, in whom spinal tumor was the first sign of neoplastic disease, accounted for 12% (38 patients). In this group, MRI raised a suspicion of neoplastic and metastatic background in 29 patients. Infectious lesions (7 non-specific and 2 tuberculous) were suspected in 9 cases due to the involvement of two or more adjacent vertebrae with intervertebral disc destruction. Each time, the macroscopic image of the resected tumors initially confirmed their neoplastic character. In this group of patients, postoperative histopathological examination showed 8 primary benign neoplasms, including: 2 cases of osteoid osteoma, 3 angiomas, 2 aneurysmal cysts, and 1 eosinophilic granuloma (Table 1).

**Table 2. Incidence of the clinical and MRI features indicating damage to nervous structures and the intraoperative status (325 patients).**

Neurogenic Pain	110	34%
Neurological deficits	88	27%
Spinal canal stenosis on MRI	127	39%
Infiltration into the dura mater on MRI	36	11%
Infiltration into the dura matter noted intraoperatively.	2	0,6%

**Table 3. Incidence of spinal instability features in clinical examination and MRI examination (325 patients).**

	Number of Patients	Percents
Pain of mechanical type	201	62%
Clinical instability	263	80%
Pathological fracture	287	88%
Instability on MRI according to Kostiuk	309	95%
Instability on MRI according to Taneichi	279	86%

The remaining cases turned out to be cancer metastases. Intervertebral disc destruction particularly often concerned young patients with breast cancer, myeloma and the cases of lymphomas.

Neurogenic pain was observed in 34% of patients, most frequently of the type of ischialgia or femoralgia. Somatic night pain affected 42% of patients. The predominant symptom was the pain associated with the instability of the spine 62%. Often, various types of pain coexisted.

The preoperative neurological examination found neurological deficits in 88 persons (27%). Complete paralysis of lower limbs, diagnosed in 24 (7%) patients, was classified as Frankel A. Deep pareses were detected in 37 (11%) patients and classified as Frankel grade B, while in 17 patients (5%) as Frankel C. Minor pareses (Frankel grade D) occurred in 10 (3%) patients. Our study did not encompass patients with quadriplegia.

Imaging examinations found absolute spinal canal stenosis in 39% of patients and infiltration into the dura mater in 11% of patients (Table 2). In the latter group, no actual infiltration into the dura mater but their close adherence was observed at surgeries (Fig. 1). The tumor could be easily dissected from the spinal canal structures that were not neoplastically transformed (Fig. 2). The actual infiltration into both the dura mater and the spinal canal was found intraoperatively in two patients. In some patients, despite the visible on imaging significant stenosis of the spinal canal, no clinical signs of nervous structure compression were observed. Infiltration into the pleura was diagnosed in 7% of patients and infiltration into the aorta in 3% of them, which was also not confirmed during the surgery.

In 57% of cases metastases were localized exclusively in the thoracic spine, 22% in lumbar and in 3% in cervical spine. In 18% of patients metastatic lesions involved more than

one section of the spine. In 22% of cases, they involved two vertebrae, and in 40% of cases, they were multisegmental. Metastatic lesions localized in 1 vertebra only concerned 38% of cases. The most common sites of the lesions were anterior elements of the spine (63% of patients). The involvement of both posterior and anterior elements concerned 32% of patients, and in 5% of cases the lesions involved exclusively posterior elements of the spine.

Most neoplastic lesions (76%) were osteolytic in nature, 19% of them were of mixed nature, and 5% were sclerotic. The intraoperative evaluation of the location and morphology of the metastasis was compatible with magnetic resonance imaging.

Despite the normal signal intensity of the vertebral bones adherent to the vertebrae involved by the neoplasm, bone decalcification symptoms of various severity were observed intraoperatively.

The screws inserted through the pedicles were anchored almost exclusively in the arches, and screwing them into the vertebral bodies required less force than in patients operated due to traumatic fractures. Each stabilization involved minimum two segments above and below the damage. When resecting vertebral bodies, particularly great effort was put into careful removal of discs due to the end plates' greater susceptibility to mechanical damage than in patients with injuries. Wide-based prostheses were implanted to minimize the risk of their settling into the vertebral bodies.

88% of patients were diagnosed with pathological fractures, while in 12% of cases metastatic lesions did not result in fracture. The spine instability, evaluated in accordance with the Kostiuk's scale, was diagnosed in 95% of patients, and in 86% of patients it was based on Taneichi (Table 3).

Symptomatic instability (visible in clinical examination), most commonly concerning patients with damage to the mo-

**Table 4.** Evaluation of vertebral instability features in different segments. The number of patients with metastases involving just one particular segment accounted for 263.

	Number of patients with metastases	Clinical instability	Instability at MR imaging in accordance with Kostiuik's scale.	Instability at MR imaging in accordance with Taneichi scale.
Cervical section	10	10	10	10
Thoracic section	182	39	173	157
Lumbar section	71	64	67	61

bile sections of the spine: cervical, lumbar, and in the cervicothoracic and the thoracolumbar junctions (80% of cases). Despite the radiological signs of instability in the thoracic section, the patients often did not experience any pain. This is because of the additional stabilization of the spine with bone architecture of the chest. The intraoperative evaluation of spinal stability was based on the assessment of the mobility of segments towards each other and was consistent with radiological evaluation (Table 4).

The comparison of the clinical detection of spinal instability (80,92%) with MR imaging method by Kostiuik (94, 77%) shows statistically significant difference at  $p=0,0000$ . No essential difference between the results of clinical examination (80,92%) and the Taneichi assessment method (85,85%) -  $p=0,1226$  for a one-sided test and  $p=0,0613$  for a two-sided test was found.

The assessment of the results of spinal stability examination in different sections did not demonstrate any significant differences between the cervical section (identical 100% detectability of all three methods) and the lumbar section. In the lumbar section, the clinical examination and the examinations using Kostiuik and Taneichi scales demonstrated detectability of 90,14%, 94,37% and 85,92%, respectively. The observed differences in detectability were of no statistical importance. Significant differences were noted in the thoracic section. The percentage of patients diagnosed clinically and using the Kostiuik's and the Taneichi methods accounted for 21,53%, 95,05% and 86,26%, respectively. Detectability in clinical examination was significantly lower when compared to MRI ( $p=0,000$ ). The comparison of the detectability of spinal instability in MR imaging and using Kostiuik and Taneichi scales suggests higher effectiveness of the first method in a one-sided test ( $p=0,028$ ) and a lack of significant differences in a two-sided test ( $p=0,056$ ).

## DISCUSSION

Spinal metastases are always symptomatic of advanced cancer, but they also happen to be its first sign. In such instance, they require differentiation from primary bone lesions, infections and metabolic disorders. According to Rougraff, the detectability of primary tumor site is successful in only 50-58% of patients [17].

Differential diagnosis of the lesions within the spine using MRI is burdened with numerous imperfections. Infectious lesions, spondyloarthroses and metabolic diseases, particularly hyperparathyroidism, may be mistaken for a neoplasm on MR imaging. Paget's disease is also difficult to

differentiate from bone tumors. According to Kamholtz's assessment, MRI has 98,5% accuracy and 98,9% specificity for detecting bone metastases [15]. Sundariam has demonstrated a lack of the link between the results of MRI and the results of histopathological examinations of bone tumors [17]. Benign bone tumors most frequently display some distinguishing characteristics allowing for their easy differentiation when localized in the long bones, which is not that easy in the region of the spine due to its difficult anatomical architecture. Primary bone malignancies are most commonly localized in one place only, very scarcely are they diffused. Most often, large soft-tissue tumor is copresent with periosteal reactions, particularly clearly visible on CT. Metastatic bone tumors are most commonly multilocal. They cause lytic bone destruction (with the exception of prostate cancer) but no periosteal reactions. The differentiation between benign and metastatic tumors is facilitated by a 'bull's eye' sign indicating benign tumor and a 'halo' sign raising suspicion of a metastasis [20]. Hanna compared the MRI results suggesting bone tumor and the histopathology results in 21 patients. Only 7 of 21 patients were diagnosed with cancer. In 14 patients the possibility of neoplastic process was ruled out [21]. Differential diagnosis is facilitated by bone scintigraphy and PET. Scintigraphy is particularly recommended for patients with contraindications for MRI and for patients with thyroid cancer in whom iodine scintigraphy can be performed [22]. Kosuda proves in his studies that MRI most clearly visualize the lesions located in vertebral bodies, while SPECT in the posterior elements of the vertebrae [23].

A lot of controversy arises as to determining indications for surgical treatment of spinal metastases. The clinical features of spinal instability and mechanical pain are indications for detailed CT and MRI examinations. Image examinations allow for precise assessment of the location, number and morphology of the tumors. They visualize pathological fractures and enable to evaluate the risk of their occurrence. They show the quality of the bones, the occurrence of tumor in soft tissues and infiltration to the important structures surrounding the spine. They allow for the assessment of the width of the spinal canal and of the risk of neurological complications. The localization of tumors in the thoracic section and the involvement of the vertebral pedicle is particularly dangerous [24, 25]. In the studies conducted by Khaw, 97% of spinal metastases involved more than half of the vertebral body. In 87,5% of cases the fracture occurred in the anterior elements of the vertebrae. In 43% of patients, dura mater compression, most frequently three-sided, (47%) was noted [22].

Our study shows clear differences between the incidence of the features of tumor infiltration into the dura mater on MRI and its actual infiltration observed at surgery. It was only in two cases that the infiltration into the dura mater was confirmed, in the remaining cases the dura mater was compressed by the tumor. MRI 'draped curtain' sign suggests infiltration of the tumor into anterior epidural space [22]. Jung has proved that posterior elements of the vertebral bodies destruction with soft-tissue infiltration is characteristic of the pathological fracture of neoplastic background [26]. In Chamberlain and Baur's opinion, fluid sign indicates osteoporotic fracture [27, 28].

Differences in results also concerned the incidence of radiological and clinical features of spinal instability which is particularly visible in the thoracic spine. It is worth noting that not all the damages that meet radiologic criteria of instability cause pain in patients and visible clinical instability. The thoracic segment of the spine is particularly compact and has reduced mobility, hence even vertebral fracture may give slight symptoms, while in patients with damage to the movable sections of the spine, namely cervical and lumbar, the symptoms are particularly pronounced. 100% clinical instability was noted in patients with damage at the interface between stiff and movable sections of the spine: cervicothoracic and thoracolumbar junction. The evaluation of spinal instability should always include clinical and imaging examination data which is of paramount importance as the basis for the qualification for the surgical treatment [1, 2, 29, 30].

## CONCLUSIONS

1. Imaging examinations, magnetic resonance in particular, are crucial for the proper planning of spinal surgery in consequence of metastatic lesions.
2. Magnetic resonance clearly visualizes the morphology of metastasis, yet does not allow for clear-cut differentiation of the etiology of bone destruction.
3. Clinical instability in the thoracic spine is significantly less common than its MRI symptoms.
4. MRI is not sufficient for clear-cut differentiation between the actual infiltration of the tumor into soft tissues, particularly into the dura mater, and its adherence and modelling.

## CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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The work is entirely my doing. I, m the only one author of this work.

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