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Preoperative estimation of metastatic vertebral tumors

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Abstract Total en bloc spondylectomy was performed in 22 patients with metastatic vertebral tumors. Osteolytic lesions were present in 15 cases while 7 cases had osteoblastic or mixed lesions. We measured the dimensions of the tumors preoperatively using magnetic resonance imaging (MRI) and computerized tomography (CT), and postoperatively by histological examination of the resected specimens. In the osteolytic group, the dorsoventral and transverse diameters of the metastatic tumor as measured on MRI were significantly greater compared to those determined by the histological examination. On the other hand, the same parameters measured by CT were smaller than the histologically determined dimensions. Although there were no significant differences between measurements of osteoblastic and osteolytic tumors, CT underestimated dimensions in osteoblastic or mixed tumors more than in those of osteolytic tumors. Estimation of tumor dimensions and local invasion using MRI and CT should be interpreted carefully.

Résumé Une spondylectomie totale en bloc a été effectuée sur 22 patients atteints de tumeurs vertébrales métastatiques. Des lésions ostéolytiques ont été décelées sur 15 sujets, tandis que les 7 autres présentaient des lésions ostéoblastiques ou mixtes. Nous avons comparé les dimensions des tumeurs vertébrales métastatiques mesurées avant l'opération par IRM et TDM aux dimensions mesurées immédiatement après l'opération lors de l'examen histologique de prélèvements vertébraux. Pour le groupe souffrant

de lésions ostéolytiques, les diamètre dorsoventral transversal relatif de la tumeur métastatique mesuré par le IRM était plus élevé que celui déterminé au cours de l'examen histologique. D'un autre côté, ces mêmes paramètres mesurés à l'aide des scanners TDM affichaient aussi une différence importante. Bien que les différences entre les mesures des tumeurs ostéoblastiques et ostéolytiques n'aient pas été très grandes, le TDM a sous-estimé les dimensions des tumeurs ostéoblastiques ou mixtes plus que les tumeurs ostéolytiques. Nos données suggèrent une interprétation prudente de l'estimation réalisée par le IRM et le TDM concernant les dimensions de tumeurs ainsi que l'invasion locale.

Introduction

Based on comparative studies between preoperative radiological findings and en bloc resected specimens it has been reported that magnetic resonance imaging (MRI) is a useful tool for measurement of tumor dimensions in the extremities [4].

We have recently developed a technique that allows a total en bloc spondylectomy of vertebral tumor [11]. This technique has been advocated for primary malignant tumors, and selected cases of metastatic tumors, which constitute a major proportion of the malignant vertebral tumors. It follows that a precise measurement of the dimensions of the tumor before surgery is important for clinical decision making.

The purpose of this study was to compare the dimensions of metastatic vertebral tumors determined preoperatively by MRI and computed tomography (CT) with those measured postoperatively by histopathological examination.

Materials and methods

Patients

Twenty-two patients with metastatic vertebral tumors surgically excised by total en bloc spondylectomy treated in our department

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Fig. 1A Large section containing all elements of the second lumbar vertebra in the axial plane in a patient with metastatic osteoblastic tumor from breast cancer (hematoxylin-eosin). *Lines a and b* represent the maximum transverse and dorsoventral (longitudinal) diameters of the tumor. **B.** MRI T1-weighted image of almost the same plane shown in A. **C.** CT scan of the same plane shown in A demonstrating osteoblastic pattern of the tumor and extension into the bone marrow

between 1992 and 1996, were included in the study. All patients had CT and MRI scans taken immediately before surgery. In all cases the diagnosis was confirmed histopathologically by using surgical or biopsy specimens. The patients included 12 males and 10 females, average age 58 (46–72) years. No patient was treated with chemotherapy or radiotherapy before surgery.

Specimens

The resected specimens were fixed with 10% buffered formalin immediately after resection. The specimens were cut horizontally in 5 mm slices through the pedicle, decalcified in 20% formic acid for 1–2 weeks and then embedded in paraffin wax and finally stained by hematoxylin and eosin. A pathologist without knowledge of the MRI and CT findings performed the histological examination. The measurement of dimensions was performed using a National Institute of Health (NIH) image program following digitalization of each image into a personal computer (Power Macintosh 8100/80, Apple Computer, Inc., Calif., USA). The maximum transverse and dorsoventral diameters of the tumor (Fig. 1) were determined and expressed as a percentage of the maximum diameter of the vertebral body.

Imaging studies

Only imaging studies obtained immediately before surgery were included in the analysis. MRI was carried out with superconductive magnets, and field strength of 1.5 T (Magnetom, Siemens). The slice thickness varied between 5 and 10 mm. The pulse sequence used was the spin echo sequence (SE) in all cases. T1-weighted images were achieved with SE and short repetition times (TR: 500 ms) and short echo times (TE: 30 ms). Tumor extension on MRI T1-weighted image was defined as the area of low signal intensity compared with normal bone marrow.

CT was carried out on a Hitachi W3000AD using a slice thickness of 5 mm. The tumor margin on CT represented the junction

between two different densities at the site of the bone marrow tumor. Furthermore, cases examined by CT were categorized into either osteolytic or osteoblastic tumors, based on the pattern of tumor extension in the bone marrow. Assessments of MRI and CT images were conducted separately by two investigators who had no knowledge of the histopathological findings. Similar to the analysis used on histopathological examination, we also determined the transverse and dorsoventral (longitudinal) dimensions of the tumor on CT and MRI. The results are expressed as percentage of the maximum diameter of the vertebral body, since absolute measurements would be meaningless because of the lack of reliability of actual dimensions on CT and MRI.

Statistical analysis

Tumor diameters measured by MRI and CT were calculated in each case and expressed as percentages of those measured on histopathological examination. Differences between groups were examined for statistical significance using the Mann-Whitney U-test. A *P*-value less than 0.05 denoted the presence of a statistically significant difference.

Results

Histological examination showed that 15 tumors were of the osteolytic type and consisted of secondary tumors from renal cell carcinomas ($n=6$), breast carcinomas ($n=2$), thyroid tumors ($n=2$), hepatocellular carcinomas ($n=2$), adrenal ($n=1$), prostate ($n=1$) and lung ($n=1$) carcinomas. The other 7 tumors were classified as osteoblastic or mixed type secondary tumors, with the primary in the breast ($n=4$), colon ($n=2$) and lung ($n=1$). All tumors were correctly classified preoperatively by CT as osteolytic or osteoblastic and mixed.

Osteolytic tumors

Compared with histological examination, MRI significantly overestimated the dorsoventral diameter by 5.2%

Fig. 2 Differences in osteolytic tumor extension measured by MRI and CT compared to that by histological examination. The ordinate represents the difference between the ratio of dorsoventral or transverse diameter of the tumor to the diameter of the vertebral body and the same ratio measured during histological examination of the affected vertebra. Data are mean $\pm$ SD of 15 tumors

($P<0.05$, Fig. 2) expressed relative to the diameter of the vertebral body. Furthermore, MRI also significantly overestimated the transverse diameter by 8.8% ($P<0.01$, Fig. 2) relative to the diameter of the vertebral body. The overestimated ratio was due to the presence of fibrous tissue, as confirmed by histopathological examination, which was considered as a reactive zone on MRI. In one case, a small tumor nest was detected in the reactive zone. However, there was no skip metastasis in the area where MRI showed normal intensity.

Analysis of CT scans indicated a significant underestimation of the dorsoventral and transverse diameters, relative to the vertebral body, by 17.2% and 15.1%, respectively ($P<0.01$), compared to the corresponding relative diameter measured on histological examination (Fig. 2). Furthermore, the values measured on MRI and CT were significantly different ($P<0.05$).

Osteoblastic or mixed tumors

On MRI the dorsoventral diameter relative to the diameter of the vertebral body, was 7.5% larger than that determined by histological examination ($P<0.05$). The relative transverse diameter was 2% larger than that determined histologically, but the difference was non-significant. In contrast, on CT these dimensions were significantly underestimated by 22% and 11%, respectively ($P<0.01$, Fig. 3). Furthermore, the values measured on MRI and CT were significantly different ($P<0.05$). Although there were no significant differences between the

Fig. 3 Differences in osteoblastic and mixed tumor extension measured by MRI and CT compared to that by histological examination. The ordinate represents the difference between the ratio of dorsoventral or transverse diameter of the tumor to the diameter of the vertebral body and the same ratio measured during histological examination of the affected vertebra. Data are mean $\pm$ SD of 7 tumors

osteolytic and the osteoblastic/mixed groups, the findings on CT in the latter group tended to underestimate the dimensions of osteoblastic/mixed tumors far more than in that of the osteolytic group.

Discussion

Metastatic vertebral tumors constitute the majority of malignant tumors of the spine. The treatment strategy of metastatic vertebral tumors must be carefully planned, taking into consideration the systemic condition, metastases in other organs, and life expectancy. When prognosis is judged to be poor, palliative surgery including posterior decompression and stabilization is warranted. However, it has been reported that these procedures often lead to neurological deterioration within 6 months due to local recurrence [9]. The development of adjuvant therapy has resulted in prolongation of life expectancy even in patients with metastases. Therefore, in selected cases with a well-controlled primary lesion and solitary vertebral metastasis, we attempt to reduce the residual spinal tumor in order to prevent local recurrence, which is often associated with neurological deterioration and pain. To excise the entire tumor, accurate assessment of tumor dimensions is very important. Especially in the spine, the surgical approach and technique would vary depending on whether the tumor extends within the vertebral body or invade the pedicle and lamina. When the tumor extends within the vertebral body, corpectomy using the anterior approach should be elected. However,

when the tumor occupies the whole vertebra, anterior and posterior approaches or posterior approach alone is advocated for total excision of the tumor.

The surgical method of choice for malignant tumors is en bloc excision with a sufficient tumor free margin. Accurate estimation of tumor dimensions in patients with primary malignant tumors of the spine is therefore important in surgical planning. Our study is of value for proper surgical planning of en bloc excision of primary tumors with a wide free margin in cases, although the materials employed in our analysis included metastatic tumors.

Previous studies have shown that MRI provides definite advantages compared to CT in demonstrating the extent of bone tumors in the extremities [1,5,6,7,10,12]. In particular, T1-weighted images are useful for such evaluation [4]. Two studies have previously compared the dimensions estimated by CT and MRI with those measured directly by histological examination of tumors in the extremities. Gillespy et al. [8] found that the average difference between macroslide and CT measurements was 16.5 mm, while the average difference between macroslide and MR imaging measurements was 4.9 mm. Bohndorf et al. [3] concluded that MRI overestimated the size of extraosseous tumors by up to 20 mm due to the surrounding edematous reactive zone.

Our results showed that MRI significantly overestimated tumor dimensions relative to those determined by histological examination while CT underestimated such dimensions, irrespective of the tumor extension into the bone marrow. There was no statistical difference between the transverse diameter on MRI and histological examination in the osteoblastic or mixed group; however, the sample number was small. In three of the seven cases, the data were not applicable with the tumor extending throughout the whole transverse diameter of the vertebral body. Further studies with a large sample size are necessary to confirm our findings in the osteoblastic or mixed tumors.

Our histopathological examination showed that the overestimated dimensions on MRI were largely due to the surrounding reactive zone. This area was composed of fibrous tissue and edema, which appeared as a low intensity area on T1-weighted images. In contrast, CT underestimation of tumor dimensions was apparently due to tumor spread into the bone marrow without destruction of the bone trabeculae. Interestingly, Beltran et al. [2] reported finding tumors in the area of the reactive zone on MRI in three out of 11 cases. In comparison, on-

ly in one of 22 cases in the present study we were able to detect tumor growth in the reactive zone. However, there were no tumor cells in the area showing normal intensity on MRI. Therefore, pre-surgical planning should include extension of the surgical margin to the area showing normal intensity on MRI so as to include all areas with potential local invasion of tumor cells.

Our findings should be interpreted carefully. Although each finding on MRI, CT and histological sections was established in almost the same section, an error is inevitable if different section planes are used. Further analysis is, however, necessary, using a larger sample size to determine the influence of histological grade on the accuracy of the radiological estimation of tumor size.

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