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ARTICLE

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# Benign vertebral hemangioma: MR-histological correlation

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**Abstract** *Objective:* To explain the magnetic resonance (MR) appearance of benign vertebral hemangioma by correlating MR and histological findings from autopsy specimens. *Design:* Sagittal T1- and T2-weighted spin-echo images were obtained in 83 spine specimens. Focal lesions consistent with vertebral hemangioma at macroscopic examination of sagittal anatomical sections were sampled for histological and quantitative analysis. At histology, the proportion of surface area occupied by adipocytes, vessels and edema, and hematopoietic cells was determined (point-counting method) in normal marrow areas and in lesion areas whose signal intensity was either high and intermediate (pattern A) or intermediate and high (pattern B) on T1- and T2-weighted images, respectively. *Results:* Nine lesions were sampled and corresponded to cavernous hemangioma at histology. The proportion of surface area occupied by adipocytes was statistically significantly higher in pattern A (78.1%) than in pattern B lesion areas (42.7%) and than in normal marrow areas (47.5%). The proportion of surface area occupied by vessels and interstitial edema was statistically significantly higher in pattern B (47.0%) than in pattern A lesion areas (15.5%) and than in normal marrow areas (0). *Conclusion:* The presence of high signal intensity on T1- or T2-weighted images of vertebral hemangioma is related to the amount of adipocytes or vessels and interstitial edema, respectively.

**Keywords** Magnetic resonance · Spine · Hemangioma

## Introduction

Vascular lesions of bones are relatively common, and hemangioma is the most frequently encountered angiomatous lesion, being seen mainly in the spine and skull [1, 2]. The majority of vertebral hemangioma (VH) are discovered incidentally because of the coarsened vertical trabeculae on radiographs and CT images or because of their distinctive appearance at MR imaging. Asymptomatic VHs demonstrate areas of increased signal intensity on both T1- and T2-weighted images with focal areas of decreased or intermediate signal intensity [3, 4, 5]. Histological analysis of these lesions is lacking because they are not biopsied. Correlation between CT and MR images suggested that fat within the lesion could explain the high signal intensity on T1-weighted images [2, 3, 4, 6]. The purpose of this study was to describe the MR appearance of presumed asymptomatic VHs observed in an autopsy study and to correlate the MR findings with the histological features.

## Materials and methods

### Patients and methods

Between August 1998 and August 1999, 201 autopsies were performed at our institution. Spine specimens available for this study were harvested from 83 non-embalmed consecutive cadavers consisting of 58 male and 23 female subjects with a mean age of 62.2 years at death. In the other 118 patients, no spine specimens were obtained because of one of the following reasons: age below 18 years, time delay between death and autopsy longer than 24 h, suspected viral infection and history of spine surgery. No clinical information relevant to back symptoms was available. Authorization from the ethics committee of our institution was obtained for the study.

Spine specimens were harvested through an anterior approach after wiping off of the paraspinal soft tissues. En-bloc resection of a mean of 5.51 vertebral bodies per autopsy (range 3–13, median 5; total of 452 vertebral bodies) was performed by cutting through all pedicles and the superior and inferior disks of lower thoracic to lower lumbar spine.

Immediately after autopsy, specimens were wrapped in plastic bags and maintained for 2–3 h in water at 30–35 °C, because a pilot study on animal specimens had shown that bone temperature could influence marrow appearance at MR imaging [7]. MR images were obtained using a quadrature knee coil on a 1.5 T magnet (Signa; GE Medical Systems, Milwaukee, Wis.; $n$=10) or a 0.5 T magnet (Philips Medical Systems, Best, The Netherlands; $n$=73). The spine specimens were imaged in the supine position only in the sagittal plane. After transverse and coronal scout views, sagittal T1-weighted [(TR (repetition time, ms)/TE (echo time, ms)/NEX (number of excitations): 600/20/4] spin echo (SE) MR images and sagittal T2-weighted [TR/TE effective echo time (ms)/NEX: 5000/120/4] fast spin echo (FSE) MR images were obtained. The MR imaging matrix was 392×512, and field of view was adapted to each specimen length. A 3 mm slice thickness and a 0.3 mm interslice gap were used for all the MR images. The total imaging time was 11 min.

Immediately after MR imaging, the specimens were frozen at –18 °C and subsequently cut into 3 mm thick sections in a sagittal plane with a band saw. For macroscopic analysis, anatomical sections were slowly unfrozen. Overview and close-up photographs of areas of interest were taken. According to previous descriptions [8], a lesion consistent with a VH is characterized by the presence of multiple red dots within a background of red or yellow color. All lesions that corresponded to this definition were sampled, along with adjacent normal-appearing marrow. Large lesions were sampled in two fragments. The largest diameter was measured in each lesion by using a 5 mm graduated ruler. Specimens were fixed in bouin solution. The same musculoskeletal radiologist (B.V.B.) performed the entire procedure with the occasional help of a second radiologist (V.B.).

Following decalcification in 10% nitric acid in 10% formalin, the specimens were embedded in nitrocellulose, cut into 14–20 μm sections, mounted on glass slides, and stained with hematoxylin-eosin.

### MR findings

Sagittal T1- and T2-weighted MR images of the spine specimens were conjointly reviewed by the two radiologists to determine signal intensities within the lesions detected at macroscopic examination of the anatomic sections. Pattern A signal intensity was defined by the presence of high signal intensity on T1-weighted spin-echo images and intermediate signal intensity on T2-weighted fast spin-echo images. Pattern B signal intensity was defined by the presence of intermediate signal intensity on T1-weighted images and high signal intensity on T2-weighted images. Intermediate or high signal intensity on T1-weighted images was defined by the presence of a signal intensity equivalent or superior to that of adjacent normal marrow, respectively. Intermediate or high signal intensity on T2-weighted images was defined by signal intensity slightly or markedly superior to that of adjacent normal marrow, respectively. Presence of linear or round areas of low signal intensity on T1- and T2-weighted images was also noted.

Lesions were considered to be homogeneous or heterogeneous depending on the presence of one or two signal intensity patterns within the lesion on T1-weighted images.

### Macroscopic examination and histological findings

A pathologist (C.G.) unaware of the MR findings reviewed the mounted slides of all sampled lesions and the photographs of the corresponding anatomical sections. Lesions were classified as homogeneous or heterogeneous on the basis of their macroscopic appearance on the photographs. Microscopic sections of all these lesions were analyzed.

### Quantitative analysis of histological findings

A radiologist (V.B.) simultaneously reviewed the T1- and T2-weighted MR images and the slides of the sampled lesions. After identification of the MR images that corresponded to the mounted slides of each lesion, the lesion areas that showed pattern A or B signal intensity on T1- and T2-weighted MR images were outlined on the corresponding histological slides. Marrow areas around the lesions that showed normal signal intensity at MR imaging were also outlined. A pathologist (C.G.) determined the proportion of surface area occupied by adipocytes, vessels and interstitial edema, and normal hematopoietic cells in all outlined areas by using a point-counting method [9, 10]. Outlined areas were examined at a magnification of ×400 using a Zeiss integrating eyepiece with 100 points. Points projected on adipocytes, vessels and interstitial edema, and normal hematopoietic cells were separately counted by the pathologist. Values were averaged to provide percentages that corresponded to the percentage of surface area that was occupied by adipocytes, vessels and interstitial edema, and normal hematopoietic cells. The pathologist was unaware of the corresponding MR appearance.

Due to lesion heterogeneity, this method enables the correlation of the signal intensity pattern at MR imaging with the proportion of fat cells/vessels-edema at histology in each individual area of VH.

### Statistical analysis

The percentages of surface area occupied by the three above-mentioned components were compared between pattern A and B lesion areas using the ANOVA method. The percentages of fat determined in pattern A or B areas were compared with the percentage of fat determined in adjacent marrow of the same vertebral body by using the paired Student's $t$-test. $P$ values lower than 0.05 were considered to be statistically significant.

## Results

### Macroscopic analysis of spine sections

Nine of 83 autopsy specimens (5 males, 4 females; mean age at death 67.9 years, range 34–87 years) each showed one vertebral lesion consistent with VH at macroscopic examination of anatomical spine sections. The mean lesion size was 14 mm (range 8 – 17 mm).

### MR imaging

On T1-weighted images, five lesions were homogeneous: three lesions with pattern A signal intensity and two lesions with pattern B signal intensity (Fig. 1). Four le-

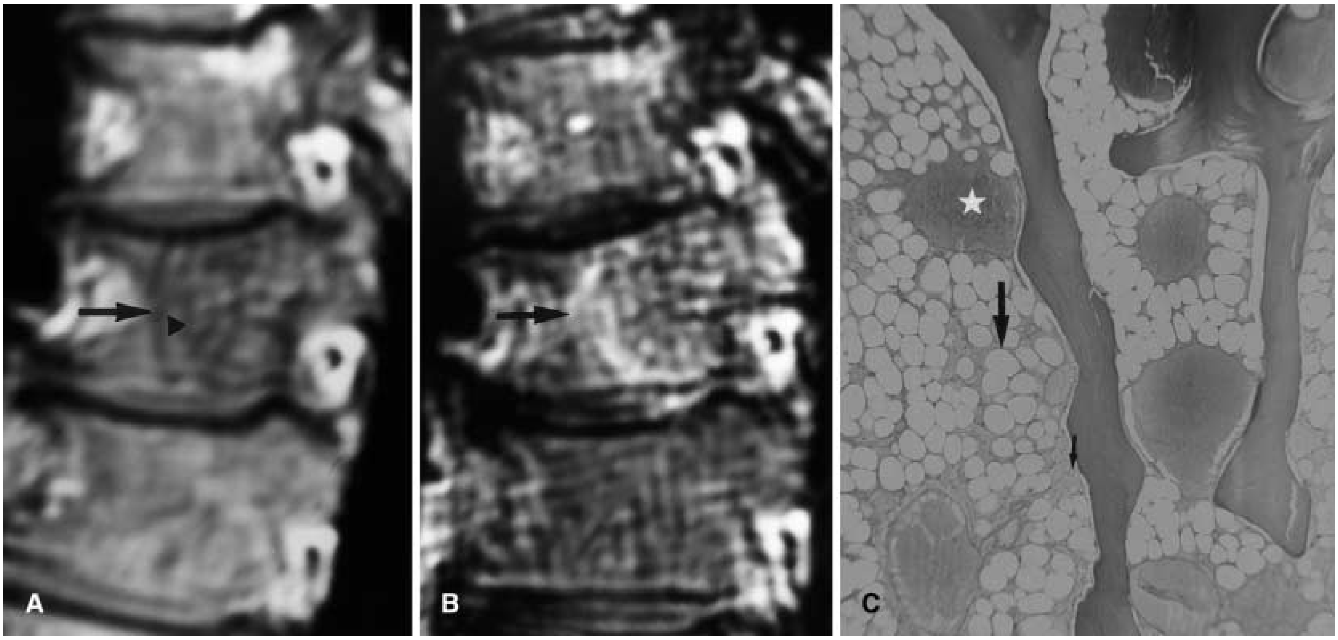


**Fig. 1** **A** Sagittal T1-weighted spin-echo image of three thoracic vertebral bodies from a 73-year-old subject shows an area of intermediate signal intensity (*arrow*) with linear and vertical areas of very low signal intensity (*small arrow*) in the posterior part of the middle vertebral body. **B** On the T2-weighted image, the signal intensity of the lesion (*arrow*) is moderately increased in comparison with adjacent normal marrow. **C** Photomicrograph (original magnification, ×150; hematoxylin-eosin stain) of the lesion shows thin-walled, dilated vessels (*star*), adipocytes (*arrow*) and interstitial edema (*small arrow*). The relative proportion of surface area occupied by thin-walled, dilated vessels and interstitial edema is equivalent to that occupied by adipocytes

sions were heterogeneous, including three lesions with centrally located pattern B signal intensity and peripherally located pattern A signal intensity (Fig. 2). In addition, linear or punctate areas of low signal intensity on both T1- and T2-weighted images were observed in two lesions (Fig. 1).

## Macroscopic examination and histological analysis

At macroscopic examination of section photographs, five lesions were homogeneous, with multiple red dots homogeneously interspersed in a background of yellow or red color. Four lesions were heterogeneous with variable amounts of red dots clustered in different lesion areas.

Histological analysis of the lesions demonstrated thin-walled, large blood-filled vessels set in a stroma of adipocytes with interstitial edema in all nine lesions that indicated cavernous hemangioma. No vessel thrombosis, hemosiderin deposition or hematopoietic cells were found.

## MR-macroscopic correlation

Pattern A areas with high signal intensity on T1-weighted images and intermediate signal intensity on T2-weighted images corresponded to yellow areas with sparse red dots at macroscopic examination (Fig. 2). Pattern B areas with intermediate signal intensity on T1-weighted images and high signal intensity on T2-weighted images corresponded to areas of more confluent red dots (Fig. 2). The five and four lesions that were respectively homogeneous and heterogeneous on T1-weighted images were also homogeneous or heterogeneous at macroscopic examination.

## MR-histological correlation

In the nine lesions, 16 areas were outlined: eight areas showing pattern A and eight areas showing pattern B. Nine areas of normal signal intensity situated outside the lesion were outlined on the nine histological slides. The proportion of surface area occupied by adipocytes was statistically significantly higher in pattern A than in pattern B signal intensity areas ($P$<0.0001) and than in normal adjacent marrow ($P$=0.02). There was no difference in the percentage of surface area occupied by adipocytes between pattern B and normal adjacent marrow of the corresponding specimen ($P$=0.84) (Table 1).

The percentage of surface area occupied by vessels and interstitial edema was statistically significantly higher in pattern B than in pattern A signal intensity areas and in pattern A areas than in normal signal intensity marrow ($P$<0.0001 for both values) (Table 1).

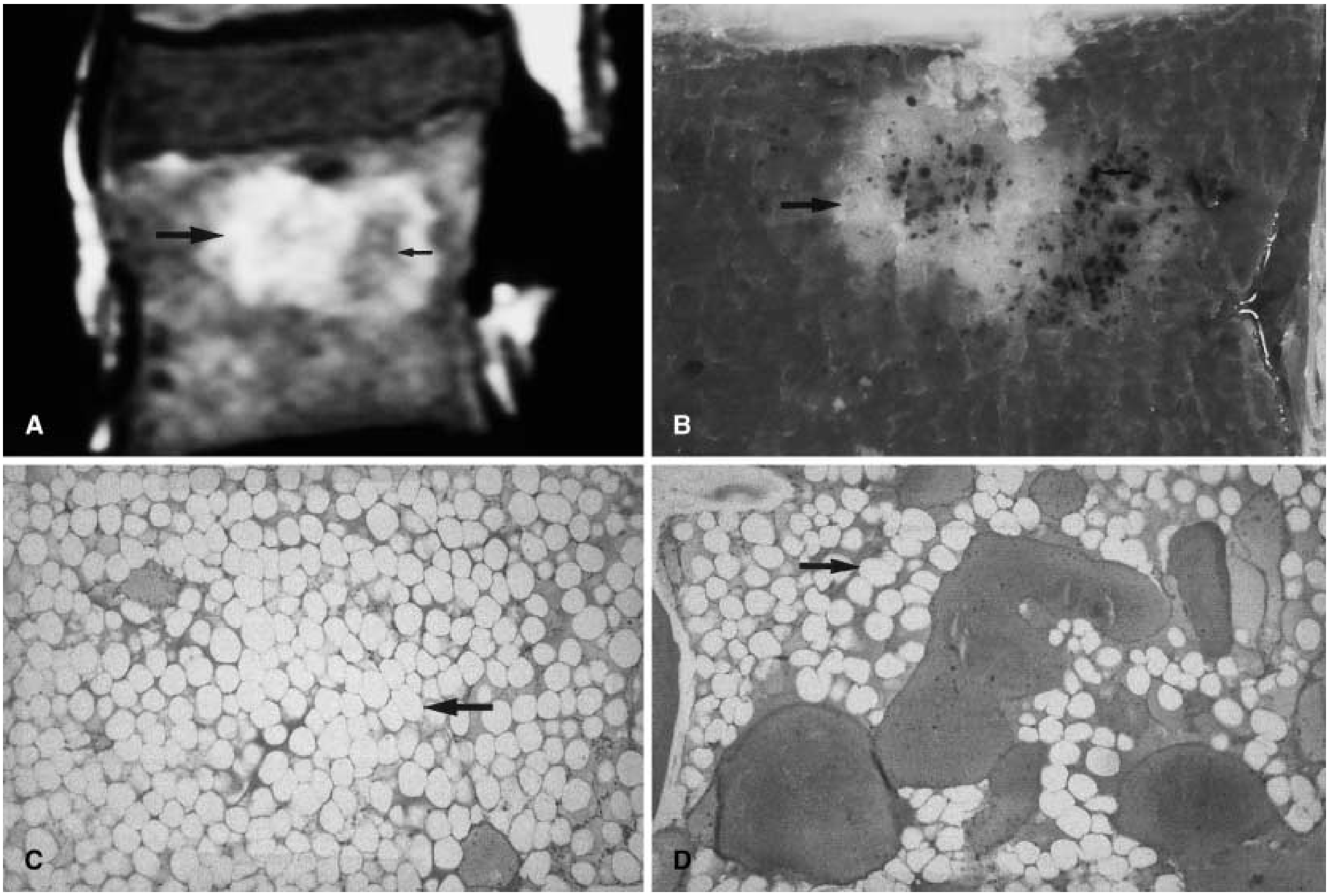


**Fig. 2 A** Sagittal T1-weighted spin-echo image of a vertebral body of the spine specimen from a 69-year-old subject shows a heterogeneous area that consists of high (*arrow*) and intermediate signal intensity (*small arrow*). **B** Photograph of the corresponding macroscopic section shows a yellow lesion (*arrow*) that contains small red dots (*small arrow*). **C** Photomicrograph (original magnification, ×150; hematoxylin-eosin stain) of marrow area with high signal intensity on the T1-weighted image (*large arrow* in **A**). The relative proportion of surface area occupied by adipocytes (*arrow*) is larger than that occupied by vessels and interstitial edema in the area of high signal intensity on the T1-weighted image. **D** Photomicrograph (original magnification, ×150; hematoxylin-eosin stain) of marrow area with intermediate signal intensity on the T1-weighted image (*small arrow* in **A**). The relative proportion of surface area occupied by adipocytes (*arrow*) is similar to that occupied by vessels and interstitial edema in the area of intermediate signal intensity on the T1-weighted image

## Discussion

The results of our study allowed us to draw the following conclusions. First, all nine lesions with MR characteristics consistent with benign VHs corresponded to cavernous hemangioma. Second, the two signal intensity patterns observed at MR imaging within the lesions were related to the relative proportion of adipocytes and of vessels and interstitial edema. Finally, the distribution of

**Table 1** Quantitative determination of the proportion of surface area occupied by fat cells, vessels and edema and hematopoietic cells in vertebral hemangiomas and normal marrow by using the point-counting method [Numbers are expressed as a percentage. Numbers in parentheses are numerators (number of point projecting respectively on fat cells, vessels/interstitial edema and hematopoietic cells) and denominators (total number of points counted in all the areas)]

| | Normal marrow[a] | Pattern A[b] | Pattern B[c] |
|---|---|---|---|
| Fat (%) | 47.5% (717/1509) | 78.1% (1712/2191) | 42.7% (1754/4107) |
| Vessels and edema (%) | 0 (1929/4107) | 15.5% (339/2191) | 47.0% (1929/4107) |
| Hematopoietic cells (%) | 26.2% (395/1509) | 0 | 0% |

[a] Normal marrow: the bone marrow adjacent to a vertebral hemangioma
[b] Pattern A: high signal intensity on T1-weighted spin-echo images and intermediate signal intensity on T2-weighted fast spin-echo images in vertebral hemangioma
[c] Pattern B: intermediate signal intensity on T1-weighted images and high signal intensity on T2-weighted images in vertebral hemangioma

the two signal intensity components on T1-weighted images reflected that on the macroscopic examination of the lesions.

Very little information is available on the histological features of benign VHs observed at MR imaging. Laredo et al. [4] found numerous packed, thin-walled vascular cavities and the absence of fatty replacement at histological analysis of compressive VH. In the current study, the nine lesions consistent with benign VHs at MR imaging corresponded to cavernous hemangioma at histology with dilated blood-filled vessels set in fatty marrow devoid of maturing hematopoietic cells. These lesions could represent hamartomas – normal tissue in an abnormal location – or varicosities within the medullary cavity [8].

The fact that adipocytes were found at histological analysis of all lesions was in good agreement with early findings based on correlations between CT and MR images [3, 4]. The current study demonstrated that adipocytes were present not only in areas with high signal intensity on T1-weighted images, but also in areas with intermediate signal intensity on T1-weighted images, although in a statistically significant lower amount. Areas with high signal intensity on T1-weighted images and intermediate signal intensity on T2-weighted images contained a larger proportion of surface marrow occupied by fat cells than areas with intermediate signal intensity on T1-weighted and high signal intensity on T2-weighted images. These latter areas contained a proportion of surface area occupied by fat cells equivalent to that of normal adjacent marrow. Moreover, lesion areas with high signal intensity on T2-weighted images contained a larger proportion of surface area occupied by vessels and edema than areas with an intermediate or slightly increased signal intensity, which suggested that the vascular component of the lesion was responsible for the high signal intensity on T2-weighted images.

Finally, the current study demonstrated that the distribution of the two signal intensity patterns at MR imaging reflected the spatial distribution of predominantly fatty or predominantly hydrated areas at macroscopic examination. Fatty marrow tended to predominate in the lesion periphery and hydrated tissue involved central regions of the lesions.

The current study was limited by the fact that MR images were obtained in autopsy specimens, which could have altered the MR appearance of the lesions. Study design was adapted to minimize this limitation by obtaining lesions from non-embalmed cadavers of patients who died less than 24 h before autopsy and by maintaining the specimens at approximately body temperature before the MR study. Another potential limitation is secondary to lesion heterogeneity and histological features, and MR signal intensity may vary from one slice to the other. To minimize this potential source of error, attempts were made to analyze sagittal MR and anatomical slices that cross the center of each lesion.

Benign VHs observed at MR imaging of autopsy specimens correspond to cavernous hemangioma and their appearance on T1- and T2-weighted images depends on the proportion of the lesion surface area occupied by either adipocytes or vessels and edema.

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