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New concepts in understanding evolution of desmoid tumors: MR imaging of 30 lesions

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Abstract. The objective of this study was to evaluate the appearance and the natural evolution of desmoid tumors on MR imaging, given histologic correlation. The MR images of 30 desmoids (20 primary and 10 recurrent) in 26 patients were scored for a multiplicity of morphological parameters, signal intensity (SI) on different pulse sequences, and behavior after contrast administration. Natural evolution was evaluated in 2 primary and 3 recurrent lesions, and correlated with evolution on histologic specimens. Desmoid tumors are mostly found in muscles of shoulder and hip girdle and are often fusiform with partially ill-defined margins. Rare subcutaneous desmoids have a more stellar morphology. Variable amounts of low-SI areas are present on all sequences. On T1-weighted images (T1-WI), most lesions are near homogeneous and isointense to muscle, whereas on T2-WI they are more heterogeneous with an overall SI equal to or slightly lower than fat. Histologic correlation reveals that SI on T2-WI cannot be explained solely by cellularity. After initial growth, spontaneous evolution of desmoids is characterized by shrinking and an increase in low-SI areas on T2-WI. While distal lesions shrink, the more recent lesions in asynchronous multicentric desmoids have a tendency to develop proximally in the same limb, and should not be confused with recurrences. Fast growth, extracompartmental spread, and bone involvement are often seen in recurrences. Follow-up MR imaging of desmoids indicates natural regression of desmoids and more aggressive behavior of recurrences, which may justify a more conservative therapeutic approach.

Key words: Desmoid – Aggressive fibromatosis – Soft tissue tumor – MR imaging

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Introduction

Desmoid tumors are rare soft tissue tumors arising from connective tissue of muscle, overlying fascia or aponeurosis. The condition has also been described as desmoid, aggressive fibromatosis or musculoaponeurotic fibromatosis. Extra-abdominal desmoids arise most commonly in the lower limb or limb girdle and in the shoulder region. Histologically abdominal as well as extra-abdominal desmoids consist of interlacing bundles of proliferating spindle cells embedded in a matrix containing varying amounts of collagen and ground substance [1]. These fibrous lesions are benign, but may be locally invasive and tend to recur after surgery. The appearance of desmoid tumors on MR imaging has already been reported and found to be variable [2–4].

The aim of this study is threefold: firstly, to describe the MR appearance of 30 desmoid tumors; secondly, to compare the natural evolution of primary desmoids with the evolution of tumor recurrence, as seen on MR imaging; and thirdly, to correlate MR findings with histology of the lesions.

Materials and methods

We retrospectively reviewed the MR images of 26 patients with 30 histologically proven desmoid tumors. They represent 3.3 % of 900 cases of soft tissue tumors examined by MR imaging and registered at the University Hospital of Antwerp (1988–1995) and in the Multicentric European Study on Magnetic Resonance Imaging of Soft Tissue Tumors (June 1993–November 1995).

Seventeen women and 9 men, ranging from 2 to 82 years (mean age 33 years), with a total of 30 desmoid tumors were included.

Of the 20 primary lesions, 15 were surgically removed and 1 is recently in follow-up. The remaining 4 lesions,

which were seen in 2 patients with multicentric desmoid, were followed by MR imaging during a period of more than 6 years. Of the 10 recurrent lesions, images of both primary and recurrent lesion were at our disposal in one case, whereas in the remaining 9, no MR images of the primary lesion were available.Three recurrences underwent follow-up MR examination after 1 year.

All lesions were studied by using T1- and T2-weighted MR sequences. Except for one pregnant patient, contrast-enhanced T1-weighted images (T1-WI) were performed. Because of the multicentric design of the study, examinations were performed on MR equipment of different field strengths and with variable pulse sequence parameters.

All tumors were scored for location (head and neck, upper limb, trunk, pelvis, or lower limb); distribution in the subcutaneous, intramuscular, or intermuscular compartments; mean size, measured by three perpendicular diameters; shape, described as fusiform, dumbbell shaped, stellar, polylobular, or irregular; spread, judged as intracompartmental or extracompartmental, with or without bone involvement. Margins were scored as well-, ill-, or partially ill-defined. Signal intensities (SIs) were evaluated on both spin-echo sequences, and scored in relation to SI of fat and muscle. Homogeneity of each lesion on T2-WI was defined as homogeneous, mostly homogeneous, or inhomogeneous.

Areas with SIs lower than muscle on T1-WI, lower than or equal to muscle on T2-WI, and without enhancement after intravenous contrast administration were noted. The amount of low-SI tissue in each lesion was estimated as below 20 %, between 20 and 50 %, between 50 and 80 %, or above 80 %. The distribution of these low-SI areas in the lesion was defined as central, peripheral, central with low SI capsule, or irregular.

When enhancing after intravenous contrast administration, degree of enhancement of each lesion was scored as minor, moderate, or strong. Pattern of enhancement was described as homogeneous, mostly homogeneous, or inhomogeneous.

Scores of all parameters were evaluated in primary vs recurrent desmoid tumors.

Cellularity of each lesion was judged on histological sections and compared with SI on T2-WI.

Growth rate of three recurrent tumors was scored by measuring changes in mean diameter during a follow-up period of 1 year. The natural evolution of primary desmoids was followed in 2 patients over a period of more than 6 years.

Results

MR appearance

The locations of the lesions are summarized in Table 1 (Fig. 1). Four patients had multiple lesions, which were distributed along the long axis of one limb. Fifty percent of the lesions had a fusiform or ovoid shape ($n = 15$). Some tumors were dumbbell shaped ($n = 3$). Two desmoids were polylobular, 7 tumors were irregularly shaped. The 3 tumors situated in the subcutis were stellar with fine peripheral tentacles of which a few were in close contact with the muscle fascia (Fig. 2). All the deep-seated tumors were situated in the muscular ($n = 21$) or intermuscular compartment ($n = 6$).

The average mean diameter of the lesions was 70 mm and varied between 30 and 180 mm.

Margins were well defined in 5 cases, ill defined in 7 cases, but mostly partially ill defined ($n = 18$). Compartmental spread and bone involvement are shown in Table 2. Intratumoral septa were not seen, neither were areas of necrosis.

The MR signal characteristics were variable. On T1-WI lesions were mostly near homogeneous or homogeneous ($n = 25$). The overall SI was rated as equal to SI of muscle in 21 cases (Table 3). The SIs on T2-WI mostly were heterogeneously distributed ($n = 24$) with an overall SI slightly lower than ($n = 15$) or equal to ($n = 8$) fat (Table 4).

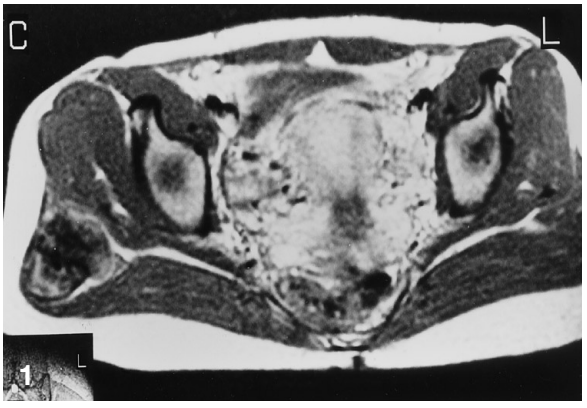
T1-WI after intravenous contrast administration in 29 desmoids mostly showed moderate ($n = 6$) to strong ($n = 14$) enhancement (Table 5), except for the areas of low SI on T2-WI which remained unenhanced. Pattern of enhancement is inhomogeneous in 14 cases, mostly homogeneous in 8 cases, and homogeneous in 3 cases. Hypointense areas were mostly curvilinear to irregular and may have a central ($n = 4$; Fig. 3) or peripheral ($n = 3$; Fig. 4) distribution within the lesion. Two cases with central low-intensity areas also show a low-SI peripheral band. The low-SI areas mostly comprise 0–20 % of the lesion ($n = 14$; Table 6).

Histology

Microscopic study of all specimens (resection and/or biopsy) reveals a relatively low cellularity in all desmoid tumors, without significant differences between primary and recurrent lesions (Fig. 5). No definite relation between cellularity and SI on T2-WI was found.

Natural evolution of primary and recurrent desmoids

In all three recurrent desmoid tumors with follow-up MR examination, an increase of 50 % in size in less than 1 year was seen (Fig. 6). Changes in size of primary desmoids could be evaluated on MR images in 2 patients over a period of more than 6 years. The first patient had a distal, rounded lesion in the popliteal fossa and a proximal, ovoid lesion posterior to the distal diaphysis of the femur (Fig. 7). On the initial examination the distal lesion is heterogeneous with a central part of low SI on all sequences, and has undulating borders. The proximal lesion was more homogeneous with sparse areas of low SI and had convex borders. During follow-up the distal lesion shrunk and became homogeneous because of the overall low SI. The proximal lesion first became more heterogeneous with irregular areas of low SI. Later it shrunk with undulating borders and ended as a near-homogeneous mass of low SI. Biopsy



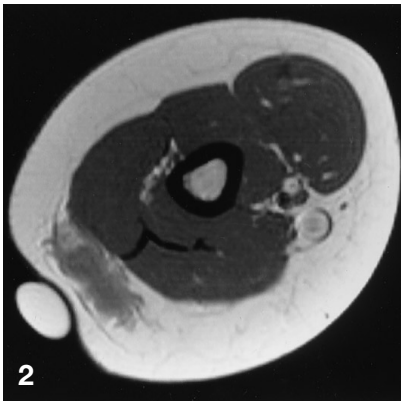
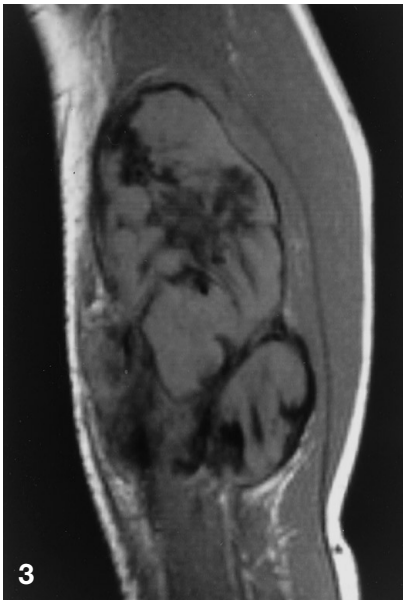


Fig. 1. Desmoid tumor in a 25-year-old woman. Axial T1-weighted image (T1-WI) after contrast administration. Rounded mass laterally between the gluteal muscles. There is moderate peripheral enhancement with central hypointense areas. This case is illustrative for a characteristic location of a desmoid tumor

Fig. 2. Superficial desmoid of the upper arm in a 44-year-old woman. Axial T1-WI after contrast administration. Stellar, nodular, infiltrating lesion within the subcutaneous fat of the deltoid region. Blurred fat plane between the lesion and the adjacent muscle fascia. This case illustrates characteristic shape and location of subcutaneous aggressive fibromatosis



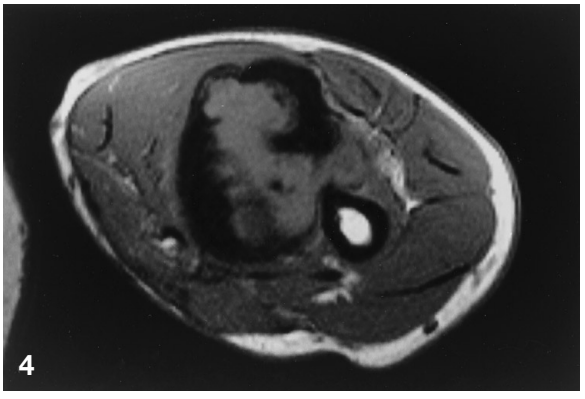


Fig. 3. Desmoid of the calf in a 23-year-old man. Sagittal T1-WI. Fusiform mass with central areas of low signal intensity (SI) and presence of a low-SI capsule around the lesion. This case of deeply seated desmoid illustrates a pattern of natural evolution where dense collagen is found in the centre and cellular parts with higher water content in extracellular spaces at the periphery of the lesion

Fig. 4. Recurrent desmoid of the forearm in a 71-year-old man. Axial T1-WI. Large mass at the volar aspect of the forearm adjacent to the interosseous membrane, involving the proximal ulnar bone and showing a broad area of low SI at the periphery of the lesion. This case illustrates extracompartmental spread, bone involvement, and rapid growth of a recurrent desmoid. Peripheral pattern of low-SI areas reflects dense collagenous tissue

Table 1. Location of primary and recurrent lesions

Location	Primary (n = 20)	Recurrent (n = 10)
Head and neck	1	0
Upper limb	4	0
Trunk	4	2
Pelvis	3	5
Lower limb	8	3

Table 2. Compartmental spread of primary and recurrent lesions as seen on MR imaging

Spread	Primary (n = 20)	Recurrent (n = 10)
Intracompartmental	7	1
Extracompartmental	13	9
Bone involvement	0	3

(performed in 1991) of both lesions revealed only a slightly decreased cellularity in the distal lesion as compared with the proximal one.

The second patient also had multicentric desmoid lesions (Fig. 8). The tumor parts apparently followed the course of the ischiadic nerve. The two distal lesions were small, irregular, and homogeneous with low SI on all pulse sequences. The proximal lesion was large with an intermediate SI on T2-WI, lacking areas of low SI. During follow-up this proximal lesion first extended cranially and later developed central areas of low SI, whereas the distal lesions remain small and unchanged. Note also that in both patients the multicentric lesions were located in the same limb and oriented along the long axis of the extremity.

Discussion

Desmoids or aggressive fibromatoses make up the major part of tumors of fibrous tissue. The term desmoid means band-like or tendon-like lesion. These tumors do not metastasize, but often are locally invasive and recurrences are common.

The reported incidence of desmoids is between three and four cases per million annually. Peak incidence in

Table 3. Overall signal intensities (SI) in primary and recurrent desmoid tumors

SI on T1-WI	Primary ($n = 20$)	Recurrent ($n = 10$)
< Muscle	5	1
= Muscle	13	8
> Muscle	2	1
= Fat	0	0
> Fat	0	0

Table 4. Overall SIs on T2-WI in primary and recurrent desmoids

SI on T2-WI	Primary ($n = 20$)	Recurrent ($n = 10$)
< Muscle	2	0
= Muscle	2	1
> Muscle	10	5
= Fat	5	3
> Fat	1	1

Table 5. Degree of enhancement after contrast administration of primary and recurrent desmoids

Enhancement	Primary ($n = 19$)[a]	Recurrent ($n = 10$)
None	2	0
Minor	4	3
Moderate	4	2
Strong	9	5

Table 6. Amount of low-SI areas on both sequences in primary and recurrent desmoids

Low-SI areas (%)	Primary ($n = 20$)	Recurrent ($n = 10$)
< 20	8	6
20–50	8	3
50–80	3	1
> 80	1	0

our study was in the third decade, in accordance with the literature (between 25 and 40 years) [5]. Mostly equal distribution in both sexes is reported. Other authors found a female preponderance as seen in our study (17 to 9) [6, 7].

The cause of desmoid tumors is unknown, but surgical or accidental trauma, pregnancy, estrogen hormones, and Gardner's syndrome (polyposis coli, bony osteoma, dermoid and epidermoid, nuchal fibroma, abdominal wall desmoid, and mesenteric desmoid) are known associations. The notion of an associated heritable defect in connective tissue formation is supported by some authors [13]. No definite association can be found in our patients, except for an abdominal desmoid tumor developing in a postpuerperal woman and a recurrent desmoid tumor demonstrating an important increase in size (400%) during pregnancy. On the other hand, antiestrogen therapy in one of our patients was unsuccessful. The localization of a large number of extra-abdominal desmoids at the lateral aspect of the shoulder and the buttocks is in favor of a possible posttraumatic (accidental or by subcutaneous injection) etiology. The localization at the interosseous membrane of the forearm and in the muscles inserting on the scapula which undergo repeated frictional trauma also supports the hypothesis of traumatic etiology. In our cases no association with Gardner's syndrome was found.

MR appearance

In accordance with Kransdorf et al. [8], the shoulder and hip girdle are preferential localizations of extra-abdominal desmoid tumors in our series. More specific localizations are hamstrings, gluteus muscle proximal to the insertion on the trochanter major, muscles with insertion on the scapula, deltoid muscle proximal to the insertion on the diaphysis of the humerus, and interosseous membrane of the forearm. The localization along the course of the ischiadic nerve, as seen in two of our patients, has already been reported [9]. Multicen-

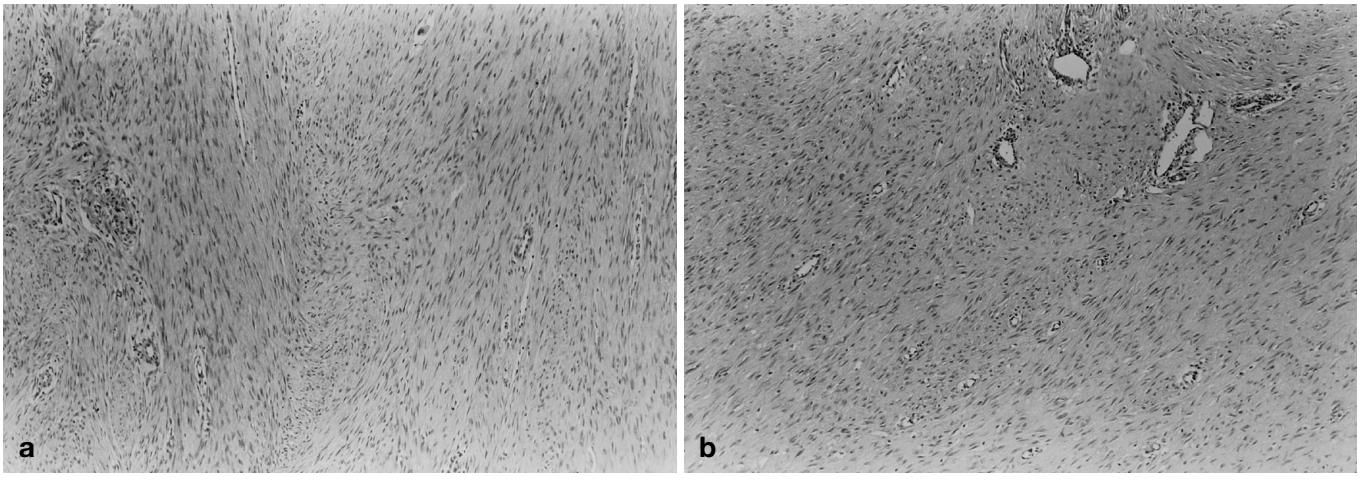


Fig. 5 a, b. Pathologic specimens (hematoxylin-eosin stain × 630). Identical histology together with comparable SIs on T2-WI (not shown) of **a** a primary and **b** a recurrent desmoid in the same patient do raise the question of whether the recurrent lesions are true recurrences or asynchronous primary desmoids

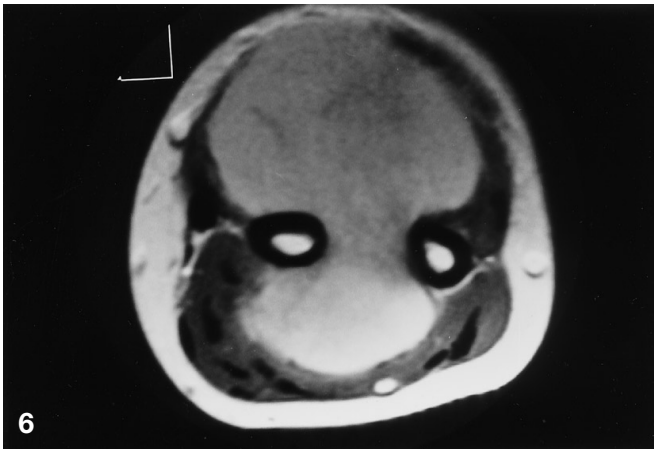


Fig. 6. Recurrent desmoid of the forearm in a 16-year-old girl 3 months after surgery. Axial T1-WI after contrast administration. Large dumbbell-shaped mass on both sides of the interosseous membrane. Marked uniform enhancement after contrast administration. This case illustrates the characteristics of a recurrent desmoid: explosive growth, extracompartmental distribution, and bone involvement (at a higher level; not shown)

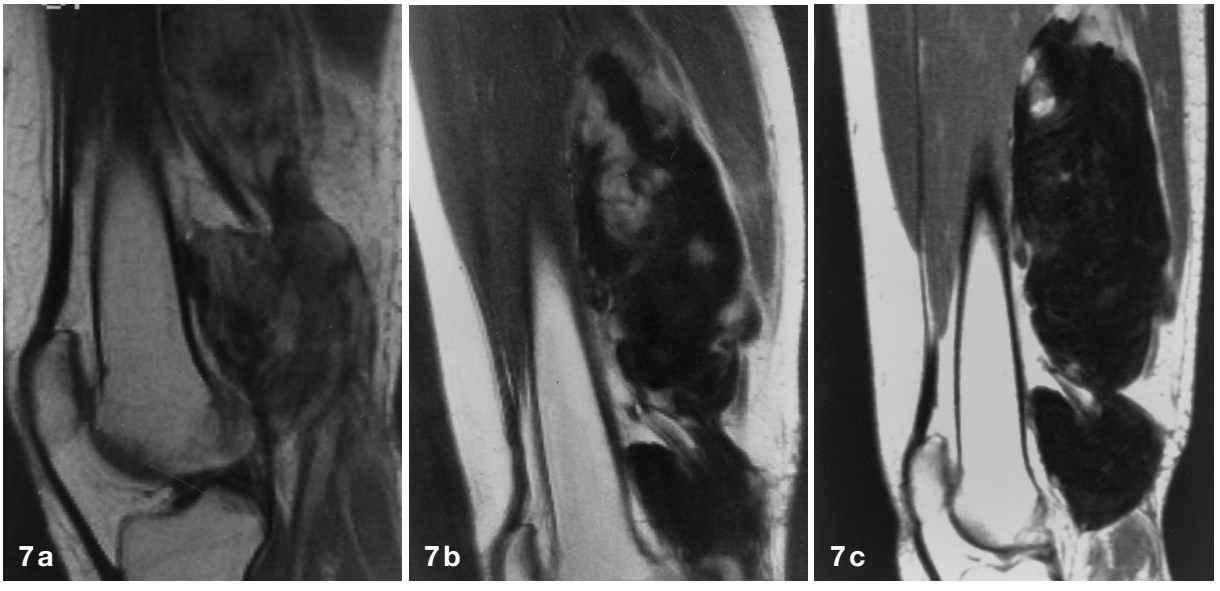


Fig. 7a–c. Desmoid of the popliteal fossa in a 28-year-old woman. Sagittal T1-WI after contrast administration. **a** January 1988. Large dumbbell-shaped mass in the popliteal fossa with marked, nonuniform enhancement of 80% of the lesion. **b** November 1991. Increased size of the proximal part of the mass with decreased size of the distal part. Limited areas (20% of the lesion) of enhancement in the proximal and no enhancement in the distal part. **c** April 1994. No further change in tumor size. Except for two small enhancing nodules within the top of the proximal lesion (5% of the lesion), the whole mass remains hypointense after contrast administration. This case illustrates the natural evolution of a primary desmoid tumor over a period of 6 years, showing the proximal migration of the lesion and the gradual decrease in enhancing areas together with an increase in nonenhancing collagenous components

tricity of desmoid tumors, as seen in four of our patients, has been described previously [10].

Most desmoid tumors are situated in the intramuscular and intermuscular compartments as they originate from the connective tissue of muscle, overlying fascia or aponeurosis. In our study 90% of the lesions were located in these compartments. Juxtacortical aggressive fibromatosis was not seen in our series [11]. Most lesions were fusiform or dumbbell shaped, except for all three desmoids situated in the subcutaneous compartment which all have a similar irregular and stellar appearance with fine peripheral tentacles of which a few are in close contact with the muscle fascia. To the best of our knowledge, this finding has not been reported in the literature. Differential diagnosis of subcutaneous desmoids includes other superficial fibromatoses such as nodular fasciitis, injection granulomas, granuloma annulare, pentazocine-induced myopathy with subcutaneous fibrosis [12], and postsurgical fibrosis.

Despite a benign microscopic appearance, desmoid tumors have an aggressive behavior by large tumor growth and infiltration of neighboring tissues [1]. In our study this was reflected by partially ill- to ill-defined margins in 83% of cases, extracompartmental spread in 73% of cases, and a large diameter (15 lesions had a mean size over 65 mm) in several cases.

Although the MR SI characteristics of desmoid tumors are variable, some patterns have been discerned. According to the literature most desmoids appear hypo- or isointense to muscle on T1-WI. They are mostly inhomogeneous on T2-WI with increased SI relative to muscle and equal SI relative to fat [3, 4]. Frequently, areas of low SI are demonstrated both on T1- and T2-WI. These areas of low SI may be found centrally [14] or peripherally [8] in the lesion and they do not enhance

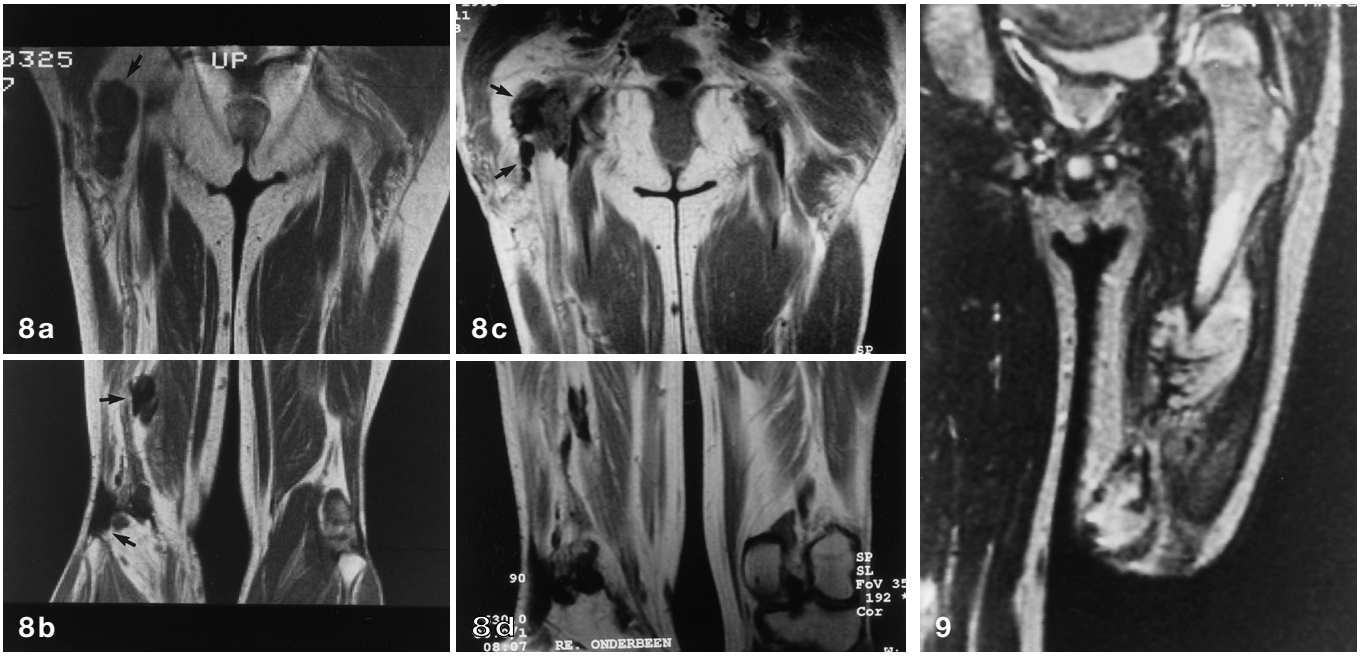


Fig. 8a–d. Multifocal desmoid of the right thigh in a 44-year-old woman. Set of coronal sections through proximal and distal parts of the upper legs to show the distribution of the lesions along the course of the ischiadic nerve. Coronal T1-WI. **a, b** April 1987. Presence of three lesions along the course of the ischiadic nerve *(arrows)*. Both distal lesions are of low SI, whereas the proximal lesion is larger and shows higher SI and convex borders. **c, d** December 1995. Unchanged appearance of both distal lesions. The proximal lesion is slightly enlarged with interspersed areas of low SI *(arrows)*. Multifocal desmoid of the lower limb demonstrating localization along the course of the ischiadic nerve and a natural evolution of a primary desmoid tumor over a period of 8 years. Gradual increase in collagen content (low SI) of the proximal lesion

Fig. 9. Desmoid of the thigh in a 13-year-old boy after previous lower-leg amputation for desmoid tumor. Coronal T2-WI. Presence of a dumbbell-shaped lesion, partially within the stump and partially deeply situated within the posterior compartment of the thigh. Lesions are mostly hyperintense with irregularly distributed areas of low SI. This case illustrates the aggressiveness of a desmoid tumor necessitating lower-leg amputation with postoperative tumoral recurrence or the presence of an asynchronous primary lesion.

after intravenous contrast administration. Our results are in accordance with the literature data. Isointensity to muscle sometimes makes desmoids hardly visible on T1-WI.

Histology

Microscopically, desmoid tumors consist of elongated spindle cells (fibroblasts) of uniform appearance, surrounded and separated from each other by varying amounts of collagen [1]. Cellularity varies but is mostly low to intermediate. Several authors have tried to explain MR SIs by histological composition of these tumors [2, 3, 15, 16]. For these authors areas with low SI on both sequences and without enhancement represent hyalinized foci of collagen, whereas areas with high SI on T2-WI and marked enhancement on T1-WI reflect compact cellular areas [3, 15, 16]. We believe that the intermediate to high SI of desmoids on T2-WI is instead a consequence of the overall low cellularity, whereas differences in SI between different tumor components and between parts of asynchronous multicentric desmoids are a consequence of the combination of variability in cellularity, amount of collagen, water content of the extracellular space, and vascularity. This could also explain why subtle changes in cellularity of tumor components may nevertheless result in substantial variance in SI on T2-WI.

Natural evolution of primary and recurrent desmoids

The natural evolution of multicentric desmoid tumors in two of our patients shares common features [17]. Initially, desmoid tumors increase in size, have convex borders, are mostly of high SI on T2-WI, and have no or minimal areas of low SI. In this first stage, lesions are found to be more cellular, have larger extracellular spaces and less areas of hyalinized collagen. Consecutively, an increase in areas of low SI is seen and the desmoid tumors become more heterogeneous on T2-WI. The remaining areas of high SI on T2-WI are the same areas which show moderate to strong enhancement on T1-WI after intravenous contrast administration. This second stage reflects the increasing amount of collagen deposited centrally or peripherally in the tumor. Finally, desmoid tumors acquire an overall low SI on both spin-echo sequences and a decrease in size with undulating borders. This final stage reflects the overwhelming fibrous composition of the desmoid tumors with decrease in cellularity and decrease in volume of the extracellular spaces and water content. All lesions in both patients demonstrate this pattern of natural evolution, but are in a different stage. The distal lesions are the most fi-

brous ones, and the proximal lesions are in a growing, cellular, and watery stage. Therefore, the distal lesions are regarded as the eldest ones chronologically. A multicentric desmoid tumor in the adductor muscles of the thigh and the homolateral psoas muscle has been reported by Feld et al. [3] and its appearance confirms this pattern of natural evolution. Recently developed lesions proximal to a resected desmoid may represent an asynchronous lesion in a multicentric desmoid, rather than recurrence (Fig. 9).

Most recurrent tumors have a different behavior and morphology [18]. In our series they show an increased frequency of extracompartmental spread, grow considerably faster than primary tumors, and have a tendency to invade bone more frequently. Although scars and hematoma due to previous surgery may mimic extracompartmental spread, these findings illustrate the more aggressive potential of recurrences as compared with primary desmoids. On the other hand, there is no obvious difference in histological presentation neither in overall signal intensity on T2-weighted images nor in proportion to low-SI areas. Variability of SI on T2-WI for primary as well as for recurrent lesions is a consequence of the same phenomena mentioned previously. Recurrent tumors are supposed to undergo the same evolution as the primary ones.

In conclusion, when you see a female patient in the reproductive age with a multicentric tumor in the muscles of the shoulder or hip girdle, which is heterogeneous and has areas of low SI on T1- as well as on T2-WI, include desmoid tumor in your differential diagnosis. Subcutaneous desmoid tumors can present as an irregular stellar mass in close contact to muscle fascia. Recurrences tend to be more aggressive, having more frequently extracompartmental spread and bone involvement, and growing considerably faster. After initial growth, spontaneous evolution of desmoids is characterized by shrinking and an increase in low-SI areas on T2-WI. Whereas distal lesions shrink, the more recent lesions in asynchronous multicentric desmoids have a tendency to develop proximally in the same limb, and should not be confused with recurrences. Follow-up MR imaging of desmoids indicates natural regression of desmoids and more aggressive behavior of recurrences, which may justify a more conservative therapeutic approach.

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