MAGNETIC RESONANCE IMAGING IN THE STUDY OF SPAVIN IN RECENT AND SUBFOSSIL CATTLE

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Summary

The ankylosis between the tarsal and metatarsal bones (spavin) of cattle which depends on several parameters (weight, age, work, etc.) can be considered a characteristic of draught animals. Magnetic resonance imaging (MRI) was used to study this fusion (spavin) in recent and subfossil cattle bones. Use of the MRI method has two requirements: The sample must contain hydrogen nuclei (H1) and its spin-spin relaxation time (T2) must be long enough to permit the detection of the nuclear magnetic resonance (NMR) signal. We took negative images of the bone matrix by saturating it with a fluid characterized by a longer T2 time than that of the bone tissue. Another limitation in using MRI in imaging archaeological bone specimens is the presence of paramagnetic or ferromagnetic substances inside the subfossil bone matrix. These drastically shorten the T2 value and create local magnetic field gradients. This results in loss of resolution and contrast.

Résumé

Imagerie par résonance magnétique nucléaire pour l'étude de l'ankylose dans des os de bovins récents et subfossiles.

Le phénomène d'ankylose sur les tarsiens et métatarsiens de bœuf dépend de certains paramètres (poids, âge et travail). Il peut être considéré comme caractéristique des bêtes de somme. Cet article présente des résultats d'imagerie par résonance magnétique nucléaire (IRM) pour l'étude de l'ankylose. Pour réaliser des images par la technique IRM appliquée aux noyaux d'hydrogène de l'échantillon analysé, deux contraintes majeures existent : l'échantillon doit posséder des noyaux d'hydrogène, et son temps de relaxation spin-spin T2 doit être suffisamment long pour permettre la détection du signal RMN. Nous avons réalisé des images négatives de la matrice osseuse en saturant ses cavités par un fluide dont le paramètre T2 est plus favorable. Une autre limitation est la présence de substances paramagnétiques ou ferromagnétiques. Ces dernières raccourcissent de façon drastique la valeur du T2 et génèrent des gradients locaux de champ magnétique.

Zusammenfassung

Kernspintomographie zur Untersuchung des Spat bei modernen und subfossilen Rindern.

Bei Rindern hängt die Ankylose zwischen Fußwurzel- und Mittelfußknochen von verschiedenen Faktoren ab. Hierzu gehören Alter, Gewicht und die Belastung beim Einsatz als Zugtier. Der Spat wurde an einem modernen und einem subfossilen Rind mit Hilfe der Kernspintomographie (MIR) untersucht. Hierzu müssen zwei Bedingungen erfüllt werden. Die Probe muß Wasserstoffkerne (H1) enthalten und die Spin-Spin-Abklingzeit (T2) muß lang genug sein, um die Erfassung des MIR-Signals zu ermöglichen. Von der Knochenmatrix wurden Aufnahmen gemacht, indem sie mit einer Flüssigkeit mit höherer T2-Zeit getränkt wurden. Das Vorhandensein para- oder ferromagnetischer Stoffe in der subfossilen Knochenmatrix sorgt bei der Darstellung per MIR für weitere Schwierigkeiten. Sie verkürzen die Zeit T2 erheblich und erzeugen örtliche Magnetfeldgradienten. Als Folge verschlechtern sich Auflösung und Kontrast.

Key Words

Magnetic resonance imaging, Spavin, Draught cattle.

Mots clés

Imagerie par résonance magnétique nucléaire, Ankylose, Bêtes de somme.

Schlüsselworte

Kernspintomographie, Spat, Zugtiere.

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Introduction

For almost a century, spavin, the ankylosis between tarsal and metatarsal bones (Nieberle and Cohrs, 1962: 895), has been interpreted as the result of fatigue and culminating minor trauma caused by draft work which ultimately leads to ankylosis (Tormay, 1906: 117). In this paper an analytical approach was adopted in studying dynamical loading and spavin.

Magnetic resonance imaging (MRI) is a method of choice in the non-invasive study of samples such as bone. To realize MRI applied to hydrogen nuclei (H1) two conditions must be met. First, the sample must contain H1. Then, its spin-spin T2 time must be long enough to permit the detection of the NMR signal. This second parameter is one of the intrinsic magnetic properties of any biological tissue and is a limiting factor when MRI is used to study the bone tissue. Its value is about 600 microns which inhibits the detection of any NMR signal when spin-warp MRI techniques are employed since the bone tissue generates a hypointense signal inside the MR image (Demeure *et al.*, 1994).

Material and methods

Spavin was studied in a series of autopodia of 15 contemporary mature draft oxen and 6 young bulls from Rumania (detailed composition: Bartosiewicz *et al.*, 1993: 70). They represent a mixture between brown cattle and the traditional "Podolian" type from southeastern Rumania.

The tarsal and metatarsal bones of a 12 year old, 478 kg draft ox with advanced spavin and a Roman Period specimen were subjected to detailed MRI studies. All experiments were run using a 4.7 Tesla (200 MHz) Bruker Biospec (Bruker, Karlsruhe, Germany) imager equipped with a non-shielded gradient hardware with a 152 mm inner diameter (rise time: 125 microseconds; maximum gradient strength: 60 mT/m). Images were created in a linearly polarized "bird cage" transmitter-receiver coil with a 70 mm inner diameter with 8 struts and distributed capacity.

Cattle bone images were acquired using a Spin-Echo pulse sequence characterized by Repetition Time/Echo Time TR/TE = 811 ms/13 ms. The Field Of View (FOV), slice thickness and image matrix were 10 cm, 1.8 mm for recent bones (3 mm for subfossil bones) and 256 by 256 pixels providing an in-plane spatial resolution of 390 microns per pixel. The problem of short spin-spin T2 time was overcome by taking negative images of the bone matrix by saturating its cavities with a fluid (Soltrol 90 oil) characterized by a longer T2 time (1s) than the bone tissue. In such images, the oil is hyperintense, whereas heavily ossified structures draw the hypointense lines. Prior to imaging, cattle bones were first placed in a controlled vacuum (2 mmHg obtained by a mechanical pump) to eliminate any extraneous gas or liquid. The samples were then filled with Soltrol 90 (aliphatic oil) in the vacuum chamber.

In addition to MR imaging, a pathological index was developed for each individual by scoring eleven types of morphological anomalies on the autopodium bones (exostoses, eburnations etc.) on an ordinal scale between 1 and 5. The condition of all four feet was expressed as the percent of maximum scores.

Results and discussion

Series of MRI pictures revealed that inside the hock joint, ankylosis starts with fusion in the mediodorsal parts of medially located bones (fig. 1), then it spreads to the rest of the articulation. Ungulate metapodia are subject to smaller bending forces: the dorsal surface of metatarsus is mostly under compression (Lanyon and Baggot, 1976). Metapodial asymmetry also shows that loading is heaviest on the medial side. In the case of subfossil samples, contamination with paramagnetic and ferromagnetic compounds involved in the *post mortem* mineralization process of bone drastically shorten the T2 value and create local magnetic field gradients which result in a poor signal-to-noise ratio in the images and lead to a loss of resolution and contrast. The studies of modern bone, however, could be used in further investigations.

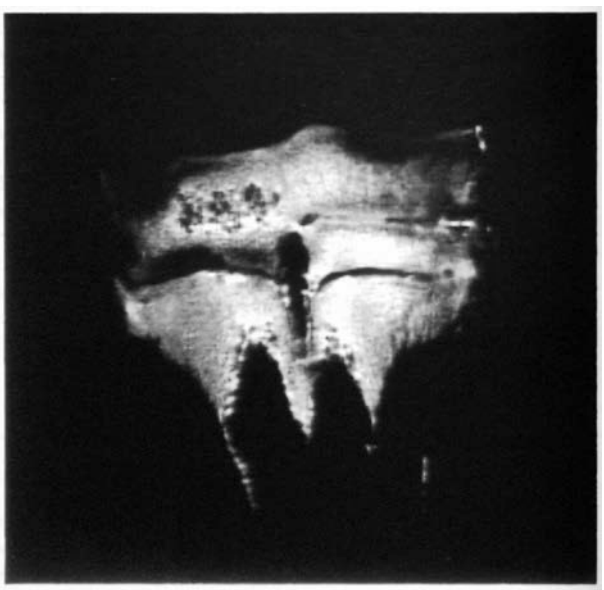

Fig. 1: MRI showing fusion points (center left side) in the dorsoventral plane 11.6 mm behind the dorsal surface of a left hock joint. Slice thickness: 1.8 mm.

Table 1: Cases of spavin in modern draft oxen arranged in the order of advancement.

No.	Pathol. score	Age (years)	Live weight (kg)	Bones fused to metatarsal	Side
11	21.964	8	850	(heavy exostoses)	both
9	13.413	12	478	2nd + 3rd tarsal	dex.
3	20.739	10	674	2nd + 3rd tarsal	both
24	5.040	?	?	centrotarsal	sin.
10	25.516	9	780	centrotarsal	dex.

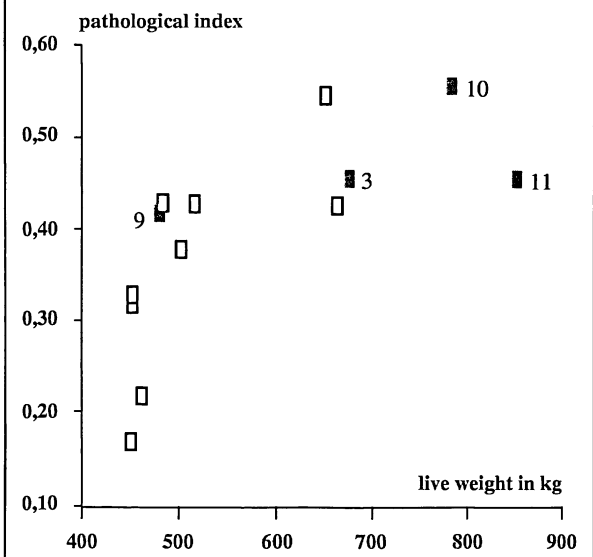

Fig. 2: Pathological index as a function of live weight. Empty: animals without ankylosis; squares: cases of spavin.

Table 2: Relationships between pathological scores (y) to age and live weight (x) in modern draft oxen.

	Pathological score (% of maximum)	Age (years)	Live weight (kg)
Mean value	12.582	8.688	569.3
Standard deviation	8.169	4.672	137.8
Variables	Coefficient of correlation	df	Regression equation
Score/Age	0.304	12	$y = 0.126 x + 9.373$
Score/Live weight	0.888	12	$y = 0.055 x - 18.327$

"Narrow hocks" (Tormay, 1887: 122) leads to a weak, desoriented gait in draft oxen. This foot conformation exacerbates the effects of strain in the hock joint. Rosenberger (1970: 491) also mentions medially turned hocks as a predisposition for spavin.

External studies of the material confirmed that spavin begins with exostoses and lipping around the proximal end of metatarsus (tab. 1) followed by the ankylosis between the metatarsus and the medially located 2nd + 3rd tarsus. This process then advances to the centrotarsal region.

Dynamical loading, however, is not the single source of spavin. Most foot disorders discussed by Nigam and Singh (1980: 623) occurred in bulls older than four years. Table 2 shows a positive correlation between ages and pathological scores in oxen. Scores are better related to live weight ($r = 0.888$; $df = 12$; 95% confidence level). A 500 kg ox would score around 20% on the pathology scale (fig. 2).

Hypoperfusion related to age is known to play a role in spavin as well (Boosman *et al.*, 1989: 153). The lack of exercise and intensive feeding exacerbated spavin in the dairy herd studied by Holmberg and Reiland (1984: 125). The movements of the tarsal joints are most restricted in ungulates (Hughes and Dransfield, 1953: 279). Interspecific comparisons, however, are biased by both scaling and selection. The legs of deer sustain a greater dynamic impact relative to live weight than do the leg bones of a large bovine (Kreutzer, 1992: 274). Still, spavin is a rarity in cervids (Van Wijngaarden-Bakker, 1981: 80) which points to the importance of selection pressure.

Gagged hocks and turned-out toes result from "social evolution" (Alur, 1975: 410) in domesticates. Individuals with poor constitution were not selected for draft work. Foot conformation has a relatively great heritability ($h^2 = 0.36$; Haring, 1955: 270).

Conclusions

MRI confirmed that ankylosis starts in the mediodorsal hock segments most exposed to loading. Prolonged and/or intensive joint use undoubtedly lead to a greater risk of spavin. Draft exploitation is thus in part responsible for the development of spavin in cattle. Heritability, however, should not be underestimated. The relationship between spavin and loading is stochastic, no individual case can be looked upon as a proof of draft exploitation.

This is the first time MRI was introduced in basic research in archaeozoology. It was successfully used in pinpointing critical links between loading and spavin in modern reference animals. Applied uses of MRI in this field, however, are not only hampered by its high cost. Another limitation in using MRI is the presence of paramagnetic or ferromagnetic substances inside the matrix of subfossil bones. These drastically shorten the T2 value of oil and create local magnetic field gradients. MR images will be blurred by this artifact of magnetic susceptibility.

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