

Morphological analysis of surgically removed menisci

Correlation with clinical findings

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Μορφολογική ανάλυση
χειρουργικώς εξαιρεθέντων μηνίσκων

Περίληψη στο τέλος του άρθρου

Key words: Meniscus, MRI, Mucoïd degeneration

Meniscus lesions are quite frequent and when they are accompanied by prominent symptoms surgery is indicated, consisting of arthrotomy or arthroscopic meniscectomy. The lesions are caused by major trauma or degenerative changes. Until recently trauma was considered to be the main cause of meniscus lesions especially in the young. Degenerative processes were thought to be an essential factor in the development of the lesion, especially of the so-called degenerative type of meniscus lesion.^{1,2}

The aim of this study was to demonstrate similarities and differences in menisci surgically removed either because of trauma or because of pain caused by degeneration.

MATERIAL AND METHOD

A control group consisted of 12 individuals aged 18–20 years with no history or evidence of knee injury or disease who died accidentally from whom the menisci were removed postmortem. The patients with complaints of pain were aged between 15 and 55 years, the majority between 20 and 40 years. From these patients were surgically removed 60 menisci, which were all analyzed histologically and histochemically. Of the removed menisci 46 were medial (35 of the right and 11 of the left knee) and 14 lateral (10 of the right and 4 of the left knee). The duration

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of the disease in 40 cases was from one month to 5–6 years, of which 30 patients had the disease for less than one year. Of the total of 60 patients only 15 had a history of knee trauma, while 45 had complaints which were not related to trauma, with the pain in the knee joint, and positive McMurray and Apley signs in 85% of cases. The knees of all patients were first visualized by arthroscopy, and five underwent magnetic resonance imaging (MRI).

A performed arthroscopy was under general or spinal anesthesia, with tourniquet. The anterolateral portal to place telescope (Karl Storz, 30 degrees tubes) was used with standard equipment (digital camera, monitor, light source) to obtain the best view of the interior of the knees.

All material for light microscopy was fixed in 10 neutral buffered formalin and paraffin embedded. Sections (5–7 μ m thick) were stained by the following methods: Hematoxylin-eosin, periodic acid Schiff (PAS) with diastase digestion, Alcian blue (pH 4.5 and 0.5), hyaluronidase procedure, Paff-Halmi, Masson trichrome, Malory collagen, toluidine blue and Giemsa. Following Paff-Halmi staining collagen fibers become yellow and green and elastic fibers violet.

RESULTS

Controls

On arthroscopy all the control menisci from individuals who died accidentally were white and firmly attached to the capsule. Histological sections of these menisci showed parallel, compact wavelike and longitudinally twisted collagen fibers (fig. 1). Between the collagen fibers there were rare elastic fibers, fibroblasts and fibrocytes. Alcian blue staining revealed hardly visible acid mucopolysaccharides, and PAS staining induced a negative reaction. Numerous blood vessels were found only at the periphery of the meniscus while the central part was avascular.



Figure 1. Normal meniscus: Parallel, compactly distributed collagen fibers (Paff-Halmi staining; magnification 10 \times).

Patients with a symptomatic knee

Interstitial lesions were found in all 5 menisci examined by MRI. Arthroscopy in the majority of the patients showed menisci of normal surface, and in 15 patients (25%) obvious meniscal lesions of the bucket-handle type. In some cases there were degenerative type lesions, some of the horizontal cleavage type.

Histological and histochemical analysis of all of the 60 menisci showed larger or smaller degenerative lesions, 10 of which included cysts. Prominent mucoid degeneration of the meniscus with abundant accumulation of mucopolysaccharides and positive Alcian blue reaction was observed in 45 cases. Collagen fibers were broken and irregularly distributed or they were absent in parts of the focus mucoid degeneration (fig. 2). Islets of mucoid degeneration with collagen fibers and multiple tiny elastic fibers usually occupied the central part of the meniscus extending towards the periphery (fig. 3).

In advanced lesions, newly formed elastic fibers were rough and hyalinized. The morphological changes in various regions of one meniscus were different depending on when they occurred. In some sites of mucoid degeneration the remains of decomposed collagen fibers could be seen, while in others they had completely disappeared with only islets of mucoid degeneration remaining. In these sites the formation of delicate elastic connections was observed with portions of mature connective tissue, rough and hyalinized. These findings indicated that the lesion does not affect the whole meniscus at once, but different parts at different time periods, resulting in morphological variety. Regions with mucoid degeneration had large numbers of chondrocytes and fibroblasts, distributed either in clusters or individually. Lacunae with chondro-

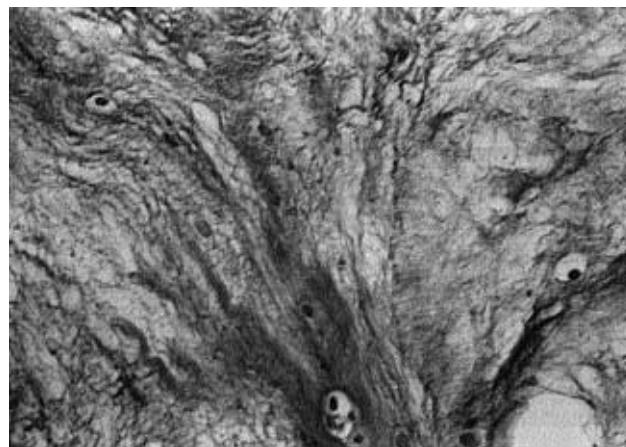


Figure 2. Removed meniscus: Irregularly distributed collagen fibers with mucoid degeneration (Paff-Halmi staining; magnification 10 \times).

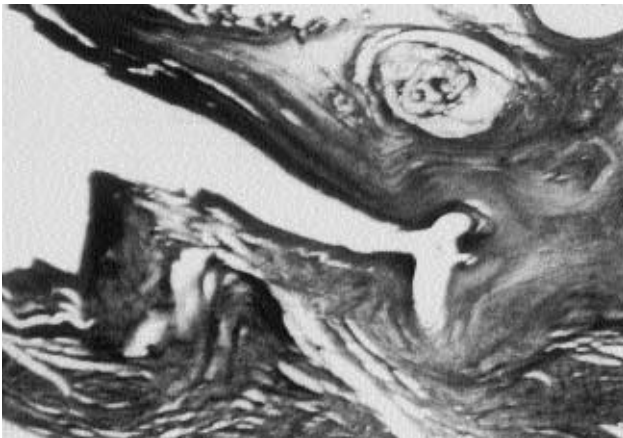


Figure 3. Degenerative meniscus lesion: Islets of mucoid degeneration with collagen fibers and tender elastic fibers (Alcian blue; magnification 10x).

cytes contained material which reacted strongly positive to Alcian blue (pH 0.5 and 4.5) or negative on the PAS method. The hyaluronidase procedure revealed no changes. Alcian blue positive material was still present after chondroitin-6-sulphatase action, which excluded the presence of mucopolysaccharide chondroitin-6-sulfate. Application of chondroitin-4-sulphatase decreased the Alcian positive material, indicating the presence of chondroitin-4-sulphate mucopolysaccharides. The Paff-Halmi staining showed multiple delicate violet elastic fibers in foci of mucoid degeneration. In the larger foci of mucoid degeneration there were no remains of broken collagen fibers, and the surrounding elastic fibers were rough and irregularly distributed. In some places, the newly produced elastic fibers were hyalinized. Signs of tissue degeneration were found in the majority (45) of analyzed menisci (fig.

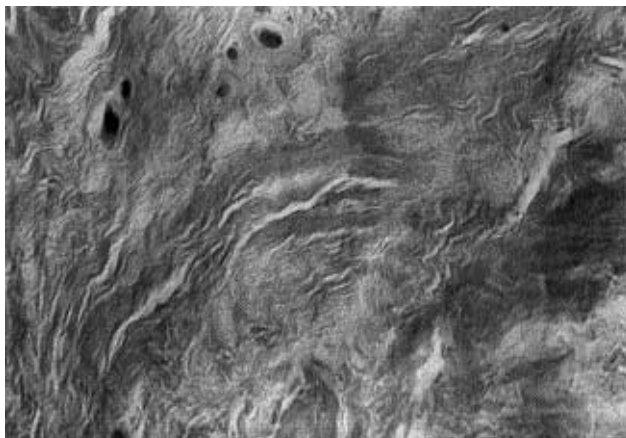


Figure 4. Meniscus tissue degeneration with destruction in meniscus lesion (Hematoxylin-eosin; magnification 10x).

4). In 5 cases the menisci had blood vessels with thickened walls, a narrowed lumen and intimal hyperplasia. Some blood vessels were completely obliterated and resembled fibrous nodules (fig. 5).

COMMENT

Menisci are semilunar cartilaginous joint bodies which originate from mesenchymal tissues. During the fetal period menisci are made up of densely distributed fibroblasts, and they are vascularized throughout their complete width. After birth the blood vessels gradually retreat to the periphery and the initial vascularization of meniscus is maintained until the age of 9 years.³ In adults blood vessels are found only in the outer 1/5 of the menisci, the inner 4/5 being non-vascularized and supplied via the synovial fluid by diffusion.⁴ Transformation of mesenchymal cells to fibroblasts and then to chondrocytes takes place in the postnatal period. The development of chondromucoids occurs at the age of about 8 years, which is proof of fibroblast metaplasia into chondrocytes.⁵

The inner 2/3 of menisci contains cells which correspond to either chondroid or cartilaginous cell types. Chondrocytes are round or oval, with foamy cytoplasm, they are encapsulated and they produce acid mucopolysaccharides. In contrast to chondrocytes, chondroid cells are incapable of producing chondroitin sulfate, otherwise typical for cartilage tissue.⁶

Microscopically, the structure of healthy menisci is characterized by wavy, parallel and longitudinally twisted collagen fibers. Between the collagen fibers as well as chondrocytes there is a small quantity of elastic connective tissue.⁷ The amount of elastic connective tissue increases in childhood and also during healing process after trauma.

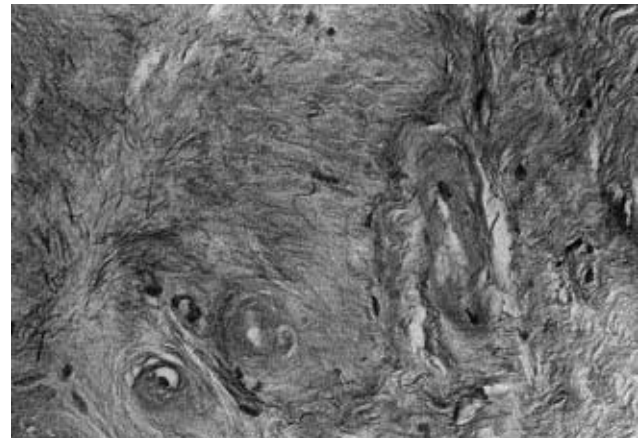


Figure 5. Degenerative meniscus lesion: Blood vessels with completely obliterated lumen (Alcian blue; magnification 10x).

Defects in menisci may result from trauma or disease (most often degenerative), each process giving completely different lesions. Meniscus lesions are diagnosed clinically, arthroscopically and by MRI, which is the most reliable method, especially in cases of intrasubstantial lesions.^{8,9} Arthroscopy and MRI may both offer significant information about the condition of the meniscus when the lesion is small and superficially visible, e.g. the horizontal degenerative type of rupture, but if the lesion is within the meniscus, the findings are positive only on MRI.¹⁰ The MRI was found to be in agreement with arthroscopy in 81% of cases, showing more signs of degeneration but less tears of the menisci than arthroscopy,¹¹ and it can be used as a first-line diagnostic examination in patients with suspected injuries of the meniscus or cruciate ligament.¹²

Noble et al¹³ found that 34% of 100 menisci investigated on autopsy had degenerative lesions. The affected menisci appeared normal on macroscopic observation and arthroscopy, but showed severe degenerative lesions on MRI and on histology.^{8,9} Degenerative tissue changes were found in 45% of a series of surgically removed menisci^{13,14} and histologically severe degenerative changes were found in up to 90% of these cases, causing meniscus fissure.¹

Longitudinal fissure (bucket-handle type) occurs in purely traumatic lesions and is more easily to observe macroscopically, in contrast to horizontal fissure which occurs as a consequence of degenerative lesions and is visualized during arthroscopy.^{15,16} Cases with traumatic meniscus fissure lacked the change in acid polysaccharide level which are characteristic of degenerative meniscus lesions (Lithonen et al cited by Noble).¹³ At least 90% of all meniscus injuries were to a certain degree the consequence of the degenerative meniscus lesions,¹³ and 35 of 68 removed menisci had a history of trauma.⁷ Histological analysis revealed mucoid degeneration of meniscal tissue with higher levels of mucopolysaccharides in the meniscal stroma.¹⁷ In menisci with mucoid degeneration horizontal fissure was more frequent, while meniscal breakage was more frequent in those with hyalinization and acellularity. The finding of an increase in elastic fibers replacing absent collagen fibers¹⁸ corresponds to the data of the present study. It is believed today that the increase in elastic fibers in place of collagen fibers is the process responsible for meniscal rupture.¹⁸

Of the 60 cases with pain in the knee analyzed in the present study only 15 had a history of meniscal trauma. In the trauma cases, no mucoid degeneration was demonstrated in meniscal tissue by applied methods, and acid

mucopolysaccharide presence was minimal, as shown by Alcian blue. Neither multiplication of elastic tissue nor increased numbers of fibroblasts and chondrocytes were observed.

The remaining 45 patients had defects which had developed while walking manifested by long-lasting pain in the knee. The majority were in their middle age but some were between 15 and 30 years, indicating that physically active young people were also affected. Their symptoms lasted 1–2 years and consisted of joint pain, an indication of chronic meniscal disease. The findings of the present study agree with statements that 45% of patients over 40 years had moderate to severe changes on MRI and only 22% of those under 30 years.¹¹ Correlation of meniscus degeneration with the age of patients showed an increase of grade 3 and 4 lesions with advancing age. In asymptomatic subjects, MRI shows an increasing prevalence of meniscus alterations which correlates with age. Especially in subjects over 50 years, a significant number of meniscus tears must be expected. This shows the potential danger of the use of MRI alone as a basis for the determination of surgical intervention.¹⁹

In the cases in the present study, the medial menisci were more often affected than lateral, and the right medial more frequently than the left. In 10 medial menisci cases with spontaneously developed defects, meniscal cysts were found especially in the lateral meniscus.

In cases without a trauma history, severe degenerative changes were found with decomposition and disappearance of collagen fibers, multiplication of elastic fibers and an abundant presence of islets of acid mucopolysaccharides (strong positive reaction to Alcian blue pH 0.5 and 4.5). In the opinion of the authors acid mucopolysaccharides cause meniscal interstitial lesion or rupture. When this happens, the meniscal function changes and tension at the meniscocapsular joint increases, resulting in pain.⁹ In sites with increased acid mucopolysaccharides, higher numbers of chondrocytes and fibroblasts were found supporting the theory that these cells excrete acid mucopolysaccharides.

Hyalinization and acellularity of newly formed elastic fibers indicates a long-lasting process, while in other foci of mucoid degeneration gentle, weblike elastic fibers were observed. Therefore, it was concluded that the process does not affect concurrently the whole meniscus at once and that the changes vary in relation to time of occurrence of the degeneration. In several cases there were signs of meniscal tissue regeneration.

The presence of blood vessels in the medial part of the meniscus where they are not normally found suggests a meniscal inflammatory process as a response to disease or trauma.

Morphological studies indicate that the destruction of collagen fibers with replacement by increased numbers of elastic fibers and severe mucoid degeneration of meniscal tissue are the main causes of interstitial lesions or of meniscal rupture. Symptoms may occur without meniscal rupture in the case of second and third degree meniscal degenerative changes which are also an indication for surgery. This was the case in the majority of the patients without clear trauma history in the present study. Histologic analysis confirmed that negative macroscopicarthroscopic findings do not necessarily mean that there is no meniscal defect. Lesions within the inner substance were often found which were symptomatic and where the histologic findings corresponded to the MRI findings.

ΠΕΡΙΛΗΨΗ

Μορφολογική ανάλυση χειρουργικών εξαιρεθέντων μηνίσκων

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Οι μηνίσκοι, που εξαιρέθηκαν χειρουργικά από 60 ασθενείς, ηλικίας 15-60 ετών, με πόνο στο γόνατο, συγκρίθηκαν με εκείνους που εξαιρέθηκαν από 12 μάρτυρες 18-25 ετών. Από τους ασθενείς, μόνο οι 15/60 είχαν ιστορικό τραυματισμού. Συχνότερα προσβεβλημένος ήταν ο μέσος μηνίσκος του δεξιού γόνατος στους μέσης ηλικίας ασθενείς. Πέντε από τους ασθενείς που εξετάστηκαν με MRI, βρέθηκε ότι είχαν διάμεσες αλλοιώσεις των μηνίσκων. Η κλινική και μορφολογική (ιστοπαθολογική και ανοσοϊστοχημική) ανάλυση έδειξε ότι η κύρια αιτία της ρήξης των μηνίσκων ήταν η σοβαρού βαθμού βλενωδής εκφύλιση και η καταστροφή των ινών του κολλαγόνου με αύξηση του αριθμού των ελαστικών ινών.

Λέξεις ευρετηρίου: Βλενωδής εκφύλιση, Μηνίσκος, MRI

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