EFFECTS OF AN IN-SUBSTANCE CONDUIT WITH INJECTION OF A BLOOD CLOT ON TEARS IN THE AVASCULAR REGION OF THE MENISCUS

by M. NAKHOSTINE, D. H. GERSHUNI and L. A. DANZIG

The purpose of this study was to test the hypothesis that healing of a stable tear in the avascular region of the meniscus occurs when a horizontal conduit, extending from the periphery to the defect, is filled with an exogenous fibrin clot. In 6 sheep a full-thickness laceration was made in the lateral meniscus, and autologous blood clot was then injected into the conduit. Three animals in the control group received identical meniscal tears but no additional treatment. Casting and a harness prevented weight-bearing and maintained the knee in a flexed position. Twelve weeks after the operation histologic examination revealed only partial healing in one animal. In both the experimental and control groups increased numbers of dividing chondrocytes on either side of the tear were seen. We conclude that an in-substance conduit in combination with the injection of a blood clot is not sufficient to facilitate complete healing of a tear within the avascular region of the lateral meniscus of the sheep when the knee is immobilized only with a harness.

Keywords : in-substance conduit ; blood clot ; meniscus ; avascular region.
Mots-clés : tunnel ; caillot sanguin ; ménisque ; région non vascularisée.

RÉSUMÉ

M. NAKHOSTINE, D. H. GERSHUNI et L. A. DANZIG. Hypothèse de la guérison d'une lésion méniscale par tunnélisation de la zone avasculaire.

Le but de ce travail était de vérifier l'hypothèse, que la guérison d'une lésion stable du ménisque dans sa partie avasculaire est possible si un conduit horizontal reliant la partie externe à la lésion du ménisque est créé et rempli d'un caillot de sang autologue.
Chez 6 moutons une lacération complète et longitudinale de 5-7 mm de long a été créée dans la partie antérieure interne et avasculaire du ménisque externe. Avec un trépan d'un diamètre de 1,85 mm, un tunnel horizontal reliant la périphérie du ménisque et la lésion fut pratiqué et le tunnel rempli d'un caillot de sang autologue.
Chez trois animaux du groupe de contrôle une lésion identique du ménisque fut provoquée mais pas traitée. La mise en charge fut empêchée chez tous les animaux par un plâtre en flexion maximale de la cheville et par un harnais maintenant le genou en position fléchie.
Douze semaines après l'opération l'examen histologique ne montra qu'une guérison partielle chez un des animaux du groupe expérimental. Le tissu de réparation montrait des vaisseaux encadrés par des cellules fusiformes et ovales avec des noyaux vésiculeux. Dans les deux groupes, des divisions accrues de chondrocytes étaient présentes des deux côtés de la lacération. Un genou du groupe expérimental était infecté et fut éliminé de l'étude.
Nous en concluons que chez le mouton un conduit horizontal rempli de sang autologue en combinaison avec l'immobilisation du genou par un harnais n'est pas suffisant pour obtenir la guérison complète d'une lacération du ménisque externe dans sa région avasculaire.

SAMENVATTING

M. NAKHOSTINE, D. H. GERSHUNI en L. A. DANZIG. Resultaat van het inbrengen van een tunnel gevuld met een bloedklonter , door een scheur van het avasculair gedeelte van de meniscus.

Het doel van deze studie is de geldigheid na te gaan van de hypothese dat een stabiele scheur van het

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avasculaire gedeelte van de meniscus kan genezen wanneer een horizontale tunnel, gevuld met een bloedklonter, ingebracht wordt van de periferie naar het defekt.
Bij 6 schapen werd een 5 à 7 mm lange, longitudinale scheur van de laterale meniscus verwezenlijkt. De tunnel was ingebracht van de periferie naar het letsel. Een autologe bloedklonter werd geïnjecteerd in de tunnel. Bij 3 controle schapen werd een soortgelijke scheur verwezenlijkt maar zonder behandeling. Door het gebruik van een gips in maximale flexie van de enkel en van een harnas, dat de knie in flexie houdt, kon geen belasting van het lidmaat gebeuren. Twaalf weken na de ingreep toonde een histologisch onderzoek slechts een gedeeltelijke genezing in één dier. Zowel in de geëxperimenteerde als in de controle groep werd een verhoogd aantal chondrocyten gezien aan de beide zijden van de scheur. Wij konkluderen dat het inbrengen van een tunnel, gevolgd met de injectie van een bloedklonter, onvoldoende is om een volledige heling van een scheur in de avasculaire streek van de laterale meniscus bij het schaap te bekomen, zelfs met volledige immobilisatie van het lidmaat, zonder belasting.

INTRODUCTION

The medial and lateral genicular arteries supply the capillary plexus within the synovial and capsular tissues adjacent to the menisci. The vessels penetrate only 10 to 30% of the width of the medial and 10 to 25% of the width of the lateral meniscus (3, 6, 13). Healing of meniscal tears appears to be based on vascular and cellular ingrowth, hormonal stimulation of cell proliferation and mechanical stability to allow the repair tissue to fill the lesion (4, 9, 13). The inability of the inner region of the meniscus to heal is thought to be due to either a lack of vascularity per se or to the absence of a hematoma and its chemotactic stimuli for cells aiding in repair (14). Total meniscectomy, or in recent years partial meniscectomy, has been advocated as suitable treatment for meniscal tears in the avascular region. However, functioning intact menisci are important for joint stability, shock absorption and load transmission (1, 11). It is therefore not surprising that several authors have reported that progressive joint degeneration frequently occurs after meniscectomy (5, 8, 12). De Haven (7) therefore recommended meniscus repair to maintain the function of the meniscus.

By creating a horizontalm core from the periphery of the meniscus to a tear located in the avascular inner half, Gershuni *et al.* (9) achieved partial healing in 3 and complete healing in 2 dogs (total of 9) after 12 weeks of moderately rigid cast immobilization. Arnoczky (4) reported healing of vertical full thickness, cylindrical lesions, measuring 2 mm in diameter, in the avascular portion of canine menisci after the defects had been filled with fibrin clots.
The purpose of the present study was to determine whether healing of a stable tear in the avascular region of the meniscus is facilitated when a horizontal conduit, extending from the periphery to the defect, is filled with an autogenous fibrin clot.

MATERIAL AND METHODS

Nine mature female sheep (73-91 kg) were divided into 2 groups. In the experimental group 6 sheep were anesthetized with intravenous sodium thiamylal (20 mgg/kg), intubated and maintained on inhalation anesthesia with halothane and oxygen. Under sterile conditions, a lateral parapatellar incision was made over the right knee. After transection of the extensor digitorum longus tendon the anterior part of the lateral meniscus was exposed and drawn forward with the aid of a small towel clip. A 5- to 7-mm longitudinal, full-thickness incision was then made in the avascular inner half. Using a 1.85-mm diameter microdissecting trephine (Roboz Products, Washington D.C.) a horizontal conduit was created from the periphery of the meniscus to the mid-portion of the lesion (fig. 1). Then, 10 milliliters of whole

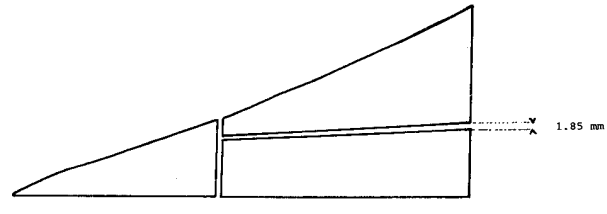

Fig. 1. — In-substance conduit extending from the meniscus periphery to the mid-portion of the tear.

blood was obtained from the animal and poured into a sterile glass flask which contained sterile glass beads (3-mm diameter). The flask was gently agitated for 3 minutes until the blood clotted. The clot was rolled in sterile gauze to remove excess serum and injected with the aid of a 3 ml syringe into the meniscal conduit. No sutures were placed in the meniscus. The arthrotomy wound was then closed in layers with absorbable sutures. The control group consisted of 3 animals that received similar meniscal lesions without the addition of conduits or fibrin clots. In both groups the operated leg was casted in maximal flexion of the ankle and with the addition of a harness which maintained the knee joint at maximal flexion, weightbearing was prevented (fig. 2).

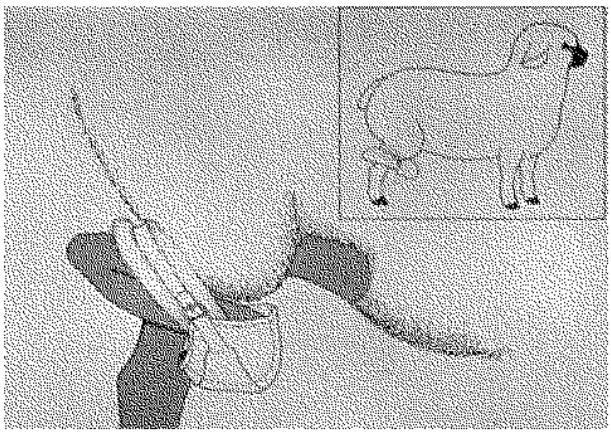

Fig. 2. — Harness applied to the sheep's hindlimb for maintenance of full flexion and non-weightbearing.

The animals were killed 12 weeks after surgery by an intravenous overdose of T-61 Euthanasia Solution. The knees were dislocated by cutting the ligaments which allowed close inspection of the menisci, articular cartilage and synovium. The lateral menisci were harvested and fixed in 10% buffered formalin. The menisci were sectioned parallel to the core at 6-micron thickness and stained with hematoxylin and eosin for light microscopy.

RESULTS

Macroscopic inspection showed no synovitis or damage of the articular cartilage in the 5 knees of the experimental or the 3 knees of the control group. The sixth knee of the experimental group became infected and was excluded from the study. Gross examination revealed no healing of the meniscal tears in either group. However, microscopy showed partial healing in one lesion of the experimental group. The healing tissue, measuring one-fourth of the height of the meniscus, spanned the mid-portion of the tear. It consisted of an eosinophilic tissue interspersed with vessels, fusiform and round-to-oval cells with vesicular nuclei (fig. 3). The morphology of the latter cells was similar to that of pluripotential cells, whereas the fusiform cells resembled fibroblasts. The healing tissue was identical to the material filling the cores except that in the latter, cyst-like cavities were seen. All the cores extended from the meniscus periphery to the tear.

Fig. 3. — Histologic section of the meniscus showing the repair tissue (center) (H + E, 25 ×).

As in a previous study (13) histologic evaluation of the experimental and control groups demonstrated increased numbers of ovoid-shaped cells lying in lacunae on either side of the tear. Some of the cells were arranged in small groups, thus resembling the chondrocyte clusters sometimes found in articular cartilage.

DISCUSSION

Blood clot is thought to act as a scaffold as well as a chemotactic stimulus for reparative cells (4). Although the origin of the reparative cells in this study is unclear, Webber *et al.* (15) showed, in an in-vitro study, that meniscal fibrochondrocytes

have the ability to extricate themselves for the meniscal matrix and migrate into fibrin clots filling full-thickness cylindrical lesions previously made in the meniscus. The blood clots have been shown to contain platelet-derived growth factor which is also capable of stimulating cell proliferation (14). A second potential source of reparative cells is the pluripotential, synovial cells and a third is from the peripheral blood circulation. Allgoewer and Hulliger (2) demonstrated the latter possibility in an in-vitro study in which mononuclear blood cells were seen to transform into fibroblasts.

The creation of an in-substance core from the periphery of the meniscus to the tear allows neovascularization and cellular ingrowth to encourage healing (9).

Although all the conduits in our series reached the meniscal defects, in only one case was partial healing observed.

We felt that there was no need to suture the meniscal tears in our experiments because the lesions did not measure more than 5 to 7 mm and were stable. Stability was defined by the inability to permanently displace any part of the meniscus in the region of the tear.

Healing of such a tear might require more than one conduit to obtain a sufficient reparative response. However, creation of multiple channels may cause more disruption of the peripheral, circumferentially-running collagen fibers, which would then interfere with sustaining the hoop stresses developing in these fibers during normal weightbearing.

To prevent the sheep from releasing the harness and then bearing weight, after the operation and prior to applying the harness for immobilization of the knee, the ankle was cast in maximal flexion. Although this immobilization was adequate to prevent weightbearing and did not provoke articular cartilage degeneration or intraarticular adhesions, it may not have been rigid enough. In fact, knee joint mobility in these uncooperative subjects may have created shear forces across the meniscus which may have prevented the reparative tissue from growing across the tear. Gershuni *et al.* (9) achieved healing in tears in the avascular portion of the dog meniscus in all 3 cases treated with a conduit with the addition of an external fixator across the joint, whereas complete healing was observed in only 2 and partial in 3 cases of a total of nine menisci immobilized with a groin-to-ankle cast. Zhongnan *et al.* (16), who reported partial or complete healing of meniscal tears in the avascular region treated with trephination and no immobilization, believe that their results would have been better with some form of immobilization.

A longer interval than 12 weeks between surgery and sacrifice would probably not have improved healing, as studies using similar techniques of an in-substance conduit showed that the meniscal defects were filled with scar tissue within 12 weeks (9, 16).

The origin of the cells in the reparative tissue remains unclear. The round-to-oval cells with vesicular nuclei resembled pluripotential cells that could have migrated from the synovial tissue. The fusiform cells may have developed from these pluripotential cells or originated from the meniscus itself.

The cells also could have been transformed from monocytes carried in the circulation by the vessels growing in from the peripheral vascular plexus. Increased numbers of oval cells lying in lacunae on either side of the lesions in both the control and experimental menisci were observed (unlike the findings of Ghadially *et al.* (10)). This suggests that the meniscus can respond to injury by cellular proliferation.

In conclusion, out study showed that an in-substance conduit in combination with the injection of a blood clot is not sufficient to facilitate complete healing of tears within the avascular region of the lateral meniscus of the sheep when the knee is only immobilized by a harness.

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