Inflammatory Repair Processes following Ureter Implantation into the Bladdear Using Mechanical Force of Permanent Magnets: An Experimental Study

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The high magnetic energy and stability of the properties of permanent magnets created from an alloy of rare-earth metals with cobalt have made it possible to use the mechanical force of permanent magnets in surgery. It is now technologically possible to exploit the interacting forces of permanent magnets for the formation of sutureless compression anastomoses of hollow organs [2-4].

A method for the creation of a sutureless ureterocystoanastomosis using the compressing forces of permanent magnets has been developed at the pediatric surgery clinic of Moscow Medical University (№ 1361753 as of August 22, 1987).

MATERIALS AND METHODS

Experiments were carried out at the Central Research Laboratory of the Department for Pediatric Surgery and Orthopedics of Moscow Medical University. Thirty-twho dogs divided into two groups were used in te experiments.

In the first series of the experiment, performed on 12 animals, we mastered the surgical technique of creating a ureterovesical connection with ring magnets.

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In the second round of experiments specific features of the formation of sutureless compression and suture ureterocystoanastomoses were studied in 20 dogs. Operations with the parallel formation of two connections: a lateral one, created with magnets, and a terminal one, using a continuous, through noose suture (Fig. 1) were performed in all animals. The bladder wall sites from the created anastomosis area were dissected as a unit and examined on days 1, 3, 5, 7, 14, 30, 90, and 180 after the operation.

The implanted magnetic mechanical elements used were made by the powder meallurgy method from an alloy of samarium with cobalt and weighed from 5 to 10 g. These elements were characterized by a specific interacting force of up

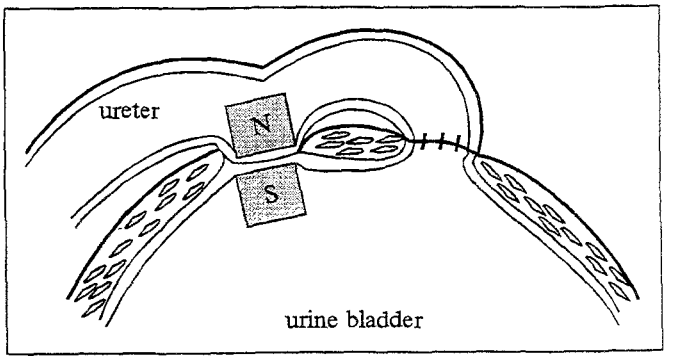

Fig. 1. Ureterocystoanastomosis created with ring–magnets and sutures.

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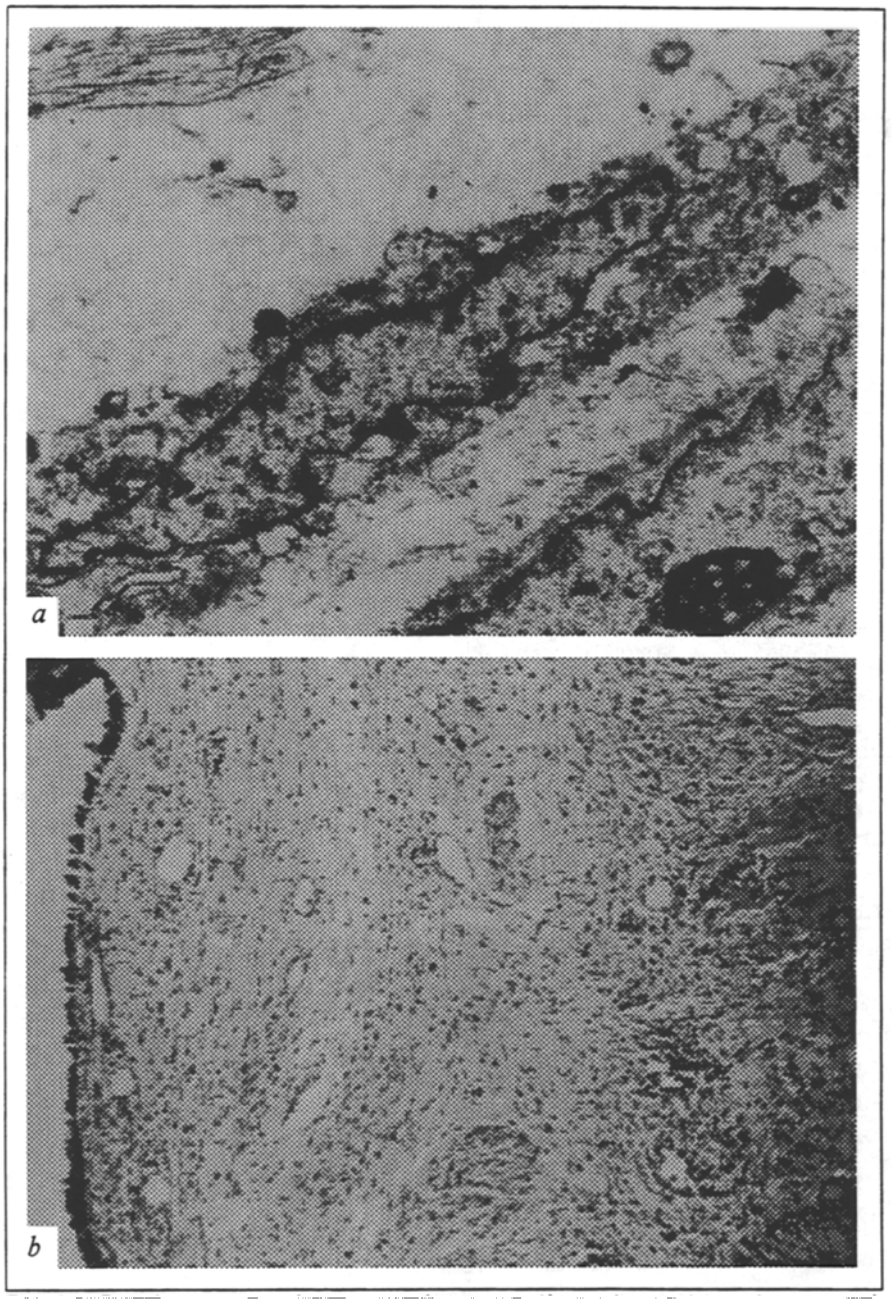

Fig. 2. Repair processes in compression magnetic ureterocystoanastomoses. *a*) young active fibroblasts forming collagen fibers in zone of anastomosis (electronogram, ×6000); *b*) young scar tissue epithelialization without signs of inflammation (follow-up day 7, Van Gieson pyrofuchsin staining, ×36).

to 0.020-0.035 N per mm^2 of compressing surface at a distance of 1.0 mm with a permanent magnetic field tension of 0.1-0.2 T.

For light optic examination paraffin sections were stained with hematoxylin and eosin, with pyrofuchsin after Van Gieson, with azan after Heidenhain, with fuchsilin after Weigert, and with toluidine blue; the Schiff reaction was performed.

For electron microscopic study the material was fixed in 1% OsO_4 solution and embedded in an epon-araldite mixture; ultrathin sections were contrast-stained with uranyl acetate and lead citrate after Reynolds and examined under a JEM-100C electron microscope.

RESULTS

Examination of the macropreparations showed that the magnets separate from the anastomosis zone on the 7th-10th day after surgery. By this time the line of connection formed by them presented as a narrow (up to 1.0 mm wide), smooth band of connective tissue. Neglible perifocal changes disappeared within 2-3 weeks. One month after the operation the new ureter anastomosis looked quite natural. The suture anastomosis in the early period (1 to 5 days) after surgery was characterized by marked edema and inflammatory infiltration of the tissues, causing narrowing of its lumen. At the end of the first month, as the inflammatory phenomena abated, a cicatricial ridge up to 3.0 mm wide, protruding into the lumen, was formed in the zone of anastomosis. By the sixth month fibrosis was somewhat less manifest due to scar tissue restructuring, but the edges of the anastomosis were still rough and rigid.

Histologic examination carried out at various stages of the inflammatory repair reaction during the formation of sutureless compression and suture ureterocystoanastomoses showed that the cells successively replacing each other participate in the inflammatory repair reaction of anastomosis tissue structures. The sequence of cellular reaction depended on the stage of granulation tissue formation, this tissue being a sort of a "temporary organ" created by the body in disease to carry out the protective and repair functions of the connective tissue [5].

In the majority of experimental animals with sutureless compression anastomoses macrophages gradually replaced neutrophils during the first 24 h, and by day 6 neutrophils had completely disappeared.

Analysis of repair features in this series of experiments showed that angiogenesis, fibroplasia, and synthesis of collagen are the three principal integral components of the response to injury. After stationary fibroblasts at the edges of the wound are stimulated, they proliferate, migrate, and form collagen, the bulk of which is accumulated in the extracellular space (Fig. 2, *a*). Newformation of capillares in the zone of anastomosis creates a new capillary network. The neovascularization process at the site of the sutureless anastomosis proceeds more intensively than after suture anastomosis formation.

Our results indicate that the more rapid purification of magnetic anastomoses from necrosis is due to the early appearance of polymorphonuclear leukocytes and phagocytizing mononuclears.

Macrophages absorbing wound tissue detritus acquire increased biochemical activity, thus promopte wound cleansing. These cells are known to release various proteases, including specific collagenases capable of dissolving different types of interstitial collagens. This process is regulated by macrophagal-lymphocytic interaction and transmitters of a lymphocytic origin. With minimal amounts of cellular and tissue detritus forming in magnetic anastomoses, the disappearance of necrosis runs a more rapid course. As a result, less bulky and less dense connective tissue is formed.

Interepithelial lymphocytes transmitting information to blood cells, thereby stimulating their proliferation, play a key role in repair [1]. Accelerated recovery of mucosal epithelium with a high count of interepithelial lymphocytes was observed in this series of experiments.

The epithelium had completely recovered in the zone of anastomosis by day 7 postoperation (Fig. 2, *b*).

In animals with suture anastomosis neutrophils were replaced by macrophages only starting from the 3rd-4th day postoperation. Deficient connective tissue formed, poor in fibroblasts and collagen fibers and infiltrated with neutrophils and lymphocytes with cytotoxic properties. Microabscesses formed around the ligatures on day 3-7; these persisted for up to 3-6 months, maintaining inflammatory foci.

A hyperergic reaction presenting as fibrinoid necrosis of vascular walls and adjacent tissue was observed in many animals of the second series. The inflammatory reaction often ran the course of a chronic immune inflammation. This was paralleled by alteration of granulation tissue structure: vertical vessels disappeared and the relationship between connective tissue and epithelium were impaired.

Hence, long-term injury resulted in chronic inflammation and the development of persistent granulation tissue in this series of experiments because of impaired autoregulatory healing mechanisms.

Comparison of the morphologic picture of the two types of ureterovesical anastomoses demonstrated obvious advantages of the sutureless compression connection. The use of a magnet helped preserve the stereotypical time course of the inflammatory repair reaction. This reaction was accompanied by adaptation of the layers of the connected organs and a reliable hermetic sealing of the anastomosis, preventing urinary infiltration of its structure. An important aspect is the balance between inflammation, regeneration, and fibrosis.

Hence, early experience gained with the use of permanent magnets for sutureless compression ureterovesical anastomosis has demonstrated the superior quality of the formed anastomosis, which bodes well for surgical treatment when this method is introduced into clinical practice.

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