METHODS

Technical Principles of Urethral Compression Anastomoses

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Traumatism and technical intricacy of forming the urethral anastomoses in the small pelvis region are the major problems of the proximal urethra reconstruction necessitated by post-traumatic strictures. The experiments based on original technical principles of urethral compression anastomoses are carried out to qualitatively improve the treatment of urethral strictures in clinic. A simple and reliable method to connect urethra in the small pelvis region is proposed, which is made with the help of controlled mechanical device supplied with a flexible drive. Technical principles which help to form reliable urethral compression anastomoses include restriction of compression force until tissue is consolidated, removal of the muscle layer from the compression zone, rounding the rims of the pressed flanges, and elimination of the possible effects of ligatures used to form the stumps.

Key Words: *urethra; stricture; treatment; compression anastomoses*

Reconstruction of the proximal urethra after post-traumatic strictures is a considerable surgery challenge. One of the major problems is traumatism and technical problems of the formation of urethral anastomoses in the small pelvis region [3-6].

The compression anastomoses (CA) in the gastrointestinal tract have been performed from the first half of the 19th century. They were widely used at the beginning of the 20th century. In this surgical procedure two compressing elements are introduced into the lumens of the fragments of an organ to be connected, which tightly press the stumps or walls of these fragments together, thereby arresting blood circulation in them. The compressed tissues are necrotized and rejected, while the adjacent parts of them accrete and form a sutureless anastomosis. Many authors noted the advantages of CA in comparison with sutural anastomoses (SA) due to simplification of surgery and shortening of the operation. However, some disadvantages of the compression devices, large number of complications, and the lack of reliable theory led to virtual oblivion of this technique [1,2,7].

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MATERIALS AND METHODS

Experiments were carried out under intravenous ketamine or droperidol anesthesia on outbred female dogs weighing 5-12 kg.

In the first three series of experiments, CA were formed by pressing a portion of urethra ligated to a guide between two compressing elements which were made of permanent cylindrical magnets supplied with axial orifices. The magnets were made of the cobalt-samarium alloy and covered with a thin polyurethane film. The abdominal cavity was opened by a suprapubic cut. The first compressing element attached to a flexible guide was placed into the pelvic portion of the urethra via an orifice made in the apex of the urinary bladder. The urethra was

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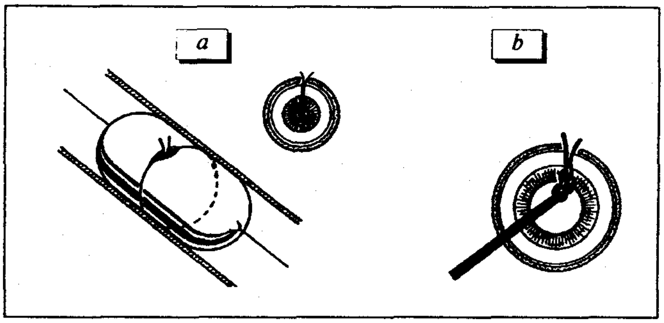

Fig. 1. Scheme of anastomosis failure resulting from exposure of ligature ends from the compression region, which occurs (*a*) when long ligature ends were left or (*b*) when the diameter of the axial orifice in the magnets was too large.

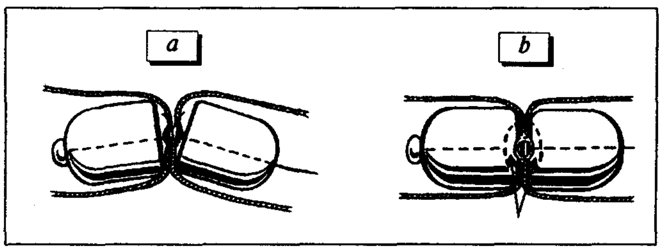

Fig. 2. Incarceration of ligature knot between the magnets: (*a*) axial shift of cylindrical magnets when ligature knot was incarcerated between the flanges of the magnets; (*b*) elimination of the nodal effect in anastomosis after making the coaxial indentations in the flanges.

ligated between the bladder and this element. The second element was conducted downwards along the guide. The operation was finished by suturing the wound and shaping the urinary fistula. On postoperative days 7-12, the compression elements were taken away by traction of the guide through the urinary fistula.

To eliminate the aversive effect on CA formation of the surgical threads used to ligate the urethra, the cylindrical magnets were supplied with coaxial indentations, the diameter of the guide was chosen to correspond to axial orifice of the magnets, and the fine-thread ligatures were cut short (Figs. 1 and 2).

The first task in the preliminary series of experiments (n=12) was the demonstration of principal possibility of compression connection of the urethra and the development of the corresponding experimental model. Experimental conditions and the parameters of magnets were corrected in the course of this study to avoid occasional complications. The magnets with diameter (*D)* 5-9 mm were used, which developed the attraction force (*F*) 30-170 g at the distance of 1 mm between them. The curvature of the rims of the compressing flanges was (*R)* 0-1.5 mm.

The quality of CA of the hollow organs and the rejection period of compressed tissues is known to depend on *R* and *F* [1-3]: therefore, optimization of these parameters for the urethra was the second experimental task. The results of urethral anastomosis made with the help of magnet cylinders were compared on postoperative day 7. The parameters of cylindrical magnets were: D=9 mm; F=100 and 180 g; R=0.2, 0.4, 0.6, 0.8, 1.0, and 1.2 mm.

In the third series of experiments (n=8), morphological analysis of CA was performed on postoperative days 1-3 (n=3), 5, 7, 14, and 90. In this series, the parameters of magnets were D=9 mm, R=0.8 mm, and F=180 g.

In the fourth series of experiments (n=18), the full-layer and submucous CA were compared with urethral SA on 1, 3, 7, 14, 45, and 90 days after resection and applying the anastomosis. The urethra was resected along the length of 0.5 cm. The compressing element was placed with the help of a guide into the distal portion of urethra, then the stumps were shaped using the blanket sutures. To form the "submucous" anastomosis, the muscular-adventitious layer of the urethral wall was dissected. The parameters of the magnets were: D=9 mm, R=0.8 mm, and F=180 g. In the control group (n=6), SA of posterior portion of urethra were applied with the help of polydioxanon 5/0, using six knotty extramucous sutures applied above the urethral catheter No. 8Ch.

In the fifth series of experiments (n=6) the problem of raising CA reliability was approached by prolongation of CA formation. To this end, in the early postoperative period the compression force was restricted using mechanical compressing devices supplied with an external power drive (Fig. 3). The first compressing element was fixed to the axial shaft, while the second element was attached to the end of a flexible tube which could slide along the guide. The other (extracorporal) end of the device had two locks separated by a dynamometric spring, which provided fixation of the axial shaft relative to the flexible tube. After cutting the urethra, guiding the first compressing element via the urinary bladder and proximal portion of the urethra into its distal part, shaping the urethral stumps, and removal of muscular layer in the compression zone, the second compressing element was guided to the junction region (against the stop) until the firm contact of the stumps was secured. This position was fixed with the first lock. After 5 days the first lock was released; the second lock was shifted along the axial shaft, the spring was compressed with a force of 2 kg, and the second lock was fixed. Rejection of the compressed tissues proceeded for 3-4 days, after which the compression device was extracted via the urinary fistula.

At the end of experiment, the CA region of the urethra was examined by pathomorphological methods.

RESULTS

In the first series of experiments, reliable urethral anastomoses were attained in 2 out of 12 dogs. Visually, on the postoperative day 14 these anastomoses had wide lumens and adequate adaptation of the layers. There were no overt inflammatory alternations in the urethral wall and periurethral tissues. However, in other 10 dogs, there were various deviations in the process of anastomosis formation: CA failure (n=6), spur-like CA due to improper fixation of the magnets (n=2), separation of the magnets (n=2). These data provided further experimental support to the effect of the following factors on the quality of connection: curvature of the rims of the compressing flanges (R), magnetic force of attraction (F), and diameter of the ligatures between the compressing flanges.

Subsequent experiments showed that uncomplicated urethral CA was formed when the cylindrical magnets had F>50 g and R=0.6-0.8 mm. With such magnets, rejection of the compressed tissues occurred on postoperative days 5-6. Variation of R resulted in drastic morphological alterations in the region of anastomosis and in the time course of rejection of compressed tissues. At R=0.4 mm, rejection of the compressed tissues occurred as early as on postoperative day 4; there were minor defects in the mucous-submucous layer along the border of CA aggravated by periurethral adhesions. A decrease in R to 0.2 mm led to enhancement of mucous-submucous diastasis of the connected portions of the urethra on postoperative day 3 and partial failure of anastomosis. The lack of rounding of the compressing flanges resulted in complete failure of CA on postoperative days 2-3. An increase in R to 1.0-1.2 mm led to formation of spur in CA and retardation of rejection of compressed tissues, which impeded extraction of the magnets.

Variation of F in the limits of 50-110 g (D=6 mm), 60-135 g (D=7 mm), and 110-220 g (D=9 mm) did not produce any significant effect on the morphology of the junction region. However, CA produced by the magnets with larger F were characterized with better fixation of connected parts.

Macroscopic examination of the full-layer urethral CA at the early postoperative period revealed an unknown stage in CA formation. On postoperative days 2-3, rejection of muscular layer occurred along the external boundary of the compression zone. The rejected flaps of muscular layer were whitish and were located along the line of connection. There was a narrow diastasis between them (0.1-0.3 mm). Histological examination on postoperative day 7 made in the region of full-layer CA revealed thinning of the urethral wall by 1.5-2.0 times in comparison with the adjacent portions of urethra. The junction region was formed predominantly by immature filamentous connective tissue and mature granulated tissue with a large number of fibroblasts. There were virtually no muscular elements in the CA region, while the adjacent regions were atrophic. On postoperative day 30, the mucous side of CA region looked like a white transversal scar which was practically inextensible, although it did not taper the urethral lumen. There were the scar adhesions attached to the external side of the CA, which also aggravated the elasticity of anastomosis. Histological examination revealed transmural proliferation of filamentous connective tissue in the CA region.

The removal of the muscular layer from the compression region markedly reduced the size of the scar, which was proved by histological examination of the "submucous" CA. On postoperative day 7, the connective tissue in the region of muscle junction was poorly developed or absent, which attested to adequate regeneration of the smooth muscles. On postoperative day 30, the "submucous" CA were elastic and inconspicuous from the outside. The periurethral adhesions were absent.

Examination of SA revealed 3 out of 6 cases where the quality of anastomoses was not satisfactory. In two dogs periurethral infiltrate was observed on postoperative days 5 and 7, which resulted from a local percolation of urine. In the third case two

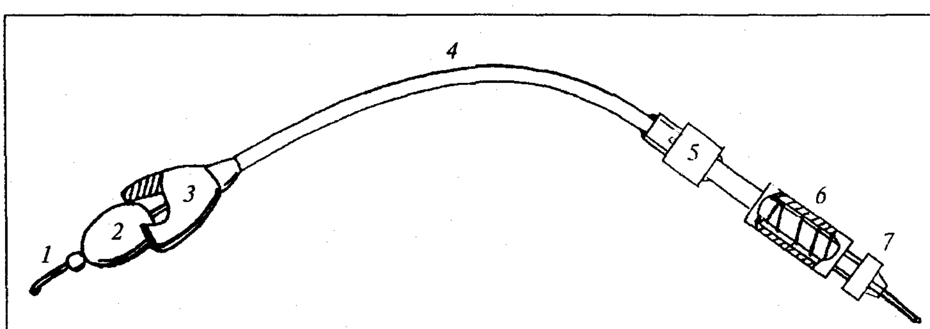

Fig. 3. Mechanical compression device with a flexible drive. *1*) axial shaft; *2*) the first compressing element attached to the axial shaft; *3*) the second compressing element attached to the end of the flexible tube; *4*) flexible tube; *5*) the first lock; *6*) spring; *7*) the second lock.

polyps which had the diameters of 2 and 3 mm, formed 3 months after the operation. Macroscopic and histological comparison of SA and "submucous" CA demonstrated the advantage of sutureless anastomoses which were accompanied by a lesser degree of intra- and periurethral cicatrization.

Technical problems involved in CA were significantly easier, and application of CA required much less time than SA.

Resection and applying anastomosis to the urethra with permanent magnets revealed severe disadvantages of the magnetic compression devices. The magnetic attraction force was not sufficient to reliably clamp the connected portions even at small tension and led to untimely rejection of compressed tissues, when consolidation was not strong enough. In addition, attraction of metallic surgical instruments and needles caused technical inconvenience during the operation.

These disadvantages were eliminated after replacing the permanent magnets by the controlled mechanical compression devices. Formation of CA was subdivided into two stages. In the early postoperative period the juxtaposed ends of the urethra were held until reliable consolidation, and then extra compression was applied to reject the compressed tissues in 3-4 days. All CA formed with the help of the mechanical compression devices were leak-proof, and their parameters were no worse than that of magnetic submucous CA.

Thus, our experiments led to the development of a comparatively simple and reliable method of connection of the urethra in the small pelvis region, using a mechanical compression device supplied with a flexible drive. The technical principles which help to form reliable urethral compression anastomoses include restriction of the compression force until tissues are consolidated, removal the muscle layer from the compression zone, rounding the rims of the pressed flanges, and elimination the possible effects of ligatures used to form the stumps.

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