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FUNCTIONAL ASPECTS OF LARGE INTESTINE AND THEIR USE IN COLORECTAL SURGERY

Introduction. *Further enhancement of surgical techniques and improvement of functional results include advanced research on anatomic and physiologic features of the colon, particularly, the passage of its content in order to use these regularities while performing surgical procedures.*

Problem Statement. *Improvement of results of surgical procedures using anatomic and functional features of the colon.*

Purpose. *To improve surgical technique by studying the colon functional features and using the obtained knowledge in clinical practice.*

Materials and Methods. *The features of content passage in colon have been studied using mathematic modeling. The results have been used while performing radical reconstructive surgical interventions.*

Results. *New terms of colonic content evacuation have been justified and defined: colonic functional segment is a section limited by two physiological sphincters and evacuative reservoir that consists of two adjacent colonic functional segments and three physiological sphincters. The features of content transit have been studied considering the established units of evacuation that have been used while choosing the resection extend and modeling intestinal anastomosis and anatomic and functional structures. This approach has enabled to improve the results of surgical procedures and quality of patient life in postop period.*

Conclusions. *Using the established colon functional features enables to improve radical surgical interventions, to elaborate new methods of reconstructive surgeries, to improve functional results of the surgical treatment and postop quality of life.*

Keywords: physiological sphincters of the colon, colonic functional segments, colonic evacuative reservoir, intestinal anastomosis, reconstructive surgical interventions, and functional results.

Improvement in functional results and quality of life of the patients after colon surgeries is explained by application of advanced technologies, in particular, laparoscopic techniques, modern staplers, new anatomical and functional structures after extensive resections and removal of functionally active sections of the colon [1–3]. However, a detailed study of the functional results of similar radical and reconstructive and reparative operations has pointed to their unexplained contradiction that is conditioned, first of all, by changes in the motility of the remaining sections of the colon and by an increase in the transit rate of contents and in the frequency of defecation [4].

In our opinion, one of the directions for the further improvement of surgical intervention techniques and postoperative functional results is to carry out an in-depth study of the anatomical and functional features of the colon, in particular, the mechanism of movement of its contents and to use the discovered regularities in the

performance of standard radical, reconstructive, and reparative operations.

The purpose of this research is to improve the results of surgical interventions by studying the functional features of the colon and applying the results in clinical practice.

In order to study the features of movement of the colon contents, the method of mathematical modeling of fluid motion in a closed cylindrical space has been used in addition to the clinical and radiological methods. This method is chosen insofar as it is impossible to perform any experimental studies and to obtain reliable data on the peculiarities of transition of the colon contents on living organisms. Therefore, mathematical models of the colon, which have shape and cross-section similar to those of the terminal section of terminal ileum, blind intestine, ascending colon, transverse colon, descending colon, sigmoid, and rectum have been created. The study was to determine the rate of movement and pressure of the contents in different sections of the colon, taking into account the anatomical flexures and physiological sphincters, the arrangement of which is presented in Fig. 1. These parameters were also studied after resection of various sections of the colon.

Based on the results of histopographic studies, the physiological sphincters are local thickenings of the circular muscular layer of the large intestine wall, predominantly between its longitudinal muscle bands [5]. Autonomy and a high intensity of blood supply in the form of peculiar arterial and venous plexus in the area of colon physiological sphincters [6], which indirectly indicate their functional activity have been established.

The most frequent anatomical and functional relationships after the typical colon surgeries (the formation of end-to-side ileotransverse anastomosis after right hemicolectomy, end-to-end transversorectal anastomosis after left hemicolectomy, end-to-side ileosigmoid anastomosis after subtotal proximal resection, end-to-end ascendorectal anastomosis after subtotal distal resection of the colon) have been studied.

A new stage was to apply the results of the study of the transit of colon contents during the development and formation of anatomical and functional structures after the removal of functionally active parts of the rectum. So, to prevent the low front resection syndrome after the low and extremely low front resection of the rectum, a method has been developed for the rectal ampulla formation (patent No. 54247) [7].

The revealed physiological features of the colon contents transit have been used in the development of reconstructive operations, namely, the method for pelvic & perineal coloplasty (Patent of Ukraine No. 41228) [8] to resume the function of fecal continence and defecation process control after standard rectal extirpation.

The study of the colon contents movement based on the mathematical modeling method has enabled to determine the following features. It has been found that in the sections of colon anatomi-

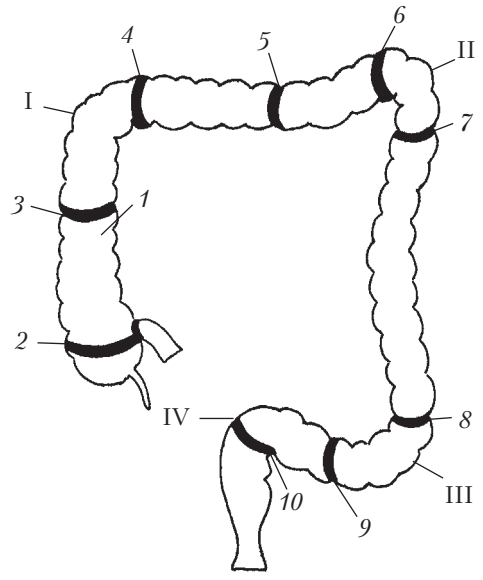

Fig. 1. Anatomic flexures and physiological sphincters of the large intestine: I — right (liver) flexure; II — left (splenic) flexures; III — sigmoid flexure; IV — sigmorectal flexure. *1 — Vorolio* sphincter; *2 — Bousi* sphincter; *3 — Hirsch* sphincter; *4 — Cannon-Brem* sphincter; 5 — *Horst* sphincter; *6 — Cannon sin.* sphincter; *7 — Payr-Strauss* sphincter; *8 — Bally* sphincter; *9 — Rossi-Mutie* sphincter; *10 — O'Bern-Pirogov-Mutie* sphincter

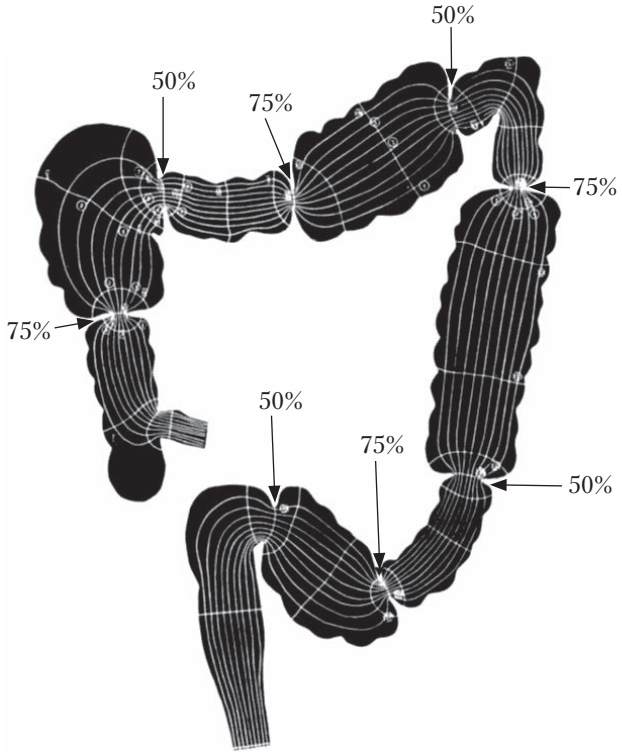

Fig. 2. Mathematical model of the large intestine. Alternating narrowing of the lumen to 50% and 75% in the localization of physiological sphincters and alternation of dimensions of the functional segments (sections between the two physiological sphincters) while filling and emptying during the transit of the contents in the large intestine

cal flexures, the transit rate of the contents decreases, with rectal pressure increasing. Moreover, the sharper the flexure angle, the longer the delay in the contents transit. Thus, in the splenic flexure, where the angle is most acute, the contents transit rate decreases 8 times and, accordingly, the lumen pressure increases the same number of times. In the region of hepatic and sigmo-rectal flexures, the angles of which are less acute, the transit rate of the contents decreases twice, with rectal pressure doubling. It has been established that the haustras do not significantly affect the contents transit rate, but increase the surface of the mucous membrane for contact with the colon contents, which contributes to improving the absorption processes.

It has been noted that the colon physiological sphincters also contribute to reducing the transit rate of the contents, mainly, in the interval between the two sphincters. In the area of anatomical flexures, the simultaneous effect of both factors – anatomical flexures and physiological sphincters – on the contents movement located in the close proximity has been reported.

The results of the studies have made it possible to substantiate and to define a new concept of the unit of evacuation – the functional segment of the colon. This is a section of the large intestine limited by two physiological sphincters. It has been established that a 50% decrease in the lumen of the large intestine in the projection of sphincters corresponds to an anatomical narrowing of the colon lumen in the haustra area and is functionally sufficient for the contents transit. This narrowing of the large intestine in the region of physiological sphincters does not affect the transit rate of the contents from one functional segment to another. Therefore, it can be reasonably suggested that the mentioned decrease in the lumen in the area of physiological sphincters (its opening) is optimal and sufficient for evacuation of the contents. A reduction in the lumen to 75% in the places of physiological sphincters leads to significant fluctuations in rate and pressure, both in the functional segments and in the area of the very sphincters. At this narrowing, in the places of sphincters, evacuation of the contents from segment to segment becomes impossible. Thus, it can be reasonably suggested that the lumen narrowing to 75% in the area of sphincters (their closure) is physiologically maximal. Complete closure of the colon lumen, its «closure-up» in the area of sphincters, can be ensured by folds of the mucosa-submucosal layer, which, in most cases, correspond to the projection of physiological sphincters [5]. The discovered regularity of consecutive alternation of the maximum physiological narrowing of the colon lumen to 75% in the area of sphincters and their contraction with the narrowing to 50% provides a temporary ordered delay in the transit of contents in the colon segments, which is required for the absorption function.

Another functional unit of evacuation, the evacuation reservoir of the large intestine, which consists of two adjacent functional segments and, correspondingly, three physiological sphincters has been identified. Taking into account its constituent structures, the evacuation reservoir is variable in time. This is explained by the fact that as the contents move, the reservoir segments and the diameter of the lumen in the area of sphincters vary. Consequently, the principle of operation of the evacuation reservoir is dual. In this case, the contents are transiting in conditions of successive changes in the diameter of the lumen in the area of physiological sphincters and functional segments. The discovered regularities of the contents transit are illustrated by the integral mathematical model of the large intestine (Fig. 2). The scheme of the peculiarities of the contents transit in the large intestine is shown in Fig. 3. The established changes in the distribution of transit rate and pressure in the segment and in the reservoir as a whole explain the well-known principle of contents passage in the large intestine – due to the proximodistal pressure gradient [4].

The idea of the paired principle of evacuating the contents of the colon has been confirmed by an x-ray study of the transit of barium sulfate in the large intestine (Fig. 4). The movement of the contents from the filled proximal segment to the empty distal one occurs within the evacuation reservoir. In this case, its proximal and distal sphincters remain closed, with the intermediate sphincter located between the two segments of the reservoir being open.

The performed studies have made it possible to establish an insignificant increase in the rate of movement of the contents in the remaining sections of the colon after removing its right or left half. This is confirmed by an increase in the defecation frequency up to 2–4 times daily and a reduction in the barium sulfate transit time in the remaining sections of the colon for 46 of 74 patients (62%) after right hemicolectomy and for 6 of 52 patients (11%) after left hemicolectomy. These mentioned results are explained by insufficient compensation of the lost parts of the large intestine by functional segments and reservoirs remaining after resection.

After subtotal proximal (19 patients) or subtotal distal (28 patients) colon resections a more than 2.5 times increase in the transit time has been reported. The defecation frequency for these patients ranged from 4 to 6 times daily. In our opinion, this functional result of extensive colon resections is explained by only one functional segment preserved. After subtotal proximal resection of the large intestine, this segment is bounded by proximal Rossi-Moutiers physiologic sphincter and by distal O'Bern-Pirogov-Moutiers sphincter. After subtotal distal resection, the segment is bounded by proximal Bousi sphincter and by distal Hirsch sphincter. The anatomical and functional

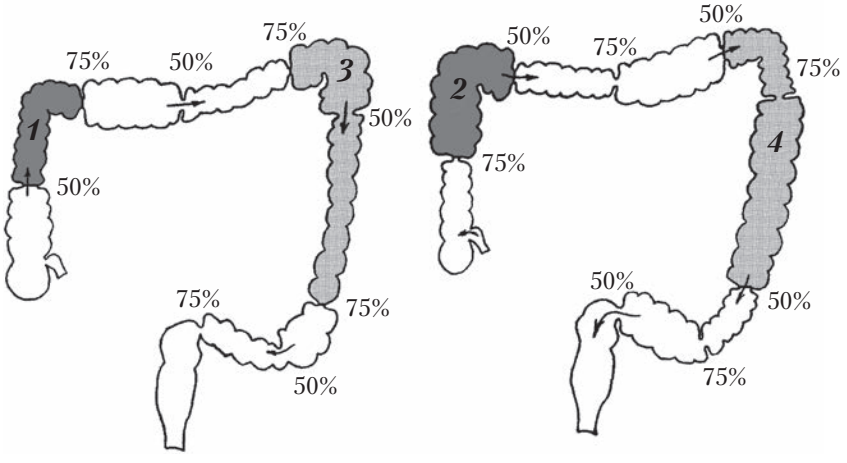

Fig. 3. Transit of contents in the large intestine. The arrows show the direction of contents transit through the area of physiological sphincters in the case of alternating dimensions of their lumen within the functional segments and evacuation reservoirs: *1*, *2* — functional segments; *3*, *4* — evacuation reservoir of the large intestine. Dynamics of changes in localization of evacuation reservoir, constituting functional segments, and diameter of physiological sphincters

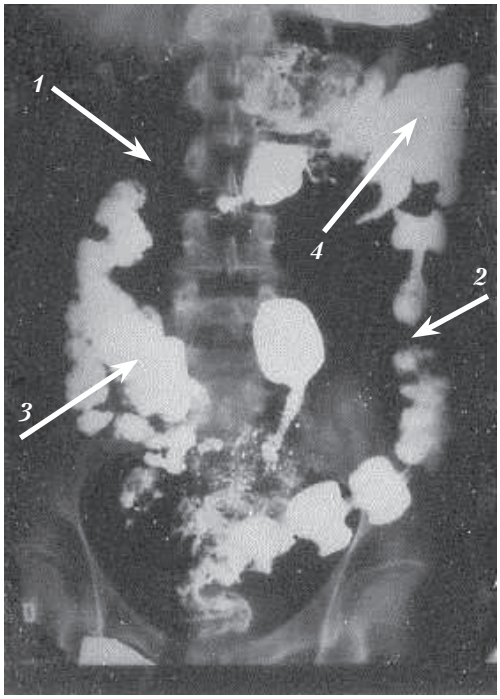

Fig. 4. X-ray contrast study of the transit of barium sulfate in the large intestine. The alternation of functional segments of the large intestine filled with barium suspension and barium-free ones: *1, 2* — segments of the large intestine, free from barium suspension; *3, 4* — segments of large intestine filled with barium suspension

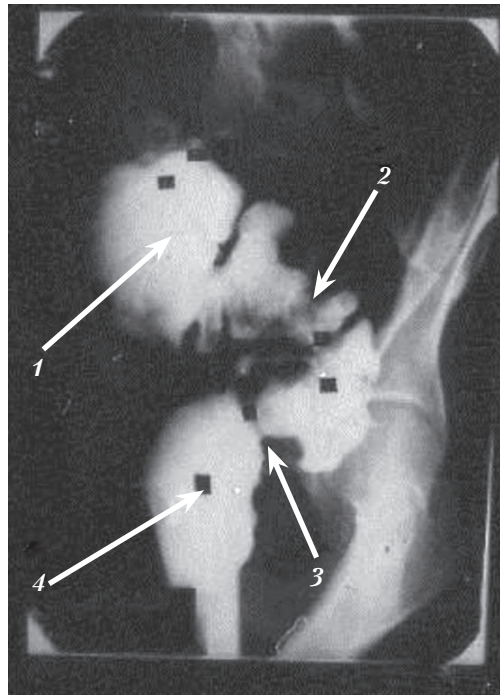

Fig. 5. X-ray picture of the remaining parts of the colon after subtotal distal colon resection and rectal resection: *1* — cecum; *2* — projection of the Hirsch physiological sphincter; *3* — projection of ascendorectal anastomosis; *4* — rectum stump

interrelations of the colon after subtotal distal resection are illustrated by an X-ray pattern (Fig. 5).

The results obtained indicate an increase in the transit rate of contents in the large intestine after the radical surgeries outlined above. This points out the need to abandon any unjustified expansion of the scope of the radical surgical interventions, as well as the advisability of preserving the colon physiological sphincters while forming enteroanastomoses given the localization of physiological sphincters.

The further use of the results of mathematical modeling of the contents movement in the large intestine is to form the anatomical and functional structures after removal of the rectum ampulla after low and extremely low anterior resection, abdominal anal resection of the rectum, and pelvic and perineal coloplasty after rectal extirpation.

The rectum ampulla was formed by excision of free and omental longitudinal muscle bands within one functional segment of the colon between the physiological sphincters of Bally and Rossi-Moutiers, proximally to the formed colanal anastomosis (Fig. 6). Using this method, 34 patients have been operated. The colanal anastomosis was formed at a distance of 2—4 cm distally to the physiological Bally sphincter. The placement of formed rectum ampulla between these physiological sphincters stimulates an increase in the reservoir capacity of this ampulla (Fig. 7), which leads to the most effective physiological retention of the contents and normalization of the defecation frequency. The defecation frequency in such patients was, at most, 1–3 times daily as early as in 2–3 weeks after the surgery. No evacuation disorders associated with the emptying process have been reported.

To reproduce the fecal continence function after extirpation of the rectum, the developed

method of pelvic-perineal coloplasty was used (Fig. 8). This method provides for the formation of retention anatomical-functional structure consisting of a fixed flexure of the colon created by making serous-muscular sutures along the mesovarian border of the gut for 12–14 cm and a retaining valve of the original design located distally at a distance of 1–2 cm from the last serous-muscular suture of the previously formed flexure. This anatomical-functional retaining structure was placed between two physiological sphincters, within the same evacuation reservoir, in certain sections of the large intestine.

The number of created retaining structures depends on the initial type of its motility. Thus, in the patients with normokinetic type of motility function and a defecation frequency of 1–2 times daily, the colonic flexure and the valve were placed between the Payr-Strauss and the Bally physiological sphincters. In the operated patients with the initial hyperkinetic type of motility and a tendency to frequent defecation (more than twice a day), another similar structure (flexure and valve) was created additionally in the area of right (hepatic) flexure of the colon, between the Hirsch and the Horst physiological sphincters. In the case of hypokinetic type of motility and a tendency to coprostasia, only one butterfly valve, between the physiological sphincters of Payr-Strauss and Bally, was formed. The pelvic-perineal coloplasty was completed by pull-through of large intestine transplant through the perineal wound. The edges of the rectum crossed levators were sewn to the wall of pulled-through transplant. Using this method of the recontinent operation, 18 patients have been operated.

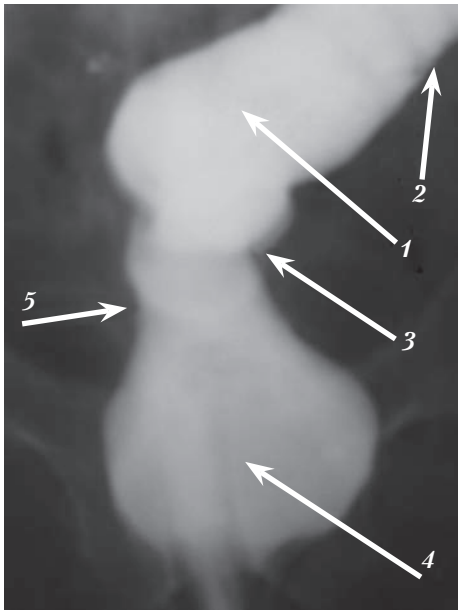

Fig. 7. X-ray picture of the formed rectum ampulla after a low anterior rectal resection: *1* — formed rectum ampulla; *2* — projection of Bally physiological sphincter of; *3* — projection of Rossi-Mutier physiological sphincter; *4* — lower ampullar section of the rectum; *5* — area of colorectal anastomosis

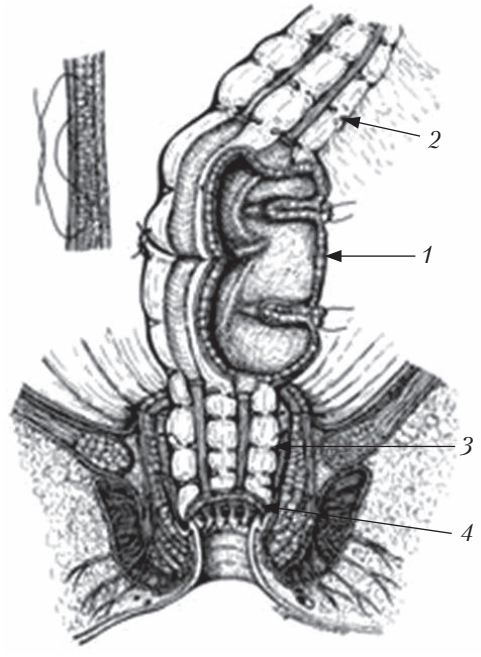

Fig. 6. Formation of rectum ampulla: *1* — neorectum; *2* — projection of Rossi-Mutie physiological sphincter; *3* — projection of Bally physiological sphincter; *4* — coloendoanal anastomosis

In these patients, a physiological retention of the contents of the colon in the area of the retaining structure was reported, which was confirmed by radiographic control of barium sulfate transit in the large intestine (Fig. 9). The defecation frequency in these patients was once per 1–3 days, after the cleansing enema. No involuntary empty-

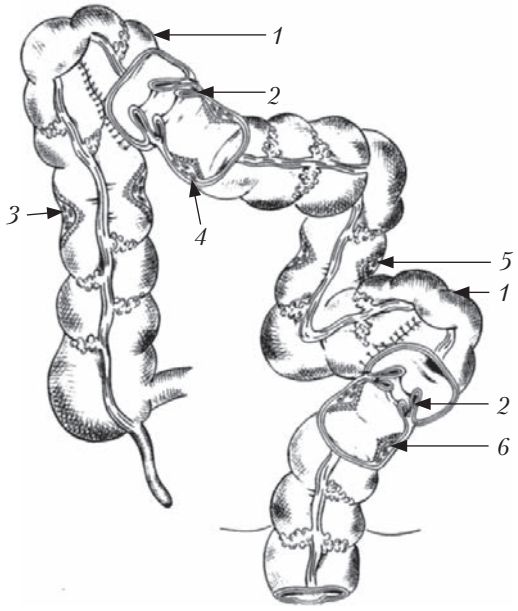

Fig. 8. Scheme of pelvic-perineal coloplasty: *1* — formed colonic flexures; *2* — retaining valve; *3* — Hirsch physiological sphincter; *4* — Horst physiological sphincter; *5* — Payr-Strauss physiological sphincter; *6* — Bally physiological sphincter

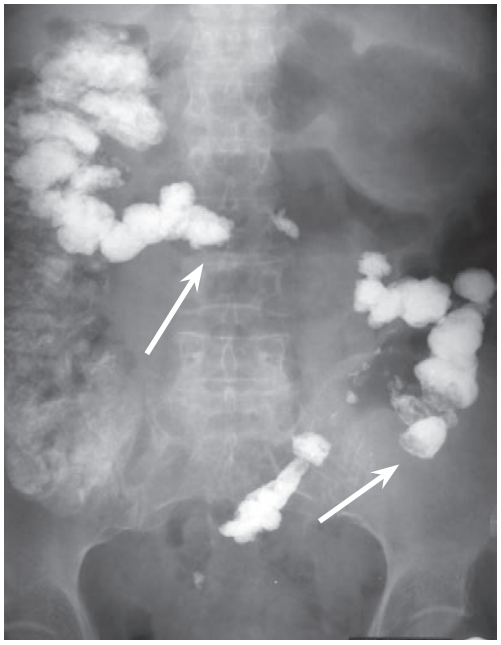

Fig. 9. X-ray study of the transit of barium sulfate through the colon after rectum extirpation and pelvic-perineal coloplasty. The arrow indicates the retention of barium sulfate in the projection of the formed retaining valves

ing between the indicated irrigations have been recorded.

The placement of anatomical and functional structure in the form of a colonic flexure and a retaining valve within one evacuation reservoir (a portion of the large intestine with the slowest rate of contents transit) has enabled to enhance the reservoir function of the formed retaining structure and to strengthen the intestinal continence component. As studies have shown, in the area of formed structures, the contents are retained only within a certain time (24–72 hours). The specified period of time is sufficient for the patients to ensure due social and domestic conditions. If there is no irrigation, after a specified period of time, an urge is formed as feeling of heaviness and fullness in the lower abdomen followed by involuntary emptying through the perineal colostomy. This confirms the physiology of the method developed.

The results of the study of features of the contents transit in the large intestine have been used in 191 patients while performing extensive resections, reconstructive and reparative operations, which provide for the formation of anatomical and functional structures after the removal of the functionally important parts of the large intestine. This has enabled to significantly improve the functional results of the performed surgeries and the life quality of the operated patients.

CONCLUSIONS

The use of established functional features of the colon has enabled to improve radical operations, to develop new methods of reconstructive and reparative operations, to improve the functional results of surgical treatment and the life quality of operated patients.

To improve the results of surgical treatment of patients with colon diseases, it is advisable to further study the functional features of the large intestine and their use for choosing radical, reconstructive, and, especially, reparative stages of surgical interventions.

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ФУНКЦІОНАЛЬНІ ОСОБЛИВОСТІ ТОВСТОЇ КИШКИ ТА ЇХ ВИКОРИСТАННЯ В КОЛОРЕКТАЛЬНІЙ ХІРУРГІЇ

Вступ. Одним з напрямків подальшого вдосконалення техніки хірургічних втручань і покращення функціональних результатів після їх виконання, на думку авторів, є поглиблене вивчення анатомо-функціональних особливостей товстої кишки, зокрема механізму просування її вмісту, використання виявлених закономірностей при виконанні хірургічних втручань.

Проблематика. Покращення результатів виконання операцій на товстій кишці шляхом використання виявлених анатомічних і функціональних особливостей товстої кишки.

Мета. Покращення результатів виконання хірургічних втручань шляхом дослідження функціональних особливостей товстої кишки та застосування отриманих результатів в клінічній практиці.

Матеріали й методи. Методом математичного моделювання було досліджено особливості транзиту вмісту по товстій кишці. Отримані результати використовували при виконанні радикальних, відновних, реконструктивно-відновних операцій.

Результати. Обґрунтовано та визначено нові поняття одиниць евакуації вмісту по товстій кишці: функціональний сегмент товстої кишки — ділянку обмежену двома фізіологічними сфінктерами і евакуаторний резервуар, що складається з двох поруч розташованих функціональних сегментів і, відповідно, трьох фізіологічних сфінктерів. Досліджено особливості транзиту вмісту по товстій кишці з урахуванням встановлених одиниць евакуації, які були використані для вибору обсягу резекції товстої кишки, формування міжкишкових анастомозів і анатомо-функціональних конструкцій. Зазначений підхід дозволив покращити функціональні результати хірургічних втручань і якість життя прооперованих хворих.

Висновки. Використання встановлених функціональних особливостей товстої кишки дозволило удосконалити радикальні операції, розробити нові способи відновних і реконструктивно-відновних операцій, покращити функціональні результати хірургічного лікування і якість життя прооперованих хворих.

Ключові слова: фізіологічні сфінктери товстої кишки, функціональний сегмент товстої кишки, евакуаторний резервуар товстої кишки, міжкишкові анастомози, реконструктивно-відновні операції, функціональні результати.

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ФУНКЦИОНАЛЬНЫЕ ОСОБЕННОСТИ ТОЛСТОЙ КИШКИ И ИХ ПРИМЕНЕНИЕ В КОЛОРЕКТАЛЬНОЙ ХИРУРГИИ

Введение. Одним из направлений дальнейшего совершенствования техники хирургических вмешательств и улучшения функциональных результатов после их выполнения, по мнению авторов, является углубленное изучение анатомо-функциональных особенностей толстой кишки, в частности механизма продвижения ее содержимого, и использование выявленных закономерностей при выполнении хирургических вмешательств.

Проблематика. Улучшение результатов выполнения операций на толстой кишке путем использования выявленных анатомических и функциональных особенностей толстой кишки.

Цель. Улучшение хирургической техники путем исследования функциональных особенностей толстой кишки и использование полученных знаний в клинической практике.

Материалы и методы. На основании метода математического моделирования были исследованы особенности транзита содержимого по толстой кишке. Полученные результаты использовали при выполнении радикальных, восстановительных и реконструктивно-восстановительных операций.

Результаты. Обоснованы и определены новые понятия единиц эвакуации содержимого по толстой кишке: функциональный сегмент толстой кишки — участок ограниченный двумя физиологическими сфинктерами и эвакуаторный резервуар, состоящий из двух рядом расположенных функциональных сегментов и соответственно трех физиологических сфинктеров. Исследованы особенности транзита содержимого по толстой кишке с учетом установленных единиц эвакуации, которые были использованы для выбора объема резекции толстой кишки, формирования межкишечных анастомозов и анатомо-функциональных конструкций. Указанный подход позволил улучшить функциональные результаты хирургических вмешательств и качество жизни оперированных больных.

Выводы. Использование установленных функциональных особенностей толстой кишки позволило усовершенствовать радикальные операции, разработать новые способы восстановительных и реконструктивно-восстановительных операций, улучшить функциональные результаты хирургического лечения и качества жизни прооперированных больных.

Ключевые слова: физиологические сфинктеры толстой кишки, функциональный сегмент толстой кишки, эвакуаторный резервуар толстой кишки, межкишечные анастомозы, реконструктивно-восстановительные операции, функциональные результаты.