

Review

<https://doi.org/10.23934/2223-9022-2022-11-1-119-128>

Rare Types of Perforation of the Gastrointestinal Tract — Diagnosis, Tactics, Treatment

D.A. Blagovestnov¹, D.M. Kopaliani^{1, 2} ✉, P.A. Yartsev^{1, 2}, V.T. Samsonov², V.G. Arutyunova³, D.S. Skukin²

Department of Emergency and General Surgery

¹ Russian Medical Academy of Continuous Professional Education

2/1 b. 1, Barrikadnaya Str., Moscow, 123242, Russian Federation

² N.V. Sklifosovsky Research Institute for Emergency Medicine

3 B. Sukharevskaya Sq., Moscow, 107045, Russian Federation

³ Peoples' Friendship University of Russia

6, Miklukho-Maklaya Str., Moscow, 117198, Russian Federation

✉ **Contacts:** David M. Kopaliani, Postgraduate student of the Department of Emergency and General Surgery of the Russian Medical Academy of Continuous Professional Education.

Email: woody_del@bk.ru

RATIONALE Hollow organ perforation is an urgent problem in abdominal surgery. According to the literature, the incidence of perforation is from 0.37% to 2.3% of cases among various acute surgical pathologies of the abdominal organs.

The greatest attention in the literature is paid to the problem of perforated gastroduodenal ulcers. At the same time, a much smaller number of publications, both Russia and foreign, are devoted to other, more rare types of perforations. This situation is most likely explained by the low prevalence of other types of perforations, which, in turn, does not make them a less urgent problem in emergency surgery, which requires a modern approach to the treatment of this group of patients.

PURPOSE OF THE STUDY Analysis of domestic and foreign literature on the diagnosis and treatment of rare types of benign intestinal perforations.

MATERIAL AND METHODS A literature review was performed for the period from 1994 to 2020 in Russian and in English, available on Pubmed, Medline, Springer, Scopus, E-library, on topics such as perforated diverticula of the small intestine, perforation of Meckel's diverticulum, perforated ulcers of the small intestine, perforation of the intestine by a foreign body.

RESULTS With all the variety of surgical techniques for various types of perforation of the gastrointestinal tract, currently in the literature there are no specific criteria for choosing a particular method of intervention with regard to the cause, level, and duration of perforation.

CONCLUSION The lack of unified approaches in the diagnosis and treatment of patients with rare GIT perforations dictates the need for a more in-depth study of this issue in order to apply and optimize the technique of videolaparoscopic approach, develop a treatment and diagnostic algorithm for patients with suspected perforations of the gastrointestinal tract using the video laparoscopic method.

Keywords: hollow organ perforation, bowel perforation, foreign body, diverticula, small bowel ulcers, Crohn's disease

For citation Blagovestnov DA, Kopaliani DM, Samsonov VT, Yartsev PA, Arutyunova VG, Skukin DS. Rare Types of Perforation of the Gastrointestinal Tract — Diagnosis, Tactics, Treatment. *Russian Sklifosovsky Journal of Emergency Medical Care*. 2022;11(1):119–128. <https://doi.org/10.23934/2223-9022-2022-11-1-119-128> (in Russ.)

Conflict of interest Authors declare lack of the conflicts of interests

Acknowledgments, sponsorship The study has no sponsorship

Affiliations

Dmitry A. Blagovestnov	Doctor of Medical Sciences, Professor, Head of the Department of Emergency and General Surgery of the Russian Medical Academy of Continuous Professional Education; https://orcid.org/0000-0001-5724-6034 , sklifkafedra@mail.ru; 25%, assessment of literature sources, editing the article
David M. Kopaliani	Postgraduate student of the Department of Emergency and General Surgery of the Russian Medical Academy of Continuous Professional Education; Surgeon of the Department of Emergency Surgery and Operative Oncology of the N.V. Sklifosovsky Research Institute for Emergency Medicine; https://orcid.org/0000-0003-3045-3169 , woody_del@bk.ru; 25%, the data search in the world literature
Peter A. Yartsev	Doctor of Medical Sciences, Professor of the Department of Emergency and General Surgery of the Russian Medical Academy of Continuous Professional Education; Head of the Department of Emergency Surgery, Endoscopy and Intensive Therapy of the N.V. Sklifosovsky Research Institute for Emergency Medicine; https://orcid.org/0000-0003-1270-5414 , peter-yartsev@yandex.ru; 16%, coordination of all stages of work, verification of literary sources, stylistic processing of the text of the article
Vladimir T. Samsonov	Candidate of Medical Sciences, Senior Researcher of the Department of Emergency Surgery, Endoscopy and Intensive Care of the N.V. Sklifosovsky Research Institute for Emergency Medicine; https://orcid.org/0000-0001-6119-6260 , samsonovvt@yandex.ru; 14%, assessment of the quality of literature sources, stylistic editing of the article text, selection of study material

Violetta G. Arutyunova	The 6th-year student of the Peoples' Friendship University of Russia; https://orcid.org/0000-0001-8419-6984 , violetta21.va@gmail.com ; 10%, editing the text of the article, statistical data processing, collaboration with the editorial staff of the Journal
Dmitry S. Skukin	Surgeon of the Surgical department of the N.V. Sklifosovsky Research Institute for Emergency Medicine; https://orcid.org/0000-0003-0475-7441 , sds57@yandex.ru ; 10%, editing the text of the article, statistical data processing, collaboration with the editorial staff of the Journal, technical work with study material

CT, computed tomography

GIT, gastrointestinal tract

US examination, ultrasound examination

ETIOLOGY AND EPIDEMIOLOGY

Among rare causes of the non-tumour perforations of gastrointestinal tract (GIT) hollow organs, the literature most commonly describes such as the small intestine diverticular disease, swallowed foreign bodies, and small bowel ulcers of various origins (acute ulcers, ulcers in infectious diseases and chronic inflammatory conditions of the small intestine). Table 1 presents a brief meta-analysis of the occurrence of various cases of rare types of perforations in foreign and domestic literature in the period from 1994 to 2020.

Table

Rare types of perforation of the gastrointestinal tract hollow organs for the period from 1994 to 2020

Duodenum diverticula	10 cases [4,8,9,10,42,65,66,67]
Jejunum diverticula	12 cases [1,2,3,6,7,12,47,55,68]
Meckel's diverticulum	23 cases [6,16,17,18,20,23,69,70,71]
Foreign bodies in the gastrointestinal tract	16 cases [23,24,26,28,29,31,45,56,72,73,74,75]
Small bowel ulcers	221 cases [32,34,38,39,64,76,77,78,79]
Crohn's disease	218 cases [36,40,41,80]
Total	500 cases

Gastrointestinal diverticula are most commonly found in the colon. Small intestine diverticulosis is much less common, occurring in only 0.06%-1.9% of cases [1, 2, 3]. According to Schnueriger B. et al., 2008, over the recent 40 years, about 80 clinical cases of small intestine diverticula have been described by Russian and foreign authors [2,4].

In the structure of small intestine diverticular disease, duodenal diverticula are most common (60-79%), followed by jejunal diverticula (18-25%), ileum diverticula (5-18%) [3, 5, 6]. About 3% of cases are caused by diverticulosis, which affects all parts of the small intestine [3]. Small bowel diverticulae are found in 0.3%-1.3% of autopsies, 0.5%–1.9% of radiological studies with contrast enhancement, as an intraoperative finding, and are more common in elderly patients [7].

Duodenal diverticula are the most common among small bowel diverticulae. [5,8]. According to the authors from the USA (J. Philip et al 2019), up to 5% of cases are detected during radiological studies, and up to 22% during autopsies, increasing with age – in most cases in people over 40 years of age. Only about 5% of duodenal diverticula cases manifest themselves with symptoms and complications. Perforation, although being the rarest complication, but it is the most serious one [9].

World literature describes a high mortality rate in this pathology, varying from 3 to 34% [9, 10]. Other American authors reported an 8% mortality rate in a review of 61 cases from 1989 to 2011. Kellie L. Mathis et al., reported only 3% in a series of studies of 34 patients treated in Surgery Departments at the Mayo Clinic College of Medicine (Rochester, Minnesota, USA) from 1969 to 2001 [10, 11].

Jejunum diverticula are no less rare pathology of the upper GIT. In some cases, diverticulae are an accidental finding during radiological, endoscopic examinations, during surgical interventions or autopsies [3, 12]. Only 10% of cases have complications [3, 13], including the perforation, which is a serious complication and occurs with an incidence of 2%-6% [3]. According to a number of foreign authors, the mortality rate from jejunal diverticulitis ranges from 0 to 5%, increasing to 40% in case of a perforation [3, 15].

Somewhat apart from all small bowel diverticulae is Meckel's diverticulum, which is a congenital true diverticulum. Meckel's diverticulum is found in approximately 2% of the population, more often in men, which makes it the most prevalent congenital pathology of the gastrointestinal tract [16-19].

A publication by a group of authors from Portugal (2019) shows the detection rate of 0.14–4.5% at autopsies [18]. Complications occur in 4-6% of cases and can present a life-threatening condition that requires an urgent treatment. Most complications occur before the age of 3 years old [16, 20]. In Soltero M.J. study of 202 patients, the lifetime risk of developing complications in Meckel's diverticulum ranged from 2% to 4%, depending on the age of the patients [21]. In an epidemiological study of the Mayo Clinic (Cullen J.J. et al.), the rate of complications in Meckel's diverticula was 12% [22].

Perforated Meckel's diverticulum is a serious complication caused by diverticulitis, bedsores caused by enteroliths, ulceration of the produced ectopic gastric mucosa in the diverticulum tissue, and by a swallowed foreign body [17, 18, 23, 24, 25].

According to another study from the Mayo Clinic (Santos B. et al.), the postoperative lethality after surgical interventions for Meckel's diverticulum was 1.5%, and the incidence of late postoperative complications during 20 years of follow-up reached 7% [18].

Up to 0.37% of patients with acute surgical diseases of the abdominal cavity are patients with foreign bodies in the gastrointestinal tract [26]. A specific group includes patients with ingested foreign bodies in the gastrointestinal tract. Meanwhile, only 10%-20% of such patients require a special treatment. In the vast majority of cases, foreign bodies pass through the gastrointestinal tract and are evacuated via a natural route, without causing any painful phenomena.

Up to 80% of these patients are children; and among adults, these are mainly people of the senile age group, neurological patients with swallowing disorders, patients in psychiatric hospitals, and people who wear dentures. In about 1% of these cases, foreign bodies result in a perforation. Swallowing of foreign bodies often occurs during meals, during the game process in children, and it can also be associated with a bad habit of holding needles, pins, nails in one's mouth while working. According to most authors, long, thin, pointed objects such as fish bones, chicken bones, and toothpicks are particularly dangerous, and can cause a GIT perforation. [26, 27, 28, 29, 30]. Such foreign bodies most often injure the intestine in the places of its most pronounced natural bends: the ileocecal junction and the rectosigmoid part of the colon [31]. Delayed diagnosis of perforation by a foreign body can lead to severe consequences, up to a fatal outcome, which amounts to 18% [26].

Rare causes of perforations also include small bowel ulcers: idiopathic [32, 33], due to the use of nonsteroidal anti-inflammatory drugs [34, 35], glucocorticosteroids [33, 35, 36], and chemotherapeutic agents [33, 34, 35]. The incidence of acute small bowel ulcer perforations, according to literature data, does not exceed 3-5% [37, 38]. At the same time, according to some authors, its occurrence has increased almost 8-fold over the recent 20 years [32], and the mortality rate has significantly increased and reaches as much as 90% [37, 38].

Also, the perforated small intestine ulcers can be caused by various inflammatory diseases. In the literature, there are data on ulcerative lesions of the small intestine as a complication of infectious diseases. Russian and foreign authors have described perforations of the small intestine in typhoid fever, cytomegalovirus infection [33], and HIV infection [33, 34, 39].

According to V. P. Zemlyanoy et al. (2018), in patients with decompensated forms of viral hepatitis combined with HIV infection and abdominal tuberculosis, the course of the disease is complicated by intestinal perforation in 29.8%-44.2% of cases [34].

To date, the problem of small bowel perforations as complications of various chronic inflammatory bowel diseases has been poorly studied [32, 33, 40, 41]. There are rare publications on small bowel perforation in Crohn's disease [36, 40, 41]. According to Y.S. Doh data from Korea, a bowel perforation occurred in 6.5% of patients with Crohn's disease, of whom the ileum was affected in 86.2% cases, jejunum in 6.4%, colon in 7.9%; and 5% of patients had perforations in several parts of the intestine. The mortality rate for perforation in

these patients was 4.6% [36]. Meanwhile, the prevalence of perforations in Crohn's disease in Western countries has been at the level of 1-2% [36, 41].

A review of the Russian and foreign literature for any studies on rare types of GIT tract hollow organ perforations has shown an extremely small amount of information on the treatment results, especially on that of long-term results. The problem requires study to determine the true incidence of pathologies and various causes of rare types of GIT hollow organ perforations.

CLINICAL PRESENTATION

Most conditions that are complicated by a hollow organ perforation may be asymptomatic for a long time. So, uncomplicated diverticulosis of various parts of the small intestine most often has no clear clinical pattern and is manifested only by dyspeptic disorders [10, 42, 43]. Only 29% of patients develop clinical manifestations [3, 44]

The leading symptoms of perforation in various parts of the small intestine include pain of varying intensity, loose stools, and fever, which often force the patient to seek doctor's advice. [10, 17, 18, 23, 25, 26, 29, 30, 43]. Most often, patients are admitted at the hospital with suspicion of another acute abdominal pathology. The literature describes cases of intestinal perforation by a foreign body, perforated Meckel's diverticulum occurring under the mask of acute appendicitis, [17, 18, 23, 24, 25, 29], or acute pancreatitis [45].

MAKING DIAGNOSIS

Various imaging techniques allow the practicing doctor to suspect the presence of a hollow organ perforation in a patient, as well as evaluate the indications for surgical treatment.

Most often, a common radiography is not informative, since free gas in the abdominal cavity is visualized only in 10% of cases, and with retroperitoneal perforation it is not detected at all. [10, 11].

Computed tomography (CT) is the imaging technique having a high diagnostic value in the diagnosis of a hollow organ perforation. CT can reveal thickening of the organ wall, small loci of free gas in the abdominal cavity, free fluid, and signs of abscess formation [7, 10, 46, 47]. Its sensitivity is 97%, and its accuracy is 98%, which is much higher compared to radiography (47% and 52%, respectively) [48].

T. Ishiguro et al. (2014) found a correlation between the amount of free fluid in the abdominal cavity, according to computed tomography, and intraoperative data. This amount was determined by the time from the moment of perforation, the size of the perforation hole, the Mannheim peritonitis index, and subsequently correlated with the incidence of postoperative complications [49].

An ultrasound (US) examination reveals only indirect signs of perforation: thickening of the intestinal wall, the presence of free fluid, and the signs of free gas in the hands of experienced specialists [30]. Some authors noted that the reliability of such ultrasound sign of hollow organ perforation as the presence of gas in the abdominal cavity tends to increase in case of the combination with a number of indirect signs: the presence of free fluid, thickening of the intestinal wall, and a decreased intestinal motility. This method can be indicated as a particularly valuable one for pregnant women and other patients for whom X-ray examination is undesirable [50, 51]. For example, ultrasound has a sensitivity of about 77-98% and a specificity of 80-99% in the diagnosis of acute diverticulitis complications [52, 53].

In doubtful cases, videolaparoscopy is a crucial diagnostic study, which, according to various data, makes it possible to make the correct diagnosis in 98% of cases and determine the optimal surgical tactics, and in 1.6% of cases to continue the operation laparoscopically to repair perforation and eliminate peritonitis [18, 23, 25]. Meanwhile, diagnostic videolaparoscopy is performed most often for suspicion of the most common acute abdominal conditions, such as acute appendicitis, and the true cause of perforation becomes an intraoperative finding [6, 17, 18, 23, 25].

SURGICAL TREATMENT FOR RARE TYPES OF GASTROINTESTINAL TRACT PERFORATION

The main treatment method for gastrointestinal perforations is surgical. Many different methods of surgical treatment have been proposed, but the issues of surgical tactics are still controversial and continue to be discussed by surgeons [54].

For example, in perforated duodenal diverticula, surgeons from Turkey recommend performing diverticulectomy and suturing with a manual or hardware suture, covering the perforation with a strand of omentum; the method of choice may be segmental duodenectomy, duodenojejunostomy [10], and in rare cases even pancreatoduodenal resection [9, 10]. However, no clear criteria for choosing a particular surgical intervention were found.

In contrast, for perforation of small bowel diverticula, Gurala D. et al. recommend performing laparotomy with segmental resection of the small intestine with primary anastomosis. The overall mortality rate after such surgery is 24% due to poor prognostic factors, such as old age and delays in diagnosis and treatment [3]. Alternative surgical methods, such as primary suturing of diverticula perforation, diverticulectomy, and invagination, in Sehgal R. et al. opinion might be associated with extremely poor outcomes and high mortality rates, and should be avoided [12]. At the same time, Russian authors have described successful results of surgical interventions such as suturing the perforating opening, diverticulectomy, resection of the diverticulum with stitching at the base, invagination of diverticula. In their opinion, such a large amount of surgical intervention is appropriate to resort to in the presence of risk factors: the patient's age, the risk of radical surgery in the presence of diffused purulent peritonitis, and the general severity of the condition [6, 55].

With complicated Meckel's diverticulum, there is also no consensus on the choice of surgical intervention. Some authors recommend segmental bowel resection with primary anastomosis for the present inflammatory changes or perforation at the base of the diverticulum. Others propose simple diverticulectomy with transverse suturing of the bowel defect [18].

Various methods of surgical treatment are offered for bowel perforation by a foreign body. The traditional treatment of foreign body perforation is an "open" surgical removal of the foreign body with local intestinal repair: simple suturing or by using suturing devices, wedge-shaped resection, and, in more severe cases, a segmental resection of the intestine or the stoma removal [24, 31, 56]. However, no clear criteria were found for choosing the method of restoring intestinal integrity.

The surgical treatment of the small intestine perforated ulcers most often consists of suturing the perforation hole or resecting the intestinal section that carries the perforation. So, in foreign studies, in Crohn's disease, the preference was given to the intestinal area resection with the primary restoration or removal of the stoma. Simple suturing of the perforation hole is associated with frequent complications and a high postoperative mortality rate [36, 41].

At the same time, in patients with acute ulcers of the small intestine the procedure is most often limited to simple suturing of perforations, especially if they occur in the postoperative period, which is caused by the severe patient condition and the risk of postoperative mortality in cases of major surgery [32]. Russian authors have described cases of simple suturing of the perforation hole [40].

THE ROLE OF LAPAROSCOPIC TECHNOLOGIES IN THE DIAGNOSIS AND TREATMENT OF RARE TYPES OF GASTROINTESTINAL TRACT PERFORATIONS

Currently, there is a tendency in the development of medicine to reduce the traumatic nature of diagnostic and treatment methods for various diseases. Undoubtedly, it should be important for any surgeon both mastering the techniques to perform high-tech surgery, and also achieving a high level of rehabilitation after these interventions [57].

Since the beginning of the 90s of the last century, reports of laparoscopic operations for peptic ulcer disease began to appear in the literature. These publications covered the issues of suturing the perforation of gastroduodenal ulcers [58, 59]. The use of laparoscopic techniques in suturing a perforated ulcer made it possible to eliminate the contradiction between the minimality of surgical intervention, i.e. the application of several stitches, and the traumatic nature of laparotomy [58].

Currently, there are various recommendations for the diagnosis and treatment of perforated gastroduodenal ulcers. For example, P. A. Yartsev et al. (2015) proposed an endoscopic classification of ulcer perforations, considering the diameter of the perforation hole of ≤ 2 mm defined as grade I; 2-5 mm as grade II; 5-10 mm as grade III; > 10 mm as grade IV; and the size of the infiltration billow of ≤ 5 mm defined as type A; from 5-10 mm as type B; > 10 mm as type C). The authors made their choice of the surgical technique based on the developed classification. For ulcers of class IA, IB, or IIA, a closure with Z-suture is indicated. An ulcer of class IC and IIB, the perforation hole is sutured with separate single-row stitches. And in ulcers of class IIIA

and IIIB, it is recommended to suture the perforation with separate double-row stitches. In case of perforated duodenal ulcers of class IIC, IIIC, IVA, IVB, and IVC, a conversion to open surgery is recommended. According to the authors, this approach to the choice of the surgical technique and equipment allows us to standardize the approaches to the treatment of patients with this pathology [60, 61].

Many publications can be found in the literature that address the issues of complications in the treatment of perforated gastroduodenal ulcers, including the perforation suture incompetence, intraabdominal complications, pneumonia, suppuration of postoperative wounds; and there are also interesting data comparing the hospital length of stay and mortality in patients treated by using laparoscopic versus "open" interventions [58].

As for rare perforation types, there are very few publications on their treatment in literature. Thus, in case of a perforation by a foreign body, a number of Russian authors consider the feasibility of video laparoscopic surgery with regard to the time from the onset of the disease, the intraoperative presentation [23, 25, 28, 29, 45, 56]. Foreign authors discuss options for a video laparoscopic approach that include the diagnosis, laparoscopic removal of a foreign body without suturing, simple suturing, and resection of a part of the intestine. [31, 62]. However, even in such studies, it is not always possible to find objective grounds for the choice of treatment method.

Many authors discuss the use of videolaparoscopic techniques, hardware methods of Meckel's diverticulum resection [18, 23, 25, 63].

In their study, Kato K., Cooper M. described a successful video laparoscopic right-sided hemicolectomy performed in a patient with a perforated terminal part of the ileum amid cytomegalovirus infection [64].

It is worth noting that absolute contraindications to the use of laparoscopic treatment for hollow organ perforations are quite rare and in fact do not differ from those for urgent laparoscopy in general. They include total abdominal adhesions, an extremely severe patient condition, and septic shock [58].

RESULTS AND DISCUSSION

Thus, despite multiple surgical techniques used for rare types of gastrointestinal perforations, currently the literature has not defined specific criteria for choosing a particular method of intervention. In addition, the long-term results of surgical treatment for rare types of gastrointestinal perforations have not been studied, and clear indications for minimally invasive methods of treatment have not been defined. There are no comparative studies of postoperative outcomes in patients with rare types of perforations, considering the perforation level, time from its onset, and the surgical treatment technique chosen. According to most opinions in the literature, a decisive role in the diagnosis and choice of a surgical technique for rare types of gastrointestinal perforations belongs to videolaparoscopy, as the most informative method.

The specific significance of videolaparoscopy lies in the possibility of combining diagnostic and therapeutic measures – diapaetical method. At the same time, clear indications and contraindications to using laparoscopic access in this pathology have not yet been determined; there are no standardized criteria for using laparoscopy, and the issues of surgical techniques for laparoscopic suturing of various types of GIT hollow organ perforations have not been completed to the full.

Moreover, we should note that having analyzed the available Russian and foreign literature sources, we have found no large-scale studies covering the diagnosis and treatment of rare causes of perforations in Russia and abroad.

CONCLUSION

The lack of unified approaches in the diagnosis and treatment of patients with rare gastrointestinal tract perforations dictates the need for a more in-depth study of this issue in order to optimize the technique of videolaparoscopic diagnostic and treatment approach, considering the etiology of perforation, the level and localization of the perforation hole, the extent of the process, and to develop a therapeutic and diagnostic algorithm in patients with a suspected gastrointestinal tract perforation by using the videolaparoscopic method.

REFERENCES

1. Yudin VA, Kochukov VP, Melnikov AA, Melnikova IA, Mokrova AV. Surgical Approaches in Diagnostics and Treatment of Perforation Jejunal Diverticulosis. *Surgical practice*. 2017;(3):43–45. (in Russ.)
2. Zdzitovetsky DE, Beloborodov AA, Danilina EP, Borisov RN, Tyapkin SI. Diverticular Disease of the Small Intestine with Perforation and Developing a Disseminated Purulent Peritonitis. *Siberian Medical Review*. 2013;(6):76–78. (in Russ.)
3. Gurala D, Idiculla PS, Patibandla P, Philipose J, Krzyzak M, Mukherjee I. Perforated Jejunal Diverticulitis. *Case Reports*. 2019;13(3):521–525. PMID: 31911765 <https://doi.org/10.1159/000503896> eCollection 2019 Sep-Dec.
4. Schnueriger B, Vorbuerger SA, Banz VM, Schoepfer AM, Candinas D. Diagnosis and management of the symptomatic duodenal diverticulum: a case series and a short review of the literature. *J Gastrointest Surg*. 2008;12(9):1571–1576. PMID: 18521693 <https://doi.org/10.1007/s11605-008-0549-0>
5. Rangan V, Lamont JT. Small Bowel Diverticulosis: Pathogenesis, Clinical Management, and New Concepts. *Curr Gastroenterol Rep*. 2020;22(1):4. PMID: 31940112 <https://doi.org/10.1007/s11894-019-0741-2>
6. Shyla RS, Mahiliavets EV, Belyuk KS, Karpovich VE, Dziashuk AN, Kovalenya PA, Kordeckiy AK. Complications Of Small Intestine Diverticula, Cases from Clinical Practice. *Journal of the Grodno State Medical University*. 2019;17(2):219–223. (in Russ.) <https://doi.org/10.2598/2221-8785-2019-17-2-219-223>
7. Sarıtaş AG, Topal U, Eray İC, Dalcı K, Akçamı AT, Erdoğan K. Jejunal diverticulosis complicated with perforation: A rare acute abdomen etiology. *Int J Sur Case Rep*. 2019;63:101–103. PMID: 31574453 <https://doi.org/10.1016/j.ijscr.2019.09.013>
8. Grigoriev EG, Pak VE, Kapsorskiy VI, Ochirova TV, Ajushinova NI, Gelfand SA, Shcherbo IV. Diverticulosis of Duodenum Complicated with Perforations and Multiple Fistulas of Digestive Tract: Anecdotal Case. *Infektsii V Khirurgii*. 2014;12(4):47–50. (in Russ.)
9. Philip J, Cocieru A. Pancreatoduodenectomy in patient with perforated duodenal diverticulum and peritonitis: Case report. *Int J Surg Case Rep*. 2019;58:48–49. PMID: 31005047 <https://doi.org/10.1016/j.ijscr.2019.04.011>
10. Moysidis M, Paramythiotis D, Karakatsanis A, Amanatidou E, Psoma E, Mavropoulou X, et al. The challenging diagnosis and treatment of duodenal diverticulum perforation: a report of two cases. *BMC Gastroenterol*. 2020;20(1):5. PMID: 31914931 <https://doi.org/10.1186/s12876-019-1154-2>
11. Thorson CM, Ruiz PP, Rosiane A, Roeder RA, Sleeman D, Casillas VJ. The perforated duodenal diverticulum. *Arch Surg*. 2012;147(1):81–88. PMID: 22250120 <https://doi.org/10.1001/archsurg.2011.821>
12. Sehgal R, Cheung CX, Hills T, Waris A, Healy D, Khan T. Perforated jejunal diverticulum: a rare case of acute abdomen. *J Surg Case Rep*. 2016;2016(10): rjw169. PMID: 27765806 <https://doi.org/10.1093/ijscr/rjw169>
13. Transue DL, Hanna TN, Shekhani H, Rohatgi S, Khosa F, Johnson JO. Small bowel diverticulitis: an imaging review of an uncommon entity. *Emerg Radiol*. 2017;24(2):195–205. PMID: 27815648 <https://doi.org/10.1007/s10140-016-1448-4>
14. Sibille A, Willocx R. Jejunal diverticulitis. *Am J Gastroenterol*. 1992;87(5):655–658. PMID: 1595658
15. Kassir R, Boueil-Bourlier A, Baccot S, Abboud K, Dubois J, Petcu CA, et al. Jejuno-ileal diverticulitis: etiopathogenicity, diagnosis and management. *Int J Surg Case Rep*. 2015;10:151–153. PMID: 25841158 <https://doi.org/10.1016/j.ijscr.2015.03.044>
16. McKelvie M, Soares-Oliveira M, Wang-Koh Y, Trayers C, Aslam A. Spontaneous Perforated Meckel Diverticulum: A Rare Case and Review of the Literature. *Pediatr Emerg Care*. 2019;35(12):881–883. PMID: 31790074 <https://doi.org/10.1097/PEC.0000000000001993>
17. Yi G, Chavda K, Omodon M. CT findings of Meckel's diverticulum perforation in a geriatric patient. *Radiology Case Rep*. 2020;15(5):592–595. PMID: 32215159 <https://doi.org/10.1016/j.radcr.2020.02.016>
18. Santos B, Pinto A, Barbosa B, Simões VC, Silva DS, Davide J. Perforation of Meckel's diverticulum by a swallowed fish bone: case report and literature review. *J Surg Case Rep*. 2019;2019(1):rjz003. PMID: 30697415 <https://doi.org/10.1093/ijscr/rjz003>
19. Goncharov AG, Bogomolov NI. Divertikul Mekkelya – nestareyushchaya problema meditsiny. In: *Aktual'nye problemy klinicheskoy i eksperimental'noy meditsiny. Chita, 17–18 oktyabrya 2013 goda*. Chita: ChGMA Publ.;2018: 25–30. (in Russ.)
20. LaFlam TN, Phelps A, Choi W-T, Kornblith AE. Meckel Diverticulum Presenting as Abdominal Pain and Subsequent Bowel Perforation. *J Emerg Med*. 2020;58(6):e251–e254. PMID: 32317193 <https://doi.org/10.1016/j.jemermed.2020.03.019>
21. Soltero MJ, Bill AH. The natural history of Meckel's Diverticulum and its relation to incidental removal. A study of 202 cases of diseased Meckel's Diverticulum found in King County, Washington, over a fifteen year period. *Am J Surg*. 1976;132(2):168–173. PMID: 952346 [https://doi.org/10.1016/0002-9610\(76\)90043-X](https://doi.org/10.1016/0002-9610(76)90043-X)
22. Cullen JJ, Kelly KA, Moir CR, Hodge DO, Zinsmeister AR, Melton LJ. Surgical management of Meckel's diverticulum. An epidemiologic, population-based study. *Ann Surg*. 1994;220(4):564–568. PMID: 7944666 <https://doi.org/10.1097/0000658-199410000-00014>
23. Kirsanov II, Makedonskaya TP, Tarasov SA, Yartsev PA. Capabilities of Video-Assisted Laparoscopy in the Diagnosis and Treatment of Perforation of the Small Intestine and Meckel's Diverticulum (2 Clinical Observations). *Russian Sklifosovsky Journal Emergency Medical Care*. 2016;(1):63–65. (in Russ.)
24. Sinenchenko GI, Verbitsky VG, Demko AE, Parfenov AO, Osipov AV, Tereshichev AA, et al. Modern opportunities of early diagnostics and minimally invasive surgical treatment of intestinal perforation by a foreign body. *Herald of North-Western State Medical University named after I.I. Mechnikov*. 2019;11(1):61–64. (in Russ.) <https://doi.org/10.17816/mechnikov201911161-64>
25. Kopalani DM, Blagovestnov DA, Yartsev PA, Samsonov VT. Role of Video Laparoscopy in Diagnostics and Choice of Treatment Tactics for Perforation of the Intestines with a Foreign Body (Four Clinical Observations). *Herald of surgical gastroenterology*. 2019;(3):18–25. (in Russ.)
26. Fomin VS, Naletov VV, Zinatulin DR, Mikhailov VG, Nikolaev DV. Toothpick Perforation of Colon: Clinical Case Report and Literature Review. *Doctor.Ru*. 2016; 1(118): 91–93. (in Russ.)
27. Ovseychik MYu. *Differentsirovanny podkhod v lechenii inorodnykh tel zheludochno-kishechnogo trakta: cand. med. sci. diss. synopsis: 14.01.17*. Volgograd; 2010. (in Russ.) Available at: <https://search.rsl.ru/ru/record/01003492187> [Accessed Apr 15, 2021]
28. Polyakov AA. Laparoscopic management of fishbone small bowel perforation. *Endoscopic Surgery*. 2016;22(5):40–42. (in Russ.). <https://doi.org/10.17116/endoskop201622540-42>
29. Ma T, Zheng W, An B, Xia Y, Chen G. Small bowel perforation secondary to foreign body ingestion mimicking acute appendicitis: Case report. *Medicine (Baltimore)*. 2019;98(30):e16489. PMID: 31348257 <https://doi.org/10.1097/MD.00000000000016489>

30. Kuzmich S, Burke CJ, Harvey CJ, Kuzmich T, Andrews J, Reading N, et al. Perforation of gastrointestinal tract by poorly conspicuous ingested foreign bodies: radiological diagnosis. *Br J Radiol.* 2015;88(1050):20150086. PMID: 25827210 <https://doi.org/10.1259/bjr.20150086>
31. Lunsford KE, Sudan R. Small Bowel Perforation by a Clinically Unsuspected Fish Bone: Laparoscopic Treatment and Review of Literature. *J Gastrointest Surg.* 2012;16(1):218–222. PMID: 21796463 <https://doi.org/10.1007/s11605-011-1610-y>
32. Zemlyanoy VP, Singaevskiy AB, Gladyshev DV, Vryblevskiy NM, Nesvit EM, Efendieva MA. Acute postoperative perforated ulcers of the small bowel as a topical problem of modern surgery. *Grekov's Bulletin of Surgery.* 2019;178(2):33–37. (in Russ.) <https://doi.org/10.24884/0042-4625-2019-178-2-33-37>
33. Freeman HJ. Spontaneous free perforation of the small intestine in adults. *World J Gastroenterol.* 2014;20(29):9990–9997. PMID: 25110427 <https://doi.org/10.3748/wjg.v20.i29.9990>
34. Zemlyanoy VP, Nakhumov MM, Letina YV, Magomedov GM, Shikhmagomedov SS. Features of the flow of perforations of hollow organs of the abdominal cavity in infectious patients. *Herald of North-Western State Medical University named after I.I. Mechnikov.* 2018;10(1):27–32. (in Russ.) <https://doi.org/10.17816/mechnikov201810127-32>
35. Ito Y, Yoshida M, Sugiyama T, Masuda H, Mori M, Kimura N, et al. Multiple Ulcerations and Perforation in the Small Intestine After Steroid Treatment in Eosinophilic Granulomatosis with Polyangiitis: A Case Report and Literature Review. *Cardiovasc Pathol.* 2020;47:107193. PMID: 32151788 <https://doi.org/10.1016/j.carpath.2019.107193>
36. Doh YS, Kim YS, Bae SI, Im JP, Cheon JH, Ye BD, et al. The clinical characteristics of patients with free perforation in Korean Crohn's disease: Results from the CONNECT study. *BMC Gastroenterol.* 2015;15:31. PMID: 25887913 <https://doi.org/10.1186/s12876-015-0262-x>
37. Stepanyan AT. Perforatsiya ostroy yavzy tonkoy kishki – prediktor neblagopriyatnogo iskhoda. *Medical Conferences Online.* 2014;4(8):994. (in Russ.)
38. Bitukov SL, Oleinik AA. The results of the treatment of perforations of stressful ulcers of the intestine in a general surgical hospital. *Koveshnikov Morphological Almanac.* 2019;17(2):6–10. (in Russ.)
39. Belov SA, Shapovalov AS, Pimenov NA, Bobyreva MG, Sudinshchikov VV. Perforated Peritonitis in Patients with HIV Infection. *Health. Medical Ecology. Science.* 2019;2(78):52–53. (in Russ.) <https://doi.org/10.5281/zenodo.824241>
40. Klimentov MN, Styazhkina SN, Neganova OA, Lyubimtseva MS, Semibratova EV, Turbin OD. Crohn's Disease Complications, Requiring Surgical Treatment. *Perm Medical Journal.* 2019;36(3):98–105. (in Russ.) <https://doi.org/10.17816/pmj36398-105>
41. Ikeuchi H, Yamamura T. Free perforation in Crohn's disease: review of the Japanese literature. *J Gastroenterol.* 2002;37(12):1020–1027. PMID: 12522533 <https://doi.org/10.1007/s005350200172>
42. Glushkov NI, Gorbunov GM, Shubinsky VD, Trosinenko GA. A Rare Complication of the Duodenal Diverticulum. *Grekov's Bulletin of Surgery.* 2006;165(3):84–85. (in Russ.)
43. López JF, Valverde MG, Sanz NM, Rodríguez MET, Blázquez AM. Acute abdomen from duodenal diverticulitis. A case report. *Rev Esp Enferm Dig.* 2016;108(10):661–662. PMID: 27701888
44. Singal R, Gupta S, Airon A. Giant and multiple jejunal diverticula presenting as peritonitis a significant challenging disorder. *J Med Life.* 2012;5(3):308–310. PMID: 23049633
45. Khalidov OK, Fomin VS, Gudkov AN, Borodin AS, Gudkov DA. Case Report: Small Bowel Perforation with a Foreign Body Mimicking Acute Pancreatitis. *Moscow Surgical Journal.* 2018;1(1):23–27. (in Russ.) <https://doi.org/10.17238/issn2072-3180.2018.1.23-27>
46. Schroeder TC, Hartman M, Heller M, Klepshick P, Ilkhanipour K. Duodenal diverticula: Potential complications and common imaging pitfalls. *Clin Radiol.* 2014;69(10):1072–1076. PMID: 25110301 <https://doi.org/10.1016/j.crad.2014.05.103>
47. Platitsyn IV, Kondratyev AV, Panin AV, Shubarkina EM, Maslov AL. Perforation of the jejunum diverticulum: the role of CT examination. *Medical Visualization.* 2019;3(3):66–76. (in Russ.) <https://doi.org/10.24835/1607-0763-2019-3-66-76>
48. Guelglat M, Kaplinskiy V, Reddy SH, DiPoce J. Clinical Guidelines for Imaging and Reporting Ingested Foreign Bodies. *AJR Am J Roentgenol.* 2014;203(1):37–53. PMID: 24951194 <https://doi.org/10.2214/AJR.13.12185>
49. Ishiguro T, Kumagai Y, Baba H, Tajima Y, Imaizumi H, Suzuki O, et al. Predicting the Amount of Intraperitoneal Fluid Accumulation by Computed Tomography and Its Clinical Use in Patients with Perforated Peptic Ulcer. *Int Surg.* 2014;99(6):824–829. PMID: 25437594 <https://doi.org/10.9738/INTSURG-D-14-00109.1>
50. Vinnik YuS, Serova EV, Prusov IA, Stratovich DV, Shilov VG, Panov YuA. Ul'trasonograficheskaya diagnostika prikrutoy perforatsii yavzy lukovitsy dvenadtsatiperstnoy kishki. *Grekov's Bulletin of Surgery.* 2016;175(6):79–81.
51. Coppolino FF, Gatta G, Grezia GD, Reginelli A, Iacobellis F, Vallone G, et al. Gastrointestinal perforation: ultrasonographic diagnosis. *Crit Ultrasound J.* 2013;5(Suppl 1):S4. PMID: 23902744 <https://doi.org/10.1186/2036-7902-5-S1-S4>
52. Reznitsky PA, Yartsev PA. Contemporary Diagnosis and Surgical Treatment of Colonic Diverticulitis Complications. *Russian Sklifosovsky Journal Emergency Medical Care.* 2017;6(1):41–50. (in Russ.) <https://doi.org/10.23934/2223-9022-2017-6-1-138-143>
53. Mazzei MA, Cioffi Squitieri N, Guerrini S, Stabile Ianora AA, Cagini L, Macarini L, et al. Sigmoid diverticulitis: US findings. *Crit Ultrasound J.* 2013;5(Suppl 1):S5. PMID: 23902791 <https://doi.org/10.1186/2036-7902-5-S1-S5>
54. Postolov MP. Vybora optimal'nogo metoda khirurgicheskogo lecheniya probodnoy yavzy dvenadtsatiperstnoy kishki: cand. med. sci. diss. synopsis: 14.01.17. Volgograd; 2017. (in Russ.) Available at: <https://www.disscat.com/content/vybor-optimalnogo-metoda-khirurgicheskogo-lecheniya-probodnoi-yavzy-dvenadtsatiperstnoi-kish/read> (Accessed Apr 15, 2021)
55. Imanaliev MR, Nazhmudinov ZZ, Guseynov AG, Magomedov MA, Saidov MG. Diverticular disease of small intestine complicated by perforation and advanced peritonitis. *Pirogov Russian Journal of Surgery.* 2017;7(7):59–60. (in Russ.) <https://doi.org/10.17116/hirurgia2017759-60>
56. Zouros E, Oikonomou D, Theoharis G, Bantias C, Papadimitropoulos K. Perforation of the cecum by a toothpick: report of a case and review of the literature. *J Emerg Med.* 2014;47(6):e133–137. PMID: 25300206 <https://doi.org/10.1016/j.jemermed.2014.06.065>
57. Chatkov IE, Barsukov YuA, Atroshchenko AO, Aliyev VA, Kuzmichev DV, Tamrazov RI, et al. History of laparoscopic surgery. *Pelvic Surgery and Oncology.* 2012;(2):35–39. (In Russ.) <https://doi.org/10.17650/2220-3478-2012-0-2-35-39>
58. Abdullaev AE. *Khirurgicheskoe lechenie perforativnykh gastroduodenal'nykh yavz s ispol'zovaniem miniinvazivnykh tekhnologiy: cand. med. sci. diss. synopsis: 14.01.17.* Moscow; 2018. (in Russ.) Available at: <https://search.rsl.ru/ru/record/01008706137> (Accessed 15 Apr, 2021)
59. Sazhin VP, Bronshteyn PG, Zaytsev OV, Kondrus' IV, Krivtsov GA, Lobankov VM, et al. Probodnaya yazva zheludka i dvenadtsatiperstnoy kishki. In: *Natsional'nye klinicheskie rekomendatsii.* Moscow: ROKh Publ.; 2015. (in Russ.)

60. Antropov IV. *Prognozirovanie agressivnosti techeniya peritonita u patsientov s perforativnoy yazvoy dvenadtsatiperstnoy kishki: cand. med. sci. diss. synopsis: 14.01.17.* Samara; 2018. (in Russ.) Available at: <https://search.rsl.ru/ru/record/01008717683> (Accessed 15 Apr, 2021)
61. Kirsanov II. *Videolaparoskopiya v diagnostike i lechenii patsientov s perforativnymi yazvami 12-perstnoy kishki i zheludka: cand. med. sci. diss. synopsis: 14.01.17.* Moscow; 2011. (in Russ.) Available at: <https://search.rsl.ru/ru/record/01005002402> (Accessed 15 Apr, 2021)
62. Dente M, Santi F, Solinas L, Bagarani M. Laparoscopic diagnosis and management of jejunal perforation resulting from accidental toothpick ingestion. *Am Surg.* 2009;75(2):178–179. PMID: 19280815
63. Korovin SA, Dzyadchik AV, Allakhverdiev IS, Zykin AP, Sokolov YY. Efficacy Of Laparoscopic Techniques in Children with Diverticulum of Meckel. *Russian Journal of Pediatric Surgery, Anesthesia and Intensive Care.* 2016;6(4):28–36. (in Russ.) <https://doi.org/10.17816/psaic288>
64. Kato K, Cooper M. Small bowel perforation secondary to CMV-positive terminal ileitis postrenal transplant. *BMJ Case Rep.* 2019;12(11):e231662. PMID: 31772132 <http://doi.org/10.1136/bcr-2019-231662>
65. Gulmez M, Yildiz MK, Odabasi HM, Abuoglu HH, Ilhan O, Kaytaz K. Perforated duodenal diverticulum: A case report. *North Clin Istanbul.* 2016;3(2):143–145. PMID: 28058403 <http://doi.org/10.14744/nci.2016.50469>
66. Yagi S, Ida S, Ohashi M, Kumagai K, Hiki N, Sano T, et al. Two cases of a perforated duodenal diverticulum after gastrectomy with Roux-en-Y reconstruction. *Surg Case Rep.* 2019;5(1):169. PMID: 31691035 <https://doi.org/10.1186/s40792-019-0738-y>
67. Shimada A, Fujita K, Kitago M, Ichisaka S, Ishikawa K, Kikunaga H, et al. Perforated duodenal diverticulum successfully treated with a combination of surgical drainage and endoscopic nasobiliary and nasopancreatic drainage: a case report. *Surg Case Rep.* 2020;6(1):129. PMID: 32514821 <https://doi.org/10.1186/s40792-020-00891-0>
68. Myakonky RV, Kaplunov KO. A Case of Diverticular Disease of the Small Intestine Complicated by Perforation of the Diverticulum, Interintestinal Abscess and Acute Intestinal Obstruction. *Volgograd Journal of Medical Research.* 2016;4(52):55–59. (in Russ.)
69. Zotin AV, Atavov RS, Kuz'menko IO, Khryachkov VV. Redkiy klinicheskiy sluchay perforatsii divertikula Mekkel'ya u rebenka. *The Scientific and Practical Journal of Medicine.* 2015;1–2(7–8):140–144. (in Russ.)
70. Cullen JJ, Kelly KA, Moir CR, Hodge DO, Zinsmeister AR, Melton LJ 3rd. Surgical management of Meckel's diverticulum. An epidemiologic, population-based study. *Ann Surg.* 1994;220(4):564–569. PMID: 7944666 <https://doi.org/10.1097/0000658-199410000-00014>
71. Wang YJ, Wang T, Xia SL, Zhang YC, Chen WB, Li B. Perforation of Meckel's diverticulum in a very low birth weight neonate with severe pneumoperitoneum and review of literature. *Turk J Pediatr.* 2019;61(3):460–465. PMID: 31916731 <https://doi.org/10.24953/turkjpmed.2019.03.025>
72. Krylov NN, Rybin VK, Bakanov AI, Drapaluk IB. Small Bowel Perforation by a Foreign Body. *Herald of surgical gastroenterology.* 2010;(1):65–68. (in Russ.)
73. Chekmarev VM, Volkov AY, Kharchenko IV, Zolkina OV. Inorodnye tela zheludочно-kishechnogo trakta, oslozhnennyye perforatsiyey. *Russian Journal of Pediatric Surgery.* 2012;(5):52. (in Russ.)
74. Taguchi T, Kitagawa H. Fish Bone Perforation. *N Engl J Med.* 2019;381:762. PMID: 31433923 <https://doi.org/10.1056/NEJMicm1900442>
75. Lim DR, Kuk JC, Kim T, Shin EJ. Surgery for intra-abdominal abscess due to intestinal perforation caused by toothpick ingestion: Two case reports. *Medicine (Baltimore).* 2019;98(36):e17032. PMID: 31490392 <https://doi.org/10.1097/MD.00000000000017032>
76. Khudaibergenov ShA, Muradov TR, Khodgaev KSh, Abdurakhmanov ShM. The case of successfully surgical treatment of primitive ulcer of thin intestine. *The Bulletin of Emergency Medicine.* 2011;(1):77–79. (in Russ.)
77. Gol'braj VA, Maskin SS, Bobyrin AV, Karsanov AM, Derbenceva TV, Lopastejskij DS, et al. Acute perforated ulcers of the small intestine in patients with total purulent peritonitis. *Journal of Experimental and Clinical Surgery.* 2012;5(1):51–53. <https://doi.org/10.18499/2070-478X-2012-5-1-51-53>
78. Lubyanskiy VG, Zharikov AN. Basic Pathogenetic Mechanisms of Acute Intestinal Perforation in Patients with Postoperative Peritonitis. *Acta Biomedica Scientifica.* 2012;(4(1)):51–55. (in Russ.)
79. Lee YC, Chiou CC, Wang JT, Yang YC, Tung SH, Hsieh SM. Non-traumatic perforation of the jejunum in a human immunodeficiency virus-infected patient receiving combination antiretroviral therapy: A case report. *Medicine (Baltimore).* 2019;98(49):e18163. PMID: 31804330 <https://doi.org/10.1097/MD.00000000000018163>
80. Wu YF, Ho CM, Yuan CT, Chen CN. Intestinal tuberculosis previously mistreated as Crohn's disease and complicated with perforation: a case report and literature review. *Springerplus.* 2015;4:326. PMID: 26180746 <https://doi.org/10.1186/s40064-015-1129-x>

Received on 27.04.2021

Review completed on 07.06.2021

Accepted on 27.12.2021