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Conservative treatment of children with traumatic ruptures of the spleen: results of 22 years of experience

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ABSTRACT

BACKGROUND: Conservative treatment options developed and tested over several decades prevent splenectomy, which leads to post-splenectomy hyposplenism associated with immunodeficiency and hematologic disorders. This article reviews 22 years of conservative management of traumatic splenic rupture, emphasizing the important role of organ preservation and minimizing surgical intervention.

AIMS: The aim was to summarize 22 years of experience in the management of children with traumatic splenic rupture.

MATERIALS AND METHODS: This observational single-center prospective study was conducted from March 2002 to March 2024 at the Ivano-Matreninskaya City Children's Clinical Hospital in Irkutsk. The medical records of 95 children with traumatic splenic rupture were evaluated. Conservative treatment was received by 83 (87.4%) patients and surgical treatment was received by 12 (12.6%) patients. The age of the affected children was 12 [8; 14] years, with 3.3 times more boys observed (73 vs. 22). For analysis, patients were divided into two groups: comparison group (n = 62; 65.3%) in the early treatment period (March 2002 to August 2012); main group (n = 33; 34.7%) in the late treatment period (September 2012 to March 2024). All children were followed for complications related to spleen injury. Comprehensive follow-up of patients after discharge ranged from 6 months to 15 years.

RESULTS: Of the 95 patients, 2 (2.1%) underwent splenorrhaphy, 3 (3.1%) underwent laparoscopic exploration of the spleen, and 7 (7.4%) underwent splenectomy. Surgical treatment required prolonged combined antibacterial therapy for 13 [10; 16] days. If the spleen was removed after discharge from the hospital, patients were prescribed preventive vaccinations. A discriminant analysis was used to identify cumulative factors that influence the choice of surgical treatment in children with splenic rupture. Combined factors included low systolic blood pressure of 95 (70; 118) mm Hg (p = 0.002); tachycardia with heart rate of 105 [100; 120] beats per minute (p = 0.019); increased shock index of 1.1 [0.9; 1.57] (p = 0.001); blood loss at admission of 13% [6.3; 19] of the circulating blood volume (p = 0.001); maximum degree of blood loss of 2 [1; 3] (p = 0.001). When comparing the groups by duration of treatment, a statistically significant difference was found in the number of days spent in the Surgery Department: the duration of hospital stay was 12 [8; 14] days in the comparison group and 7 (7; 9) days in the main group (p = 0.001). Patients did not differ in terms of blood loss and hemodynamics. Recently, however, the number of surgeries for splenic rupture has decreased 2.6 times, from 16.1% to 6.1%. When evaluating immediate outcomes after splenectomy, it was found that 71.4% (n = 5) of the children had thrombocytosis on day 3–6 after surgery. After spleen removal, all children had an elevated ESR of 25 [23; 39] mm/h for 2 weeks. Long-term results showed that 57.1% of patients had frequent infectious diseases. No symptoms of hyposplenism were observed with conservative management.

CONCLUSIONS: Conservative management of children with traumatic splenic rupture is safe and clinically effective. Non-surgical management can be used in 93.9% of cases. Based on the results obtained, the active use of conservative treatment options for traumatic splenic rupture in children is recommended as the preferred option, with an individualized approach to patient monitoring.

Keywords: spleen injury; children; conservative management; surgical treatment.

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Консервативное лечение детей с травматическими разрывами селезенки: результаты 22-летнего опыта

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АННОТАЦИЯ

Актуальность. Консервативные методы, разработанные и апробированные на протяжении нескольких десятилетий, позволяют избежать спленэктомии, последствием которой становится синдром постспленэктомического гипоспленизма, сопровождающийся иммунодефицитом и гематологическими нарушениями. В данной статье мы рассматриваем 22-летний опыт консервативного лечения травматических разрывов селезенки, подчеркивая важность сохранения органа и минимизации хирургического вмешательства.

Цель — обобщить 22-летний опыт лечения детей с травматическими разрывами селезенки.

Материалы и методы. Проведено обсервационное одноцентровое проспективное исследование в период с марта 2002 по март 2024 г. на базе Городской Ивано-Матренинской детской клинической больницы Иркутска. Анализировали истории болезни 95 детей с травматическим разрывом селезенки. Консервативное лечение получили 83 (87,4 %) пациента, хирургическое — 12 (12,6 %). Возраст пострадавших детей составил 12 [8; 14] лет, мальчиков наблюдалось в 3,3 раза больше (73 против 22). Для анализа пациенты были разделены на две группы: группа сравнения (n = 62; 65,3 %) — ранний период лечения (март 2002 – август 2012 г.); основная группа (n = 33; 34,7 %) — поздний период лечения (сентябрь 2012 – март 2024 г.). Осложнения, связанные с повреждением селезенки изучены в катамнезе у всех детей. Комплексное обследование пациентов после выписки продолжалось на протяжении от 6 мес. до 15 лет.

Результаты. Из 95 пациентов у 2 (2,1 %) выполнена спленорафия, у 3 (3,1 %) — лапароскопия с ревизией селезенки, и у 7 (7,4 %) — спленэктомия. При оперативном лечении детям требовалась длительная комбинированная антибактериальная терапия в течение 13 [10; 16] дней. При удалении селезенки после выписки из стационара пациентам назначалась вакцинопрофилактика. При дискриминантном анализе выявлены совокупные факторы, влияющие на выбор в пользу оперативного лечения детей с разрывами селезенки. Совокупные факторы: низкое систолическое артериальное давление — 95 (70; 118) мм рт. ст., p = 0,002; тахикардия — частота сердечных сокращений 105 [100; 120] в минуту, p = 0,019; повышенный шоковый индекс Альговера — 1,1 [0,9; 1,57], p = 0,001; кровопотеря при поступлении — 13 % [6,3; 19] ОЦК, p = 0,001; максимальная степень кровопотери — 2 [1; 3], p = 0,001. При сравнении групп по периоду лечения выявлено статистически значимое различие по количеству койко-дней в отделении хирургии: в группе сравнения срок госпитализации составил 12 [8; 14] дней, в основной группе — 7 (7; 9), p = 0,001. Пациенты не отличались по показателям кровопотери и гемодинамики. Однако за последнее время количество операций при разрыве селезенки снизилось в 2,6 раза, с 16,1 до 6,1 %. При анализе непосредственных исходов после спленэктомии отмечено, что у 71,4 % (n = 5) детей выявлен тромбоцитоз на 3–6-е сутки после операции. После удаления селезенки в течение 2 нед. у всех детей отмечалось повышенное СОЭ 25 [23; 39] мм/ч. При исследовании отдаленных результатов у 57,1 % пациентов отмечались частые инфекционные заболевания. При консервативном лечении симптомов гипоспленизма не выявлено.

Заключение. Консервативное лечение детей с травматическими разрывами селезенки безопасно и клинически эффективно. Неоперативное ведение возможно применять в 93,9 % случаев. В свете полученных результатов, мы рекомендуем активное использование консервативных методов лечения травматических разрывов селезенки у детей как предпочтительный вариант, с акцентом на индивидуальный подход мониторирования состояния пациентов.

Ключевые слова: травма селезенки; дети; консервативное лечение; оперативное лечение.

Как цитировать
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二十二年儿童创伤性脾破裂保守治疗经验总结

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摘要

背景。在过去几十年中，发展和验证的保守治疗方法使得能够避免脾切除术，后者会导致术后脾切除综合征，表现为免疫缺陷和血液学异常。本文总结了对创伤性脾破裂保守治疗的22年经验，强调保留器官及减少手术干预的重要性。

研究目的。总结对儿童创伤性脾破裂的22年治疗经验。

材料与方法。本研究为单中心前瞻性观察研究，时间跨度为2002年3月至2024年3月，研究地点为Ivano-Matreninsky Children's Clinical Hospital (Irkutsk)。分析了95例儿童脾破裂患者的病历，其中83例（87.4%）接受了保守治疗，12例（12.6%）接受了手术治疗。患者年龄范围为8至14岁，男性数量是女性的3.3倍（73例对22例）。根据治疗时间将患者分为两组：对照组（n = 62，65.3%）为早期治疗阶段（2002年3月–2012年8月）；主要组（n = 33，34.7%）为晚期治疗阶段（2012年9月–2024年3月）。所有患者的脾损伤相关并发症在出院后均进行了随访，随访时间为6个月至15年。

结果。在95名患者中，2例（2.1%）接受了脾修补术，3例（3.1%）接受了脾镜检查，7例（7.4%）进行了脾切除术。手术患者需要接受长达10至16天的联合抗菌治疗。脾切除术后，患者需接种疫苗预防感染。通过判别分析发现，以下因素是影响选择手术治疗的主要因素：低收缩压 [95 (70;118) mmHg]（p = 0.002）；心动过速 [心率105 (100;120) 次/分]（p = 0.019）；高阿尔戈夫休克指数 [1.1 (0.9; 1.57)]（p = 0.001）；入院时血容量减少 [13% ± 6.3]（p = 0.001）；最大失血等级 (2 [1; 3])（p = 0.001）。对照组患者平均住院时间为12至14天，而主要组为7至9天（p = 0.001）。最近10年，脾破裂的手术率下降了2.6倍（从16.1%降至6.1%）。脾切除术后，71.4%（n = 5）的患者在术后3至6天出现血小板增多，所有患者在术后2周内出现ESR升高（25 (23; 39) mm/h）。远期结果显示，57.1%的脾切除患者易患感染性疾病，而保守治疗患者未发现脾功能低下症状。

结论。保守治疗儿童创伤性脾破裂安全且临床有效。在93.9%的病例中，可选择非手术管理。基于本研究结果，建议在儿童创伤性脾破裂的治疗中积极采用保守治疗方法，强调对患者状况的个体化监测与管理。

关键词：脾损伤；儿童；保守治疗；手术治疗。

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BACKGROUND

Total splenectomy causes the syndrome of post-splenectomy hyposplenism associated with immunodeficiency and hematologic disorders. Fulminant sepsis is the most dangerous late complication after splenectomy with a mortality rate of 50%–70% [1, 2]. Primary prevention of post-splenectomy complications includes spleen preservation through non-surgical management [3, 4]. Non-surgical management of children with ruptured spleen was implemented in our clinic in March 2002 after 5 years of experience in therapeutic and diagnostic laparoscopy. The use of active laparoscopy for splenic injuries in children has shown that laparotomy can be avoided in more than 70% of cases due to the absence of persistent bleeding [5]. The fact that splenic hemorrhage in children resolved spontaneously led to a revision of the treatment strategy in favor of conservative, organ-sparing options. Our study provides a detailed analysis of clinical cases, observational findings, and long-term outcomes, as well as practical recommendations for healthcare professionals.

The study aimed to summarize 22 years of experience in the management of children with traumatic splenic rupture.

MATERIALS AND METHODS

This observational single-center prospective study was conducted from March 2002 to March 2024 at the Ivano-Matreninskaya City Children's Clinical Hospital in Irkutsk, Russia. Data of 95 children with traumatic splenic rupture were evaluated. Non-surgical treatment was received by 83 (87.4%) patients and surgical treatment was received by 12 (12.6%) patients. The age of the affected children was 12 [8; 14] years, with 3.3 times more boys observed (73 vs. 22).

Eligibility criteria. Inclusion criteria were blunt abdominal trauma, splenic rupture, hemoperitoneum. Non-inclusion criteria were splenic injury without peritoneal bleeding, concomitant abdominal trauma with hemoperitoneum.

Intervention description

When a child presented to an Emergency Unit with abdominal pain and a history of abdominal trauma, a physical examination and hemodynamic assessment were performed. The Allgower's Shock Index (SI) was calculated as the ratio of maximum heart rate (HR) to minimum systolic blood pressure (SBP). The shock index was adjusted for childhood age. SI cut-off values were >1.2 (age up to 6 years), >1.0 (7–12 years), and >0.9 (over 12 years) [6]. An elevated SI was defined as a criterion for hemodynamic instability in children. The hemodynamic status was considered as a factor of the treatment choice in patients with splenic rupture.

If hemodynamics were stable and abdominal ultrasound showed hemoperitoneum, the patient was admitted to a Surgery Unit with physical activity restriction for 3 days. Physiological functions (SBP, heart rate, SI, urine output, temperature) were monitored every 6 hours. Laboratory tests (hemoglobin, platelet count, white blood cell count, erythrocyte sedimentation rate) were evaluated. Hemostatic and antibacterial therapy was prescribed for 3–7 days. Echo ultrasound was performed every 6 hours for the first day, then on the second day, and then at discharge.

If the SI was elevated, the child was admitted to the Intensive Care Unit (ICU). Bolus therapy was administered at 20–40 mL/kg of body weight. Clinical and laboratory parameters were monitored. If hypotension persisted despite the use of crystalloids, blood components were transfused at 10–15 mL/kg body weight. If the hemoglobin level was below 70 g/L, blood transfusion was also performed. If the SI remained elevated despite blood transfusion, an emergency laparotomy was performed. To monitor peritoneal blood volume, ultrasound monitoring was performed every 2 hours for 6 hours after admission, then every 6 hours for the first day and once a day thereafter [7–9].

To calculate the abdominal volume, the method for determining the free fluid volume in the abdomen (patent RU No. 2830196 C1, issued on November 14, 2024) was used;

$$V = V_{ultrasound} \times BSA \times K;$$

where, V is the hemoperitoneum volume; $V_{ultrasound}$ is the hemoperitoneum volume calculated using the formula for an ellipsoid; BSA is the body surface area, m^2; K is a coefficient equal to 2.35 for hemoperitoneum up to 11 mL/kg of body weight, 1.35 for hemoperitoneum 11–22 mL/kg of body weight and 1.0 for hemoperitoneum more than 22 mL/kg of body weight.

All children were followed for complications related to spleen injury. Comprehensive follow-up of patients after discharge ranged from 6 months to 15 years.

Subgroup analysis. For analysis, patients were divided into two groups: the control group (n = 62; 65.3%) in the early treatment period (March 2002 to August 2012); the study group (n = 33; 34.7%) in the late treatment period (September 2012 to March 2024).

Statistical analysis. Data samples were tested for normality of distribution at a significance level of $p < 0.05$ (frequency histogram, Lilliefors test, Shapiro-Wilk test). The significance of differences between groups was assessed using a non-parametric procedure; results were presented as median (Me), 25th and 75th quartiles [Q_1; Q_2]. Groups were compared using the Mann–Whitney U test Categorical criteria were compared using the chi-squared test (χ^2). Discriminant analysis was used to predict outcomes when assessing the combined differences in multiple factors between groups. The risk prediction model was represented graphically by constructing a receiver operating characteristic (ROC) curve, which is a graphical representation of the dependence of two values: sensitivity (Se) and specificity (Sp). The corresponding area under the curve (AUC) was calculated. The model was

tested for validity using the Hosmer–Lemeshow test, and the null hypothesis was accepted if $p > 0.05$. Statistical data were processed using Statistica v.10.1, MedCalc statistical software. The confidence level was set at $p < 0.05$.

RESULTS

Injury-to-hospitalization time was 2.9 [1.6; 7.1] hours; 73.7% of children were admitted within the first 6 hours. Of 95 patients, 62 (65.3%) children required hospitalization in the ICU. The number of bed days was 3.5 [2; 5] days in the ICU and 8.7 [6; 13] days in the Surgery unit. The spring/summer period was the season with the highest hospitalization rate at 67.4% of the total patient cohort.

The surgical treatment rate was 12.6% ($n = 12$). Initially, four (4.2%) patients received surgical treatment within the first 2 hours of admission; three patients underwent laparotomy due to hemodynamic instability; one patient underwent laparoscopic exploration due to risk of the hollow organ injury. Due to persistent bleeding, six patients (6.3%) underwent surgery, five patients after 6–12 hours of hospitalization and one patient after 24 hours of hospitalization. Persistent intraperitoneal bleeding with a tendency to hypotension was an indication for surgery in 4 patients. In 2 cases, laparoscopic abdominal lavage was performed at 12 hours after admission due to persistent abdominal pain and unclear ultrasound and radiologic findings. Two patients (2.1%) underwent laparotomy on days 5 and 6 after injury due to delayed bleeding.

Of 95 patients, 2 (2.1%) underwent splenorrhaphy, 3 (3.1%) underwent laparoscopic exploration of the spleen, and 7 (7.4%) underwent splenectomy. All splenectomized patients underwent autotransplantation of splenic tissue. In he surgical management group, children required long-term combination antibacterial therapy for 13 [10; 16] days, which was statistically significantly longer than in the non-surgical management group, where antibacterial prophylaxis was given for 5 [3; 7] days ($p = 0.001$). If the spleen was removed after discharge from the hospital, patients were prescribed preventive vaccinations.

Discriminant analysis was used to identify the combined variables associated with surgical treatment (Table 1).

Statistically significant combinations of factors of the surgical treatment choice for traumatic splenic rupture were identified: low SBP of 95 [70; 118] mmHg, $p = 0.002$; tachycardia with HR of 105 [100; 120] per minute, $p = 0.019$; elevated SI of 1.1 (0.9; 1.57), $p = 0.001$; blood loss at admission of 13% [6.3; 19] of circulatory volume, $p = 0.001$; maximum blood loss of 2 [1; 3], $p = 0.001$.

The ROC curve in Figure 1 shows the overall reliability of the model for the identified factors associated with surgical treatment.

The model validity test was positive ($\chi^2 = 12.3$; $p = 0.14$). The test sensitivity was 95.2% [95% confidence interval (CI): 86.7–99.0], specificity was 100% (95% CI: 59–100). The overall confidence level was 95.7% (95% CI: 88.0–99.1; Table 2).

The model fit each identified factor well (AUC > 0.6). When the identified parameters were pooled, the area under the curve (AUC) was 0.90 ± 0.07 (95% CI: 0.81–0.96), indicating excellent model quality.

Five combined factors of the surgical treatment choice were identified, which were associated with blood loss and hemodynamics.

Table 1. Discriminant analysis of factors influencing the choice of surgical treatment for splenic rupture in children ($n = 71$)
Таблица 1. Дискриминантный анализ факторов, влияющих на выбор хирургического лечения при разрыве селезенки у детей ($n = 71$)

Factor	Variables					
	***Me* [25; 75]**	**Wilks' Lambda**	**Partial Lambda**	***F*-remove (1,58)**	***p*-value**	**1-Toler. (*R*-Sqr.)**
Age, years	13 [7; 14]	0.417	0.997	0.186	0.667	0.232
Systolic blood pressure, mmHg	95 [70; 118]	0.489	0.848	10.35	0.002	0.936
Diastolic blood pressure, mmHg	55 [40; 60]	0.417	0.995	0.287	0.594	0.871
Heart rate, per minute	105 [100; 120]	0.457	0.910	5.762	0.019	0.961
Glasgow Coma Scale	15 [13; 15]	0.416	0.999	0.042	0.839	0.291
Vegetative Kerdo's index, relative units	48 [39; 60]	0.415	0.999	0.001	0.979	0.918
Shock index	1.1 [0.9; 1.57]	0.529	0.784	15.95	0.001	0.971
Blood loss at admission, %	13 [6.3; 19]	0.516	0.805	14.06	0.001	0.828
Maximum blood loss	2 [1; 3]	0.600	0.692	25.81	0.001	0.827
Injury-to-hospitalization time, hours	2 [1; 6]	0.424	0.9792	1.229	0.272	0.158

Note. Result of discriminant function analysis. Number of variables in the model: 10; grouping: by surgery. Wilks' Lambda: 0.415, approx. $F(10,58) = 8.16$, $p < 0.0000$
Примечание. Итог анализа дискриминантной функции. Количество переменных в модели: 10; группировка: операция. Wilks' Lambda: 0,415 approx. $F(10,58) = 8,16$, $p < 0,0000$

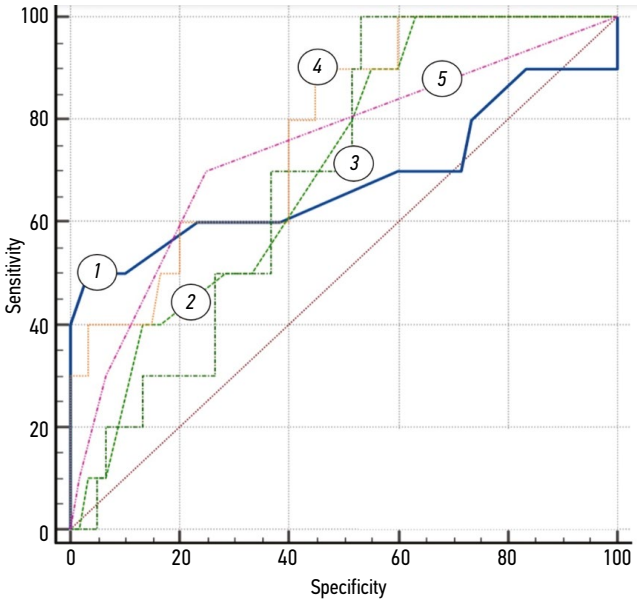

Fig. 1. Receiver operating characteristics (ROC) curve based on combined factors: systolic blood pressure (*1*), heart rate (*2*), shock index (*3*), % percentage of blood loss from circulating blood volume (*4*), and maximum degree of blood loss (*5*)
Рис. 1. Кривая рабочих характеристик по совокупности факторов систолического артериального давления (*1*), частоты сердечных сокращений (*2*), индекса Альговера (*3*), % кровопотери от объема циркулирующей крови (*4*) и максимальной степени кровопотери (*5*)

In the early stages of management of splenic rupture in children, the factors of the surgical treatment choice included polytrauma, persistent bleeding, and depression of consciousness. The combination of blood loss and hemodynamic factors has been used since September 2012 to divide patients into two groups. It should be noted that the incidence of splenic injury has decreased 1.9-fold over the past decade (62 vs. 33).

Table 3 shows clinical and epidemiological characteristics of patients in control and study groups.

No differences were found in age, injury-to-hospitalization time, or bed days in the ICU. A statistically significant difference was found in the number of days spent in the Surgery Unit: the duration of hospital stay was 12 [8; 14] days in the control group and 7 (7; 9) days in the study group (p = 0.001). Patients in the groups compared did not differ in ISS, Glasgow Coma Scale, blood loss, or hemodynamics. Table 4 shows the main categorical parameters of the treatment choice in the evaluated groups.

Over 22 years, there were no statistically significant differences in the incidence of polytrauma, persistent bleeding, hemodynamic parameters, or blood transfusions between the groups. However, it should be noted that over the past 11 years, the incidence of splenic rupture surgery decreased 2.6-fold from 16.1% to 6.1%. Non-surgical management of splenic rupture in children in the study group was 93.9%.

When evaluating immediate outcomes after splenectomy, it was found that 71.4% (n = 5) of the children had thrombocytosis on day 3–6 after surgery; the platelet count was 430 [369.8; 431] × 10^9/L. In the non-surgical management group, the maximum platelet count during the 3–6 day period was 256 [210; 279] × 10^9/L (p = 0.002). After spleen removal, all children had an elevated ESR of 25 [23; 39] mm/h for 2 weeks. In the non-surgical management group, the ESR on days 5–7 was 6 [4; 8] mm/h (p = 0.001).

To evaluate the long-term outcome of splenic rupture in children, 100% (n = 95) of patients were followed up for the first 6 months, 38.9% (n = 37) were followed up between 6 months and 3 years, and 10.5% (n = 10) were followed up at 3 years and later. In the late phase after splenectomy, three patients (42.8%) had frequent infections up to 5–7 times per year. One patient (14.3%) had up to 3–4 infections per year. No hyposplenism was reported during the non-surgical management of splenic rupture.

DISCUSSION

Non-surgical management of splenic rupture in children is becoming the gold standard of care. Preservation of the injured spleen is the goal of primary prevention of hyposplenism and its complications associated with post-splenectomy infection [10]. International guidelines for non-surgical management of children with splenic rupture have been published in the last decade [11–13]. Foreign literature showed that when these guidelines were followed, the rate of non-surgical management was 42.5%–97.2%, while the rate of surgical treatment varied from 2.8% to 31.8%, and splenectomy was performed in 0.0%–7.5% of children. Special focus should be

Table 2. Predictive accuracy of ROC curve for identified factors in discriminant analysis
Таблица 2. Прогностическая ценность ROC-кривой выявленных факторов при дискриминантном анализе

Parameters	AUC	95% confidence interval
Systolic blood pressure	0.68 ± 0.13	0.56–0.79
Heart rate	0.70 ± 0.08	0.58–0.81
Shock index	0.77 ± 0.08	0.66–0.87
Blood loss at admission, %	0.69 ± 0.07	0.57–0.79
Maximum blood loss	0.74 ± 0.09	0.62–0.84
Combination of factors	0.90 ± 0.07	0.81–0.96

Table 3. Characteristics of patients with splenic rupture in early and late treatment groups
Таблица 3. Характеристики пациентов с разрывом селезенки в группах раннего и позднего периодов лечения

Parameters	Control group (n = 62), Me [Q_1; Q_2]	Study group (n = 33), Me [Q_1; Q_2]	p
Age, years	11 [8; 14]	12 [7; 14]	0.75
Injury-to-hospitalization time, hours	2.3 [1; 8]	3.5 [2; 7]	0.2
Number of bed days in the Intensive Care Unit	3 [2; 4]	2.8 [2; 5]	0.4
Number of bed days in the Surgery Unit	12 [8; 14]	7 [7; 9]	0.001
Injury Severity Score (ISS)	9 [9; 13]	9 [9; 13]	0.9
Glasgow Coma Scale, score	15 [15; 15]	15 [15; 15]	0.7
Ultrasound volume of hemoperitoneum at admission, mL	200 [100; 400]	175 [90; 350]	0.45
Ratio of hemoperitoneum volume to admission weight, mL/kg	4.9 [2.4; 9.1]	4.5 [2.7; 8.1]	0.54
Blood loss at admission, % of circulatory volume	7.1 [3.4; 13]	6.4 [3.8; 11.6]	0.54
Maximum blood loss, % of circulatory volume	8.5 [4; 17.6]	11.4 [5.5; 16.2]	0.72
Maximum blood loss	1 [1; 2]	1 [1; 2]	0.81
Systolic blood pressure, mmHg	110 [100; 118]	115 [106; 120]	0.11
Diastolic blood pressure, mmHg	65 [60; 77]	70 [63; 75]	0.13
Heart rate, per minute	100 [90; 110]	98 [90; 110]	0.51
Shock index	0.9 [0.8; 1.1]	0.85 [0.76; 1.0]	0.27

Table 4. Key categorical parameters in groups of different observation periods
Таблица 4. Основные категориальные параметры в группах разных периодов наблюдения

Parameters	Control group (n = 62)		Study group (n = 33)		p
	n	%	n	%	
Polytrauma					
Yes	23	37.1	10	30.3	0.51
No	39	62.9	23	69.7	
Persistant bleeding:					
Yes	14	22.6	10	30.3	0.41
No	48	77.4	23	69.7	
Elevated Allgower's Shock Index at admission:					
Yes	16	25.8	7	21.2	0.62
No	46	74.2	26	78.8	
Blood transfusion:					
Yes	7	11.3	5	15.2	0.59
No	55	88.7	28	84.8	

paid to the widespread use of angioembolization in children with splenic injury, ranging from 1.2% to 42.5% according to the references reviewed [14–17].

The literature review highlights papers that address the practice of treating children with splenic injury. For example, Filipescu et al. [18] showed that the incidence of splenectomy during treatment was 1.5% in a pediatric hospital and 14.4% in an adult hospital (p = 0.01). The authors reported that children admitted to pediatric hospitals had a higher severity of splenic injury. However, children were more likely to receive blood transfusions in adult hospitals. Miyata et al. [19] showed that in clinics with extensive experience in the management of children with splenic rupture, the rate of splenectomy was low (odds ratio: 0.5; 95% CI: 0.3–0.8). Gorelik et al. [20] showed that the effectiveness of conservative management of traumatic splenic rupture in children during primary hospitalization in a tertiary hospital was 94.1%. In community hospitals, 58.8% (n = 53) received surgical treatment, with the rate of splenectomy of 47.8% (n = 43). The study data were consistent with our findings

that the incidence of surgery decreased from 16.1% to 6.1% with long-term patient management.

In Russian publications, the rate of laparoscopy for splenic injury with hemoperitoneum remains high [21, 22]. In our study, 3 (3.1%) children required laparoscopic treatment. The following practically significant facts were highlighted in the literature, which led to the decision to stop the routine use of laparoscopic treatment of splenic injury in children: the incidence of spontaneous hemostasis of splenic rupture in children was 78%–85%, laparoscopy for isolated splenic injury was a diagnostic sign in only 61%–72% [23–26]. The decision was made to use minimally invasive treatment options in patients with persistent abdominal pain and controversial findings of ultrasound and multispectral computed tomography. With the parameters described, laparoscopy is very rarely used for abdominal injuries. In the American College of Surgeons Pediatric Trauma Centers Consortium (ATOMAC) study, 5 (1.3%) of 410 children with splenic injury underwent laparoscopy 42 [21; 90] hours after admission. Laparoscopy was usually required for concomitant abdominal injury [26].

When the immediate outcomes of splenic rupture treatment were evaluated, it was found that splenectomy was associated with thrombocytosis and elevated ESR. A literature review found splenectomy in 4.5% of all causes of thrombocytosis in children [27]. Thrombocytosis can lead to thrombosis due to blood clotting disorders in blood vessels. Thrombosis of the portal vein system is particularly dangerous in the early post-splenectomy period and can develop for up to 1 month after surgery [28]. Deep vein thrombosis and pulmonary embolism develop in up to 3.5% of adolescents aged 12–17 years in the late post-splenectomy period [29]. A persistent increase in body temperature and persistently elevated CRP levels (up to 55 mg/dL), leukocytosis (up to 22×10^9/L), and elevated ESR (up to 20 m/h) were reported in children during the first week after splenectomy [30].

In our study of long-term splenectomy outcomes, 57.1% of patients reported frequent infections. The data obtained are consistent with other scientific papers. Splenectomy has been shown to significantly disrupt the interaction between T and B lymphocytes, leading to antiviral resistance. Over 90% of children are predisposed to frequent seasonal viral infections, herpes, inflammatory skin lesions, and exacerbation of chronic diseases [30, 31].

Non-surgical management of children with splenic rupture is shown not to cause symptoms of hyposplenism.

CONCLUSION

Twenty-two years of treating children with traumatic splenic rupture have demonstrated the clinical efficacy and safety of non-surgical management which is possible in 93.9% of cases. Many years of our experience confirm the effectiveness of the used organ-preserving options. These findings confirm the importance of a personalized approach for each pediatric patient based on both the clinical picture and the regenerative potential of the body. The non-surgical option not only minimized the need for surgery, but also helped to better restore spleen function, which is a way of primary prevention of hyposplenism.

Therefore, our results serve as a basis for further research in this area and highlight the need to develop a strategy to preserve the spleen that will undoubtedly have a positive impact on the long-term health of children who have experienced traumatic injury to this organ.

ADDITIONAL INFO

Authors' contribution. All authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study. The contribution of each author: V.V. Podkamenev — the concept and design of the study, writing a text, editing; I.A. Pikalo — the concept and design of the study, collection and processing of material, patient supervision, statistical analysis, writing a text, editing; V.A. Novozhilov, N.I. Mikhailov, E.M. Petrov, V.Kh. Latypov, S.V. Moroz, D.Yu. Khaltanova — patient supervision, forming of a scientific database and its analysis; O.A. Karabinskaya — processing of material, statistical analysis.

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