Original Article
An experimental rat model of hilar splenic vessel ligation versus splenectomy for spleen trauma

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Abstract: Background: The most prevalent method of treating splenic injury is by splenectomy. This method is followed by postoperative complications. Therefore, less invasive procedures such as splenic angioembolization are introduced. This technique needs appropriate training, a high-tech setting and could be followed by complications. Thus, not all surgeons agree to do this procedure. Splenic hilar ligation of main vessels is a non-invasive procedure which has similarities to a splenectomy with unknown results. Objectives: We aim to evaluate and compare splenectomy and hilar ligation. Methods: Thirty rats were divided into splenectomy and splenic hilar ligation groups. An identical grade 3-spleen injury was performed on all rats. After 6 weeks blood samples were obtained and hematologic and immunologic aspects were measured in their serum. Giemsa stained peripheral blood smears were obtained from the ligation group. Results: Comparing the above-mentioned variables before and after the surgery in each groups showed statistical significance in all aspects except IgM, C4 and platelets levels in ligation group (P value: 0.213, 0.059 and 0.649 respectively). Analysis revealed significant deference in postoperative WBC, IgM and C4 levels between splenectomy and ligation group (P value: < 0.001, < 0.001 and 0.026 respectively). Conclusion: Splenic hilar ligation of main vessels is an easy way of treating splenic injury in hemodynamically stable patients with less postoperative complications. Therefore, it can be performed by all surgeons in all kind of medical centers. Spleen remains viable and continues its role although some aspects of its function become interrupted.

Keywords: Splenectomy, spleen, therapeutic embolization, animal experimentation, ligation

Introduction

The spleen is one of the vulnerable intraperitoneal solid organs, and 40% of laparotomies in unknown blunt abdominal traumas are perform due to its injuries [1, 2]. The most established method of treating splenic injuries is splenectomy [3]. The reasons why this procedure has become legitimate are: the spleen is not a vital organ although it has a role in our immunity and filtering blood, controlling massive ongoing blood loss immediately to prevent death in traumas, conservative managements resulted in 90-100% mortality rate, and suturing laceration are impossible in some cases [4, 5]. Despite its safety and efficacy, asplenic patients suffer from several major drawbacks [6-9]. These complications entice researchers to reconsider the old method [10]. Most of the surgeons try to save the spleen through differ-

ent methods, in order to decrease the side effects of splenectomy. Thus, different methods have been described to prevent splenectomy including splenic arteriography and embolization (SAE), suturing lacerations (splenorrhaphy), applying omental flap or collagen into the bed of the lacerations, splenectomy with sparing splenic tissue in situ, partial splenectomy with stapling and reimplanting splenic tissue in the peritoneal cavity [3, 4, 11-13]. Nevertheless, performing these procedures require appropriate training [11, 14]. Furthermore, in unstable hemodynamic state with multiple ruptures or hilar injuries, splenectomy is inevitable [8, 9]. SAE is one of the new prevalent nonoperative managements of splenic traumas [15]. Various studies showed frequent long-term minor (14%) and major (34%) postoperative complications although the state of the immune function in this method is not yet fully understood [9,
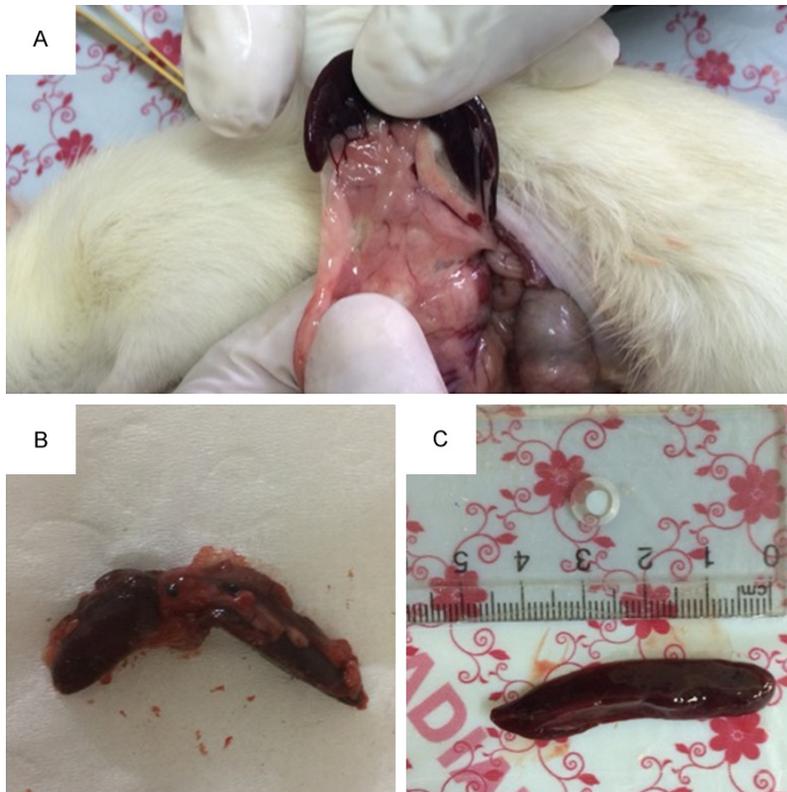
Figure 1. Surgical approach to rat with midline abdominal incision. A. Normal peritoneal anatomy of rat. Right hand is spleen and left hand is gastrointestinal upper tract, splenocolic ligament is evident. B. Traumatized spleen with ligated vessel. C. Normal spleen size (4.5 cm).

simultaneously and compare its postoperative outcomes with the splenectomy. Instead of a risky surgery, which could result in many postoperative complications, the surgeon can consider ligating both vessels, which could be an easy way to manage stable splenic injuries, without requiring high technology machines and a high level of experiences [3]. There has been little discussion regarding simultaneous main splenic artery and vein ligation at hilum instead of SAE (which is being used more often these days), SAL alone or splenectomy. The effects of main splenic vessels (artery and vein) ligation on the immune and blood system has not been fully elucidated and studied. Thus, this experimental study conducted for the first time to compare outcomes of splenectomy with main hilar splenic vessels ligation after third grade splenic trauma in rats. This study aims to evaluate and compare aspects of hematologic and immunologic functions of spleen postoperatively.

Methods

Animals

Thirty healthy male New Zealand rats weighting between 290-350 grams and aged 6-8 weeks were obtained from Animal Lab Bank of our university in February 2017. None of the rats had any history of surgery or other medical interventions. The animals were kept under controlled conditions in a pathogen-free environment under constant ambient temperature of 24 degree centigrade and humidity with free access to food and water. The rats fasted for 6 hours the night before the surgery. They were allocated into two groups of 15 rats using a block randomization procedure with matched subjects in each block. Exclusion criteria consisted of rats that died during the study due to

16-18]. Additionally this method requires special and expert vascular surgeons with high-tech settings, which are not available in all health care facilities [19, 20]. Therefore, due to the lack of enough experiences, updated technology and sufficient evidences, it seems that surgeons would still rather open up the patient and perform splenectomy. In 1977, two kids with spleen injuries were treated by splenic artery ligation (SAL) instead of splenectomy. After 25 years, they had a viable spleen with normal vessels, sufficient immunoglobulins, normal complement protein levels, and normal reaction to vaccinations [12, 13, 21]. Thus far, SAL has only been applied to a small number of dogs, pigs, rabbits, rats and children or their experimental data, methodology, and sample size were rather limited or not comprehensively analyzed. HØivik et al. said that SAL is more difficult than splenectomy [3]. We assumed this difficulty was due to separating and ligating hilar artery from vein. Therefore, it occurred to us to ligate both hilar splenic artery and vein
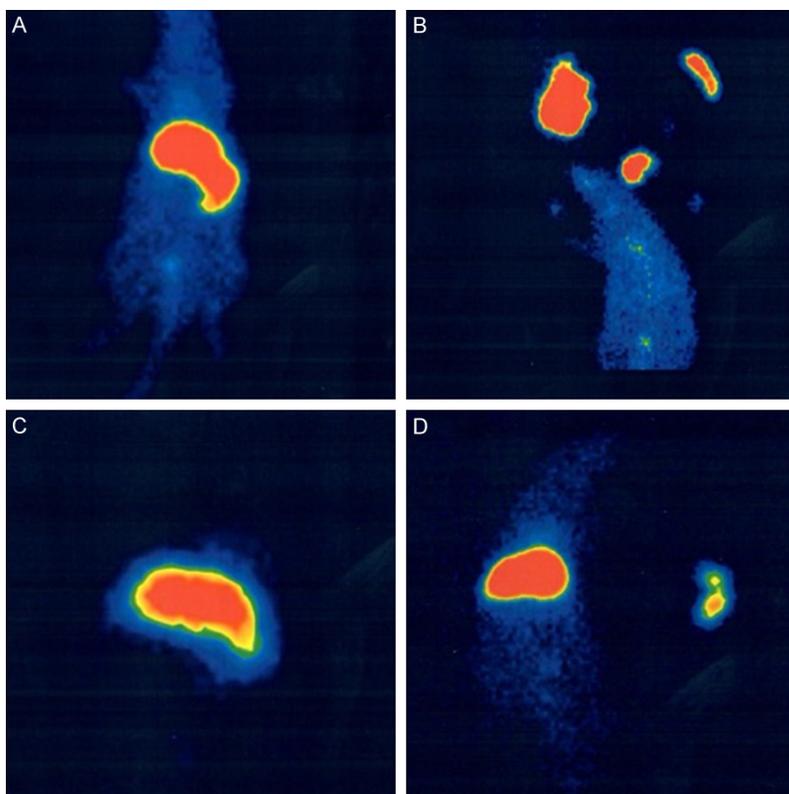
Figure 2. Spleen radionuclide scan. A. Normal spleen in alive rat. B. Spleen, Stomach and Liver. Spleen counts 3688 waves with 26 backgrounds. C. Spleen with ligated main hilar vessels. D. Dumbbell-shaped ligated spleen with hilar atrophy counts 2111 waves with 28 backgrounds.

sterile condition, we made a 4.5 cm midline incision with a Number 15 Scalpel on the abdomen. To unify the trauma for all of the rats, we simulate a grade 3-spleen injury due to their spleen size. We made a >0.5 cm laceration in mid zone of spleen. Afterwards in splenectomy group, we ligated all of the vessels and cut all of the ligaments then removed the spleen from peritoneal cavity (**Figure 1**). In the ligation group, after traumatization and total separation of spleen, splenocolic ligament was cut and splenic artery and vein were double ligated with silk sutures (4/0 Taft, Yazd, Iran) at hilum. Gastrosplenic ligament, which contains short gastric vessels, remained intact. Finally, the incised area of the skin was repaired with running single layer 3/0 Nylon suture and then the rats were left in a room with a suitable temperature (23°C-25°C) to become conscious. Surgery time recorded with chronometer, started after opening the abdomen, and stopped just before closing the abdomen in all rats. Blood loss during the surgery was measured based on gauze consumption. All animals were kept on regular diet after surgery. The study period was six weeks after the surgery. External suture were removed on the 7th day using local anesthetics.

other reasons. All procedures were conducted in agreement with the National Institutes of Health Guide for Care and Use of Laboratory Animals.

Interventions

Splenic hilum ligation (SHL) as intervention and splenectomy as control was performed on each group of 15 male rats after 6 hours of overnight fasting. Procedure for all subjects was carried out under the same standard conditions by one surgeon. Anesthesia was induced and maintained intraperitoneally with a mixture of Ketamine (Ketamine Hydrochloride Rotexmedica, Germany) and Xylazine (Xylazine Hydrochloride ZooPharm, Colorado, USA). We made the solution by mixing 9 cc Ketamine and 1 cc Xylazine. Then we injected 0.1 cc of this formula per 100 grams of rat body weight [22]. While anesthetized, each rat was laid on supine position on a surgical table and the abdominal skin was shaved using hair removal cream (Veet®, French) and disinfected with 10% betadine. Under

Outcome assessment

Blood samples (10 ml) were obtained from the orbital sinus in medial cantus via capillary tube one week before the surgery and 6 weeks after the procedures in both groups. White blood cell (WBC) and platelet counts, hemoglobin (Hb) level, complement proteins (C3 and C4) and immunoglobulins G, A, and M (IgG, IgA and IgM) assessed using ELISA (monobind kit from USA). Peripheral blood smears (PBS) obtained and stained with Giemsa from SHL group to evalu-

Table 1. Comparison of pre and postoperative hematologic and immunologic variables in ligation and splenectomy group each

Variables	Ligation Group			Splenectomy Group		
	Before	After	P-value	Before	After	P-value
WBC count	7480 ± 623	11292 ± 1841	0.001	8160 ± 1130	16341 ± 4718	0.001
Hemoglobin	15.10 ± 0.89	11.44 ± 1.5	0.001	14.28 ± 0.86	12.43 ± 0.93	0.001
Platelets	861000 ± 177133	869769 ± 263201	0.649$	826600 ± 108487	1195167 ± 413396	0.017
C3	88.20 ± 12.56	55.61 ± 16.30	0.001	73.60 ± 9.53	50.58 ± 16.41	0.009
C4	12.40 ± 7.97	7.06 ± 1.68	0.059$	13.16 ± 7.90	5.53 ± 1.87	0.016
IgG	197.40 ± 93.22	306.30 ± 54.12	0.033	232.00 ± 17.90	284.25 ± 51.78	0.002
IgM	15.80 ± 4.77	20.84 ± 7.76	0.213$	25.40 ± 9.33	5.08 ± 4.07	0.041
IgA	4.40 ± 2.17	1.76 ± 1.09	0.006	5.12 ± 1.27	2.0 ± 1.04	0.006

$Not statistically significant.

Table 2. Comparison of postoperative (6th week) hematologic and immunologic variables between ligation and splenectomy group

Postoperation variables	Splenectomy	Ligation	P value
WBC count	16341 ± 4718	11292 ± 1841	< 0.001*
Hemoglobin (g/dl)	12.43 ± 0.93	11.44 ± 1.5	0.77
Platelet count	1195167 ± 413396	869769 ± 263201	0.87
C3 level (mg/dl)	50.58 ± 16.41	55.61 ± 16.30	0.347
C4 level (mg/dl)	5.53 ± 1.87	7.06 ± 1.68	0.026*
IgG level (mg/dl)	284.25 ± 51.78	306.30 ± 54.12	0.295
IgM level (mg/dl)	5.08 ± 4.07	20.84 ± 7.76	< 0.001*
IgA level (mg/dl)	2.0 ± 1.04	1.76 ± 1.09	0.538
Anisocytosis (%)	2.15 ± 0.63	1.61 ± 0.48	0.419
Poikilocytosis (%)	3.85 ± 0.55	2.33 ± 0.31	0.726
Schistocytes (%)	1.4 ± 0.47	2.26 ± 0.37	0.639

*Statistically significant is considered p-value < 0.05.

ate the spleen function in removing premature (e.g. target cells, Schistocytes, Poikilocyte and Anisocyte), nucleated red blood cells (RBC) and inclusions like Howell-jolly bodies. The smears are then interpreted by an expert blinded hematologic pathologist. In addition, we gave technetium 99 m sulfur colloid (Tc^{99m}SC) to rats after 6 weeks and took a gamma-scan (Scintigraphy) with the Adac Forte machine to further compare the activity of the spleen with normal vessels before the surgery and with ligated vessels after the surgery. The protocol started with injecting one millicori Tc^{99m}SC intravenously into the rat's tail vein, after 2 minutes an anterior 128*128 matrixes with high-resolution collimator picture was obtained. After completing the procedure, all of the spleens were removed and a region of interest was drawn all around the spleen with Pegasus software of the Adac machine (**Figure 2**). Any complications of the

intervention including adverse effects related to systemic anesthesia, infection, bleeding, and death were assessed.

Statistical analysis

The data was analyzed and reported only for rats, which completed the study. Data analysis was performed using IBM SPSS statistics software version 22.0 (Chicago, USA). Mean ± standard deviation (SD) values were evaluated for body weight, length of surgery, serum WBC, platelet, Hb, C3, C4, IgG, IgM and IgA levels before the surgery and six weeks after the surgery in each group. The normal distribution of all studied parameters was checked with Kolmogorov-Smirnov test. To compare qualitative variables between groups, a Chi-square test was performed. Student t-test and paired t-test were used for variables that were distributed normally; Mann-Whitney and Wilcoxon tests were also performed for variables, which did not have normal distribution. P value of ≤ 0.050 was considered significant.

Results

All of the rats were alive before starting the procedures. No significant differences in body weight were found between splenectomy and ligation groups (316.20 ± 15.66 vs. 321.66 ± 17.57 grams P Value: 0.412). In the control group, one rat died during the operation and
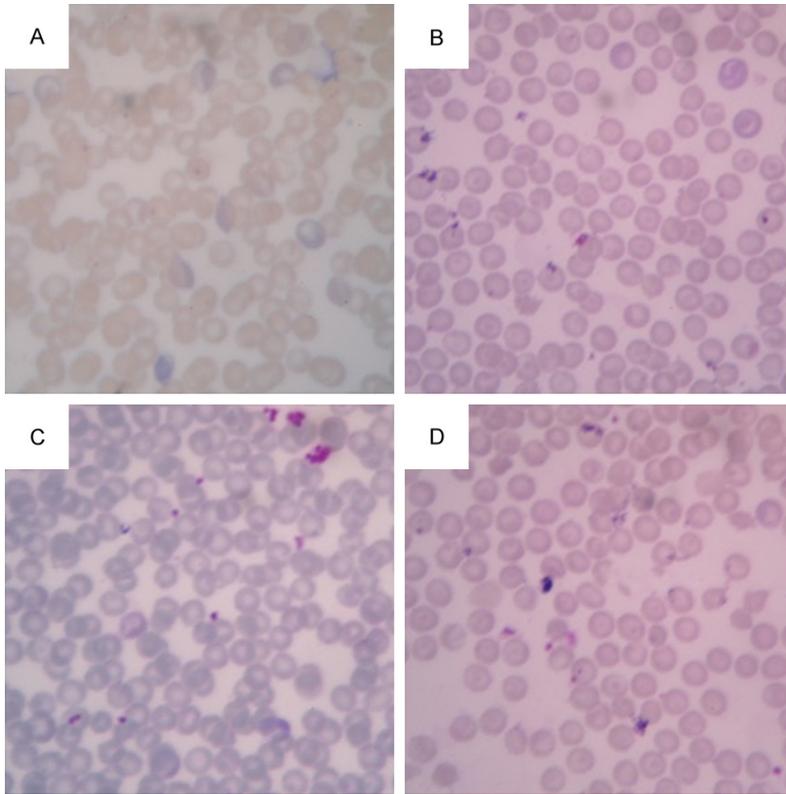
Figure 3. (×1000 magnification in light microscopy with immersion oil) peripheral blood smears stained with Giemsa in ligated-vessel spleen. A. Indicating +1 anisocytosis, +1 target cell and blue discoloration demonstrating increased reticulocyte count. B. Indicating +3 target cell, +1 poikilocytosis, +1 anisocytosis and +1 echinocyte. C. Indicating +3 Schistocytes. D. Suggesting +1 anisocytosis, +1 target cell and +1 reticulocytes.

significantly more in the ligation group in comparison to the control group (16341.67 ± 4718.90 vs. 11292.31 ± 1841.85, p value < 0.001) while Hb level and platelets count in the ligation group were lower than the splenectomy group. However, the Mann-Whitney Test showed that these differences were not statistically significant (p value: 0.77 and 0.87 respectively). Furthermore, we found more complement proteins (C3; 55.6154 ± 16.30 vs. 50.58 ± 16.41, C4; 7.06 ± 1.68 vs. 5.53 ± 1.87) and higher levels of IgG and IgM (IgG; 306.307 ± 54.12 vs. 284.25 ± 51.78, IgM; 20.84 ± 7.76 vs. 5.08 ± 4.07) in the ligation group. Among these differences, C4 and IgM levels were significantly higher in the SHL group (p value: 0.026 and < 0.001 respectively).

According to the radioisotope scan, the mean wave count from normal rat spleen and spleen with ligated vessels were 5755 ± 1113 and 1417 ± 793 respectively (p value = 0.31). Radioisotope scans of normal and ligated vessels spleens are illustrated in **Figure 2**, viability and up taking Tc^{99m} in normal and ligated vessels are evident (normal spleen: 3688 with 26 background count, ligated spleen: 2111 with 28 background count).

two died on day 10 and 13 after the procedure. In the ligation group, two rats died after completing the surgery within the third week. In their evaluation, we did not find any internal hemorrhage or infection. In fact, the reason of death became unclear. Their blood samples before surgery were excluded from the analysis.

Table 1 is indicating before and after surgery comparisons of each variable in splenectomy and SHL groups separately. All variables are significantly different between the two groups except platelet counts, C4 and IgM level in SHL.

Table 2 is comparing postoperative results of splenectomy and SHL. The surgery lasted longer in the splenectomy groups although it was not statistically significant (8.42 ± 1.45 vs. 7.90 ± 1.05 minutes; p value: 0.88). Six weeks after the surgery blood samples were analyzed and the resulted are as follow: WBC count was

Figure 3 is a PBS from the SHL group six weeks after the surgery, stained with Giemsa and captured with ×1000 magnification of light microscope. In these smears some pathological features of RBCs are evident including anisocytosis (+1 in part A, B and D), target cell (in part A and D, +1 and in part B, +3), increased reticulocyte count (in part A, B and D), Schistocytes (+3 in part C) and poikilocytosis (+1 in part B). However, we did not find any Howell-Jolly bodies or nucleated RBCs in these smears. Our pathologist reported these changes are normal in

main splenic vessels occlusion and may not cause serious problems for patients.

Discussion

Trauma is the most prevalent cause of death in Iran [23], and splenic rupture is one of the most frequent emergency surgeries with different source of bleeding (arterial or venous) [9]. There are not enough surgeons with sufficient experience in all emergency centers for managing spleen injuries [24].

This study is conducted for the first time to clarify a way for future surgeries in humans. In this study, we evaluated precisely and comprehensively hilar splenic artery and vein ligation in simulated type three splenic trauma instead of splenectomy.

Comparing preoperative and postoperative blood samples of each groups demonstrating splenectomy causes significant decrease in blood levels of immunologic factors like complement proteins C3 and C4, immunoglobulins IgM, IgG and IgA postoperatively. Moreover, Hb level, WBC and Platelets count suggesting significant hematologic differences after splenectomy. These results are advocating the major role of the spleen in our immune and blood system. Although some of the above-mentioned parameters decreased significantly in the ligation group, some immunologic proteins (C4 and IgM) did not change significantly (**Tables 1** and **2**). This suggests ligating hilar main vessels of the spleen is not the same procedure as splenectomy because some beneficial aspects of the spleen are preserved in this method.

Comparing postoperative results of the two groups indicated WBC count was significantly lower in ligation group. However, hemoglobin and platelet counts were not different between these two groups suggesting that this procedure did not increase the chance of anemia or blood transfusion, thrombocytopenia, infection and sepsis postoperatively. In the ligation group, complement proteins (C3 and C4) and immunoglobulins (IgG and IgM) levels were higher than the splenectomy group signifying that lack of these immunologic agents in splenectomy lead to overwhelming post-splenectomy infections (OPSI). Consequently, vaccination against deleterious encapsulated bacteria (like *Streptococcus pneumoniae, Haemophilus in-*

fluenzae, and *Neisseria meningitidis*) should be performed before exceeding two weeks after the surgery [25]. Therefore, it seems with hilar splenic vessels ligation, the chance of OPSI reduces and postoperative vaccination deadline time increases into multiple weeks due to having higher levels of immunologic factors after six weeks or maybe vaccinations are not required anymore.

According to our Radioisotope scan (scintigraphy), the spleen with ligated large vessels had less but not zero wave count compared to the normal spleen. In addition, the ligated spleens had hilar atrophy with bipolar viable tissues (dumbbell-shaped) (**Figure 2**) suggesting collateral branches like short gastric and gastroepiploic vessels can keep the tissue alive and help to continue its role without becoming necrotic or putrescent. Although, bleeding was controlled in a minimal way.

By ligating the most supplying and draining vessels of the spleen, it may seem removing senescence and pathologic RBCs become disrupted. While some abnormal figures (e.g. Target cells, Schistocytes, Anisocytosis and Reticulocytes) were seen in Giemsa stained PBS (**Figure 3**), according to their low count and our hematologic pathologist's opinion, they would not cause any serious systemic problems and we expected to see them in this situation.

Splenectomy is indicated for abdominal traumas with hilar splenic injuries, shattered splenic parenchyma, and any higher than grade II injury in a patient with multiple injuries or coagulopathy [26, 27]. Splenectomy can make some serious variations in our immune system including decreased levels of T and B lymphocytes, low serum IgM level, fluctuations in IgG and IgA levels, diminished filtering of inclusions in RBCs (e.g. Howell-Jolly bodies), reduced levels of opsonizing agents like Properdin, significantly decreased levels of complement proteins C3 and declined phagocytosis activity [6]. In our splenectomy group, complement proteins (C3 and C4) and immunoglobulins (IgM and IgA) had a significant decrease postoperatively.

In addition, splenectomy can cause bacterial infections, which in the worst case is OPSI. Other complications may include: thrombosis (heart disease, ischemic stroke, hemorrhagic stroke, pulmonary embolism, deep vein throm-

bosis, and portal vein thrombosis), thromboembolism, pulmonary arterial hypertension, type II diabetes mellitus and cancer [7-9].

Splenectomy has other miscellaneous hematologic and nonhematologic indications with different success rates (e.g. idiopathic thrombocytopenic purpura, thrombotic thrombocytopenic purpura, sickle cell disease, hereditary spherocytosis, chronic lymphocytic leukemia, thalassemia, etc.) in which hilar ligation may be beneficial as it was for trauma [26-29].

In 1977, SAL was performed on two kids for the first time. Spleen preserving procedures in pediatric spleen injuries like that of SAL along with splenorrhaphy and partial splenectomy with or without omentoplasty have been evaluated for extended periods of time started in 1990s. SAL outcomes in adult population has not been discussed sufficiently. They demonstrated except complement protein C3 and mean number of Howell-Jolly bodies in peripheral smear, other immunological factors were not different between their groups [4, 6, 9, 13, 21]. Besides, these hematologic changes had been seen in other studies although some of those studies did not confirm these changes and this can be due to different cases and sample size.

To show the efficacy of dearterialization, Keramidas et al. traumatized 28 dogs with a knife and suggested with the exception of one case which was due to a wound infection and septic peritonitis, spleen morphology and histology, hematocrits, WBC count, IgM and bone marrow aspiration remained within normal range with homogenous radioactive reuptake scintigraphy indicating an active spleen [21]. In our study, we simulated grade-three spleen injury with bistoury in 30 rats and ligated hilar splenic artery and vein with silk sutures. Although we had to exclude five rats from the study, after autopsy, we did not find any sign of infection or massive bleeding. We also demonstrated extended difference in hematologic and immunologic factors. The scintigraphy illustrated a dumbbell-shaped spleen after the surgery indicating hilar atrophy due to hilar ligation of main vessels; however, accessory branches supply the remained tissue and keep them alive. According to the ligation group postoperative blood samples, the spleen maintained its

function and produced enough amounts of immunologic factors.

HØivik et al. said that SAL is more difficult than splenectomy [3]. Surgery did not last significantly longer in our ligation group, which means hilar ligation is as fine and precise procedure as splenectomy and is not much more difficult. Moreover, ligation can be performed by laparoscopic approach as well. We assumed separating splenic artery from splenic vein at hilum was a difficult procedure compared to splenectomy. However, ligating both vessels simultaneously does not seem to be a problematic method for treating the spleen traumas. Perioperative scintigraphy of five traumatized patients in HØivik et al. study implied maintained normal splenic function after arterial ligation [3]. We tried to evaluate more aspects of hematologic and immunologic factors in this study. In our scintigraphy, it is evident that the spleen becomes dumbbell-shaped after the hilar ligation and shows a bipolar reuptake pattern. Horton et al. suggested ligating the splenic artery greatly reduced *pneumococcal* clearance and concluded that the spleen lacked the functional ability to filter blood [3, 16, 30]. In contrast, to show a replica of removing blood borne opsonized encapsulated bacteria, Schwalke et al. injected anti-Rh-antibody-coated Chromium[51]-radiolabeled autologous RBCs into 21 SAL and normal spleen patients and revealed there was no difference between the normal and ligated group. They determined SAL did not diminish clearance of these kinds of particulates from the blood [16, 31]. This may be due in part to having a viable and functioning spleen with immune cells producing factors (e.g. Immunoglobulins, Tuftsin, Opsonin and etc.) against blood borne microorganisms [21]. It has been shown that after SAL, collateral branches become larger than they were before [3]. According to Michel's study on splenic arterial circulation, by ligating the splenic artery, only 6% of patients may suffer from inadequate collateral circulation [3].

Recently, angioembolization has been revealed and used more often instead of SAL. This procedure is one of the diagnostic modality and non-operative management approaches for blunt abdominal traumas with spleen injuries. To avoid increasing short-term failure rate, appropriate patients should be selected for this procedure. Although several studies suggested

increased numbers of complications (including splenic abscesses (6.8%), complete splenic infarction (2.3%), cyst formation (2.3%), contrast-induced renal insufficiency (2.3%), pancreatitis, intestinal perforation, left-sided pleural effusions (17%), coil migration (14.8%), and fever (9.1%)) [17], there is insufficient evidence on continuing splenic function with this procedure. However, there are some preserved aspects of splenic function like removing Howell-Jolly bodies and producing antibodies against antigens [9, 16, 17]. According to the American Association for the Surgery of Trauma (AAST) scoring system for splenic injuries, surgeons have agreed to use nonoperative managements in type 1-2 splenic injuries [32]. Nonetheless, they all agreed rapid intervention (less than 60 minutes) is the key of success in type 3-5 injuries. SAE in grade 3 splenic injuries (According to AAST) failed in 10-30% of the cases and has remained one of the most controversial topics in blunt abdominal trauma managements [8]. The West Trauma Association (WTA) algorithm suggests that all patients with blunt abdominal traumas which are in a stable hemodynamic state should get an abdominal computed tomography scan (CT-Scan) with intravenous (IV) contrast. In case of extravasation, the first step would be nonoperative management, and SAE is preferable in most of the cases. However, if SAE leads to failure, consider the splenectomy [18, 32, 33]. Interestingly, WTA stated these studies are based on observational data, expert opinion and local resources, which are different around the world [8, 34]. Finally, current studies are not clear on the indication for nonoperative managements and/or SAE instead of surgery for splenic injuries [9]. SAE is one of the high-tech procedures, which needs an expert vascular surgeon and expensive settings [33]. It can be concluded that this procedure is neither available nor possible in every trauma centers or for all trauma cases. Although it seems any surgeon with a slight degree of experience would be able to ligate an artery and a vein with silk suture to prevent bleeding.

To note some of our limitations, we suggest these rats should be monitored for more than 6 weeks to further evaluate their risk of infection and mortality. We simulated grade-three spleen trauma therefore, outcomes of other grades should be evaluated as well. This study should be performed on larger animals like rabbit, pig and dog before trying it on humans.

Conclusion

After all these years, it seems not only ligating the splenic artery, but also ligating its vein with silk sutures seem easier, can be done with minimal invasion and with less postoperative complications. Scintigraphy and peripheral blood smears indicating a viable spleen without eliminating its role in our immunity and ability to purify our blood. Ultimately, in stable spleen traumas, a splenic hilar ligation instead of the splenectomy seems to be a safe and effective approach while avoiding massive invasion and complications.

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Disclosure of conflict of interest

None.

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