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### ► To cite this version:

Olivier Boillot, Sophie Chopinet, Emilie Gregoire, Laurent Milot, Philippe Petit, et al.. Partial splenectomy in children undergoing liver transplantation or venous shunt for severe hypersplenism: A case control comparative study. *Clinics and Research in Hepatology and Gastroenterology*, 2022, 46 (6), pp.101929. 10.1016/j.clinre.2022.101929 . hal-04183798

**HAL Id: hal-04183798**

**<https://hal.science/hal-04183798v1>**

Submitted on 22 Jul 2024

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## **Partial splenectomy in children undergoing liver transplantation or venous shunt for severe hypersplenism: a case control comparative study**

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This work did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

None of the authors declare any conflict of interest and financial disclosure.

Key words: Hypersplenism, splenomegaly, partial splenectomy, liver transplantation, venous shunt, outcome.

Word count of the manuscript including references: 4233

Word count of abstract: 243

Number of figures: 5

Number of tables: 3

Author contributions:

Olivier Boillot had the idea of the project, collected the data, participated in analysis and interpretation of data.

Olivier Boillot and Jérôme Dumortier wrote the manuscript.

Olivier Boillot, Laurent Milot, Philippe Petit, Barbara Rohmer, Bertrand Roquelaure, Anne Dariel, Nicoleta Panait, Jean Hardwigen, Sophie Chopinet and Emilie Gregoire were involved in the medical and/or radiological and/or surgical management of the patients reported here, critically reviewed and approved the manuscript.

**Abbreviations:**

LT: Liver Transplantation, VS: Venous Shunts, PS: Partial Splenectomy, WBC: White Blood Cell, SL: Splenic Length, SV: Splenic Volume, CT: Computed Tomography, PHSLR: Patient Height Splenic Length Ratio, MRS: Meso-Rex Shunt, LLS: Left Lateral Section, LD: Living Donor, LL: left liver, WL: Whole Liver, SSSRS: Side-to-Side Spleno-Renal Shunt, GRWR: Graft-to-Recipient Weight Ratio, D: Day, W: Week, M: Month, Y: Year.

## **Abstract**

*Background and aim:* Hypersplenism is a consequence of portal hypertension and splenomegaly secondary to cirrhosis or portal cavernoma in children. In order to avoid persistent hypersplenism and splenomegaly after liver transplantation (LT) or venous shunt (VS), partial splenectomy (PS) may represent a relevant therapeutic option. The aim of this retrospective study was to evaluate the results of PS performed in children presenting hypersplenism.

*Methods:* The following end-points were evaluated: (1) reversion of hypersplenism and its durability over time, (2) postoperative outcome, (3) courses of spleen size and volume and (4) comparison to a control group in which PS was not performed.

*Results:* Between 1996 and 2020, 16 children underwent PS associated with LT (8 cases) for cirrhosis or VS (8 cases) for portal cavernoma. From Day 0 to 1 month, mean platelet and white blood cell counts (WBC) dramatically improved from  $48\pm 19$  at day 0 to  $176\pm 70 \times 10^9/L$  ( $P<0.0001$ ) and from  $2469\pm 853$  to  $7198\pm 3982/L$  ( $P=0.001$ ) respectively. PS allowed significant reduction of splenic length and volume from  $176\pm 33$  to  $112\pm 24$  cm ( $P<0.0001$ ) and from  $1228\pm 464$  to  $450\pm 297$  cm<sup>3</sup> ( $P=0.0003$ ) respectively. After a mean follow-up of  $92.6\pm 84.7$  months (range: 4.1-210.7), 14 patients are alive with normal platelet and WBC counts and persistent spleen size reduction. Compared to control group, PS was associated with a significant platelet count rise from baseline to one year.

*Conclusions:* PS appears to be effective for treatment of hypersplenism and splenomegaly in combination with LT or VS without compromising outcome.

## **Introduction**

Hypersplenism is a frequent consequence of severe portal hypertension and splenomegaly secondary to cirrhosis or portal cavernoma in children, and represents a life-threatening situation in some cases. Complications include gastrointestinal bleeding, sepsis, growth retardation, altered quality of life and even death [1, 2]. Surgical intervention may be required in order to treat portal hypertension and restore normal peripheral blood counts of platelets, leukocytes and erythrocytes. Focusing only on treatment of portal hypertension may be, in some cases of massive splenomegaly and profound reduction of peripheral hematologic cells, inefficient to achieve restoration of normal levels of these cells and may expose these patients to the risk of severe infections and bleeding or even mortality [1, 2].

In order to avoid persistent hypersplenism and splenomegaly following liver transplantation (LT) or venous shunt (VS), partial splenectomy (PS) may represent a relevant surgical option. According to Christo description “*Spleen usually consists of four or five segments or parenchymal units, each one with its own hilar arterial blood supply and venous drainage, separated one from the other, by paucivascular planes; the segments are named superior, midsuperior, middle, midinferior and inferior*“ [3]. Surgical technique of PS was first described by Christo in 1959 [4]. PS or segmentectomy was achieved by first isolation and selective ligation of hilar vessels corresponding to the dedicated parenchymal segment and then by cutting off the resulting ischemic splenic territory [5].

Several studies pointed out the feasibility and the benefit of PS in children presenting splenomegaly related to cirrhosis, portal cavernoma and even some splenic disease [6-12]. Herein, we present the results of a series of PS performed during a LT or a VS procedure in children presenting severe hypersplenism with massive splenomegaly secondary to advanced cirrhosis or portal cavernoma.

## **1. Patients and methods**

### *1.1. End-points and decision making*

All patients who underwent a PS for the treatment of hypersplenism between December 1996 and June 2020 in Lyon and Marseille university hospitals were included in this retrospective study. The following end-points were evaluated: (1) reversion of hypersplenism and its durability over time as well as of portal hypertension, (2) early and late postoperative morbidity and mortality, (3) courses of spleen length (SL) and volume (SV) and (4) comparison to a control group in which PS was not performed. All data analysed in the present study were retrospectively collected from medical charts and/or electronic records; demographic characteristics and clinical data were reviewed.

LT was considered for patients with advanced cirrhosis and VS for portal cavernoma with threatening portal hypertension in patients with normal liver. PS was considered for selected pediatric patients who had severe and symptomatic portal hypertension, hypersplenism with deep thrombocytopenia ( $< 50 \times 10^9/L$ ) and massive splenomegaly (almost double than normal SL) with volume-related symptoms. Surgery was undertaken after all parents had given informed consent for their child.

### *1.2. Radiologic and hematologic evaluation*

Radiographic evaluation of liver, spleen and splanchnic venous vascularization was performed on ultrasonography and Doppler examination and axial and coronal computed tomography (CT) studies with multiplanar reconstructions using “*Philips® IntelliSpace Portal, version 10.1, CT Liver Analysis application, Philips, Best, The Netherlands*” with particular attention to the description of splanchnic venous patency (i.e. splenic and mesenteric veins, extension of portal venous thrombosis if present, left renal vein and inferior vena cava, spontaneous portosystemic shunts, intraabdominal varices and measurements in size (coronal length) and volume of the spleen and of importance for surgical strategy, the description of the number of secondary vascular pedicles entering in the lower hemi-part of the spleen. Splenic volumetry was performed using MultiModality Tumor Tracking (MMTT, Philips Healthcare) on volumetric CT data, which is a program designed for semi-

automated segmentation of tumors. In the present case, the spleen was defined as the target lesion, leading to its initial semi-automated segmentation from the entire CT dataset. The contours were then adjusted by the radiologist to ensure appropriate coverage of the entire spleen and avoid averaging with surrounding structures (in particular the left lobe of the liver). Results were displayed as splenic total volume. The same procedure was repeated at each time point.

Measurements of SL in cm were performed pre and post-operatively and at 1 and 3 years. SV in mL was assessed before and after PS during the first 3 months. Initial patient SL was compared to established guidelines for normal splenic sizes at different ages according to sex by using a reproductive sonographic method [13]. Moreover, in order to establish more accurate comparison between patients of different heights regarding spleen size, the patient height spleen length ratio (PHSLR) reflecting the proportion of SL by patient height was used according to the same time points of SL. Intraoperatively, splanchnic venous pressures were undertaken before and after the completion in who underwent VS. Pre and postoperative venous flows were studied by ultrasonography and Doppler.

Hematologic (platelet and leukocyte counts) evaluation was performed in the pre and post-operative period and at each outclinic visit and at least once a year in the long-term follow-up.

### *1.3. Surgical technique of partial splenectomy*

All patients but one (JH) were operated on by a single surgeon (OB). Following LT and VS completions when portal hypertension was eliminated, partial lower splenectomy (midinferior and inferior in all cases) was undertaken. After division of the splenocolic and splenophrenic ligaments, the spleen was mobilized up and down in the abdominal cavity in order to achieve easier access to its lower vascular pedicles (usually 2 or 3) which were carefully dissected, tied and cut and the corresponding splenic parenchyma appeared then distinctly ischemic. Transection was then carried on within the ischemic parenchyma closed to the demarcation line using Ultracision harmonic scalpel (Ethicon, Cincinnati, USA) without significant bleeding and hemostasis of the cut surface

was easily controlled by bipolar diathermy or argon beam and in some rare cases with stiches (Figures 1 and 2).

Early postoperative morbidity was assessed according to Clavien-Dindo classification within the hospital stay or within 90 days from operation as well as mortality. Clinical follow-up was defined as last recorded communication or visit with the patient or death. Date and cause of death were obtained from medical records.

In the aim to evaluate the benefit of PS, we compared the study group to a control group of patients presenting portal hypertension and hypersplenism who underwent LT and VS in whom PS was not performed.

#### *1.4. Statistical analysis*

Quantitative variables were described using mean +/- SD normally distributed, otherwise with median +/- interquartile range (IQR). Qualitative values were tabulated and percentages were calculated. Qualitative variables were compared using the  $\chi^2$  test or Fischer's exact test when appropriate. Quantitative variables were compared using the Student t-test or non-parametric tests (Mann-Whitney, Kruskal-Wallis or Wilcoxon tests) when appropriate. Statistical analysis was performed with SPSS version 23.0 (IBM, New York, USA); p values lower than 0.05 were considered to be statistically significant.



## 2. Results

### 2.1. Patients and operative characteristics

Sixteen children (8 males and 8 females) with a median age of 8.5 years (range: 1.8–16), a median weight of 25.5 kg (range: 10–56) and a median height of 127 cm (range: 80–160) underwent PS following a LT (8 cases) or a VS (8 cases). Medical complications were gastrointestinal bleeding in 4 cases, decompensated cirrhosis in 8 cases and abdominal discomfort in 6 cases. Previously, 8 children had surgical procedures, Kasai operation in 5, LT in 2 and a failed meso-*rex* shunt (MRS) in the last patient. Indications for LT were biliary atresia (4 cases), autoimmune hepatitis (2 cases), progressive familial intrahepatic cholestasis (1 case) and primary sclerosing cholangitis (1 case). Indications for VS were neonatal cavernoma in 6 cases and portal vein thrombosis after LT for biliary atresia in 2 cases. All patients presented severe portal hypertension, hypersplenism with a mean platelet count of  $48 \pm 19 \times 10^9/L$ , (range: 17–82) and a mean WBC count of  $2459 \pm 853/L$  (range: 900–3700) and massive splenomegaly which was almost the double in mean coronal length compared to normal values according to the age and sex established by Rosenberg *et al* ( $176 \pm 33$  vs  $87 \pm 13$  cm,  $P < 0.0001$ , Figure 3) [13]. Eight LT were performed using left lateral section (LLS) from living donor (LD) in 3 cases and one left liver (LL) including the middle hepatic vein from a split liver and 4 cadaveric whole livers (WL). Central side-to-side spleno-renal shunts (SSRS) were constructed in 7 children and a last child had a MRS. Mean duration of PS was  $26 \pm 12$  minutes without significant bleeding. Intraoperative red blood cell exogenous transfusion was higher in LT recipients than in shunt patients ( $1.4 \pm 1.1$  vs  $0.2 \pm 0.7$  units respectively,  $P = 0.063$ ). Two out of 8 LT patients did not require intraoperative exogenous transfusion whereas it was 7 out of 8 shunt patients. Patient and operative data are presented in Table 1.

### 2.2. Postoperative outcomes

None of the children who had PS complained any more about abdominal discomfort after the operation. According to Clavien Dindo classification, post-operative complications in 6 patients were classed II in 4 patients, IIIb in 3 patients and V in 2 patients who died independently from PS

from multiple organ failure and chronic rejection 4.1 months and 18.2 years respectively after LT. Surgical revision was required in 3 patients after LT for 1 abscess at the site of splenic resection (11.7%), 1 postoperative abdominal bleeding and 1 biliary stenosis.

### *2.3. Platelet and WBC courses*

Mean platelet counts dramatically and rapidly improved after surgery from  $48 \pm 19$  at day 0 to  $176 \pm 70 \times 10^9/L$  at 1 month ( $P < 0.0001$ ) respectively (Figure 4A) as well as mean WBC counts which increased from  $2459 \pm 827$  to  $7198 \pm 3982/L$  ( $P = 0.001$ ) during the same period. Among the 15 patients who reached at least 1 year of follow-up, mean paired comparison with initial values of platelet and WBC counts were  $42 \pm 16$  vs  $162 \pm 30 \times 10^9/L$  ( $P < 0.0001$ ) and  $2291 \pm 790$  vs  $5117 \pm 1498/L$  ( $P = 0.0003$ ) respectively.

### *2.4. Portal pressure, courses of spleen length and volume*

Following completion of 8 VS, mean splanchnic venous pressure significantly dropped from  $27 \pm 10$  mmHg to  $15 \pm 10$  ( $P = 0.0004$ ) (Figure 4B).

PS allowed significant reduction of SL from  $176 \pm 33$  cm to  $112 \pm 24$  cm ( $P < 0.0003$ ) respectively (Figure 4C) and a significant increase of PHSLR from  $7.03 \pm 1.66$  to  $12.06 \pm 2.36$  ( $P < 0.0001$ ). SV before and after PS was available in 8 patients, PS led to a dramatic reduction of volume from  $1228 \pm 464$  cm<sup>3</sup> to  $450 \pm 297$  ( $P = 0.0003$ ) (Figure 4D).

After a mean follow-up of  $92.6 \pm 84.7$  months (range: 4.1-210.7), 14 patients are alive and well with normal platelet and white blood cell counts and all 8 VS are patent.

### *2.5. Case control comparative study*

In our series, 16 hypersplenic (platelet count below  $100 \times 10^9/L$ ) patients with splenomegaly who did not have PS served as controls (Table 2). The review of our series of 160 pediatric LT and children who underwent VS, led to select 8 transplanted patients (5.2%) and 8 children with 6 SSSRS, 1 MRS and 1 meso-caval shunt with hypersplenism. There were no significant differences for age, height, weight and intra and peri-operative parameters. Nevertheless, compared to the PS group the non PS group had significant higher initial mean platelet and WBC counts ( $67 \pm 27$  vs

48±19 x 10<sup>9</sup>/L, *P*=0.029 and 3637±1152 vs 2469±853 /L, *P*=0.003) respectively, and smaller SL (145±37 vs 176±33 cm, *P*=0.024). Inversely, one year after surgery, mean platelet count was significantly less in the non PS group compared to the PS group (119±37 vs 165±42 x 10<sup>9</sup>/L, *P*=0.006). After surgery, in the PS group, occurrence of ascitis and/or pleural effusion requiring intervention was less (12.5% vs 43.7, *P*=0.049), SL was significantly shorter (112±24 vs 141±31 cm, *P*=0.01) and PHSLR significantly higher (12.06±2.36 vs 8.85±1.95, *P*=0.0005) compared to non PS patients. Moreover they was a trend to less post-operative infections (18.7% vs 43.7%, *P*=0.127) in the PS group. Incidence of surgical revision and 1-year survival were identical in both groups (3/16 and 93.75% respectively). Figure 5 shows significant raise of platelet count from baseline as soon as the first day after PS compared to the non PS group in which platelet count remained comparable to baseline during the first postoperative week. Finally, comparing only the transplant with PS versus transplant-alone (Table 3), those patients who had PS were older with greater weight and height but due to the small number of samples the differences were not significant. No significant differences were found regarding total bilirubin, Graft-to-recipient weight ratio (GRWR), transplant duration, blood transfusion, surgical complications and revisions, infections, and one-year patient and graft survivals. On the other hand, the platelet count rise following LT was more rapid in the PS group at each time points with significant differences at day (D) 1, week (W) 1, month (M) 1 and year (Y) 1 with normal and durable counts from M1 to Y3 contrary to that in patients who did not have PS. Looking to the WBC counts after PS, they were significantly higher during the first post-operative week and remained not significantly higher from M1 to Y3. In the PS group versus the non PS group, at Y1, SL and PHSL were significantly shorter and higher respectively.

### 3. Discussion

In our experience reported herein which started 18 years ago, indication to add PS to LT or VS was based upon criteria of severe hypersplenism including thrombocytopenia less than  $50 \times 10^9/L$  and/or leukopenia below 2500/L and massive prominent splenomegaly (almost double normal length), palpable in the lower part of the abdomen. Simultaneous PS combined with surgical treatment of portal hypertension by LT or VS was able to rapidly, efficiently and durably reverse hypersplenism. Splenic length returned to subnormal values at about 30% length reduction when compared to normal splenic sizes established by Rosenberg *et al.* [13] by sonographic coronal measurements according to age and sex.

Height patients in whom PS was not performed were classified hypersplenic only ( $< 100 \times 10^9/L$  and  $> 50 \times 10^9/L$ ) and served as control. PS was not performed because thrombocytopenia was not considered life-threatening and splenomegaly was pauci-symptomatic; whether or not PS should have been done remains a matter of debate. In spite of the fact that platelet count was higher in the control group compared to the PS group ( $67 \pm 27$  vs  $48 \pm 19 \times 10^9/L$ ), PS was shown to better restore platelet count at normal levels immediately and durably while that of the non PS group remained at low levels until the end of the first year ( $119 \pm 37$  vs  $165 \pm 42 \times 10^9/L$ ) (Figure 5). Moreover, it was associated with less episodes of ascitis and/or pleural effusion and there was a trend to less infection (Table 2). By contrast, when PS was not performed in these hypersplenic patients, platelet count remained comparable to baseline during the first postoperative week and even did not reach normal levels at one year which could expose them to higher risks of infectious and hemorrhagic complications [2]. This can emphasize the potentially protective role of quick normalization of platelet count during the first postoperative week without compromising outcome. When comparing only transplant with PS to transplant-alone, recipients who underwent PS were older (median: 8 vs 5 years) with higher weight (median: 25 vs 15.5 kg) even if it was not significant due to the limited number of cases and presented a more pronounced hypersplenism and splenomegaly probably

because of a longer course of the disease. In spite of that, PS was shown to better restore normal hematologic cell counts in the long term compared to the transplant group alone. These results underline the effectiveness of the strategy of combining PS with LT also described by others [9-12]. In order to overcome the risks of small-for-size syndrome and/or persistent portal hypertension in children with a body weight over 25 kg, we allocated them either a LL or a WL.

On the other hand, some can argue that hypersplenism can spontaneously improve without PS after restoration of normal portal flow after LT or VS. Egami et al have demonstrated a reduction of spleen size and normalization of hypersplenism in a group of children after LT [14] as well as Wei et al who pointed out a similar normal platelet count two years after LT whether or not these children underwent PS [12]). Nevertheless, it was also demonstrated that if spleen size significantly decrease after LT, it never reaches normal values [15,16] as it was the case in our 8 transplanted patients at 3 years who did not benefit from PS. In the series of Wei et al [12], in 13 children who underwent LT and PS compared to 8 others who had only LT, post-operative outcomes were similar in both groups in terms of complications, suggesting that PS did not bring any advantages. Nevertheless, in accordance with our observations, restoration of normal platelet and leucocyte counts was quicker achieved and maintained in the PS group compared to low and incomplete recovery of platelet count in the non PS group. A part the abdominal comfort brought by the reduced spleen size, the immediate restoration of platelet and leukocyte counts allows early use of therapeutic doses of immunosuppressive (ant-metabolites) and antiviral agents which would not be possible in hypersplenic transplant recipients with thrombocytopenia and leukopenia because of the hematologic toxicity of these agents.

Hypersplenism is usually defined by platelet and WBC counts below  $100 \times 10^9/L$  and  $3000/L$  respectively, and enlarged splenomegaly. Severe hypersplenism could be characterized as platelet count below  $50 \times 10^9/L$  and symptomatic massive splenomegaly. [12].

Honda et al have shown that persistent thrombocytopenia at 12 months after pediatric LT was associated with pre-operative low platelet count [17]. In adults, Ben Hamida *et al* demonstrated that

deep thrombocytopenia  $<50 \times 10^9/L$  during the first week post-LT represented a significant mortality risk factor [2]. Predictive factors for persistent thrombocytopenia and splenomegaly after LT were shown to be pre-transplant platelet count below  $50 \times 10^9/L$  and spleen volume (in adults) to body surface area ratio  $\geq 400$  [18] and low platelet count at one week and one month post-LT as it was observed in our control group [19].

Regarding the choice of the type of venous shunts constructed, the MRS represents the ideal way in restoring physiological splanchnic flow [20]; unfortunately it can only be used in very few cases without cirrhosis and with patent intra-hepatic patent portal veins (only one of our patients fulfilled these criteria). In cases of portal vein thrombosis with normal liver and no patent intra-hepatic portal veins, our choice was to perform a central spleno-renal shunt instead of distal spleno-renal shunt because it can suppress portal hypertension in the whole splanchnic bed. Moreover, none of our children developed encephalopathy in the long term follow-up.

Preoperative radiological evaluation by angio-CTscan or Magnetic Resonance Imaging is mandatory to assess splenic pedicles and segmentation and main arterial and venous trunks (to be preserved) in order to plan the number of pedicles to be cut and the extent of splenic parenchymal resection. Pre and postoperative spleen length and volumetry should become part of radiological assessment in order to optimize the amount of parenchymal resection and surgical result.

Our choice was to perform PS after resolution of portal hypertension by either LT or VS in the aim to make resection in a more bloodless field with normal venous pressure. In all cases, PS was done easily, safely and rather quickly without significant bleeding.

We believe that the benefits of PS outweigh the risks. Our results, as well as other series [9-12] strongly support that PS combined with LT or VS has a low morbidity rate and allows to preserve the immune role of spleen in children [21].

Some alternative strategies to PS have been proposed. Total splenectomy is radical to treat hypersplenism; nevertheless, it exposes patients to potentially severe complications such as life-threatening infections and venous thrombotic events [22-24]. Partial splenic embolization, which is

considered as a minimal invasive therapy, carries its own risk of severe postembolization syndrome and infections [25] and was shown to be inefficient with time with high recurrence rate in case of severe hypersplenism and massive splenomegaly [26]. Recently, Vittorio *et al.* reported results of partial splenic embolization in a series of 26 children. These authors successfully achieved temporary significant good results without life-threatening complications; nevertheless it was only temporary and a majority of patients with ongoing liver disease and portal hypertension were later subjected to various surgical procedures (LT, VS, splenectomy) in delays ranging from 7 to 55 months [27]. On the other hand, our one-step strategy (LT or VS combined with PS) may bring a definitive cure of the whole illness.

In conclusion, PS appears to be safe, reproducible and effective for treatment of severe hypersplenism in combination with LT or VS in children with deep thrombocytopenia and leukopenia and massive splenomegaly. Comparison with a case control group without PS suggested a beneficial effect of PS without compromising outcome.

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**Table 1.** Preoperative and operative characteristics in 16 patients who underwent partial splenectomy

Patient characteristics	N=16
Median age, years (range)	8.5 (1.8-16)
Sex (M/F)	8/8
Median weight, kg (range)	25.5 (10 -56)
Median height, cm (range)	127 (80 - 160)
Diseases	
Neonatal cavernoma, n	6
Post-LT* portal vein thrombosis, n	2
Cirrhosis, n	8
Previous digestive hemorrhage, n	4
Mean spleen length, mm (range)	176±33 (129 – 257)
Mean splenic volume, ml (range)	1265±488 (574 – 1760)
Mean platelet count x 10 <sup>9</sup> /L (range)	48±19 (17–82)
Mean white blood cell count /L (range)	2469±853 (900–3700)
Abnormal liver blood test, n	8
Previous surgery	8
Kasai procedure	5
Liver transplantation	2
Meso-Rex shunt	1
<b>Surgery</b>	
Main surgical procedures	16
Side-to-side spleno-renal shunt	7
Meso-Rex shunt	1
Liver transplantation	8
Total mean surgery duration, min	302±132
Venous shunt	193±36
Liver transplantation	412±95
Mean partial splenectomy duration, min	26±12
Mean weight of removed spleen, g	297±155
Mean splanchnic venous pressure, mmHg (range)	
Before shunt	27±10 (16 – 43)
After shunt	15±10 (-1 – 33)
Delta	9
No exogenous transfusion	9
Mean autotransfusion (11 patients), ml	231±262

LT\* Liver Transplantation

**Table 2.** Characteristics of LT and VS patients who underwent or not PS

Patients	With PS (n=16)	Without PS (n=16)	<i>P</i>
Mean age (years)	8±5	5.8±3.9	0.116
Mean height (cm)	121±27	110±29	0.258
Mean weight (kg)	27±13	22±13	0.333
Main types of surgery (n)			
LT	8	8	
VS	8	8	
Types of liver grafts			
Split LLS	1	4	
LD LLS	3	2	
WL	4	2	
Types of venous shunts			
SSRS	7	6	
MRS	1	1	
MCS	0	1	
Mean surgery duration (min)	302±132	242±123	0.2
Mean RBC units transfusion	0.8±1.1	1.2±1.7	0.486
Mean autotransfusion (ml)	231±262	161±307	0.501
Mean platelet count x10 <sup>9</sup> D0	48±19	67±27	0.029
Mean platelet count x10 <sup>9</sup> 1 year	165±42	119±37	0.006
Mean WBC count/L D0	2469±853	3637±1152	0.003
Mean WBC count/L 1 year	4933±2219	4579±1485	0.624
Mean Hg level g/L D0	102±16	104±19	0.787
Mean Hg level g/L 1 year	122±16	110±30	0.237
Mean SL before surgery (cm)	176±33	145±37	0.024
Mean SL after surgery (cm)	112±24	141±31	0.01
Mean PHSLR before surgery	7.03±1.66	7.52±1.51	0.4
Mean PHSLR after surgery	12.06±2.36	8.85±1.95	0.0005
Postoperative ascitis and/or pleural effusion	2/16	7/16	0.049
Postoperative infection	3/16	7/16	0.127
Surgical revision	3/16	3/16	
1 year survival	93.75%	93.75%	
Mean follow-up (range) (months)	92.6±85	187.2±85	0.0037

LT: Liver Transplantation, VS: venous Shunt, PS: Partial Splenectomy, LLS: Left Lateral Section, LD: Living Donor, WL: Whole Liver, SSSRS: Side-to-Side SplenoRenal Shunt, MRS: Meso-Rex Shunt, MCS: Mesenterico-Caval Shunt, RBC: Red Blood Cells, D0: Day 0, WBC: White Blood Cells, Hg: Hemoglobin, SL: Splenic Length, PHSLR: Patient Height Splenic Length Ratio.

**Table 3.** Characteristics of LT patients who underwent or not PS

Patients	With PS (n=8)	Without PS (n=8)	<i>P</i>
Mean age (years)	8.3±4.9	5±2.7	0.121
Mean weight (kg)	25.4±11.5	17.6±6.7	0.122
Mean height (cm)	120±28	101±23	0.161
Mean total bilirubin (µmol/L)	314±277	345±309	0.839
Mean LT duration (min)	412±95	331±91	0.107
Mean GRWR (%)	2±0.3	2.1±0.8	0.669
Mean duration of PS (min)	25±7	-	-
Mean PS weight (g)	398±153	-	-
Mean blood transfusion (mL/kg weight)	27±12	60±80	0.272
Surgical complications (n)	3	3	1
Surgical revision (n)	3	3	1
Infections (n)	3	4	0.614
1 year patient & graft survival (%)	87.5	100	0.301
PL D0	45±18	56±24	0.322
PL D1	80±40	41±13	0.021
PL D3	63±19	45±19	0.095
PL D5	82±47	51±18	0.11
PL W1	130±101	54±14	0.05
PL M1	184±83	110±38	0.038
PL Y1	178±45	111±31	0.005
PL Y3	192±61	135±46	0.61
WBC D0	2307±986	3895±1309	0.016
WBC D1	11288±6107	5388±2914	0.027
WBC D3	8675±4303	3390±1658	0.005
WBC D5	9165±5063	3993±2009	0.017
WBC W1	15050±8482	4496±998	0.003
WBC M1	7972±4705	6843±2760	0.567
WBC Y1	4825±2863	4190±1228	0.576
WBC Y3	4948±1717	3947±1435	0.24
SL before surgery (cm)	192±33	157±45	0.101
SL Y1 (cm)	109±28	141±26	0.047
SL Y3 (cm)	111±25	139±32	0.084
PHSLR before surgery	6.4±1.7	6.6±1.4	0.856
PHSLR Y1	11.7±2.3	8±1.6	0.004

LT: Liver Transplantation, PS: Partial Splenectomy, GRWR: Graft to Recipient Weight Ratio, ACR: Acute Cellular Rejection, PL: Mean Platelet count  $\times 10^9$ , WBC: Mean White Blood Cells Count/L, D: Day, W: Week, M: Month, Y: Year, SL: Mean Splenic Length (cm), PHSLR: Mean Patient Height Splenic Length Ratio.

## **Legends for figures**

Figure 1. Technique of partial splenectomy. A. Preoperative imaging. B. Inferior spleen devascularization by dividing lower pedicles. C. Spleen transection along the ischemic limit by harmonic scalpel. D. Control of hemostasis on the cut surface.

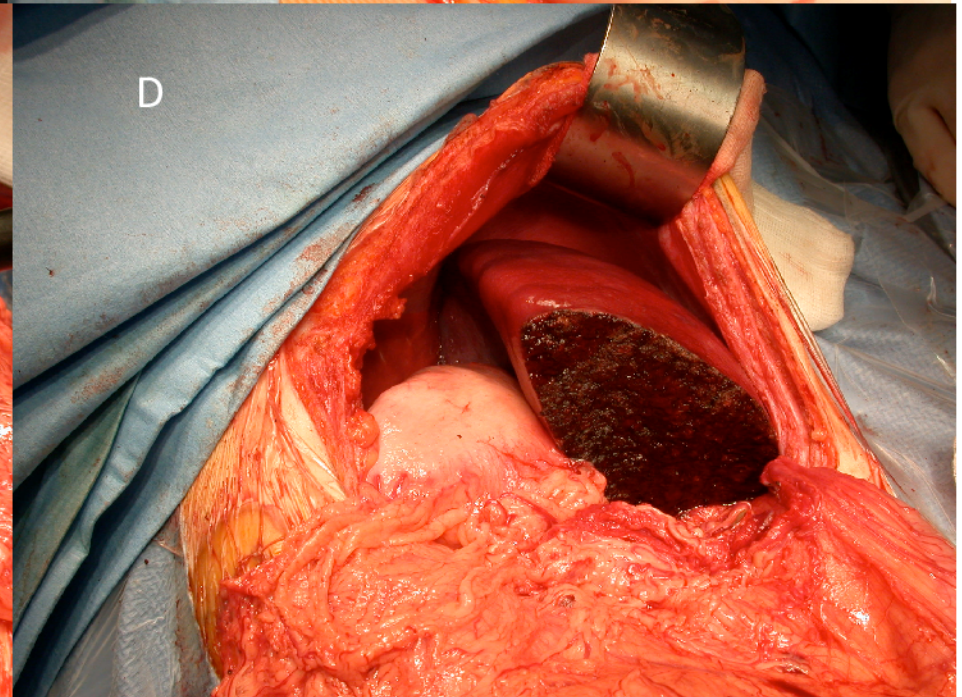
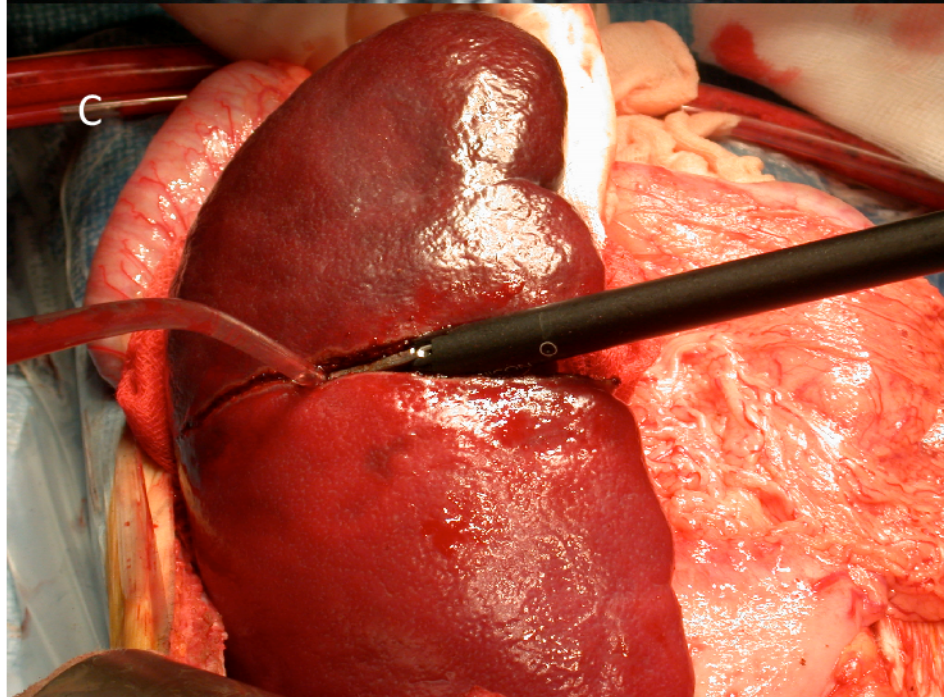
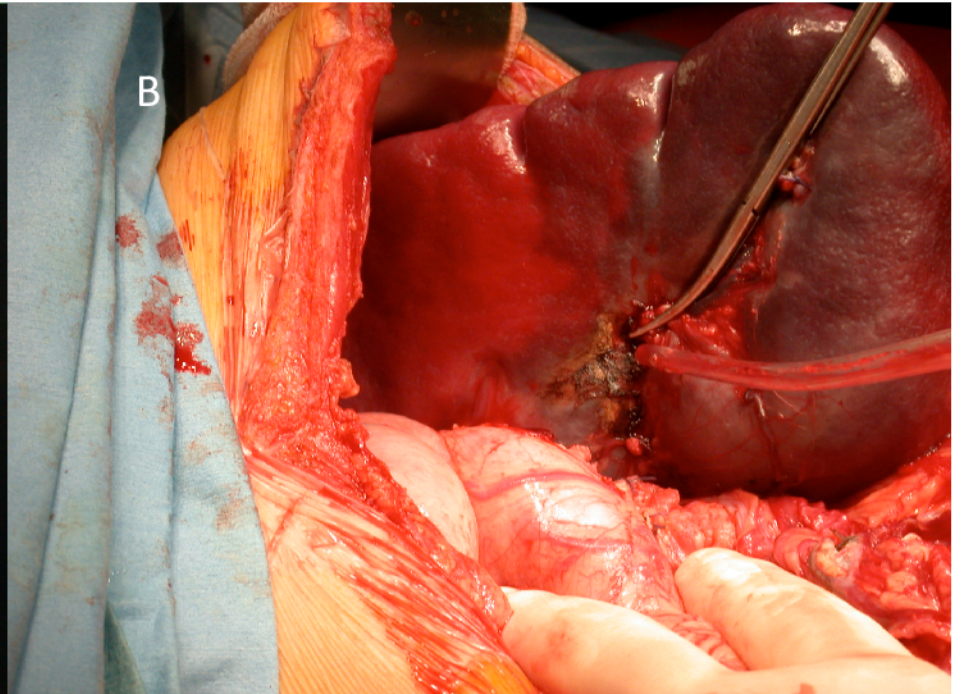
Figure 2. A. Living donor liver transplantation in an infant with massive splenomegaly, B. after partial splenectomy.

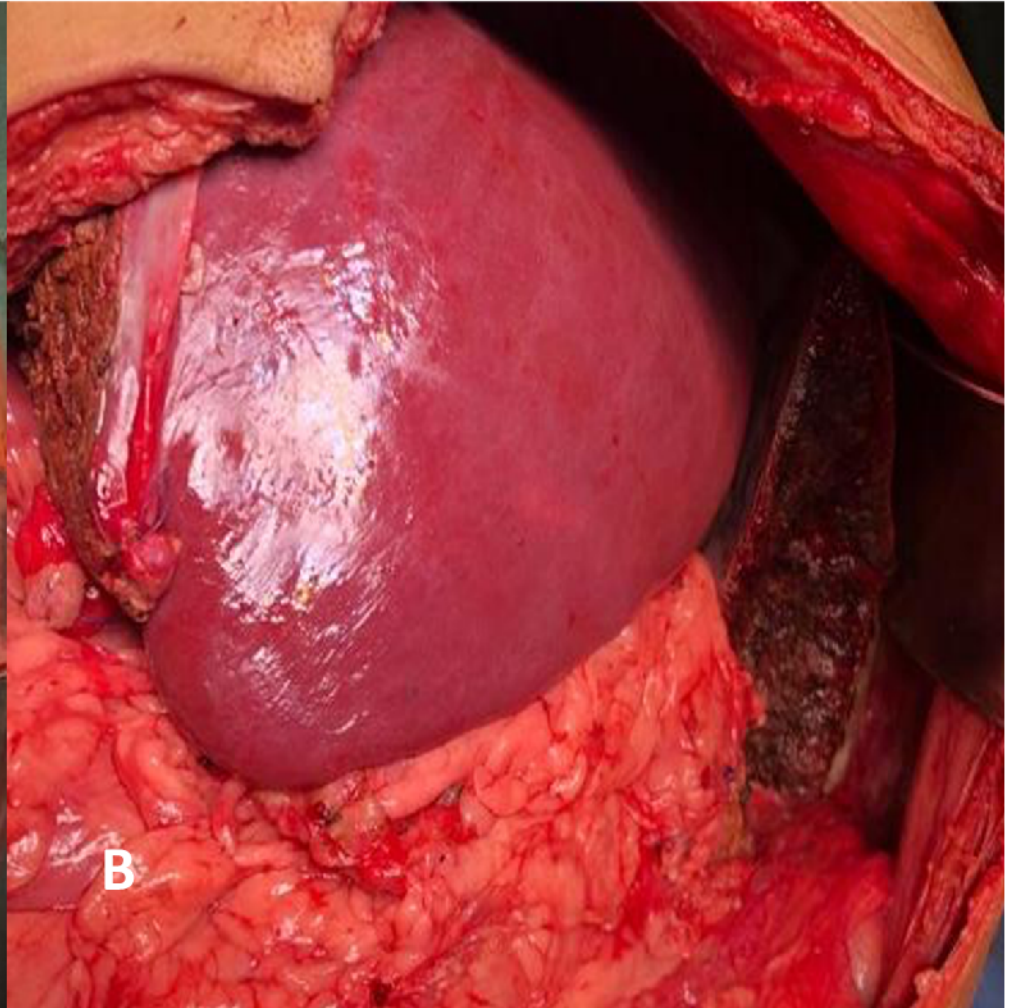
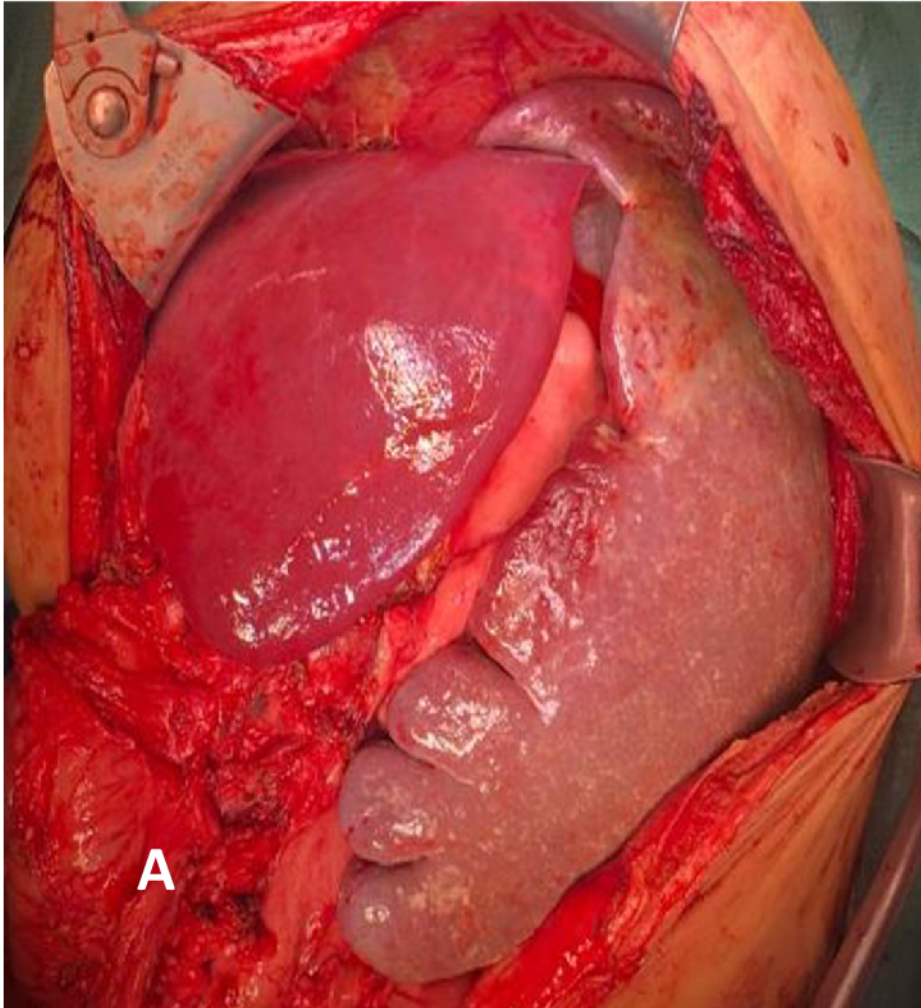
Figure 3. Spleen lengths in patients compared to normal lengths (mm) according to the age and sex (Rosenberg et al [12]).

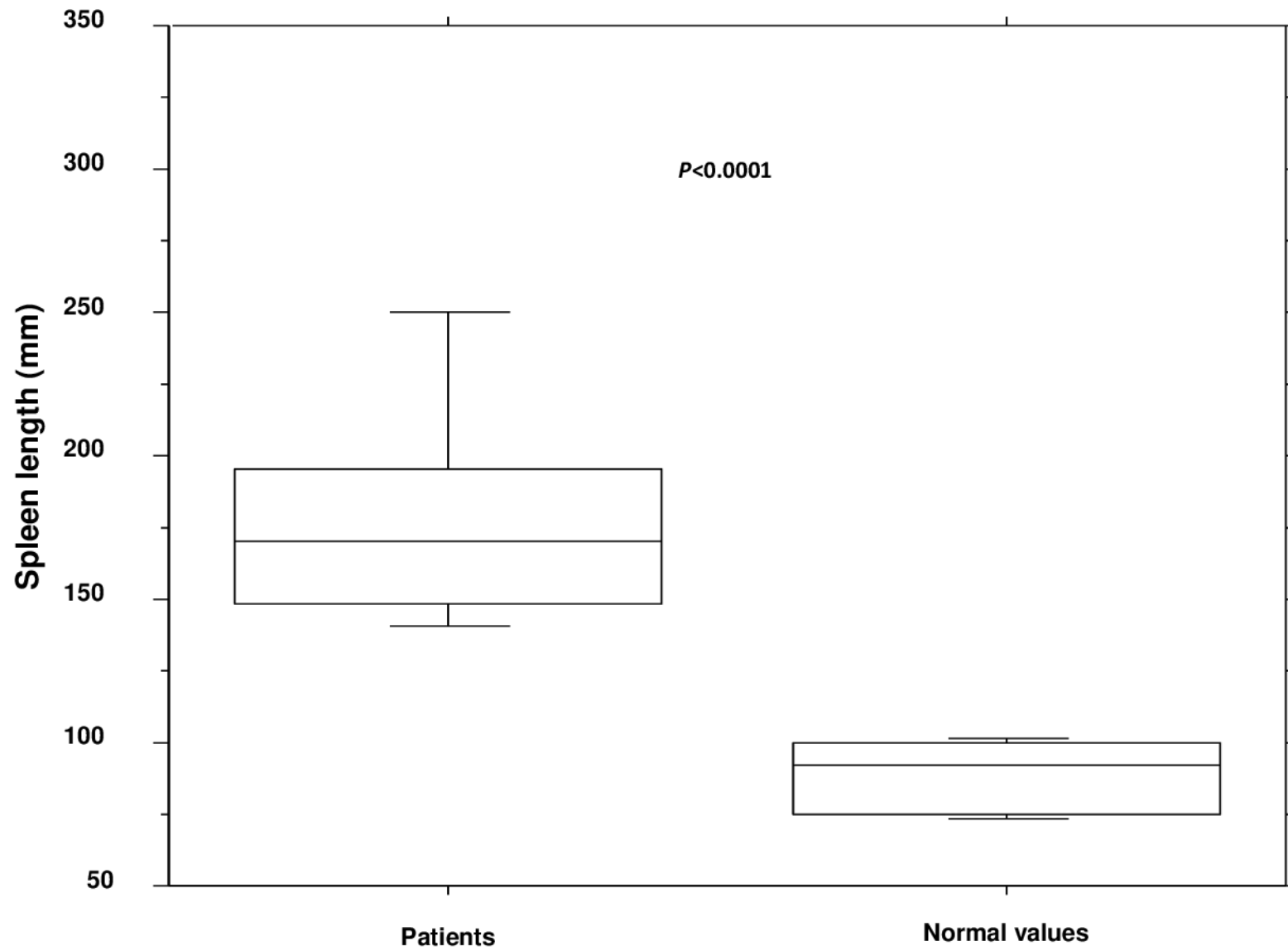
Figure 4. A. Courses of platelet count, B. Splanchnic pressure after venous shunting, C. Spleen length, and D. Spleen volume after paa Department of Digestive Diseases, Edouard Herriot Hospital, Hospices Civils de Lyon, France,

b University Claude Bernard Lyon 1, France, rtial splenectomy.

Figure 5. Course of platelet count compared to baseline after surgery with and without partial splenectomy.

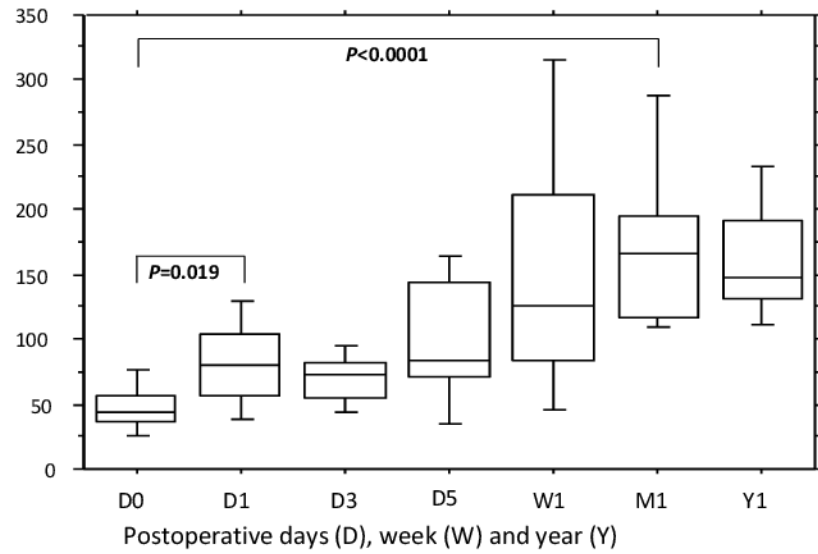




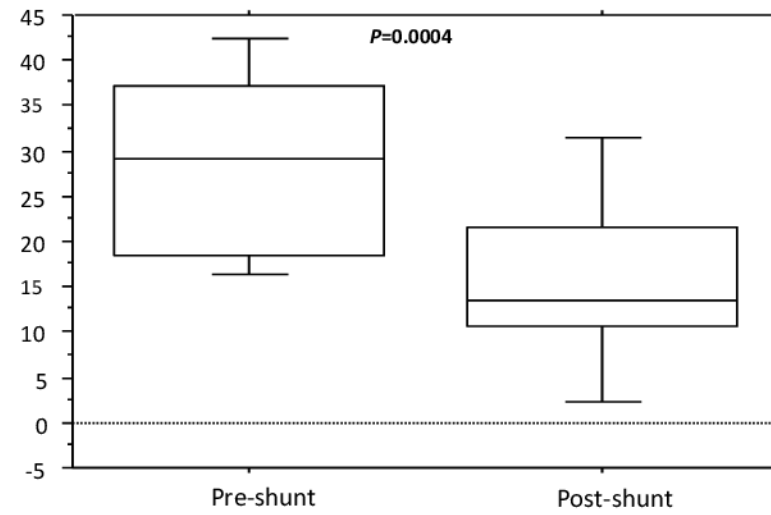




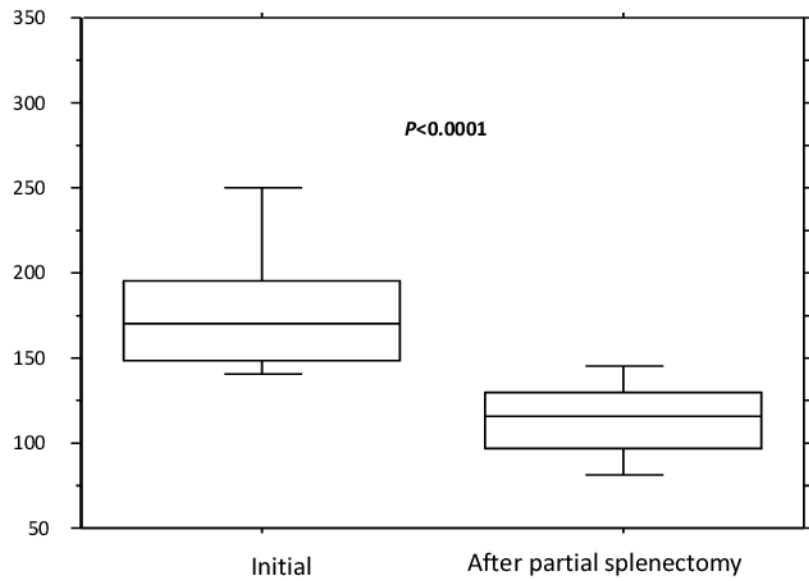
**A. Course of platlet counts ( $\times 10^9/L$ ) after partial splenectomy**



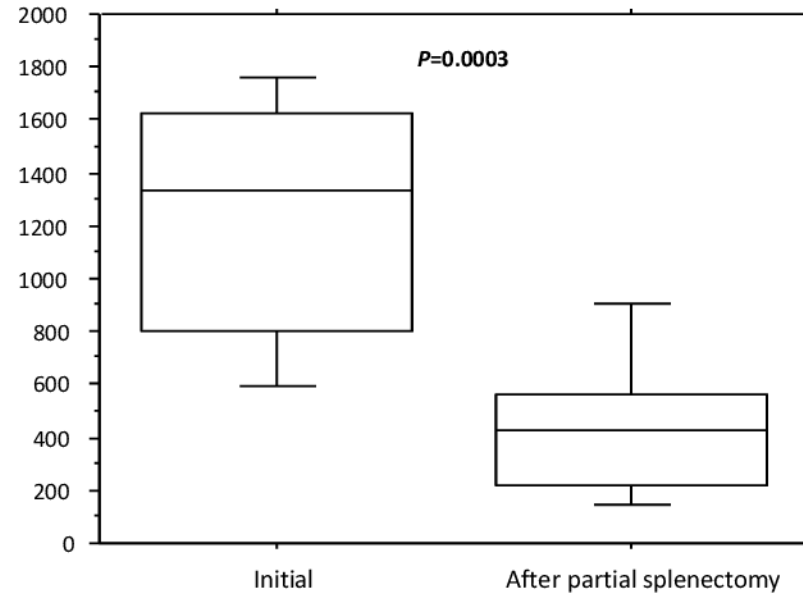
**B. Splanchnic pressure (mmHg) before and after shunt**

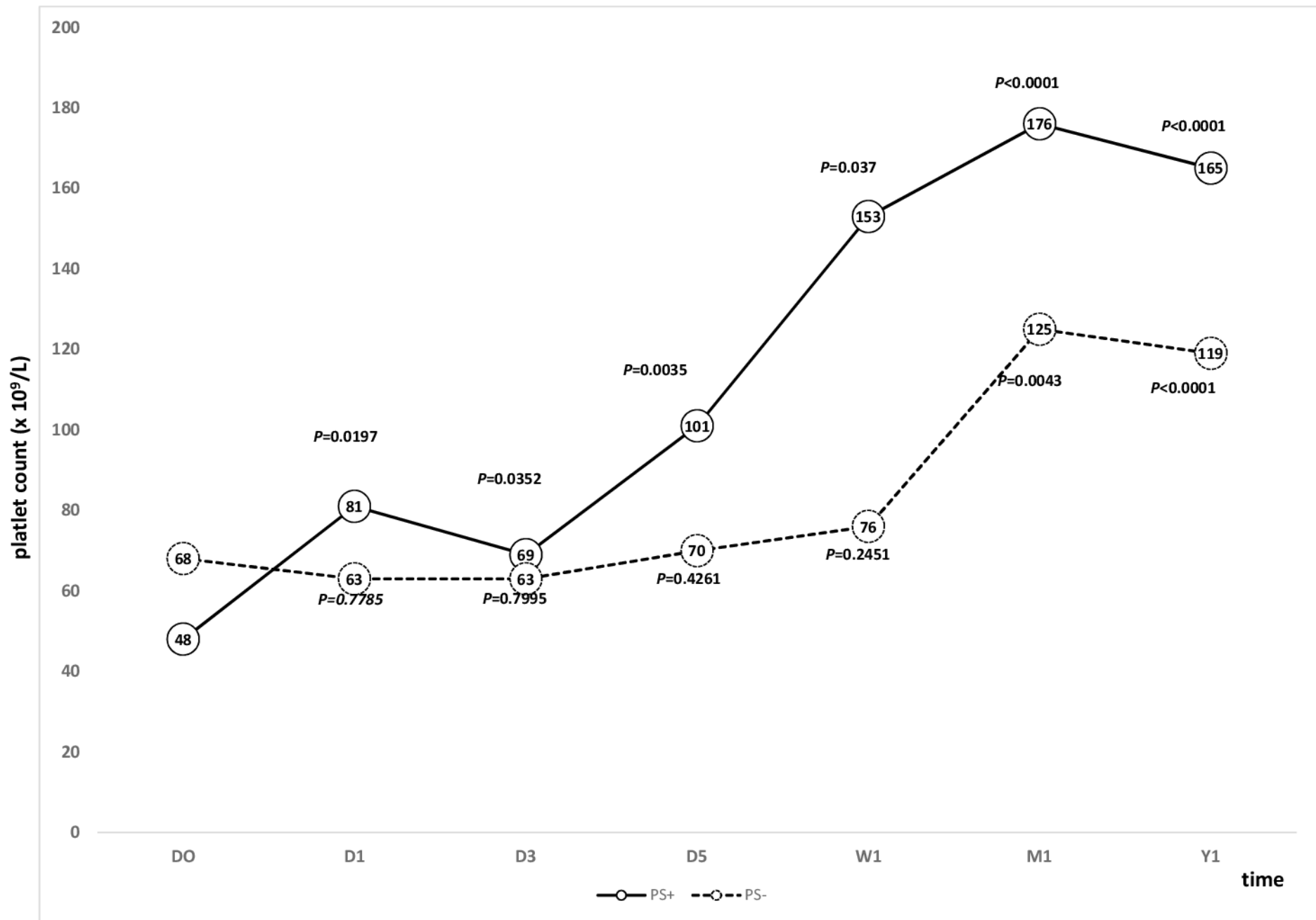


**C. Spleen length (mm) before, and after partial splenectomy**



**D. Spleen volume ( $cm^3$ ) before and after partial splenectomy**





D : day, W : week, M : month, Y: year