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Perioperative spleen embolization as a useful tool in laparoscopic splenectomy for simple and massive splenomegaly in children: a prospective study

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Abstract
Objective The purpose of this prospective study is to evaluate the efficiency of perioperative spleen embolization prior to laparoscopic splenectomy indicated for hypersplenism.
Methods We conducted a prospective study exploring a technique combining ultra-selective perioperative embolization and splenectomy. Between January 2008 and March 2013, 16 splenectomies were performed in children suffering from hypersplenism due to varying hematologic diseases. Spleen embolization was performed by an interventional radiologist in the operating room (OR) just before splenectomy and during the same general anesthesia. Ages varied from 3 to 17 years. Spleen volume was measured by preoperative ultrasound. One patient underwent a laparotomy because of suspected adhesions due to previous surgery. All other operations were performed laparoscopically.
Results One complication arose from embolization: a perforation of the splenic artery. After immediately placing a platinum coil proximal to the perforation, the splenectomy was carried out as usual. Fourteen children (87.5 %) had splenomegaly, of which eight (50 %) had massive splenomegaly. There were no deaths, no conversions to laparotomy, no reoperations and none of these patients had to be transfused.
Conclusions Perioperative spleen embolization performed in the OR by an interventional radiologist makes laparoscopic splenectomy a safer procedure. We propose a preoperative method for spleen measurement that is adapted to children: simple and massive splenomegaly is defined through patient body weight and a preoperative ultrasound. We conclude that spleen size is no more a limiting factor for laparoscopic splenectomy in children.

Keywords Splenic artery embolization · Laparoscopic splenectomy · Single-port splenectomy · Splenomegaly · Splenic size in childhood

For laparoscopic splenectomy, the literature describes conversion and transfusion rates up to 20 and 30 %, respectively, which can reach 37.5 and 87.5 % for massive splenomegaly [1–12]. Mortality varies from 0.6 to 1.4 % [4, 6, 7, 11]. Laparoscopic splenectomy is not yet considered to be the standard surgical approach for enlarged spleens [1, 2, 13, 14]. Transumbilical single-incision laparoscopic surgery (SILS) is an attractive surgical technique, especially in children as it leaves no scar; however, it can be a challenging procedure, particularly for large spleens [8, 15–18].

In adults, splenomegaly is often defined as a long axis exceeding 15 cm, but this measurement is not applicable to children as spleen size varies with growth [19]. We therefore used splenic volume related to body weight as parameter for splenomegaly, as described by Schlessinger [20]. Given the risks of laparoscopic splenectomy, we developed a surgical protocol combining spleen embolization and laparoscopic splenectomy (with or without SILS) during the same general anesthesia. Postoperative outcomes of these patients were then explored.

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Patients and methods

Between January 2008 and March 2013, we performed 16 splenectomies in children suffering from hypersplenism due to hematologic diseases such as sickle cell anemia [5], spherocytosis [5], β-thalassemia [3], idiopathic thrombocytopenic purpura [2] and nodular hyperplasia of the liver [1]. There were seven boys and nine girls. Patient ages varied from 3 to 17 years (mean = 8 years), and body weight went from 13 to 54 kg (mean = 29 kg). Each patient had a preoperative ultrasound, and spleen volume was calculated in milliliters using the formula for an ellipse (length × width × thickness) × 0.523 [21, 22]. Spleen volumes varied from 100 to 1310 ml (mean = 417 ml). These were compared to normal standards as a function of body weight (0.7 + (4.6 × body weight)) [20]. The ratio volume/normal volume for weight varied from 0.4 to 8. (Table 1). Operative data, complications and 6-month follow-up were prospectively recorded and analyzed using a structured pro forma.

We performed a two-step surgical procedure:

First step: To begin with, an interventional radiologist performs a spleen embolization on the child, who is under general anesthesia. Using the Seldinger technique, a 2.7-French microcatheter (Progreat™, Terumo Europe) is brought into the splenic artery. Through this microcatheter and after dilution with an iso-osmolar iodinated contrast medium (Iohexol 350 mg/ml, GE Healthcare),150–250 micron calibrated polyvinyl alcohol microparticles (Bead Block™, Biocompatibles, Terumo Europe) are slowly injected in the distal portions of the two major division branches of the splenic artery. Injection is performed using the "free flow" technique, until visual stagnation is obtained, which is secondary to obstruction of the capillary system by the injected particles. Several platinum coils, from 3 to 6 mm (Tornado™ microcoils 018, Cook Medical), are subsequently implanted (Fig. 1) in the proximal splenic artery until a complete visual stop of the injected contrast is observed at the level of the proximal splenic artery (Fig. 2)

Second step: The anesthetized child is moved from the catheterization room to the operating room (which are within the same operating block in our institution), and immediate splenectomy is performed.

We performed 16 total splenectomies. Two of the 16 procedures were associated with cholecystectomy for gallstones; liver biopsies were done in three patients. One patient underwent laparotomy because of suspected adhesions due to a previous surgery. The remaining 15 operations were performed laparoscopically, all by the same surgeon. Three were done by SILS and four were started by SILS, but required the introduction of one or two additional ports. Eight interventions were performed by conventional laparoscopy using three or four ports. Spleen dissection was performed using LigaSure (Valleylab®) and monopolar hook.

Table 1 Data on spleen length and volume

Patient	Age (years)	Pw (kg)	Sw (g)	S-axes (cm)	Sv-c (ml)	Sv-n (ml)	Ratio
1	3	13.6	230	15 × 9 × 4.5	316	63	5
2	4	15	159	10 × 10.5 × 5	273	70	4
3	6	19	336	14 × 10 × 5	364	88.1	4
4	16	47	1300	20 × 14 × 9	1310	216.9	6
5	13	54	138.6	11 × 7.5 × 3	128.7	249	0.5
6	6	26	240	11 × 9 × 4	206	120	1.7
7	6	21	370	15 × 13 × 3	304	97.3	3
8	6	26	402	18 × 5 × 4	561	120	4.6
9	3	17.5	399	15 × 12 × 7	655	81.2	8
10	6	17	299	14 × 11 × 6.5	520.5	77.2	6.7
11	12	41	326	15.5 × 12 × 4	386.9	189.3	2
12	3	17.5	155	15 × 10 × 2.5	195	81.2	2.4
13	17	47	250	15 × 11 × 3.5	300.3	216.9	1.4
14	10	30	765	19 × 11.5 × 7.5	852	138.7	6
15	8	50	99.4	10 × 5.5 × 3.5	100	230.7	0.4
16	6	21	231	12 × 11 × 3	205.9	154.4	2

Pw patient weight, *Sw* spleen weight, *S-axes* spleen length–depth–width

Sv-c calculated spleen volume (l × d × w × 0.52)

Sv-n normal spleen volume in relation to body weight [0.7 + (4.6 × body weight)]

Ratio: Sv-c/Sv-n

Fig. 1 Implantation of microcoils into the proximal splenic artery

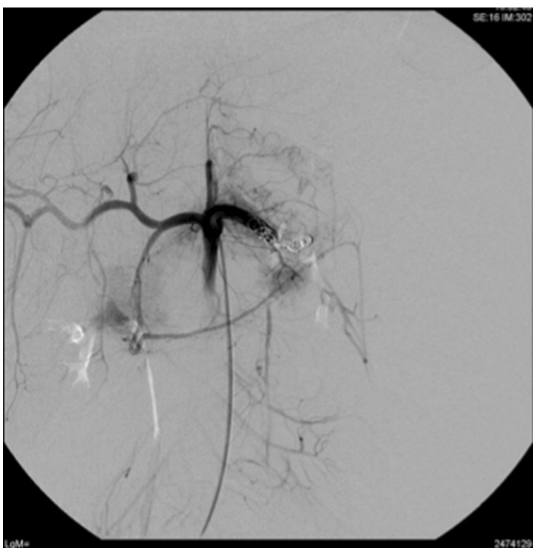

Fig. 2 Angiogram after completion of embolization, demonstrating normal perfusion of the small gastric and gastroduodenal arteries

Results

Embolization

In all patients, the embolization resulted in spleen ischemia (Fig. 3). There was one embolization-related complication: a splenic artery perforation. A platinum coil was immediately positioned proximal to the perforation, making it impossible to inject the microparticles. Nevertheless, the procedure was performed without any further complications. Mean embolization time was 87 min.

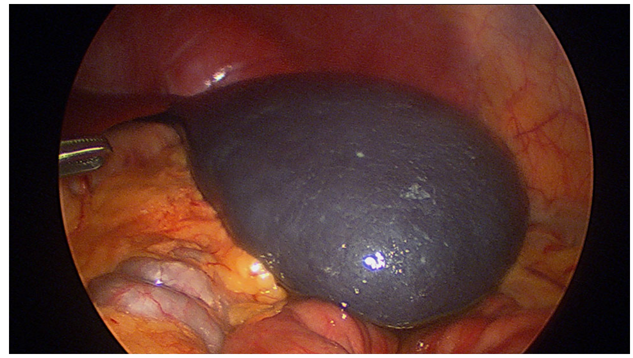

Fig. 3 Intraoperative view: splenic infarction

Surgery

After complete dissection, the spleen was fractioned inside an endobag and then removed through the umbilical incision in 13 patients. In two patients, a Pfannenstiel incision had to be performed to remove the spleen as it was too large to fit in an endobag. Mean operation time was 184 min. SILS was performed with straight instruments and therefore responsible for longer operating times. If we withdraw the SILS procedures and combined operations (associated cholecystectomies or liver biopsies), mean operation time becomes 128 min. Blood loss was negligible (<20 ml) except in the patient with the splenic artery perforation during embolization who lost 250 ml of blood. For this particular patient, the spleen was massive (with a volume six times higher than normal), and the operation had to be performed by inserting four ports. There were no deaths, no transfusions, no conversions, no endobag perforations and no patients needed drainage. There were no reoperations.

Complications

Eight patients developed 12 postoperative complications. Five patients suffered from pleural effusions, but only one of them had to be drained; three of these five had a concomitant pneumonia. A standard postoperative blood sample was taken at 48 h. For three patients, blood work showed a mild elevation of serum amylase without clinical signs of pancreatitis which resolved spontaneously within 4 days. One sickle cell patient suffered from an acute chest syndrome. We also noticed one biological inflammatory syndrome without obvious reason, one left subphrenic abscess, treated conservatively, and one central catheter sepsis. Follow-up at 6 months showed no surgery-related complications.

Discussion

The complications associated with laparoscopic splenectomy as described in the literature sustain the idea that it is a challenging procedure, with splenomegaly being a significant risk factor for intraoperative bleeding [1–3, 14, 19]. Some authors consider massive splenomegaly as a limiting factor or even a contraindication for laparoscopic splenectomy [1, 2, 13, 14]. In adults, splenomegaly is defined as a long axis exceeding 15 cm and massive splenomegaly as a long axis exceeding 20 cm [4, 19]. Others use spleen weight as an indicative factor [13]. In the SAGES Manual of Strategic Decision Making, simple splenomegaly is defined as a spleen enlarged to more than 50 % the average adult organ, and massive splenomegaly as an adult spleen more than 25 cm in length or 900 g in weight. [23]. In children, some authors use the same criteria, but others consider these measurements irrelevant because spleen size is relative to body size [12, 19]. The European Association for Endoscopic Surgery (EAES) defines massive splenomegaly in children as a spleen larger than four times normal for age [19].

There are some unpublished data of normal spleen lengths for age (Tables 2, 3), but spleen volume related to body weight seems to be more reliable [20]. All our patients had preoperative ultrasound measurements of spleen volume. These were compared to normal standards developed by Schlessinger in a large CT scan study [20]. Sonographic measurements of the spleen have been shown to correlate closely with splenic volumes determined by CT scan [22]. In this series, 14 children (87.5 %) had splenomegaly, eight of which (50 %) had massive splenomegaly, their spleens being four to eight times larger than normal.

Table 2 Normal craniocaudal splenic length in relation to age°

Age group (months)	Splenic length (cm)
0–3	3.3–5.8
3–6	4.9–6.4
6–12	5.2–6.8
Age group (years)	
1–2	5.4–7.5
2–4	6.4–8.6
4–6	6.9–8.8
6–8	7.0–9.6
8–10	7.9–10.5
10–12	8.6–10.9
12–15	8.7–11.4
15–20	9.0–11.7

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Table 3 Normal craniocaudal splenic length in relation to age°

Age group (months)	Splenic length (cm)
0–3	6
3–6	6.5
6–12	7
Age group (years)	
1–2	8
2–4	9
4–6	9.5
6–8	10
8–10	11
10–12	11.5
12–15	12
15–20	12 for girls
	13 for boys

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In our opinion, perioperative spleen embolization makes laparoscopic splenectomy a safer procedure, especially for splenomegaly. There are some reports of pre- or perioperative spleen embolization with good results, but the technique has yet to become widespread [2, 3, 24–26]. This may be due in part to the fact that complications secondary to the injection of microparticles have been described [2, 3, 24]. Another possible obstacle is the difficulty to combine embolization and splenectomy during the same anesthesia because one needs a catheterization room close to the operating room, which is not always the case. The two procedures can be split and performed on different days. This can result in a decrease in splenic volume and may facilitate laparoscopic dissection [3]. However, this alternative involves two anesthesias and 30–100 % of patients present postembolic pain [3, 25]. For these reasons, we preferred combining both procedures during the same anesthesia [26].

Embolization can be performed by simple insertion of coils in the main splenic artery. In this series, we performed ultra-selective embolization. First, microparticles are injected into the capillary bed of the spleen using the “free flow” technique in order to avoid reflux in the collateral arteries. Then, several coils are placed in the proximal splenic artery. The advantage of this technique is a complete vascular obstruction with no bleeding at all, whereas simple coil placement does not avoid venous bleeding. In one of our patients, embolization resulted in a splenic artery perforation managed by simple coil placement. The microparticles could not be injected, and this patient with a spleen six times larger than normal lost 250 ml of blood. All the others lost less than 20 ml. Another advantage of complete vascular lock is the possibility of performing splenectomy by SILS as the spleen is less vulnerable. Nevertheless, in our scarce experience with single-incision laparoscopic splenectomy, the benefit is only esthetic, the procedure being responsible for longer operating times, especially if performed with straight instruments.

The overall postoperative complication rate (50 %) was higher than those reported in the literature, with pleural effusions and temporary elevation of amylases being most frequent [1–3, 5, 9, 10]. Most of these complications were minor and had few clinical repercussions, particularly the elevation of serum amylase, which was a biological finding without any clinical manifestation of pancreatitis. Some publications hold the embolization responsible for these two complications, especially the injection of microparticles, but the relationship is not clearly established [2, 3, 25]. On the other hand, we encountered no major perioperative complications: no death, no transfusion, no conversion and no patients required abdominal drainage. In our series, there was no need for transfusion nor for conversion to laparotomy. In our opinion, these major advantages of perioperative embolization largely overrule the described complications.

Conclusions

In this series, we were able to define simple and massive splenomegaly in children based on their body weight and a preoperative ultrasound. In our experience, splenomegaly, even massive, is not an obstacle for laparoscopic splenectomy. Perioperative embolization is a helpful tool and can be performed in the OR just before splenectomy. It is a safe procedure that can lower major perioperative complications, and it can reduce the mortality rate of laparoscopic splenectomy to zero. An increase in minor postoperative complications might be due to the injection of microparticles, but this observation has to be proven on a comparative basis. In the future, with the conception of minimally invasive surgery, it would be advantageous to accommodate operating blocks with an integrated catheterization room.

Compliance with ethical standards

Disclosures Drs. Erwin Van Der Veken, Marc Laureys, Gregory Rodesch and Henri Steyaert have no conflicts of interest or financial ties to disclose.

References

1. Delaitre B, Champault G, Barrat C, Gossot D, Bresler L, Meyer C, Collet D, Samama G (2000) Laparoscopic splenectomy for hematologic diseases. Study of 275 cases. French Society of Laparoscopic Surgery. Ann Chir 125(6):522–529
2. Poulin EC, Mamazza J, Schlachta CM (1998) Splenic artery embolization before laparoscopic splenectomy. An update. Surg Endosc 12:870–875
3. Wu Z, Zhou J, Pankaj P, Peng B (2012) Comparative treatment and literature review for laparoscopic splenectomy alone versus preoperative splenic artery embolization splenectomy. Surg Endosc 26(10):2758–2766
4. Walsh RM, Brody F, Brown N (2004) Laparoscopic splenectomy for lymphoproliferative disease. Surg Endosc 18(2):272–275
5. Corcione F, Pirozzi F, Aragiusto G, Galante F, Sciuto A (2012) Laparoscopic splenectomy: experience of a single center in a series of 300 cases. Surg Endosc 26(10):2870–2876
6. Rosen M, Brody F, Walsh RM, Tarnoff M, Malm J, Ponsky J (2002) Outcome of laparoscopic splenectomy based on hematologic indication. Surg Endosc 16(2):272–279
7. Winslow ER, Brunt LM (2003) Perioperative outcomes of laparoscopic versus open splenectomy: a meta-analysis with an emphasis on complications. Surgery 134(4):647–653
8. Perger L, Aprahamian CJ, Muensterer OJ, Chong AJ, Lacher M, Yu D, Yannam GR, Harmon CM (2013) Single-incision pediatric endosurgery (SIPES) splenectomy: a case-control series. J Laparoendosc Adv Surg Tech A 23(2):162–165
9. Ahad S, Gonczy C, Advani V, Markwell S, Hassan I (2013) True benefit or selection bias: an analysis of laparoscopic versus open splenectomy from the ACS-NSQIP. Surg Endosc 27(6):1865–1871
10. Deng XG, Maharjan A, Tang J, Qiu RL, Wu YH, Zhang J, Zhou JJ, Zeng LX, Chen MJ, Xiang YQ, Deng JM (2012) A modified laparoscopic splenectomy for massive splenomegaly in children with hematological disorder: a single institute retrospective clinical research. Pediatr Surg Int 28(12):1201–1209
11. Ardestani A, Tavakkoli A (2013) Laparoscopic versus open splenectomy: the impact of spleen size on outcomes. J Laparoendosc Adv Surg Tech A 23(9):760–764
12. Park A, Heniford BT, Hebra A, Fitzgerald P (2000) Pediatric laparoscopic splenectomy. Surg Endosc 14:527–531
13. Mahon David, Rhodes Michael (2003) Laparoscopic splenectomy: size matters. Ann R Coll Surg Engl 85:248–251
14. Marte G, Scuderi V, Rocca A, Surfaro G, Migliaccio C, Ceriello A (2013) Laparoscopic splenectomy: a single center experience. Unusual cases and expanded inclusion criteria for laparoscopic approach. Updates Surg 65(2):115–119
15. Bruzoni M, Dutta S (2011) Single-site umbilical laparoscopic splenectomy. Semin Pediatr Surg 20(4):212–218
16. Bell R, Boswell T, Hui T, Su W (2012) Single-incision laparoscopic splenectomy in children. J Pediatr Surg 47(5):898–903
17. Targarona EM, Pallares JL, Balague C, Luppi CR, Marinello F, Hernández P, Martínez C, Trias M (2010) Single incision approach for splenic diseases: a preliminary report on a series of 8 cases. Surg Endosc 24(9):2236–2240
18. Monclova JL, Targarona EM, Vidal P, Peraza Y, Garcia F, Otero CR, Pallares L, Balague C, Trias M (2013) Single incision versus reduced port splenectomy—searching for the best alternative to conventional laparoscopic splenectomy. Surg Endosc 27(3):895–902
19. Habermalz B, Sauerland S, Decker G, Delaitre B, Gigot J-F, Leandros E, Lechner K, Rhodes M, Silecchia G, Szold A, Taragona E, Torelli P, Neugebauer E (2008) The clinical practise guidelines of the European Association for Endoscopic Surgery (EAES). Surg Endosc 22:821–848
20. Schlesinger AE, Edgar KA, Boxer LA (1993) Volume of the spleen in children as measured on CT scans: normal standards as a function of body weight. AJR Am J Roentgenol 160(5):1107–1109
21. Dittrich M, Milde S, Dinkel E, Baumann W, Weitzel D (1983) Sonographic biometry of liver and spleen size in childhood. Pediatr Radiol 13(4):206–211

22. Yetter EM, Acosta KB, Olson MC, Blundell K (2003) Estimating splenic volume: sonographic measurements correlated with helical CT determination. AJR Am J Roentgenol 181(6):1615–1620
23. Skeete D, Swanström L, Casaccia M, Sharafuddin M (2008) Splenectomy for massive splenomegaly. In: Scott-Conner CEH (ed) The SAGES manual of strategic decision making. Springer, New York, pp 387–403
24. Reso A, Brar MS, Church N, Mitchell P, Dixon E, Debru E (2010) Outcome of laparoscopic splenectomy with preoperative splenic artery embolization for massive splenomegaly. Surg Endosc 24(8):2008–2012
25. Takahashi T, Arima Y, Yokomuro S, Yoshida H, Mamada Y, Taniai N, Kawano Y, Mizuguchi Y, Shimizu T, Akimaru K, Tajiri T (2005) Splenic artery embolization before laparoscopic splenectomy in children. Surg Endosc 19(10):1345–1348
26. Naoum JJ, Silberfein EJ, Zhou W, Sweeney JF, Albo D, Brunicardi FC, Kougias P, El Sayed HF, Lin PH (2007) Concomitant intraoperative splenic artery embolization and laparoscopic splenectomy versus laparoscopic splenectomy: comparison of treatment outcome. Am J Surg 193(6):713–718