*Clinical Research Report*

*Journal of* INTERNATIONAL MEDICAL RESEARCH

Journal of International Medical Research
2018, Vol. 46(10) 4111–4119

DOI: 10.1177/0300060518786419
journals.sagepub.com/home/imr
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# Splenic artery embolization with detachable balloons for hypersplenism

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**Abstract**

**Objective:** This study was performed to investigate the efficacy of proximal splenic artery embolization using detachable balloons for patients with hypersplenism and portal hypertension.

**Methods:** Twelve patients diagnosed with hypersplenism with thrombocytopenia or leukocytopenia caused by portal hypertension were treated by proximal splenic artery embolization with detachable balloons and metallic fibered coils. All patients were followed for up to 6 months. Blood parameters, coagulation factors, and liver function indicators were measured. Enhanced computed tomography and abdominal ultrasonography examinations were also performed in advance to confirm the infarction area and evaluate the changes in spleen size.

**Results:** Postoperative angiography demonstrated complete embolization of the proximal splenic artery in all 12 patients. Thrombocyte and leukocyte counts rose significantly in all patients in 2 weeks and stayed significantly higher than those before embolization throughout the 6-month follow-up. The total bilirubin concentration and prothrombin activity recovered significantly and returned to normal levels 6 months later. Computed tomography revealed partial infarction and liquefaction of the splenic parenchyma in nine patients.

**Conclusions:** Proximal splenic artery embolization using detachable balloons could be considered a safe and effective therapeutic modality in alleviating hypersplenism secondary to portal hypertension.

**Keywords**

Portal hypertension, hypersplenism, balloon embolization, splenic artery, cirrhosis, infarction

Date received: 11 April 2018; accepted: 11 June 2018

## Introduction

Hypersplenism is defined as an increased activity of the spleen leading to pancytopenia that especially affects platelets (PLTs).[1,2] Both splenectomy by surgery

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and partial splenic embolization (PSE) by endovascular techniques are the principal methods for hypersplenism; nevertheless, they have some limitations and disadvantages. With the increasing awareness of the indispensable role of the spleen in immune system function[3] and the higher and more severe complication rate after PSE with a large volume of infarcted spleen than partitioned and repeated PSE,[4] a new therapeutic modality was established: total embolization of the proximal splenic artery with detachable balloons, thus reducing the splenic parenchyma blood supply and portal hypertension (PTH). To our knowledge, no reports in the English-language literature have described the treatment of hypersplenism and PTH by complete embolization of the proximal splenic artery with detachable balloons. The present clinical study was performed to evaluate the feasibility, efficacy, and safety of occlusion of the proximal splenic artery with detachable balloons in patients with hypersplenism secondary to PTH, and to summarize our experience with this technique.

## Materials and methods

### Patients

From September 2013 to February 2014, patients diagnosed with hypersplenism and PTH were admitted to the department of interventional therapy at our hospital. All patients were diagnosed with secondary hypersplenism, PTH, and liver cirrhosis by contrast-enhanced computed tomography (CT), abdominal ultrasonography, gastroscopy, angiographic findings, and clinical laboratory data or pathological examination. The inclusion criteria were hypersplenism (PLT count of $\leq 80 \times 10^9$/L) and splenomegaly (Figure 1(a)).[5] We excluded patients undergoing periesophagogastric devascularization. This study was approved by the institutional ethical committee of our hospital, and written informed consent for participation was obtained from all patients before the procedure.

### Methods

The patients were hemodynamically stable at admission or shortly after initial symptomatic treatment without the need for blood transfusions. After discussion with gastroenterologists, hepatologists, and hepatic surgeons at our institution, we decided to occlude the splenic artery with detachable balloons to improve hypersplenism, reduce PTH, and prevent further gastrointestinal hemorrhage. In general, detachable balloons (BALT Extrusion, Montmorency, France) and metallic fibered

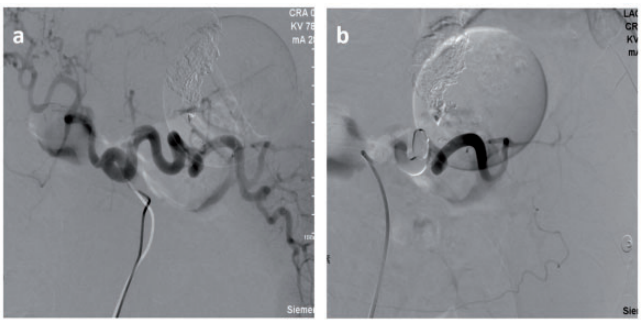


**Figure 1.** A 59-year-old man with hypersplenism due to liver cirrhosis was admitted for hematemesis and melena. He underwent splenic artery embolization with detachable golden balloons and coils. (a) Selective celiac angiography before embolization showed splenomegaly and a markedly dilated tortuous splenic artery. (b) Post-embolization angiography demonstrated faint collateral filling of the spleen tissues

coils (Cook Medical, Bloomington, IN, USA) were applied as embolic agents in this series either singly or in combination. All interventional procedures were performed with a digital subtraction angiography machine (Artis Zee floor system; Siemens, Erlangen, Germany) by two experienced interventional radiologists at the department of interventional radiology.

Under strict aseptic conditions, vascular access was gained with an 8-Fr sheath in the right femoral artery via the modified Seldinger technique in all 12 patients. A 5-Fr hepatic catheter (Terumo, Tokyo, Japan) was then inserted for celiac trunk, splenic artery, superior mesenteric artery, and indirect portal vein angiography to identify the configuration and distribution of the splenic artery, collateral circulation routes, and portal patency and hemodynamics. We precisely measured the vascular inner diameter of the splenic artery on digital subtraction angiography to choose the appropriate balloons and coils. Next, an 8-Fr guiding catheter was deployed over the exchanged guide wire proximal to the splenic artery. A 2.1-Fr latex balloon catheter (BALT Extrusion) was then inserted into the splenic artery across the opening site of the dorsal pancreatic artery after coils were placed to avoid migration of the balloons (Figure 1(b)). Under fluoroscopic guidance, isotonic contrast medium (total volume, 0.5–1.0 mL) was injected slowly into the balloon through the microcatheter until the balloon was well filled and the main splenic artery had achieved complete embolization. Splenic collateral branch vessels from the left gastric artery or gastroepiploic artery on selective celiac axis angiography were monitored for prevention of wide-area splenic infarction before releasing the balloon. Finally, a repeat selective angiogram of the splenic artery was obtained to evaluate the efficacy of the proximal splenic artery embolization (Figure 1(b)).

### Follow-up

All patients remained hospitalized until any post-embolization complications had disappeared and were then followed up regularly at 2 weeks and 1, 3, and 6 months after embolization. The type and frequency of procedure-related complications were appropriately recorded every day before discharge and during the 6-month follow-up.

Routine blood test parameters, including PLT and white blood cell (WBC) counts, were collected at 2 weeks after embolization, at 1 month after embolization, and at 3-month intervals thereafter. To determine the potential influence of embolotherapy on liver and coagulation function, the total bilirubin concentration and prothrombin activity were also measured during the follow-up period.

Abdominal contrast-enhanced CT and ultrasonography were routinely carried out to evaluate splenic infarction and assess the changes in splenic size by measuring the length of the spleen 6 months after embolization.

### Statistical analysis

The data were analyzed using SPSS 19.0 software (IBM Corp., Armonk, NY, USA). All quantitative data are shown as mean $\pm$ standard deviation. Changes in laboratory results and splenic size between the pre- and post-embolization groups were analyzed using the paired t-test. A P value of $<0.05$ was considered statistically significant.

## Results

### Patients

Twelve patients (seven men and five women) with a mean age of $52.2 \pm 8.7$ years underwent proximal splenic artery embolization with detachable balloons and/or coils. Eleven patients had previously bled from esophageal varices, and one had

previously bled from the nose and gingiva. According to the Child–Pugh classification system, three patients had Child–Pugh class A liver disease, four patients had Child–Pugh class B liver disease, and five patients had Child–Pugh class C liver disease. Data were collected on demographics, clinical presentation and causes of PHT, embolic materials, and Child–Pugh class and are summarized in Table 1.

### Primary procedure results

The hypersplenism occurred secondary to PTH caused by cirrhosis in all patients. Among them, eight patients had hepatitis B virus-related hepatic cirrhosis, one had hepatitis C virus-related hepatic cirrhosis, one had alcoholic cirrhosis, one had drug-induced cirrhosis, and one had autoimmune cirrhosis. Eleven patients were admitted for symptoms of hematemesis and melena, and the remaining patient was admitted for epistaxis and gingival hemorrhage. Third-degree gastroesophageal varices were detected during gastroscopic examination in all 12 patients.

Complete embolization of the proximal splenic artery was achieved in all patients, showing flow interruption immediately after balloon deployment. All 12 patients were alive without severe procedure-related complications or rebleeding during the 6-month follow-up. The mean hospitalization time was $3.7 \pm 1.1$ days (range, 2–6 days) after balloon embolization, and no episode of mortality was recorded during follow-up. The most common adverse events were epigastric pain and fever. Nine patients developed mild abdominal pain that tended to be localized in the left hypochondrium for 1 to 3 days with spontaneous remission. Fever usually accompanied pain in the present study, but it never exceeded 38.5°C. Fever occurred in eight patients and was controlled after conservative therapy. Nausea developed in three patients but disappeared by the second day.

### Changes in laboratory data

Complete embolization of the proximal splenic artery was achieved in all 12 patients during follow-up. The PLT count responded promptly to splenic artery embolization, increasing from $39.7 \pm 20.2 \times 10^9$/L before the procedure to $131.7 \pm 47.2$, $116.5 \pm 40.7$, $110.0 \pm 38.6$, and $102.1 \pm 30.8 \times 10^9$/L at 2 weeks and 1, 3, and 6 months after the procedure, respectively. The WBC count rose from $2.1 \pm 0.8 \times 10^9$/L before the procedure to $4.2 \pm 1.5$, $4.8 \pm 1.2$, $4.5 \pm 1.0$, and $3.9 \pm 0.6 \times 10^9$/L at 2 weeks and 1, 3, and 6 months after embolization, respectively. The PLT and WBC counts significantly increased during follow-up and remained higher than the pre-embolization levels ($P < 0.05$). The total bilirubin concentration and prothrombin activity recovered significantly compared with the preprocedural values ($P < 0.05$) and returned to normal levels 6 months later.

### Changes in splenic size

The results of the contrast-enhanced CT scans and ultrasound examinations performed after embolization were available for all 12 patients. There was no evidence of splenic artery trunk recanalization, massive splenic infarction or abscess formation, or venous or arterial thrombosis on contrast-enhanced CT scans in any patient. In nine patients, partial infarction and liquefaction of the splenic parenchyma were shown on CT scans 1 month after the procedure. The infarcted areas were located between the normal splenic tissue or located peripherally and comprised <50%. Splenic shrinkage and absorption of the liquefied zone were observed on CT scans at 6 months. The mean length of the spleen

**Table 1.** Clinical characteristics of 12 patients who underwent embolization of the proximal splenic artery.

| No. | Sex | Age (y) | Clinical presentation | Cause of PTH | Embolization material | Child–Pugh class |
|---|---|---|---|---|---|---|
| 1 | M | 49 | Hematemesis, melena | HBV-related hepatic cirrhosis | Two 9- × 11-mm balloons | C |
| 2 | M | 44 | Epistaxis, gingival hemorrhage | HBV-related hepatic cirrhosis | Two 9- × 11-mm balloons | A |
| 3 | F | 47 | Hematemesis, melena | HBV-related hepatic cirrhosis | Two 9- × 11-mm balloons | B |
| 4 | F | 62 | Hematemesis, melena | HCV-related hepatic cirrhosis | Two 10- × 50-mm coils, two 9- × 11-mm balloons | B |
| 5 | M | 40 | Hematemesis, melena | HBV-related hepatic cirrhosis | Two 12- × 50-mm coils, three 9- × 11-mm balloons | B |
| 6 | F | 61 | Hematemesis, melena | Drug-induced cirrhosis | Two 10- × 50-mm coils, two 9- × 11-mm balloons | A |
| 7 | M | 43 | Hematemesis | HBV-related hepatic cirrhosis | Two 12- × 50-mm coils, two 9- × 11-mm balloons | C |
| 8 | M | 59 | Hematemesis, melena | HBV-related hepatic cirrhosis | One 12- × 50-mm coil, one 10- × 50-mm coil, two 9- × 11-mm balloons | C |
| 9 | M | 48 | Hematemesis | HBV-related hepatic cirrhosis | Two 12- × 50-mm coils, two 9- × 11-mm balloons | C |
| 10 | F | 51 | Hematemesis, melena | Autoimmune cirrhosis | Two 10- × 50-mm coils, two 9- × 11-mm balloons | C |
| 11 | M | 54 | Hematemesis, melena | Alcoholic cirrhosis | Two 12- × 50-mm coils, two 9- × 11-mm balloons | B |
| 12 | F | 68 | Hematemesis, melena | HBV-related hepatic cirrhosis | One 10- × 50-mm coil, two 9- × 11-mm balloons | A |

M, male; F, female; PTH, portal hypertension; HBV, hepatitis B virus

after embolization was $13.1 \pm 1.9$ cm (range, 9.3–15.6 cm), compared with $16.1 \pm 2.0$ cm (range, 12.9–19.4 cm) before the procedure. Comparative analysis of the splenic size before and after embolization showed a highly significant decrease ($P < 0.05$).

## Discussion

Hypersplenism is a common manifestation of PTH caused by cirrhosis.[6] Thrombocytopenia is the most frequent manifestation of hypersplenism and might contribute to esophageal and gastric variceal bleeding.[7] Splenic destruction of peripheral blood cells is especially rapid, and any drug therapy may prove inadequate.[8]

The traditional therapeutic methods for hypersplenism are splenectomy and PSE.[9–11] Surgical splenectomy is a well established method to eliminate blood cell destruction caused by hypersplenism, but the higher risk of post-splenectomy infection and severe complications including pancreatitis, pneumonia, and subphrenic abscess, regardless of whether laparoscopic or open surgery is performed, should not be ignored.[12] The spleen produces important immunologic mediators, and splenectomy is linked to a high potential risk of septic events.[13,14] Therefore, the consensus is that splenectomy should be avoided as much as possible, and more interventional approaches should instead be used. PSE has recently become a popular interventional treatment modality for hypersplenism resulting from liver cirrhosis. This technique provides a recognized therapeutic effect of improving pancytopenia, but it can cause various complications such as severe pain and splenic abscess formation.[15,16] Complete embolotherapy of the proximal splenic artery by detachable balloons was performed in the present study as a new therapeutic modality for treating hypersplenism while preserving normal splenic function. We anticipated that this new method would show good efficacy and fewer complications.

Approximately 30% of total PLTs are collected in normal spleen tissues. This rate increases with the development of splenomegaly, and the enlarged spleen is thought to result in a marked decrease in peripheral blood cell counts.[17] To increase the PLT and WBC counts, shrink the splenic volume, and avoid serious adverse events, we embolized the proximal splenic artery in the treatment of hypersplenism caused by PTH in the present study. Total embolization of the main splenic artery has previously been performed to treat traumatic splenic injuries, lower portal pressure, and reduce the risk of bleeding in patients with PTH.[18–20] No reports to date have described the management of hypersplenism with complete embolotherapy of the proximal splenic artery using detachable balloons. In the present study, we achieved favorable results with a significant increase in the PLT and WBC counts, shrinkage of the splenic size, and improvement in coagulation and liver function in all 12 patients.

Proximal splenic artery embolization was performed to reduce blood flow and produce hypotension in the spleen, allowing the spleen to repair itself with a decreasing splenic volume.[21] After embolization of the splenic artery trunk, the blood flow supplying the spleen tissues may stop, but the collateral vessels from gastroepiploic, intrapancreatic, and left gastric arteries still provide some blood to the spleen (Figure 1(b)). This explains why no acute and complete splenic infarctions occurred after embolization in our study.[22,23] Additionally, all patients were alive without severe procedure-related complications during follow-up. Only partial infarction of the splenic parenchyma was shown by CT in nine patients and was one of the factors associated with the increase in the PLT and WBC counts. We speculate that these

two above-described mechanisms contributed to our encouraging results.

Epigastric pain occurred in nine patients, fever in eight patients, nausea in three patients, and partial splenic infarction in nine patients, but with low severity. With respect to the physiological characteristics of these complications, the pain was associated with ischemia, the fever was associated with the release of inflammatory mediators by the necrotized cells, and the splenic infarction was associated with a reduced splenic volume;[24,25] therefore, we considered these adverse effects to be effective signs of underlying physiological processes. Additionally, because of collateral vessel formation, the course of the splenic infarction after embolization was relatively slower than the course of acute infarction after PSE. The inflammatory mediators released from necrotic tissues were likely gradually absorbed, which could explain why no severe complications occurred. Even among the five patients with Child–Pugh class C liver disease, we encountered no serious complications. Therefore, poor liver function is not an absolute contraindication to splenic artery embolization with detachable balloons.

In this study, both the PLT and WBC counts were significantly higher at 2 weeks and 1, 3, and 6 months after than before embolization. The relatively high PLT and WBC counts could be attributable to this new treatment method. Complete embolization of the proximal splenic artery might have several advantages, such as fewer complications, persistent maintenance of normal WBC and PLT counts, and improvement of liver and coagulation function.

By using balloons, the area of infarction could be controlled to $<50\%$, and serious post-embolization complications could be avoided. Use of balloons also allowed preservation of adequate splenic tissues and thereby safeguarded against overwhelming post-splenectomy infection. Given the clinical success in all patients in our series, total embolization of the proximal splenic artery with detachable balloons should be considered as a safe, feasible, and valid alternative treatment for hypersplenism due to PTH, especially in patients for whom surgical splenectomy or PSE represents a considerable risk.

In summary, this technique was performed on 12 patients for treatment of secondary hypersplenism due to PTH. It resulted in chronic ischemia of much of the functional spleen and even partial splenic infarction, followed by a decrease in hypersplenism and splenomegaly with preservation of adequate functional splenic tissues to prevent the occurrence of overwhelming infection and severe complications. This procedure was especially suitable for patients in poor general condition combined with a high risk of splenectomy and serious peri- or post-embolization complications. Although the present results are encouraging, this approach still requires further evaluation. Additionally, our study had some limitations. It was not a comparative study, the number of patients was small, and no control group was used. Randomized controlled trials are needed for further evaluation of the long-term clinical efficacy and safety of this procedure.

## Declaration of conflicting interest

The authors declare that there is no conflict of interest.

## Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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## References


1. Abdella HM, Abd-El-Moez AT, Abu El-Maaty ME, et al. Role of partial splenic arterial embolization for hypersplenism in patients with liver cirrhosis and thrombocytopenia. *Indian J Gastroenterol* 2010; 29: 59–61.
2. Petermann A, Chabrot P, Cassagnes L, et al. Hypersplenism due to portal hypertension: retrospective evaluation of 17 patients treated by splenic embolization. *Diagn Interv Imaging* 2012; 93: 30–36.
3. Nakae H, Shimazu T, Miyauchi H, et al. Does splenic preservation treatment (embolization, splenorrhaphy, and partial splenectomy) improve immunologic function and long-term prognosis after splenic injury? *J Trauma* 2009; 67: 557.
4. Hayashi H, Beppu T, Okabe K, et al. Risk factors for complications after partial splenic embolization for liver cirrhosis. *Brit J Surg* 2008; 95: 744–750.
5. He X, Li W, Peng W, et al. Total embolization of the main splenic artery as a supplemental treatment modality for hypersplenism. *World J Gastroenterol* 2011; 17: 2953–2957.
6. Gu J, He X, Li WT, et al. Safety and efficacy of splenic artery coil embolization for hypersplenism in liver cirrhosis. *Acta Radiol* 2012; 53: 862–867.
7. Hermos JA, Altincatal A, Weber HC, et al. Thrombocytopenia and bleeding in Veterans with non-hepatitis C-related chronic liver disease. *Digest Dis Sci* 2013; 58: 562–573.
8. Tomikawa M, Akahoshi T, Sugimachi K, et al. Laparoscopic splenectomy may be a superior supportive intervention for cirrhotic patients with hypersplenism. *J Gastroen Hepatol* 2010; 25: 397–402.
9. Akahoshi T, Tomikawa M, Kawanaka H, et al. Laparoscopic splenectomy with interferon therapy in 100 hepatitis-C-virus-cirrhotic patients with hypersplenism and thrombocytopenia. *J Gastroen Hepatol* 2012; 27: 286–290.
10. Yoshidome H, Kimura F, Shimizu H, et al. Usefulness of preoperative partial splenic embolization in hepatocellular carcinoma and hypersplenic thrombocytopenia. *Hepato-Gastroenterol* 2010; 58: 2062–2066.
11. Hadduck TA and McWilliams JP. Partial splenic artery embolization in cirrhotic patients. *World J Radiol* 2014; 6: 160–168.
12. Elmonem SA, Tantawy HI, Ragheb AS, et al. The outcome of partial splenic embolization for hypersplenism in the cirrhotic patients. *The Egyptian Journal of Radiology and Nuclear Medicine* 2011; 42: 35–42.
13. Zhu K, Meng X, Qian J, et al. Partial splenic embolization for hypersplenism in cirrhosis: a long-term outcome in 62 patients. *Digest Liver Dis* 2009; 41: 411–416.
14. De Porto A, Lammers A, Bennink RJ, et al. Assessment of splenic function. *Eur J Clin Microbiol* 2010; 29: 1465–1473.
15. Hadduck TA and McWilliams JP. Partial splenic artery embolization in cirrhotic patients. *World J Radiol* 2014; 6: 160–168.
16. Yoshida H, Mamada Y, Taniai N, et al. Partial splenic embolization. *Hepatol Res* 2008; 38: 225–233.
17. Ojiri Y, Noguchi K, Shiroma N, et al. Uneven changes in circulating blood cell counts with adrenergic stimulation to the canine spleen. *Clin Exp Pharmacol Physiol* 2001; 29: 53–59.
18. Kim JH, Kim KW, Gwon DI, et al. Effect of splenic artery embolization for splenic artery steal syndrome in liver transplant recipients: estimation at computed tomography based on changes in caliber of related arteries. *Transplant Proc* 2011; 43: 1790–1793.
19. Zhu X, Tam MD, Pierce G, et al. Utility of the Amplatzer Vascular Plug in splenic artery embolization: a comparison study with conventional coil technique. *Cardiovasc Inter Rad* 2011; 34: 522–531.
20. Gaba RC, Katz JR, Parvinian A, et al. Splenic artery embolization: a single center experience on the safety, efficacy, and clinical outcomes. *Diagn Interv Radiol* 2013; 19: 49–55.

21. Wang W, Tam MD, Spain J, et al. Gelfoam-assisted amplatzer vascular plug technique for rapid occlusion in proximal splenic artery embolization. *AJR Am J Roentgenol* 2013; 200: 677–681.
22. Li ES, Mu JX, Ji SM, et al. Total splenic artery embolization for splenic artery aneurysms in patients with normal spleen. *World J Gastroenterol* 2014; 20: 555–560.
23. Madoff DC, Denys A, Wallace MJ, et al. Splenic arterial interventions: anatomy, indications, technical considerations, and potential complications. *Radiographics* 2005; 25(suppl_1): S191–S211.
24. Petermann A, Chabrot P, Cassagnes L, et al. Hypersplenism due to portal hypertension: retrospective evaluation of 17 patients treated by splenic embolization. *Diagn Interv Imaging* 2012; 93: 30–36.
25. Medzhitov R. Origin and physiological roles of inflammation. *Nature* 2008; 454: 428–435.