

Long-term outcomes of elective transcatheter dense coil embolization for splenic artery aneurysms: a two-center experience

Wujie Wang¹, Haiyang Chang¹, Bin Liu¹,
Wei Wang¹, Zhe Yu¹, Chao Chen¹, Yuliang Li¹,
Zhenting Wang² and Yongzheng Wang¹ 

Abstract

Objective: This study was performed to analyze the long-term follow-up safety and efficacy of transcatheter dense coil embolization for splenic artery aneurysms.

Methods: Thirty-two patients (18 women, 14 men; age range, 23–56 years; mean age, 43.1 ± 13.6 years) who underwent dense coil embolization for treatment of splenic artery aneurysms from August 2010 to January 2018 were retrospectively reviewed. The size and location of the splenic artery aneurysms, the technical and clinical outcomes of the procedure, and the complications related to the procedure were reviewed.

Results: The technical success rate of embolization was 100% (mean aneurysm size, 29.4 ± 6.9 mm; range, 20–43 mm). Two (6.3%) patients underwent a successful repeat intervention procedure for recurrent aneurysm perfusion during follow-up (mean, 36 months; range, 6–72 months). No aneurysm ruptured during follow-up. Splenic infarction was observed in 8 of 32 (25%) patients. No patients developed major adverse events related to the procedure, such as splenic abscess or pancreatitis.

Conclusions: Percutaneous elective transcatheter dense coil embolization is safe and effective to prevent aneurysm rupture and overcome aneurysm recanalization during long-term follow-up.

¹Department of Interventional Medicine, The Second Hospital of Shandong University, Institute of Tumor Intervention, Shandong University, Jinan City, Shandong Province, China

²Medical Imaging Institute of Shandong Province, Jinan City, Shandong Province, China

Corresponding author:

Yongzheng Wang, Department of Interventional Medicine, The Second Hospital of Shandong University, 247 Beiyuan Street, Jinan City, Shandong Province 250033, China.
Email: wyzwxy911@sohu.com



Keywords

Transcatheter, coil embolization, splenic artery aneurysms, safety, efficacy, long-term follow-up

Date received: 2 April 2019; accepted: 9 August 2019

Introduction

Visceral artery aneurysms are reportedly present in approximately 10% of autopsies. The estimated prevalence of splenic artery aneurysms (SAAs) is 60% among visceral artery aneurysms with a rupture rate of 25% and mortality rate of up to 70% after rupture.¹ An SAA should be treated when its diameter is >2 cm, even if asymptomatic.² Treatment options include surgery, percutaneous coil embolization, and stent implantation.^{3,4} Percutaneous interventional treatment for SAAs has become widespread because of its high success rate and low incidence of complications.^{3,5-7} Transcatheter coil embolization is becoming an increasingly popular method for the treatment of SAAs.⁸⁻¹⁰ Although some progress has been made in embolization techniques and materials for the treatment of SAAs during the past several years, aneurysms can recur during follow-up because of incomplete aneurysm embolization or reperfusion of collateral arteries.^{8,11,12}

Dense coil embolization is performed in our centers to reduce the recurrence rate of SAAs. The aneurysm sac and splenic artery (i.e., the inflow and outflow arteries) are densely embolized with coils. In the present study, we retrospectively analyzed patients with SAAs who were treated by elective transcatheter dense coil embolization in our two centers and underwent long-term follow-up. The technical and clinical outcomes of the procedure and its complications were assessed.

Materials and methods

Patients

This study was approved by the institutional ethics committee of our medical centers, and written informed consent was obtained from all patients (approval number: KYLL-2019(Lu) 011; date: 18 February 2019). Consecutive patients diagnosed with SAA and treated with percutaneous transcatheter coil embolization from August 2010 to January 2018 were included in this retrospective study. Contrast-enhanced computed tomography (CT) was used to diagnose SAA and define the location, size, and shape of the aneurysm before the procedure and to perform follow-up examinations after the procedure.

All patients enrolled in this study met the following inclusion criteria a true SAA had been diagnosed, the largest diameter of the aneurysm was ≥ 2 cm, and the aneurysm was treated by elective transcatheter dense coil embolization. Patients who were more likely to have a pseudoaneurysm, severe cardiopulmonary disease, or uncorrectable coagulopathy were excluded. Patients with asymptomatic small true SAAs (diameter of <2 cm) were regularly followed up. Embolization was considered for SAAs located in the main splenic artery, especially in the splenic hilum. To distinguish between true SAAs and pseudoaneurysms, we relied on risk factors (e.g., pregnancy, portal hypertension, and pancreatitis) and imaging characteristics. This process was carried out

by two interventional radiologists with at least 10 years of experience.

Dense coil embolization

All patients underwent SAA embolization after consultation with vascular and general surgery specialists. Written informed consent was obtained before the procedure. All angiography and embolization procedures were performed by experienced interventional experts. Antibiotic agents were not routinely used before the procedure.

The procedure was performed under local anesthesia using digital subtraction angiography. The right femoral artery approach was selected to insert a 5-Fr sheath in all patients. A 5-Fr Simmons angiography catheter (Cook Medical, Bloomington, IN, USA) was used to perform angiography of the celiac trunk and superior mesenteric artery. The collateral blood supply of the spleen and the location and size of the SAAs were identified. A coaxial microcatheter (2.7-Fr Progreat; Terumo Medical Corporation, Somerset, NJ, USA) was introduced to catheterize the aneurysm sac, outflow artery, and inflow artery. The dense coil embolization was performed in combination with packing using the sandwich technique.¹³ Nester coils (Cook Medical) and Interlock coils (Boston Scientific, Natick, MA, USA) were densely inserted into the aneurysm sac and in the artery on either side of the aneurysm. The number of coils used and the average cost were positively correlated with the size and volume of the aneurysm. The number of coils used was also related to the coil diameter and length. Interlock coils with a diameter close to the aneurysm diameter were preferred for embolization. Other coils were densely packed in the target aneurysm to occupy the volume. Angiography was performed after embolization to confirm that no contrast flowed into the aneurysm sac.

Follow-up and study definitions

The primary care physician contacted the patients via telephone to perform the follow-up visit in the outpatient department. Contrast-enhanced CT or magnetic resonance imaging was performed to identify the coil packing and aneurysm recanalization at 1 and 6 months after the procedure and then annually thereafter. Abdominal contrast-enhanced CT images were acquired using a gemstone energy spectrum CT system (General Electric Medical Systems, Milwaukee, WI, USA).

Technical success was defined as complete termination of infusion into the aneurysm sac and inflow vessel after the angiogram. Clinical success was defined as no evidence of aneurysm reperfusion or rupture at follow-up. Complications related to the procedure were recorded, including postembolization syndrome, splenic infarction, splenic abscess, pneumonia, pleural effusion, and loss of appetite.

Statistical analysis

Continuous variables are expressed as mean \pm standard deviation. The t test was used for comparison of the platelet count before and after the procedure. A P value of <0.05 was considered statistically significant. All statistical analyses were conducted using SPSS version 24 (IBM Corp., Armonk, NY, USA).

Results

In total, 32 patients were included in this study (18 women, 14 men; average age, 43 years; range, 23–56 years). All aneurysms were located in the main splenic artery (5 in the proximal part of the splenic artery, 12 in the middle part, and 15 in the distal part). Eleven (34%) patients had portal hypertension, 10 had abdominal

pain, and 4 had back pain. One patient was diagnosed with a ruptured aneurysm during pregnancy. The remaining six patients were asymptomatic. The baseline characteristics of the patients and aneurysms are shown in Table 1.

All 32 aneurysms (mean size, 29.4 ± 6.9 mm; range, 20–43 mm) were successfully embolized with coils during the first procedure, with complete cessation of contrast flowing into the aneurysm. The technical success rate was 100%.

Two (6%) of the 32 patients exhibited recurrent aneurysm flow during follow-up. Repeat intervention was performed to exclude the aneurysm. One of the two patients was a 23-year-old woman who was diagnosed with a ruptured SAA during pregnancy (Figure 1(a)–(c)). The patient presented with hemorrhagic shock upon admission. After a rapid multidisciplinary consultation involving specialists in obstetrics and gynecology, general surgery, and interventional medicine, intracavitary treatment was deemed necessary. Angiography and coil embolization were urgently performed to ensure bleeding control immediately after the procedure (Figure 1(d)). However, the aneurysm recurred 6 months later (Figure 1(e)). The catheter was advanced through the collateral feeding artery to further densely embolize the aneurysm sac with coils (Figure 1(f)). The aneurysm was completely occluded during the 4-year follow-up (Figure 1(g), (h)). In the other patient with recurrent aneurysm flow, repeat intervention was performed 3 months after the first procedure. The recurrent aneurysm was managed with reperfusion of the collateral branch afferent to the left gastric artery. The aneurysm and target vessel were catheterized and coil-embolized. No evidence of aneurysm rupture or enlargement was found in the other 30 (94%) patients during the follow-up period (mean, 36 months; range,

Table 1. Baseline characteristics of patients and aneurysms.

Patient No.	Sex	Age (years)	Size (mm)	Location
1	F	23	35	Distal
2	F	53	22	Distal
3	F	51	24	Middle
4	M	28	28	Distal
5	M	53	25	Distal
6	F	26	27	Middle
7	F	54	33	Distal
8	M	56	31	Middle
9	M	53	25	Middle
10	F	54	23	Distal
11	F	26	42	Middle
12	F	53	22	Distal
13	M	35	41	Proximal
14	M	30	33	Distal
15	F	29	24	Middle
16	M	30	26	Distal
17	F	54	23	Middle
18	M	24	43	Proximal
19	M	56	27	Distal
20	F	54	23	Middle
21	F	53	22	Proximal
22	F	24	20	Distal
23	M	30	34	Middle
24	M	55	41	Middle
25	F	54	26	Distal
26	M	24	28	Proximal
27	F	54	34	Distal
28	M	53	26	Middle
29	F	55	24	Distal
30	M	25	31	Proximal
31	F	56	42	Distal
32	F	55	35	Middle

F, female; M, male.

6–72 months), and the clinical success rate was 94%.

No patients developed major adverse events related to the procedure, such as splenic abscess or pancreatitis. Splenic infarction with <50% of the total volume occurred in eight patients who experienced mild left upper abdominal pain and fever 1 day after the procedure. These symptoms

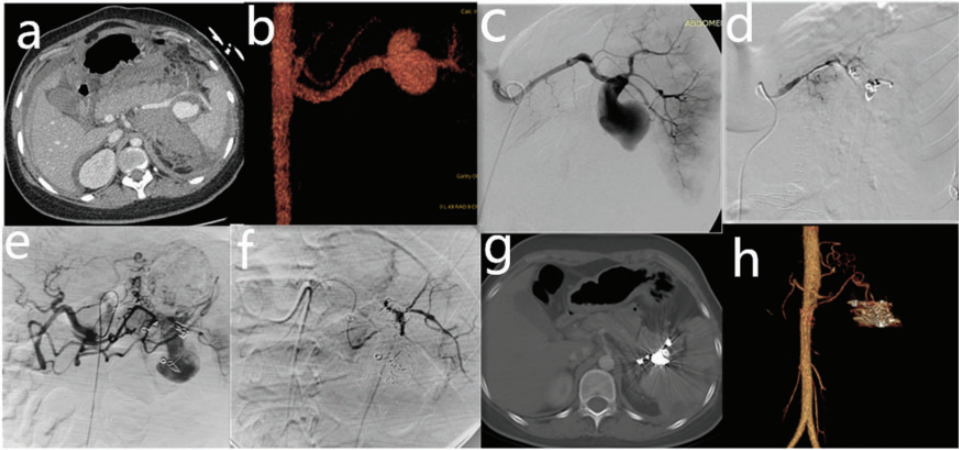


Figure 1. Images of a 23-year-old woman with a ruptured splenic artery aneurysm during pregnancy. (a) Preprocedural contrast-enhanced computed tomography. (b) Three-dimensional reconstruction image. (c) Preprocedural angiogram. (d) Postprocedural angiogram showing disappearance of the aneurysm. (e) Celiac angiogram 6 months later showing aneurysm recurrence. (f) A catheter was advanced through the collateral feeding artery to further densely embolize the aneurysm sac with coils. (g) Contrast-enhanced computed tomography 4 years after the procedure demonstrating no blood flow within the aneurysm. (h) Three-dimensional reconstruction image.

were classified as postembolization syndrome and treated with nonsteroidal anti-inflammatory drugs. Six of the eight patients had portal hypertension and thrombocytopenia and recovered well 1 week later with a significantly increased platelet count. The median platelet count was $59.3 \times 10^9/L$ before the procedure and $108.4 \times 10^9/L$ after the procedure ($P < 0.05$). One patient developed a small amount of pleural effusion that resolved within a few days.

Discussion

Several authors have reported SAA as a rare but potentially life-threatening disease since Beaussier¹⁴ first found this disease during an autopsy in 1770.¹⁵ The SAAs were treated based on the natural history of this disease, which is poorly defined because of the high mortality rate of 10% to 40% following rupture.^{16,17} Akbulut and Otan¹⁸ reviewed 69 papers and reported

that giant SAA with a diameter of >5 cm was associated with a mortality of 33.3% in ruptured cases. Another literature review by Yagmur et al.¹⁹ revealed that spontaneous rupture could be considered the most critical complication of splenic artery pseudoaneurysm. Therefore, the general consensus is that all splenic artery pseudoaneurysms and SAAs meeting the criteria should be treated to reduce the potentially life-threatening risk associated with rupture.²⁰

Surgical treatment of SAAs was first successfully performed by Winkler²¹ in 1905, and laparoscopic repair of SAAs was initially performed by Saw et al.²² in 1993. Open surgery currently remains the gold standard treatment method. Other treatments such as aneurysmectomy and/or splenectomy, splenic artery ligation and/or aneurysmectomy, and distal pancreatectomy are occasionally performed when necessary.^{20,23} The mortality and morbidity rates associated with open surgery are approximately 1.3% and 9.0%, respectively.²⁰

Laparoscopic excision is the treatment of choice in patients with small aneurysms and during early pregnancy. However, this procedure is not suitable in hemodynamically unstable patients and those with large aneurysms and dense adhesions.²⁴ Sticco et al.²⁵ analyzed a nationwide inpatient sample in the United States and found that endovascular treatment could be justified as the first treatment strategy for SAA instead of open surgery because of the lack of a significant difference in perioperative mortality and the lower resource cost and complication rate.

Endovascular treatment methods have become preferential because of their high technical success rates and low morbidity rates since Probst et al.²⁶ successfully performed the first transcatheter embolization in 1978.^{11,27,28} These techniques provide alternatives to surgery, particularly for poor surgical candidates and patients with high operative risk.⁵

Transcatheter embolization and endovascular stent grafting are the most common endovascular options. Although a stent graft can be used to achieve a patent main splenic artery, it cannot be applied in tortuous arteries. Percutaneous endovascular stent grafts have been described in case reports or small retrospective reviews.^{7,29-31} Reed et al.³² reported that endovascular stent repair failed in 2 of 10 patients because of excessive vessel tortuosity; therefore, coil embolization was used as a salvage treatment option.

Transcatheter coil embolization is an effective and safe approach among elective treatment methods. The reported success rate of this technique is 90% to 100%.^{4,5,7} This rate is consistent with our findings. This technique is also recommended for ruptured aneurysms in high-risk patients.²⁹ In our study, a pregnant young woman with a ruptured SAA was successfully treated with transcatheter coil embolization.

Coils are the most commonly used embolic material. Embolization techniques often include coil deployment into the aneurysm sac or arteries on either side of the aneurysm. Aneurysms have recurred during follow-up in several studies because of incomplete aneurysm embolization or reperfusion of collateral arteries.^{8,11,12} Yasumoto et al.³³ analyzed the clinical data of 16 patients with true SAAs to evaluate the relationship between the packing density of coils and recanalization, and they found that insufficient embolization and large aneurysms were more likely to lead to recanalization.

Two patients in the present study were found to have developed aneurysm recurrence during follow-up. We believe that this occurred because dense embolization was not achieved during the initial procedure. Aneurysm reperfusion can occur if the feeding vessels are not thoroughly embolized. Therefore, the aneurysm sac should also be thoroughly embolized because a potential blood supply via a gastric or mesenteric arterial branch may lead to aneurysm reperfusion.³⁴ To improve the embolization technique in the present study, the coils were densely inserted into the aneurysm sac (i.e., the inflow and outflow arteries of the aneurysm). After adopting this dense embolization technique, no aneurysms recurred during the long-term follow-up. Our study demonstrates that dense embolization can safely and effectively prevent aneurysm rupture and overcome aneurysm recanalization during long-term follow-up.

A common adverse event associated with coil embolization is splenic infarction.^{8,10,12,13} Preservation of a patent splenic artery is not absolutely necessary because the spleen can be supplied by the collateral gastric and pancreatic vessels to prevent infarction.¹¹ However, preservation of this artery is beneficial for patients with portal hypertension and hypersplenism who are at high risk of hemorrhage due to

thrombocytopenia. Percutaneous partial splenic artery embolization is commonly used as an effective method to treat thrombocytopenia caused by hypersplenism in the clinical setting.³⁵ In this retrospective study, six patients with portal hypertension and thrombocytopenia had a significantly increased platelet count. Improvement of thrombocytopenia reduces the occurrence of hemorrhage.³⁶ Among the 11 patients with portal hypertension, 6 (54.5%) developed splenic infarction, indicating that portal hypertension may be an important risk factor. Postembolization syndrome was noted in eight (25%) patients, all of whom recovered within 1 week. No patients developed severe complications such as splenic abscesses or pancreatitis.

This study had several limitations. First, this was a retrospective study with a small sample size, which could have led to selection bias and might have affected the generalization of the study findings. Second, although magnetic resonance imaging is the first choice for evaluating aneurysm recanalization to avoid the influence of coil artifacts with no exposure to ionizing radiation, contrast-enhanced CT was the only image modality used in some patients. CT is not sufficiently accurate to evaluate aneurysm due to coil artifacts.

In conclusion, percutaneous elective transcatheter coil embolization should be the first-choice treatment for SAAs. Dense embolization can safely and effectively prevent aneurysm rupture and overcome aneurysm recanalization during long-term follow-up.

Declaration of conflicting interest

The author(s) declare that there is no conflict of interest.

Funding

This work was supported by the Shandong Provincial Natural Science Foundation, China

[grant numbers ZR2018PH033 and ZR2018PH032] and the National Natural Science Foundation of China [grant number 61671276].

ORCID iD

Yongzheng Wang  <https://orcid.org/0000-0001-5889-2118>

References

1. Pasha SF, Gloviczki P, Stanson AW, et al. Splanchnic artery aneurysms. *Mayo Clin Proc* 2007; 82: 472–479.
2. Abbas MA, Stone WM, Fowl RJ, et al. Splenic artery aneurysms: two decades experience at Mayo clinic. *Ann Vasc Surg* 2002; 16: 442–449.
3. Hogendoorn W, Lavidia A, Hunink MG, et al. Open repair, endovascular repair, and conservative management of true splenic artery aneurysms. *J Vasc Surg* 2014; 60: 1667–1676.
4. Tulsyan N, Kashyap VS, Greenberg RK, et al. The endovascular management of visceral artery aneurysms and pseudoaneurysms. *J Vasc Surg* 2007; 45: 276–283.
5. Gabelmann A, Görlich J and Merkle EM. Endovascular treatment of visceral artery aneurysms. *J Endovasc Ther* 2002; 9: 38–47.
6. Kasirajan K, Greenberg RK, Clair D, et al. Endovascular management of visceral artery aneurysm. *J Endovasc Ther* 2001; 8: 150–155.
7. Sachdev U, Baril DT, Ellozy SH, et al. Management of aneurysms involving branches of the celiac and superior mesenteric arteries: a comparison of surgical and endovascular therapy. *J Vasc Surg* 2006; 44: 718–724.
8. Patel A, Weintraub JL, Nowakowski FS, et al. Single-center experience with elective transcatheter coil embolization of splenic artery aneurysms: technique and midterm follow-up. *J Vasc Interv Radiol* 2012; 23: 893–899.
9. Lakin RO, Bena JF, Sarac TP, et al. The contemporary management of splenic artery aneurysms. *J Vasc Surg* 2011; 53: 958–965.

10. Fankhauser GT, Stone WM, Naidu SG, et al. The minimally invasive management of visceral artery aneurysms and pseudoaneurysms. *J Vasc Surg* 2011; 53: 966–970.
11. Sessa C, Tinelli G, Porcu P, et al. Treatment of visceral artery aneurysms: description of a retrospective series of 42 aneurysms in 34 patients. *Ann Vasc Surg* 2004; 18: 695–703.
12. Pilleul F and Dugougeat F. Transcatheter embolization of splanchnic aneurysms/pseudoaneurysms: early imaging allows detection of incomplete procedure. *J Comput Assist Tomogr* 2002; 26: 107–112.
13. Loffroy R, Guiu B, Cercueil JP, et al. Transcatheter arterial embolization of splenic artery aneurysms and pseudoaneurysms: short- and long-term results. *Ann Vasc Surg* 2008; 22: 618–626.
14. Beaussier M. Sur un anévrisme de l'artère splénique dont les parois se sont ossifiées. *J Med Toulouse* 1770; 32: 157.
15. Hoegler F. Klinikdes Milzarterienaneurysmas. *Wien Arch Int Med* 1920; 1: 543–562.
16. Yadav S, Sharma P, Singh PK, et al. Giant splenic artery aneurysm: a rare but potentially catastrophic surgical challenge. *Int J Surg Case Rep* 2012; 3: 533–536.
17. Karsidag T, Soybir G, Tuzun S, et al. Splenic artery aneurysm rupture. *Chirurgia (Bucur)* 2009; 104: 487–490.
18. Akbulut S and Otan E. Management of giant splenic artery aneurysm: comprehensive literature review. *Medicine (Baltimore)* 2015; 94: e1016.
19. Yagmur Y, Akbulut S, Gumus S, et al. Giant splenic artery pseudoaneurysm: a case report and literature review. *Int Surg* 2015; 100: 1244–1248.
20. Al-Habbal Y, Christophi C and Muralidharan V. Aneurysms of the splenic artery - a review. *Surgeon* 2010; 8: 223–231.
21. Winkler V. Ein fall von milzexstirpation wagen aneurysma der arteria lienalis. *Zentralbl Chir* 1905; 1: 257.
22. Saw EC, Ku W and Ramachandra S. Laparoscopic resection of a splenic artery aneurysm. *J Laparoendosc Surg* 1993; 3: 167–171.
23. Sachdev-Ost U. Visceral artery aneurysms: review of current management options. *Mt Sinai J Med* 2010; 77: 296–303.
24. Bakhos CT, McIntosh BC, Nukta FA, et al. Staged arterial embolization and surgical resection of a giant splenic artery aneurysm. *Ann Vasc Surg* 2007; 21: 208–210.
25. Sticco A, Aggarwal A, Shapiro M, et al. A comparison of open and endovascular treatment strategies for the management of splenic artery aneurysms. *Vascular* 2016; 24: 487–491.
26. Probst P, Castañeda-Zuñiga WR, Gomes AS, et al. Nonsurgical treatment of splenic-artery aneurysms. *Radiology* 1978; 128: 619–623.
27. McDermott VG, Shlansky-Goldberg R and Cope C. Endovascular management of splenic artery aneurysms and pseudoaneurysms. *Cardiovasc Intervent Radiol* 1994; 17: 179–184.
28. Varnagy D, Sendzischew M, Hertz JA, et al. Endovascular management of a ruptured splenic artery aneurysm. *Vasc Endovascular Surg* 2007; 41: 68–72.
29. Larson RA, Solomon J and Carpenter JP. Stent graft repair of visceral artery aneurysms. *J Vasc Surg* 2002; 36: 1260–1263.
30. Carrafiello G, Laganà D, Dizonno M, et al. Endovascular ligation of splenic artery aneurysm with Amplatzer Vascular Plug: a case report. *Cardiovasc Revasc Med* 2007; 8: 203–206.
31. Góes Junior AM, Góes AS, de Albuquerque PC, et al. Endovascular treatment of giant splenic artery aneurysm. *Case Rep Surg* 2012; 2012: 964093.
32. Reed NR, Oderich GS, Manunga J, et al. Feasibility of endovascular repair of splenic artery aneurysms using stent grafts. *J Vasc Surg* 2015; 62: 1504–1510.
33. Yasumoto T, Osuga K, Yamamoto H, et al. Long-term outcomes of coil packing for visceral aneurysms: correlation between packing density and incidence of coil compaction or recanalization. *J Vasc Interv Radiol* 2013; 24: 1798–1807.

34. Ierardi AM, Petrillo M, Bacuzzi A, et al. Endovascular retreatment of a splenic artery aneurysm refilled by collateral branches of the left gastric artery: a case report. *J Med Case Rep* 2014; 8: 436.
35. Sangro B, Bilbao I, Herrero I, et al. Partial splenic embolization for the treatment of hypersplenism in cirrhosis. *Hepatology* 1993; 18: 309–314.
36. Liangpunsakul S, Ulmer BJ and Chalasani N. Predictors and implications of severe hypersplenism in patients with cirrhosis. *Am J Med Sci* 2003; 326: 111–116.