Proximal Splenic Artery Embolization for Blunt Splenic Injury: Clinical, Immunologic, and Ultrasound-Doppler Follow-Up

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Background: **To evaluate the clinical, US (ultrasound)-Doppler and hematologic findings after proximal splenic artery embolization (PSAE) for blunt injury.**

Methods: **From August 1998 to February 2003, 37 patients (28 men and 9 women; 20–89 years old, mean 40 years) underwent PSAE for blunt injuries. One patient required secondary splenectomy after PSAE. Early complications were investigated during the hospital stay. Delayed follow-up included review of the outpatient records, telephone interview, consultation, US-Doppler splenic study, Howell–Jolly body search, and serum antibody titer determinations (pneumococcus and *Haemophilus influenzae B*).**

Results: **No early postprocedural complications were depicted. Ten patients were lost on follow-up. Two patients had a telephone interview that revealed no complication. Twenty-four patients were examined 6 to 63 (mean 26) months after the embolization. No late complication was reported. Splenic measurements were in the normal range: length (53–110 mm; mean, 73), width (49–110 mm; 76), thickness (26–56 mm; 38), volume (61–508 mL; 226), standard ellipsoid formula volume (32–265 mL; 118), corrected volume (29–238 mL; 106), and splenic volumetric index (2.3–18.8; 8.4). The spleen was homogeneous in 23 patients (96%). Intrasplenic vascularization was present and splenic vein was patent in all patients. Howell–Jolly bodies were found in two patients. All patients (24 of 24) evaluated for exposure-driven immunity against Haemophilus Influenza b had sufficient immunity. Seventeen of the 18 patients (94%) evaluated for exposure-driven immunity against pneumococcus had sufficient immunity. Five of the six patients (83%) evaluated for pneumococcus vaccine response had a sufficient response.**

Conclusions: **Proximal splenic artery embolization in blunt splenic injuries is a well-tolerated technique without major long-term impact on the splenic anatomy and immune function.**

Key Words: **Spleen, Trauma, Interventional procedures, Embolization.**

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After blunt abdominal trauma, the spleen is one of the most frequently injured organs. Nonoperative management by means of strict bed rest and observation has been widely used and rapidly became the standard of care in hemodynamically stable patients. The major endpoint of nonoperative management is to save the spleen and preserve its functions, mainly the immune function that allows protection against overwhelming sepsis. Splenic artery embolization has been proposed as an adjunct to nonoperative management in the following conditions: (1) traumatic splenic injuries associated with vascular injury demonstrated by arteriography (i.e., contrast material extravasation, arteriovenous fistula, or pseudoaneurysm),[1,2] (2) American Association for the Surgery of Trauma (AAST) grade III to V splenic injuries[3] and/or splenic injuries associated with CT evidence of active contrast extravasation or blush.[4] Various techniques of splenic artery embolization have been reported, regarding the targeted site of occlusion (i.e., main splenic artery or intrasplenic branches) or the occluding agents (gelatin sponge pledgets or coils). However, the impact of splenic artery embolization on the spleen parenchyma, vascularization, and function has been poorly evaluated. Killeen et al. reported a large CT study mainly focused on infarcts after embolization.[5] Only scattered evaluations of splenic function after embolization, mainly using scintigraphy, are available.[6,7] As it mimics surgical splenic artery ligation, proximal splenic artery embolization (PSAE) does not theoretically impair the splenic function.[8–10] However, to our knowledge, there are no studies reporting the clinical follow-up, ultrasound (US)-Doppler findings, and immunologic status of patients after PSAE.

The purpose of this study was to report the clinical events, to characterize the US-Doppler appearance of the spleen, and to explore the immune function of the spleen after PSAE.

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PATIENTS AND METHODS

Patients

From August 1998 to February 2003, 37 consecutive patients underwent splenic arteriography and PSAE at our

institution. The indication for PSAE was AAST grade III to V splenic injuries and/or splenic injuries associated with CT evidence of active contrast extravasation or blush.

The patients (28 men and 9 women) ranged in age from 20 to 89 years (mean, 40 ± 17). Mechanisms of injury were motor vehicle crash (n = 25), fall (n = 8), assault (n = 3), and sport-related trauma (n = 1). The mean Injury Severity Score was 28.8 ± 2.9 (range 4–66). Three patients had coagulation disorders (anticoagulation therapy [n = 2], Von Willebrand disease [n = 1]) and one had a splenomegaly caused by chronic lymphocytic leukemia at time of embolization. One patient was HIV positive and another was hepatitis C virus (HCV) positive. All patients underwent an initial helical 8- or 16-row multislice CT (Lightspeed; General Electrics, Milwaukee, WI) after intravenous contrast material injection: the mean splenic injury CT grade was 3.7 ± 0.7 (range III–V), active contrast extravasation/blush was depicted in 14 patients (38%), and hemoperitoneum was depicted in 34 patients (92%).

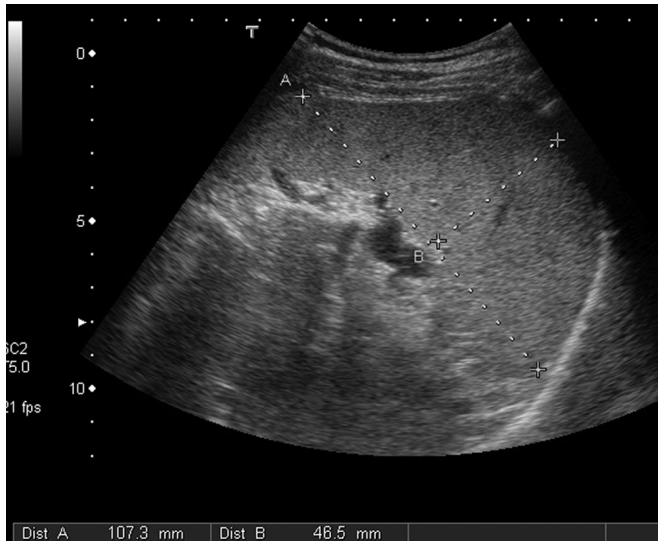

Fig. 1. *Axial US scan shows the spleen with measurements of* (A) *the width (107.3 mm) and* (B) *the thickness (46.5 mm).*

Technique of Embolization

Arteriography was performed by initially obtaining an anteroposterior celiac and splenic arteriogram. Then, the main splenic artery was selectively cannulated using 5-French catheters. Whenever necessary a coaxial 3-French microcatheter was used to place the tip of the catheter at least beyond the origin of the dorsal pancreatic artery. The embolization was performed using 0.035-inch coils or 0.018-inch microcoils (Tornado; Cook, Bjaeverskov, Denmark) placed in the proximal (i.e., main) splenic artery. The endpoint was a complete absence of opacification of the splenic artery distal to the coils, requiring a total of one to six coils or microcoils (mean 3.2). The procedure was then followed by bed rest and observation. Any complication occurring during the procedure (particularly coil migration) was recorded.

Follow-Up

Early Follow-Up (During Hospital Stay)

Patients underwent daily physical examination, vital signs monitoring, blood cell counts, and monitoring of hemoglobin and hematocrit levels. Medical records were reviewed to determine the outcome of patients, including the need for repeat arteriography, splenectomy, or any percutaneous intervention. We also recorded data regarding antibiotherapy and immunization against *S. pneumoniae* and *Haemophilus Influenzae* type b.

Delayed Follow-Up

Outpatient records were reviewed for delayed complications. At the end of the retrospective collection of data, all the patients were contacted by phone and asked to come for a consultation with an interventional radiologist. They were told to come with their vaccinations certificate and any information regarding medical consultation, infections, and antibiotics therapy. The patients were also informed that the consultation would include US-Doppler examination and laboratory tests, thus necessitating a 6-hour fast. When patients refused the consultation we performed a brief telephone interview focusing on infectious events, left flank pain, or any symptoms that necessitated medical consultation after PSAE.

During the consultation, the interventional radiologist performed the following:

- Asked for any fever, infection, or systemic antibiotic treatment;
- Recorded the indications and conclusions of any medical consultation, percutaneous intervention, surgery, or hospitalization;
- Recorded additional Pneumococcal or *H. Influenzae* type b vaccination; and
- Performed a US-Doppler using a portable sonograph SonoSite 180 (SonoSite, Bothell, WA) and a 5- to 2-MHz broadband curved array transducer. The US-Doppler examination was always performed and interpreted by a senior radiologist with at least 10 years of experience in abdominal ultrasound. The measurements were obtained on screen.

The US-Doppler study evaluated the following parameters:

1. The craniocaudal length (L), width (W), and thickness (T) of the spleen (Figs. 1 and 2), which enabled calculation of the so-called splenic volume ($L \times W \times T$), the splenic volume using the standard ellipsoid formula ($L \times W \times T \times 0.523$), the corrected volume ($14.23 + 0.469[L \times W \times T]$)[11] and the splenic volumetric index ($[L \times W \times T]/27$).[12]
2. The echomorphology of the spleen. Particular attention was accorded to the presence of heterogeneous echogenicity that can represent incomplete healing,[13] linear echogenicity band assumed to represent a scar,[13] hypoechoic

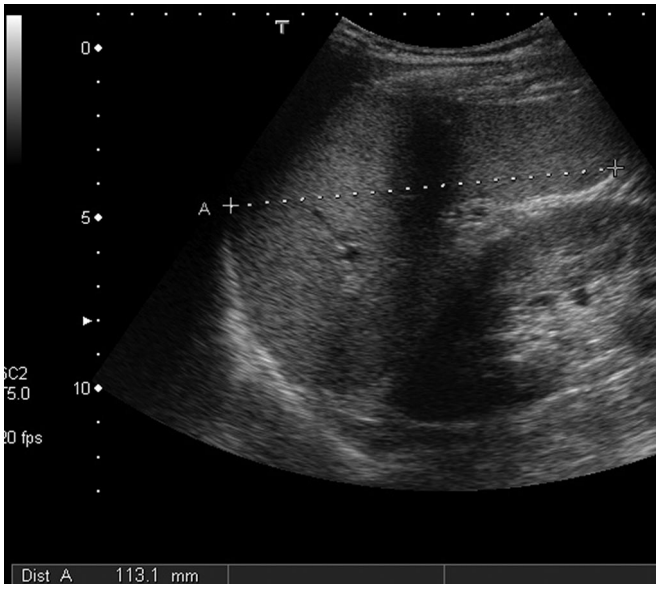

Fig. 2. *Sagittal US scan shows the spleen with measurement of the craniocaudal length (113.1 mm).*

collection that can be seen in abscess, anechoic structure presumably representing a posttraumatic cyst,[14] and intrasplenic air that can be seen in abscess.[15]

3. The presence of intrasplenic vascularization using color Doppler and Power Doppler was noted as present or absent.
4. The patency of the splenic vein and direction of the flow using directional color Doppler.

Immediately after the consultation, blood samples were collected for hematologic and immunologic tests.

Blood smears were stained by the May–Grunwald–Giemsa method for Howell–Jolly body search. Indeed, the absence of Howell–Jolly bodies in peripheral blood smears has been widely used as an indicator of persistant phagocytic, filtration function.[10,16]

Serum antibody to *H. Influenzae* type b were quantified by Enzyme Linked ImmmunoSorbant Assay (ELISA) on antigen-coated plates using validated laboratory procedures. Immunity was considered present if anti-*H. Influenzae* type b immunoglobulin G was $\geq$0.2 mg/L.

Serum antibody titers to three common pneumococcal serotypes (14, 19F, 23F), selected for their prevalence in Switzerland and for their higher, average, or lower relative immunogenicity were measured by ELISA. We used a modified ELISA protocol based on the third-generation consensus assay recently adopted by a World Health Organization expert group.[17] In the absence of well-defined normal values for antipneumococcal antibodies, conservative definitions were used. Evidence of normal exposure-driven antibody responses to pneumococcal polysaccharide antigens was defined by the presence of a minimal antibody titer of 0.5 mg/L, based on protective antibody titers against invasive infections in adults (0.25–0.3 mg antibody nitrogen/mL) and against nasopharyngeal colonization in children (0.2 mg antibody nitrogen/mL).[18] It is generally considered that at least half of the serotypes tested should have a concentration above predefined minimum values to allow for a possible lack of exposure to certain serotypes.[18,19] To allow for a possible lack of exposure to a given serotype, evidence of normal exposure-driven responses to *S. pneumoniae* was considered as demonstrated if antibodies were above threshold values for two or more of the three selected serotypes.[18–20] In the six patients that received the vaccine, evidence of a positive vaccine response was defined by a minimal postvaccination titer of 1 mg/L for two or more of the three serotypes tested. This value is slightly lower than the one previously reported (1.3 μg/mL)[19] before the recommendation of preadsorbing sera with both C-polysaccharide and polysaccharide of serotype 22F, which reduces antibody titers.[21]

Finally, patients were categorized as follows:

- Sufficient exposure-driven immunity against *H. Influenzae* type b: minimal titer of 0.2 mg/L.
- Sufficient exposure-driven immunity against *S. pneumoniae*: minimal titer of 0.5 mg/L for two or more of the three serotypes tested.
- Sufficient *S. pneumoniae* vaccine response: minimal titer of 1 mg/L for two or more serotypes tested.

Patients failing to reach these thresholds were considered as insufficient immunity patients.

RESULTS

All patients underwent PSAE without immediate complication. All the coils were delivered at the targeted site. None of the coils migrated distally into the hilum or intrasplenic branches or proximally into the splenic artery, celiac axis, or aorta.

Follow-Up Complications

Early Follow-Up

Thirty-six of the 37 patients (97%) treated with PSAE were successfully managed without surgery, enabling spleen salvage. All patients underwent only one procedure and no repeated angiography or embolization was needed. A 38-year-old man involved in a car crash required secondary splenectomy after PSAE. The Injury Severity Score was 41 and the initial CT scan had revealed a grade III splenic injury with active contrast extravasation and hemoperitoneum. Two days after PSAE, the patient suddenly experienced hemodynamic instability with systolic blood pressure $<$90 mm Hg and tachycardia. Exploratory laparotomy showed continued splenic hemorrhage that motivated a splenectomy.

Nine patients (25%) received broad-spectrum systemic antibiotics during the postprocedure period, mainly for associated open fractures.

On day 6 after PSAE, one patient complained of left flank pain and mild fever that were associated with moderate hyperleukocytosis. Abdominal CT examination showed mul-

tiple small gas bubbles in a splenic area fluid collection. A splenic abscess was suspected and percutaneously sampled under CT guidance. The fluid was macroscopically typical of hematoma and the culture did not indicate any abnormalities.

Four patients received a Pneumococcal vaccine during the first week after PSAE. None of the patients received either the *H. Influenzae* b or the Meningococcal vaccine.

Delayed Follow-Up

Review of the outpatient records of the 36 patients with spleen salvage did not depict any complication related to PSAE.

Among these 36 patients, 26 were contacted by phone and 10 were lost on follow-up. Two patients refused the consultation but telephone interview revealed no infection or complication after PSAE. Twenty-four patients came to the consultation 6 to 63 (mean 26) months after the embolization:

- One patient complained of a benign angina. Neither severe infection, nor unexplained fever was reported;
- No medical consultation, hospitalization, percutaneous intervention, or surgery because of delayed bleeding or a possible PSAE complication were recorded;
- Two patients had received Pneumococcal vaccine 2 months (n = 1) and 1 year (n = 1) after PSAE. None of the patients received additional *H. Influenzae* b.

The US-Doppler study was always technically feasible. The craniocaudal length, width, and thickness of the spleen ranged from 53 to 110 mm (mean, 73 ± 18), 49 to 110 mm (76 ± 17), and 26 to 56 mm (38 ± 7). The splenic volume ranged from 61 to 508 mL (226 ± 115), the splenic volume using the standard ellipsoid formula ranged from 32 to 265 mL (118 ± 60), the corrected volume ranged from 29 to 238 mL (106 ± 54), and the splenic volumetric index ranged from 2.3 to 18.8 (8.4 ± 4). The spleen was homogeneous in 23 patients (96%). In one patient, the US examination showed a 20-mm linear hypoechoic band. Intrasplenic vascularization was present in all patients. A patent splenic vein with physiologic flow was seen in all 24 patients.

Laboratory Tests

Howell–Jolly bodies were found in 2 of 24 patients. Twenty-four of 24 patients, in whom *H. Influenzae* B immunity was explored, demonstrated evidence of exposure-driven immunity. Seventeen of 18 patients explored for exposure-driven immunity to *S. pneumoniae* polysaccharides had levels of antigen-specific immunoglobulin G antibodies providing evidence of immunity, as did five of six patients in whom *S. pneumoniae* immunity was explored after immunization. The single nonresponding patient had chronic lymphocytic leukemia.

DISCUSSION

The optimal management of hemodynamically stable patients with blunt splenic injury remains controversial. Nonoperative management is widely considered as the standard of care, and generally involves bed rest, serial physical examinations, and serial hematocrit determinations. However, recent series described the usefulness of selective or proximal splenic artery embolization in selected patients.[1,2,4] In addition to the controversies regarding the indications and techniques of splenic embolization, there are concerns regarding the complications and the impact of the procedure on splenic function, which have been poorly studied, and the need for vaccination.

Reported complications of splenic artery embolization in trauma patients are abscess, infarcts, vascular iatrogenic injury, and coil migration.[1,2,5] In one of the largest series ever published (140 patients), Haan et al. reported abscesses in four patients (3%), a complication that we did not encounter.[1] In one patient of the current series, a splenic fluid collection containing multiple small gas bubbles suggesting abscess was percutaneously sampled to rule out infection. This case, and a recent series, suggest that air after embolization is a concern but does not necessarily constitute a sign of infection.[15] We did not evaluate the splenic infarcts that have been reported elsewhere as significant in 19% to 29% of proximal embolizations and 27% to 50% of distal embolizations.[1,5] It should be noted that these studies possibly overestimated the prevalence of infarcts that are also reported after splenic trauma in the absence of embolization.[22] Killeen et al. also demonstrated that proximal embolization is associated with less frequent and smaller infarcts than distal embolization.[5] We did not encounter any iatrogenic injury to vessels or coil migration, which are inherently associated with transcatheter embolization procedures. Splenic vein thrombosis could be another potential complication of PSAE. In the current study, the splenic vein Doppler examination was normal in all the explored patients. Color Doppler and Power Doppler study showed intrasplenic vascularization in all the patients and no evidence of image suggesting false aneurysm.

Our US-Doppler study also demonstrated that the spleen size and four volumetric measurements were in the normal range after PSAE.[11,12,23,24] These data suggest that no major or total infarct occurred after PSAE, and that there is residual splenic tissue after these procedures. The spleen was homogeneous in all but one patient (96%). In the latter patient, the US examination showed a linear hypoechoic band assumed to be a scar that might be attributed to embolization or simply to trauma.[13]

A few series, with a limited number of patients, have reported encouraging data regarding splenic function after distal and proximal embolization based on the absence of Howell–Jolly bodies or the normal uptake on technetium-99 scans, or both.[6,25] Moreover, experimental and clinical series also demonstrated the absence of Howell–Jolly bodies, normal uptake on technetium-99 scans, and normal clearance of opsonized red blood cells after splenic artery ligation, a surgical equivalent to PSAE.[8–10,26]

In the current study, Howell–Jolly bodies were found in two patients, suggesting a functional impairment of splenic

phagocytic function. However, these patients had 12- and 41-month follow-ups without evidence of infectious complication. Moreover, one patient had been vaccinated and showed sufficient *S. pneumoniae* vaccine response with antibody titers above 1 mg/L for all the three serotypes tested. The other patient had sufficient exposure-driven immunity against *S. pneumoniae* with antibody titers above 0.5 mg/L for all the three serotypes tested. These observations indicate that impaired splenic phagocytic function was rare after PSAE and that it was not associated with antigen-specific humoral deficiency.

Our immunologic study shows that all the patients (24 of 24) explored for exposure-driven immunity against *H. Influenzae* b had sufficient immunity. This essentially reflects the acquisition of *H. Influenzae* b immunity during childhood. Seventeen of the 18 patients (94%) explored for exposure-driven immunity against *S. pneumoniae* had sufficient immunity and only one had insufficient immunity. The latter was a 72-year-old woman who showed no evidence of infectious complications during the 36 months after the procedure. As it is not possible to conclude if the insufficient titers of antibodies reflected an insufficient immunity or an absence of recent exposition to *S. pneumoniae*, a pneumococcal vaccination was recommended.

Five of the six patients explored for pneumococcal vaccine response had a sufficient response and only the patient with chronic lymphocytic leukemia, a condition that is known to be associated with poor response to pneumococcal vaccine, had an insufficient response.[27] Whether this insufficient vaccine response is caused by the embolization or the leukemia can not be distinguished. In total, 22 of the 24 explored (92%) patients had satisfactory immunologic status after PSAE. In the two other patients, it was actually not possible to attribute definitively unsatisfactory immunologic status to embolization or another cause (i.e., absence of recent exposure to pneumococcus and hematologic disorder, respectively). Pneumococcal vaccine was only recommended in one patient.

This is, to our knowledge, the first reported series of clinical, US-Doppler, and immunologic follow-up after proximal splenic artery embolization for splenic injuries. The main limitations are the retrospective aspect of the study and the absence of a control population. Despite these limitations, our series shows that PSAE in severe blunt splenic injuries is a well-tolerated technique without major impact on the splenic anatomy and immune function. Large prospective studies are needed to confirm the absence of functional impairment after PSAE and allow a definite consensus regarding vaccination issues in embolized patients.

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