

The Role of Interventional Radiology in Splenic Trauma

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Abstract

The purpose of this case report is to discuss the different treatment options available in splenic trauma patients by following the story of Mr. H. I will focus particularly on the role of splenic arterial embolisation (SAE)—an interventional radiological procedure—and how it weighs up against its surgical counterparts. In order to give a balanced view this case report includes a literature review around splenic artery embolisation. This report concludes that when managing splenic trauma, interventional radiology (IR) is a useful tool particularly when used in conjunction with surgery. The future of this field needs to allow SAE to become a stand-alone therapy. Furthermore, research needs to investigate which cohorts of patients are best suited to which intervention such that we can capitalise on the advantages of each intervention for the benefit of all.

Keywords

Interventional Radiology, Spleen, Trauma, Surgery, Laparoscopy, Embolisation

1. Introduction

The spleen is an organ often forgotten about despite its numerous physiological roles and common injury following abdominal trauma. Management of a damaged spleen is therefore very important to understand and can take the form of medical, surgical, or radiological interventions. Which is the best to use and when should we use it?

Splenic embolization was first described by Maddison in 1973 [1]. It involves selectively disrupting the arterial blood supply at the end arterioles resulting in partial splenic infarction, decreased spleen size and increased circulating platelet count [2]. The current internationally accepted indication for SAE is the pres-

ence of extravasation of contrast medium detected on CT scan [3].

Current guidelines and research focus on SAE being offered to stable patients with low grade splenic injuries as an adjunct to non-operative management (NOM) [4] [5] [6].

However, given the many benefits that this procedure offers and its great potential, it is limiting to use it only as an adjunct to NOM. In order to fully identify its strengths and weaknesses, research needs to study SAE both in isolation as well as compared to other treatment modalities. The literature review included in the following case report aims to do this.

2. What Is the Spleen and Why Is It Important?

2.1. Anatomy

The spleen is an oval-shaped lymphoid organ located in the left upper quadrant of the abdomen between the ninth and twelfth ribs. It is approximately 12 cm long, 7 cm wide and 3 - 4 cm thick, weighing 150 g. It sits inferior to the diaphragm, posterolateral to the stomach fundus, lateral to the left kidney and superior to the splenic flexure of the colon. The spleen is held in place by the spleno-renal and gastrosplenic ligaments, formed by foldings of the peritoneum. Its surrounding capsule of thin grey connective tissue is thicker at the splenic hilum where arteries and nerves enter; and venous and lymphatic vessels leave.

The surrounding fibrous capsule stems many trabeculae that carry blood vessels into and out of the parenchyma. Attached to the trabeculae is a reticular fibre network providing the structural framework of the organ. The interstices of this network are filled with venous sinuses and the parenchyma—split into the lymphocyte-rich white pulp, and the red pulp [7] [8].

2.2. Function

In the red pulp, macrophages remove senescent erythrocytes and pathogens from the circulation. The inner white pulp is organised lymphoid tissue, here macrophages engulf antigens for presentation to T- and B-lymphocytes stimulating antibody-secreting plasma cell formation. Interestingly during foetal development, the spleen acts as a minor site of haematopoiesis however this function can reappear in adulthood as a compensatory mechanism in those with chronic anaemia [8] [9].

2.3. Blood Supply

Approximately 5% - 10% of the cardiac output reaches the spleen via the splenic artery, a branch of the coeliac artery. Within the spleen, the artery divides many times to supply the pulp as shown in **Figure 1**.

Whilst we know that the terminal arterial capillaries deliver blood to the splenic sinuses, the method of delivery is not completely understood. There are currently two theories of splenic arterial circulation: closed circulation and open.

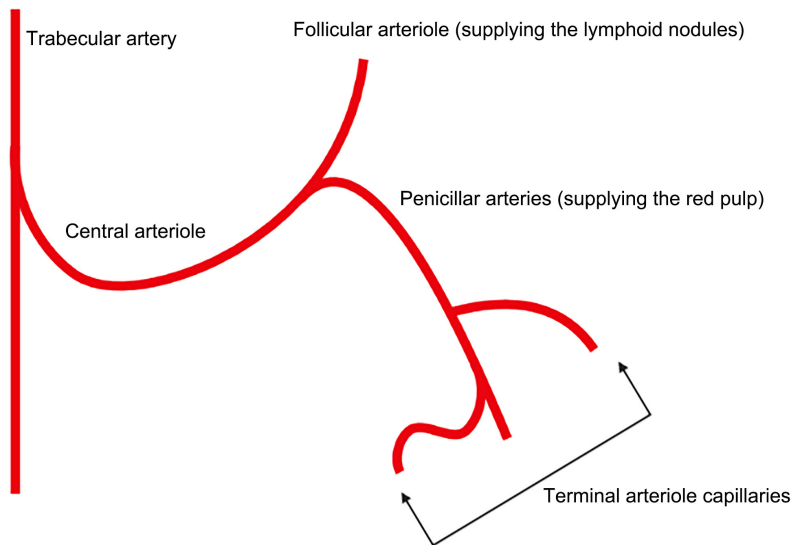


Figure 1. Example of the arterial branching tree within the spleen.

The closed circulation theory argues that the endothelial lining of the terminal arterial capillaries is continuous with that of the sinus [10]. On the other hand, the open-circulation theory states that the capillaries terminate before reaching the sinusoids, and blood drains through the red pulp into the sinuses [11]. That said, some believe that both systems co-exist – a combined open and closed circulation [12].

The splenic sinuses are drained by small veins of the pulp that merge to form the splenic vein, a tributary of the portal vein.

3. Splenomegaly

Splenomegaly is an abnormal increase in spleen size and is the most common clinical splenic abnormality. William Osler once said “nearly all diseases of the spleen are of a secondary nature” [13]. Thus, whilst splenomegaly is often the first manifestation of disease, even in 1908 Osler was aware that numerous different pathologies manifest as splenomegaly, making it a diagnostic challenge [14].

Radiologically we can classify splenomegaly as:

Moderate—the largest dimension is between 11 - 20 cm.

Severe—the largest dimension is greater than 20 cm [15].

The pathophysiology of splenic enlargement varies with aetiology. In the case of acute infection such as endocarditis, there is increased workload of clearing antigens and producing antibodies. The spleen responds by increasing its capacity of reticuloendothelial cells to compensate splenic hyperplasia.

The spleen can also enlarge due to a vascular change. As a result of long-term liver disease and cirrhosis, portal hypertension can occur. The splenic vein drains into the hepatic portal vein however in portal hypertension this becomes congested and thus the splenic vein engorges due to the backlog [16].

As mentioned earlier, the spleen may also re-assume a haematopoietic role in adults with chronic anaemia. This extramedullary haematopoiesis is often exhibited in myeloproliferative disorders and causes an increase in spleen size to accommodate the added function.

Finally, as with any organ in the body, the spleen is a potential site for infiltration. This may either be invasion of foreign cells such as metastases, or neoplastic changes within resident immune cells as seen in lymphoma [16] [17].

Complications

The most feared complication of splenomegaly is splenic rupture, usually caused by blunt abdominal trauma. In very thin individuals, the degree of trauma can be minor and may even be unnoticed.

The reason splenic rupture is so dangerous is because life-threatening intraperitoneal haemorrhage may follow. If there is associated hypersplenism also present, haemorrhage is even more dangerous due to thrombocytopaenia slowing clot formation [16].

4. Common Splenic Interventions

4.1. Splenectomy

If splenic rupture is severe to the extent that the spleen has been avulsed from its vascular pedicle, an emergency splenectomy would be necessary.

Splenectomy refers to the surgical procedure in which the spleen is partially or totally removed, this can be performed laparoscopically or open. Elective splenectomies favour a laparoscopic approach provided the spleen is not too big whilst the open technique is usually reserved for emergency trauma, or spleens which are massively enlarged [18] [19].

4.2. Other

For less severe damage, modern thrombostatic surgical or radiological techniques can sometimes permit partial preservation such that the entire spleen need not be removed.

5. Case Clinical History and Examination

The following section will discuss the case of Mr. H, a 54-year-old gentleman whose story forms the centrepiece of this report and allows a case-based view on splenic pathology and management.

Between April and June 2020, Mr. H noticed his urine had become more “sticky”. On presenting to his GP, a diagnosis of diabetes mellitus was confirmed by HbA1c. A full blood count performed at the same time showed a profound iron deficiency anaemia and on further questioning, it became apparent that the patient had also experienced weight loss and a few episodes of night sweats. As a result, the patient was referred to a haematology lymphoid clinic where a CT scan showed a moderately enlarged spleen and some enlarged abdominal lymph

nodes. CT-guided biopsy confirmed these changes to be due to a low-grade B-cell non-Hodgkin lymphoma. Due to being low grade, the initial management plan was to watch and wait.

By the end of January 2021 however, an MDT discussion decided that because the patient's symptoms were worsening it would be suitable to commence treatment with R-CVP (rituximab, cyclophosphamide, vincristine, and prednisolone).

In April, Mr. H suffered a fall out of bed landing on his front sustaining a left-sided chest and abdominal injury. His A&E clerking notes reported that he was pale and shivering with confusion, hypotension and a tender and distended LUQ abdomen. A CT abdomen showed a splenic laceration with active bleeding and a large volume haemoperitoneum. His notes showed that a prior abdominal ultrasound revealed splenomegaly of 17.6 cm. The patient was given a blood transfusion and referred to the surgical emergency unit where a joint decision was made for Mr. H to be managed with SAE under IR.

During the procedure, a focal active bleed was found at the lower splenic pole, supplied by multiple splenic branches. These were selectively cannulated with a co-axial microcatheter and embolised with multiple micro-coils. No further bleeds or abnormalities were seen and the splenic artery supply to the majority of the spleen was preserved. Mr. H suffered no post-procedure complications and on examination his abdomen was distended but soft with some tenderness on palpation but no signs of bleeding.

6. What SAE Is and Involves

Patients who injure their spleen can broadly be categorised into those who are unstable, and those who are stable. Unstable patients generally undergo laparotomy and splenectomy due to the emergent nature of the injury and the increased risk of mortality [20]. Stable patients with lower grade injuries are treated more conservatively with non-operative management (NOM), with or without SAE added as an adjunct to increase the success rate of NOM [20] [21] [22].

SAE can be categorised into two main types – proximal and distal. Proximal SAE (PSAE) acts to decrease systolic arterial perfusion pressure whilst simultaneously promoting haemostasis and healing due to maintenance of blood flow via collateral pathways. Distal SAE (DSAE) is more beneficial in cases of focal injury. Given that blunt splenic trauma more commonly causes a multifocal injury, it is unsurprising that PSAE is the more commonly carried out procedure [23].

Figure 2 shows the major blood vessels supplying the spleen. The splenic artery is one of three branches of the coeliac trunk. Its first large branch is typically the dorsal pancreatic artery which bifurcates into left and right branches; the left branch continuing as the transverse pancreatic artery. The second large branch of the splenic artery is the greater pancreatic artery.

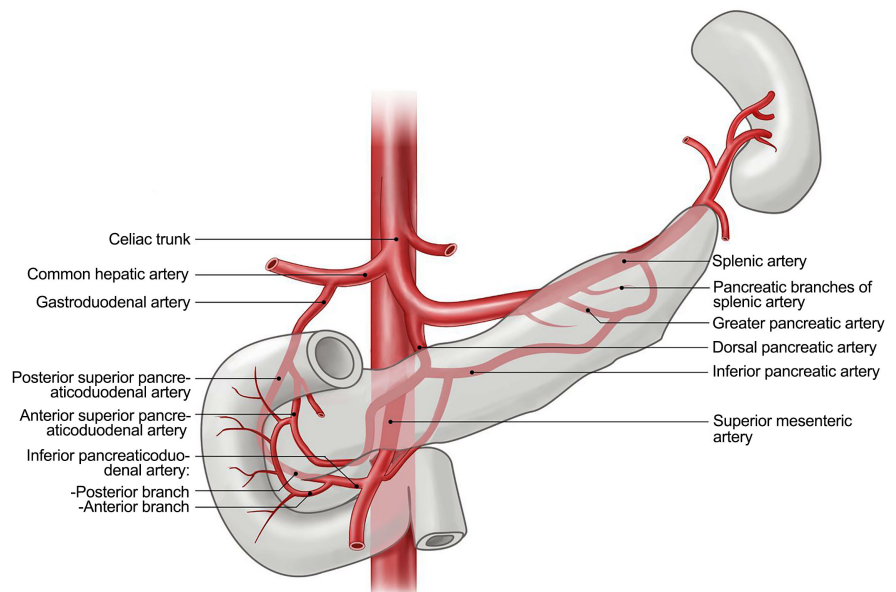


Figure 2. Major blood supply to spleen and surrounding structures Ref amboss.com.

Embolisation Technique

SAE is typically performed via a trans-femoral approach. The coeliac trunk is engaged using a 5 Fr reverse curve catheter. Coeliac angiogram is then performed, with images evaluating splenic artery patency, tortuosity, size, and pattern of injury. The other branches of the coeliac trunk are also evaluated as these will be important in supplying collateral perfusion to the spleen following PSAE.

To perform DSAE, a microcatheter and microwire are advanced to the site of the vessel injury and embolisation occurs with particles, glue (such as N-butyl cyanoacrylate), gel-foam and/or coils. For PSAE, vascular plugs and/or coils can be used between the dorsal pancreatic artery and great pancreatic artery. Alternatively, PSAE can be performed following DSAE, the rationale for this combined approach being that some vascular injuries may not be visible on initial angiogram and may lead to delayed bleed once vasospasm subsides [24] [25].

7. Literature around IR Embolisation

As mentioned earlier, other interventions for managing splenic pathology do exist, so why do we perform SAE?

7.1. Advantages of SAE

SAE has been shown to have numerous benefits in a wide number of settings. Vittorio et al showed that prophylactic SAE significantly improved platelet count in 80.8% of paediatric patients with thrombocytopenia. Furthermore, children with prior oesophageal varices showed improvement after SAE with only 34.6% requiring further endoscopic therapy. The group concluded that prophylactic SAE is a safe and effective alternative in the management of different groups of paediatric patients [2].

SAE also preserves functional spleen mass (and therefore immunological function) while avoiding post procedure acceleration of underlying liver disease [23]. This is supported by studies from Kis *et al.* who used IgM memory B cell levels as a quantitative measure of immunological function to show that long-term immune function is preserved in cancer patients post-SAE [23] [24]. A few years later, the same group showed that SAE improved platelet counts in cancer patients despite different aetiologies of splenomegaly [23]. Other groups have also confirmed the absence of Howell-Jolly bodies in patients post SAE thus confirming preserved splenic phagocytic function.

Splenic insufficiency due to splenectomy has the major clinical manifestation of an increased susceptibility to sepsis caused by encapsulated bacteria such as pneumococci, meningococci, and *Haemophilus influenzae*. This is due to the decrease in phagocytic capacity and antibody production. All asplenic individuals therefore must be vaccinated against these agents to reduce septic risk. Since SAE does not result in asplenia, these problems are completely avoided reducing future hospitalisations and deaths due to septic complications.

The procedure itself is much less invasive compared to surgical management. This has benefits on two fronts, first it gives SAE the versatility of being performed in both emergent and elective settings. Second it allows for faster recovery, reduced hospitalisation time and radiation dose from repeated imaging and ultimately reduced cost [25].

On the topic of cost, studies by Yip *et al* have shown that splenic embolisation is a low-cost procedure when compared against previously modelled data from overseas studies. The use of ICU for monitoring after a procedure significantly increases its cost, hence surgical interventions are more likely to be more expensive [25].

Parihar *et al* showed that patients who underwent SAE followed by NOM had a significant increase in haemoglobin, haematocrit levels and systolic blood pressure compared to those who were only managed with NOM. The mean length of hospital stay was lower in the SAE group and the need for secondary splenectomy was significantly lower as well. The authors suggested that this difference may be due to better haemostasis, facilitation of clot formation, and earlier healing achieved by SAE. On the other hand, patients managed with NOM may have continuous ongoing bleeding from the injured spleen leading to delayed and slowed healing [21].

Overall, there are clearly numerous benefits of SAE. It is for these many reasons that groups such as Clements *et al* argue that SAE should become a stand-alone treatment option for splenic trauma as opposed to an adjunct to NOM [26]. This also adds to the bigger picture of the rising predominance of IR as a field and how this fast-growing specialty will soon be performing a lot of unique procedures that will change the world of surgery.

7.2. Disadvantages of SAE

It would be blind to assume that SAE is a technique without faults. The follow-

ing section will discuss some of the negative aspects of SAE.

As with any procedure, SAE does have risks and complications attached to it. Many post-op patients, suffer from transient abdominal pain, distention and fever secondary to perisplenic abscesses [27].

More severe complications include splenic rupture and infarction; pancreatic infarction; severe hepatic insufficiency; and cardiac insufficiency all of which can cause death.

Duchesne *et al.* reported a higher incidence of acute respiratory distress syndrome (ARDS) after SAE, something that is concerned about now more than ever given the association of ARDS with Covid-19 related deaths [26]. A theoretical disadvantage of SAE is re-bleeding distal to the coils/plugs. This would necessitate re-intervening endovascularly through collaterals to perform subsequent embolisation, thus adding on the risks of further interventions [27].

Furthermore, it could be argued that another disadvantage of SAE is the exposure to ionising radiation, particularly to the operators. However, to counter this, a recent study by Omer *et al.* showed no significant short-term danger to the health of personnel by placing TLD dosimeters at different body areas [22].

All these aside however, the worst fact of all is that the potential long-term complications resulting from SAE are unknown in the trauma population and what we do not know, we cannot protect our patients against [28].

8. Is IR the Saviour of the Spleen?

How does IR SAE compare against its surgical counterparts? 30 years ago, the world of surgery was celebrating the innovation of laparoscopic techniques, has IR made those redundant?

Some of the benefits of SAE over surgery have already been mentioned such as the reduced invasiveness of IR as well as the functional splenic mass that is left over. Both allow for faster recovery and fewer long-term complications associated with asplenia [14]-[19]. For such reasons, many trauma centres are now performing more embolisation procedures than splenectomies [21] [25].

However, to say that SAE is better than a surgical approach is too simplistic.

Before the rise of IR, splenectomy was commonly performed in cases of splenomegaly increasingly laparoscopically. The advantages of such minimally invasive surgery were dramatic on their impact on postoperative pain, morbidity, and length of hospitalisation. The views that modern laparoscopes allow, give clarity in viewing anatomical structures allowing careful navigation around the many splenic vessels, such that they can be safely and appropriately ligated and transected [13].

Where laparoscopic splenectomy (LS) is a weaker intervention are in cases of massive splenomegaly where open splenectomy (OS) is a safer alternative. In fact, studies have shown that the most dangerous operations were those where initial LS had to be converted to OS due to the large size of the spleen [27]. Thus, spleen size is a very important factor when deciding which intervention will be the most beneficial [12] [28].

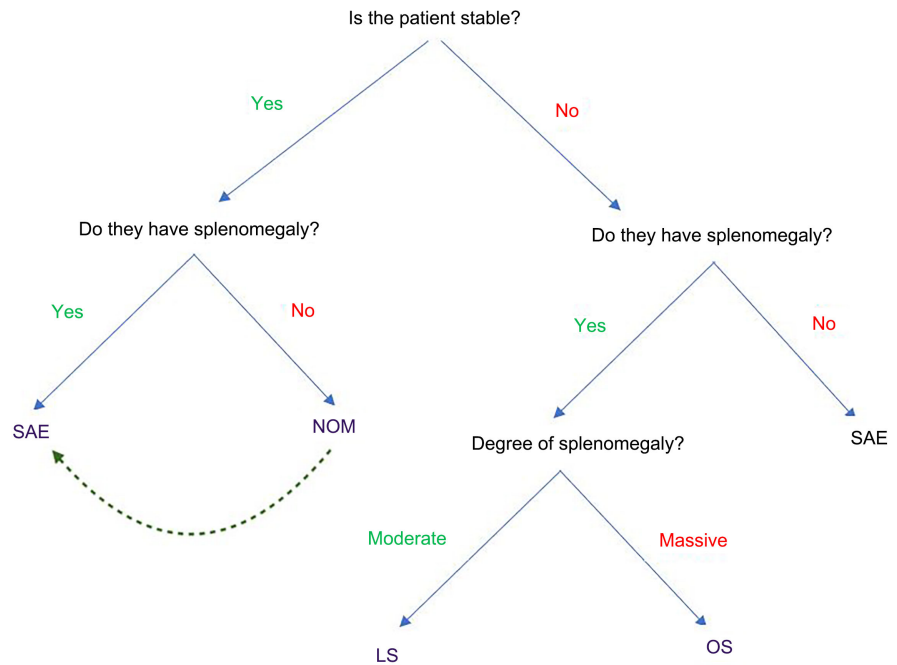


Figure 3. Flowchart suggesting a method of dividing the different managements of splenic laceration dependent on patient stability and degree of splenomegaly. * Massive splenomegaly represents a spleen exceeding 1000 g of weight and 20 cm in greatest dimension [30]. Alternatively, one can use a radiological criterion [9]. SAE: splenic artery embolisation; NOM: non-operative management; LS: laparoscopic splenectomy; OS: open splenectomy.

It is also important not to forget the importance of NOM and the large shift towards NOM in the past decade. The benefits include there being even less risk of infection with encapsulated bacteria compared to SAE. Furthermore, it can be helpful in cases where a patient may not be fit enough for invasive intervention.

The disadvantages of NOM include a risk of delayed splenic rupture, the possibility of re-bleeding as well as complications of embolisation. A more niche point is that unlike with surgical intervention, with NOM there is no intra-operative view that can be obtained of other visceral organs allowing less of an assessment of overall disease progress [15].

9. Conclusions

A study in 2016 showed that just under 200,000 people die each year from injury, 1 person every 3 minutes [29] [30]. The prevalence of intra-abdominal injury amongst emergency department patients is around 15%, and the spleen is the most injured organ in blunt abdominal trauma [30] [31].

This case report has used the example of Mr. H to discuss the different managements of splenic laceration. We have seen that SAE is becoming increasingly popular due to its reduced invasiveness, minimal splenic disruption, and faster recovery times with fewer post-op complications. That said, its surgical counterparts are still advantageous depending on both the degree of splenomegaly, and the stability of the patient.

The future of this field therefore needs to allow SAE to become its own stand-alone therapy rather than just being an adjunct to NOM. Furthermore, research needs to investigate which cohorts of patients are best suited to which intervention such that we can capitalise on the advantages of each intervention for the benefit of all. **Figure 3** shows one example of how we may divide up these interventions, it could be altered to fit different criteria such as AAST grade of injury.

Hopefully, this report has made it clear that regarding management of the spleen, IR is a rising star but currently I do not believe that it can replace surgical intervention altogether.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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