Use of Splenic Artery Embolization as an Adjunct to Nonsurgical Management of Blunt Splenic Injury

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Background: Splenic artery embolization (SAE) has been used as an adjunct to the nonsurgical treatment of blunt splenic injuries since 1981. It is imperative to define the role of SAE in the management of splenic trauma and to establish a guideline for its use.

Methods: In this study, 39 consecutive patients with blunt splenic ruptures were evaluated. All the patients were treated according to the authors' protocol, which included SAE as an adjunct. Angiographic study was performed for patients with any of the following presentations: recurrent hypotension despite fluid resuscitation, significant hemoperitoneum or extravasation of contrast media on computed tomography, grade 4 or 5 splenic injury, or progressive need for blood transfusion. Laparotomy was reserved for patients with unstable hemodynamics or failure of SAE.

Results: Four patients were excluded from the study, and 6 of the 35 remaining patients (male-to-female ratio, 22:13) received SAE. One of the six SAE patients underwent operation because of persistent hemorrhage after SAE. Nonoperative treatment was successful for 31 patients. Splenic artery embolization increased the success rate for nonsurgical management from 74% (26 of 35 patients) to 89% (31 of 35 patients).

Conclusions: Judicious use of SAE for patients with blunt splenic injury avoids unnecessary surgery and expands the number of patients who can retain their spleen.

Key Words: Nonsurgical management, Splenic injury, Splenic artery embolization (SAE).

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Splenic injury is a common finding in patients after blunt abdominal trauma, and the use of abdominal computed tomography (CT) scan for stable patients has helped to increase the accuracy of this diagnosis. An abdominal CT scan is a reliable method for identifying hemoperitoneum and staging splenic injury. It also is a useful way to exclude other associated injuries.[1–3]

In the early 1990s, splenectomy was the treatment of choice for splenic ruptures. Because overwhelming postsplenectomy infection has occurred, along with its associated high mortality, surgeons make every effort to preserve the spleen using various surgical and nonsurgical approaches.[1,3–6] Moreover, during the past decade, the treatment of splenic rupture has been switched to nonsurgical management for most cases.[1,3,4]

Although an abdominal CT scan is an effective diagnostic tool for splenic injury, it still has drawbacks, such as interobserver variability and inability to detect ongoing bleeding that needs further intervention.[2,7,8] Splenic artery embolization (SAE) was first introduced by Sclafani[9] for splenic injuries in 1981. Its use thereafter was expanded by some centers.[2,7,10,11] Currently, the use of SAE still is limited because there is no consensus on the role of SAE as an adjunct to the nonoperative treatment of splenic injury.[7,10,11] It is essential to define the indications of SAE for patients with splenic ruptures, and to establish a guideline for its use as an adjunct to nonsurgical management. This article presents the authors' experience with the nonsurgical approach to blunt splenic injury, focusing on a new management algorithm that uses SAE as an adjunct to treatment.

MATERIALS AND METHODS

From January 2001 to June 2002, 39 consecutive adult patients 18 years of age or older with blunt splenic rupture diagnosed by abdominal CT scan or laparotomy findings and treated at the authors' institution were evaluated. All the patients with blunt abdominal trauma were initially assessed and resuscitated in the emergency department according to the advanced trauma life support (ATLS) guidelines. The patients with stable hemodynamics and those who became stable rapidly after resuscitation underwent an abdominal CT scan as indicated. The severity of splenic injury was graded according to the classification of the American Association for the Surgery of Trauma.[12]

In their institution, the authors have followed a protocol for the nonsurgical management of patients with splenic injuries since 1995. At the beginning of 2001, they revised the algorithm for blunt splenic injury (Fig. 1). Their selection of patients for a nonsurgical approach in this study was based on the following criteria: hemodynamic stability at admission or shortly after initial resuscitation, maintenance of hemody-

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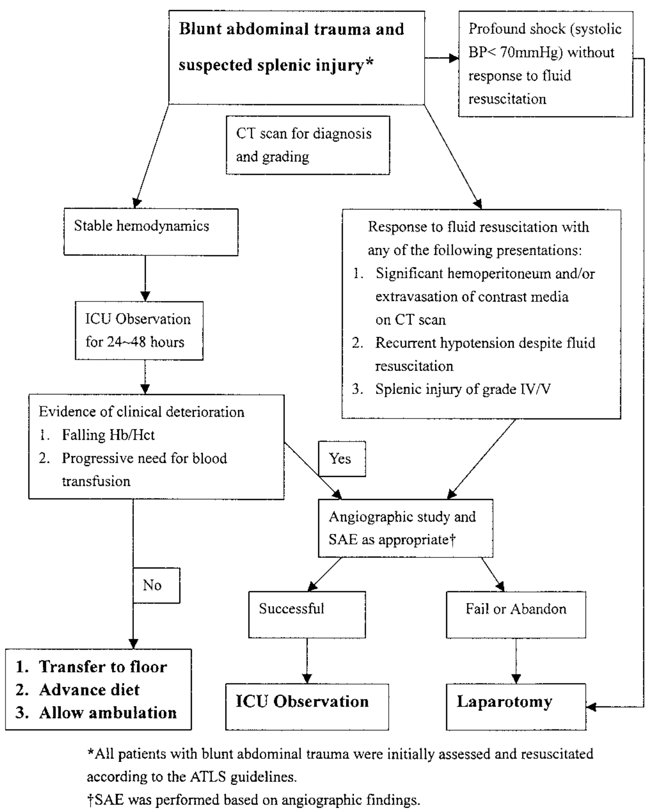

Fig. 1. *Algorithm for blunt splenic injury.*

namic stability without the need for excessive blood transfusions (less than 1,000 mL of red blood cells), no obvious peritoneal signs, no decreased sensorium at physical examination, and no associated multiple traumas requiring immediate surgical management.

All the patients considered as candidates for a nonsurgical approach were admitted to the intensive care unit for close hemodynamic monitoring, strict bed rest, frequent hemoglobin and hematocrit measurements, and sequential abdominal evaluations. In January 2001, the authors began using angiographic studies for patients who had one or more of the following presentations: significant hemoperitoneum or extravasation of contrast media on CT scan, recurrent hypotension despite fluid resuscitation, grade 4 or 5 splenic injury, and falling hematocrit level and progressive need for blood transfusions (Fig. 1). Significant hemoperitoneum was defined as three or more collections of blood in the peritoneal cavity (right or left subphrenic spaces, right or left paracolic gutters, and pelvic cavity). According to the old criteria, these patients did not meet the criteria for nonsurgical therapy. However, as part of their new criteria, the authors used SAE as another option for avoiding unnecessary surgery. The trauma surgeon in charge decided whether the use of angiography was appropriate and supervised the procedure. The authors considered that angiography should be performed early after initial stabilization of the patients if the criteria were met. In the case of rapid clinical deterioration, the procedure was abandoned, and the patient underwent immediate emergency surgery. Splenic preservative techniques were attempted during surgery, if feasible, on the basis of surgical findings and patients' conditions. Patients with hematologic disorders, such as a tendency for bleeding, or severe cardiovascular disease were excluded as unsuitable candidates for nonsurgical management or SAE. Before angiographic study, the authors explained the conditions and their plan to the patients and the family, if available, and obtained consents for these cases.

The angiographic study included conventional and digital subtraction angiography. First, an abdominal aortagram was obtained. Next, celiac and splenic arteriograms were obtained after administration of 76% iopamidol. The patients were divided into five groups on the basis of angiographic findings according to the modified classification.[10] The angiographic findings were (1) extravasation of contrast media extending beyond the splenic parenchyma, (2) extravasation within the splenic parenchyma, (3) abnormal vasculature without extravasation such as disruption of terminal arteries, (4) a variable degree of avascularity and irregularity in accumulation of contrast media, and (5) displacement of intrasplenic arterial branches resulting from subcapsular hematoma. The authors routinely considered SAE for patients with conditions 1, 2, 3, and 4.

The SAE technique used mainly a microcatheter for selective embolization by stainless steel coils. Sometimes small pledgets of gelform were applied or a combination of both methods for occlusion of bleeding vessels. The authors preferred to occlude the bleeder selectively with coils, which is different from the method described by Sclafani et al.[2] If no obvious bleeder was found, as in patients with condition 4, an attempt was made to embolize the focal distal branches of the splenic artery using small pledgets of gelform. Finally a splenic arteriogram was repeated to confirm the success of SAE. After successful SAE, the patients were observed closely in the intensive care unit for 24 to 48 hours and treated with prophylactic broad-spectrum antibiotics for 7 days. If SAE failed, emergency laparotomy was performed.

All SAE patients underwent an ultrasound follow-up examination 1 week later, and a CT scan 1 month thereafter. All the patients underwent splenic function evaluations by peripheral blood smears on days 7 and 30 and technetium-99 scans on day 30, if available. No other studies of immune function, such as T-cell function and circulating tuftsin levels, were performed because these studies are not routinely performed in the authors' hospital, and were not necessary for patients whose splenic function was kept intact after selective SAE.

The data were analyzed using Student's t tests, χ^2 tests, and Mann–Whitney U tests. A p value of 0.05 or less was considered significant.

Table 1 Demographic Profile of 35 Patients With Blunt Splenic Injury

	Nonsurgical Group	Surgical Group
Number of patients (M/F)	31 (19/12)	4 (3/1)
Age (years)	38 ± 15[a]	42 ± 9[a]
ISS	19.7 ± 15.3[a]	46.0 ± 18.7[a]
CT grade	2.5 ± 1.0[a]	3.3 ± 0.4[a]
SBP at presentation (mm Hg)	118 ± 26[a]	85 ± 30[a]
Mean transfusions (mL)[b]	444	688

ISS, Injury Severity Score; CT, computed tomography; SBP, systolic blood pressure.

[a] These results are reported as mean ± standard deviation.

[b] Total amount in the first 72 hours.

RESULTS

A total of 39 patients with blunt splenic injury were evaluated. Four patients were excluded because they had sustained multiple traumas and needed immediate surgical management (1 for severe liver laceration and shock, 2 for bowel perforation, 1 for pancreatic transection and peritonitis). Of the 35 remaining patients, 22 were male and 13 were female. Four patients underwent surgical management (3 splenectomies and 1 splenorrhaphy). The mean Injury Severity Score (ISS) in the surgical group was 46 ± 18.7, and the mean injury grade by CT was 3.3 ± 0.4. The mean ISS of the nonsurgical group was 19.7 ± 15.3, and the mean CT grade was 2.5 ± 1.0 (Table 1). There was a significant difference in the mean ISS between the nonsurgical and surgical groups. This implied that patients with more severe, multiple injuries usually underwent surgical treatment, as reflected by the ISS.

Six patients (4 males and 2 females) underwent angiographic study. The main reason for angiography was significant hemoperitoneum (1 patient), grade 4 splenic injury and contrast media extravasation (2 patients), significant hemoperitoneum and grade 4 splenic injury (2 patients), and a falling hematocrit level and progressive need for blood transfusion (1 patient) (Table 2). Delayed splenic rupture was diagnosed for two of six SAE patients, and both were treated successfully with SAE. Only one of the SAE patients needed surgical intervention for persistent bleeding (Table 2). The authors used SAE to increase the success rate for nonsurgical management from 74% (26 of 35 patients) to 89% (31 of 35 patients). Overall splenic salvage was possible for 91% of the patients (32 of 35). There were no immediate deaths related to splenic injury in the series. However, three late deaths were the result of multiple trauma complicated by sepsis (n = 2) and severe head injury (n = 1).

Although splenic injury grade by CT scan cannot accurately predict the outcome for patients, the authors believe that CT findings are a useful guide for patient management. For example, one patient (SAE 4) showed contrast media extravasation on CT scan and underwent an immediate angiographic study in the emergency department. The results of the angiographic study showed a pseudoaneurysm with contrast media extravasation located in the superior segmental branch of the splenic artery. Selective embolization with coils was performed successfully (Fig. 2).

One patient (SAE 2) with condition 4 angiographic findings received SAE by gelform cubes in the emergency department. The post-SAE radiograph showed no more bleeding, but the patient underwent surgery 2 days later because of a falling hematocrit level and suspicion for persistent bleeding. During surgery, a ruptured intraparenchymal hematoma with active oozing was found. Because the attempt at splenorrhaphy failed, the patient underwent a splenectomy. All the SAE patients were discharged without complications, and five successful cases showed normal splenic function by peripheral blood smear, spleen scan study, or both.

DISCUSSION

In the past, the standard treatment for splenic injury was splenectomy. However, it is well known that both asplenic children and adults have an increased risk for overwhelming

Table 2 Clinical Characteristics of Patients Undergoing Splenic Artery Embolization (SAE)

Patient	Gender	Age (years)	CT Grade/Indications for Angiography	Angiographic Finding per Group	Technique for SAE	Result of SAE	Complications
1	F	62	III/SH	1	Coils, selective embolization	Successful	None
2[a]	M	49	IV/SH	4	Gelform cube	Failed (splenectomy)	Thrombocytosis
3[a]	M	29	IV/SH	2	Coils, selective embolization	Successful	None
4	M	39	IV/CE	1	Coils, selective embolization	Successful	None
5	F	57	III[b]	1	Coils, selective embolization	Successful	None
6	M	27	IV/CE	4	Coils, selective embolization	Successful	None

SH, significant hemoperitoneum; CE, contrast media extravasation.

[a] Delayed splenic rupture.

[b] Progressive need for blood transfusion.

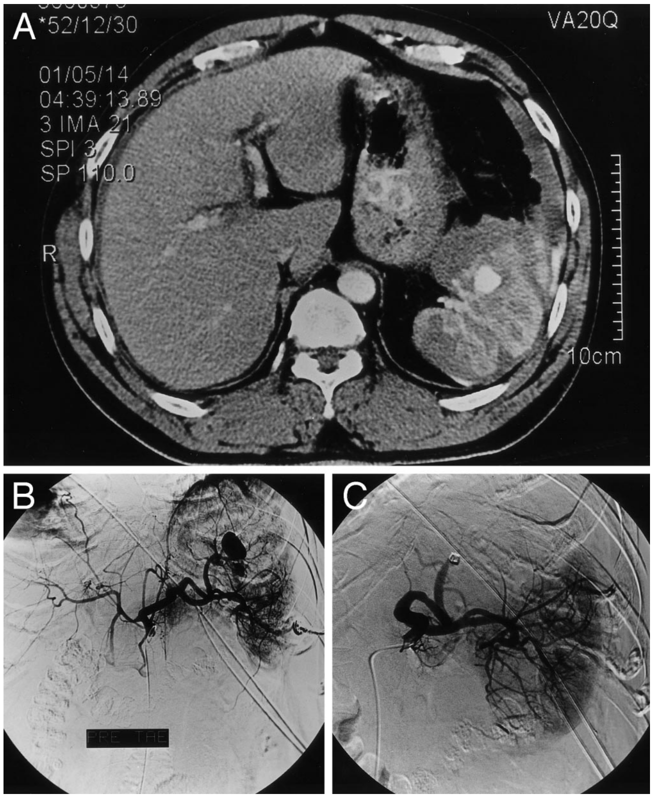

Fig. 2. *(*A*) Computed tomography scan of splenic artery embolization in (SAE) patient 4 showing a grade 4 splenic injury with contrast media extravasation. (*B*) The angiographic study demonstrates a pseudoaneurysm of the superior polar branch of the splenic artery. (*C*) After selective embolization of the pseudoaneurysm with coils, the post-SAE radiograph shows no contrast media extravasation.*

postsplenectomy infection and early postoperative complications including pneumonia, subphrenic abscess, pancreatitis, and the like.[4,13] In terms of the immunologic aspect, the spleen functions as a filter, removing particulate antigens, bacteria, and old red cells from circulation. The spleen also produces important mediators such as immunoglobulin M, tuftsin, and properdin.[4] The role of the spleen in the immune response has prompted the use of various methods to salvage the injured spleen.[1,4,5] In addition to the development of splenic preservation techniques for use during surgery, nonsurgical approaches for blunt splenic injury have been used for both children and adults. These techniques have a success rate that reaches 90%.[1,2,4,14,15] Recent studies have helped in the development of guidelines that can be used to select patients suitable for nonsurgical therapy, and most surgeons make every effort to reduce the incidence of splenectomy and its associated complications.[13–19] The current recommendation for adult and pediatric patients with splenic injuries is nonoperative management if they are hemodynamically stable and have no other injuries requiring laparotomy.[4,5]

Abdominal CT scans are widely used in the assessment of patients with abdominal trauma. These CT scans provide a reliable way to estimate the amount of hemoperitoneum, to stage splenic injury, and to exclude associated injuries that may require surgery.[1,4,5] However, CT scans still have drawbacks that limit their general use, and they do not indicate whether the source of bleeding is arterial, venous, or parenchymal. Neither can they show the presence of persistent bleeding. Many previous reports have shown that abdominal CT scans are inaccurate in estimating the severity of splenic injury.[2,7–10]

Angiography for further study and embolization for hemostasis have been described as effective tools that increase the success rate for patients undergoing a nonsurgical approach to splenic injury.[2,5,7,10,11] In 1981, Sclafani[9] first reported the splenic artery infusion of Pitressin, gelform pledget embolization, and coil occlusion of the proximal splenic artery as hemostatic methods for splenic injury. He concluded that coil occlusion of the proximal splenic artery was the best method for splenic hemostasis. In 1995, Sclafani et al.[2] reported a larger SAE series, in which angiography was used for triage and embolization for hemostasis. Their results showed that the absence of extravasation on angiography was a reliable indicator of successful nonsurgical therapy, and none of these patients needed delayed laparotomy for recurrent or persistent hemorrhage. These researchers concluded that SAE expanded the number of patients who can be managed nonsurgically.[2]

In their institution, the current authors set up criteria for the nonsurgical management of blunt splenic trauma in 1995. Their success rate for the nonsurgical treatment of adult patients reached 78% (unpublished data). Their initial results were comparable with the results of others described in the literature, although the use of angiographic studies was not included in their protocol at the beginning. Beginning in 2001, they tried SAE as a rescue therapy for patients who were not suitable candidates for nonsurgical therapy according to the nonsurgical criteria. They currently use SAE selectively, and the surgeon must supervise the whole procedure. Their radiologists are on call 24 hours and can complete SAE in 1 to 2 hours. Good communication between surgeons and radiologists is the key to success. The operating room is prepared at the same time, and surgery can be performed immediately if SAE fails or is abandoned because of rapid clinical deterioration of the patients. Angiographic study is not routinely used because most patients with blunt splenic injury can be managed successfully by bed rest and close observation alone, and no further procedures are necessary for hemostasis,[1,2,4] and because this invasive procedure may result in serious complications such as anaphylactic shock resulting from an allergic reaction to contrast media and delayed surgical treatment. From the beginning of this study, the authors assumed that angiographic study for all patients with splenic injury was not cost effective, and that it should be applied selectively. The results at the end of this study showed that only 17% (6 of 35) of the study patients needed further interventions for hemostasis.

The authors' technique for SAE differs from that described in previous reports. Their radiologists are skilled at performing SAE and prefer selective embolization of the bleeder with coils. This is because they have extensive experience in selective arterial embolization for cases of hepatoma treated with transcatheter arterial embolization as supplementary treatment and for cases of hypersplenism treated with partial splenic embolization. The authors believe that selective embolization of the bleeder with coils maintains the splenic immune function and achieves hemostasis more completely. In this study, the use of SAE raised the success rate of nonsurgical therapy from 74% to 89% for adult patients. The SAE success rate for splenic injury was approximately 87%, and only one SAE patient with grade 4 splenic injury underwent laparotomy and splenectomy. The failure of SAE for this patient may be attributable to the fact that no definite bleeder was detected by SAE initially and gelform pledgets were used instead of coils. Partial splenic infarct complicated by abscess formation may occur after SAE, but the authors believe the use of broad-spectrum antibiotics for 7 days after SAE will reduce the incidence of complications. The management for splenic infarct usually is conservative. Splenic abscess needs treatment with antibiotics in combination with percutaneous drainage or even splenectomy.

Currently, the authors even expand their protocol for patients who sustain multiple trauma such as closed long bone fractures and chest trauma, which do not need immediate operation. Most patients with multiple trauma may present with recurrent hypotension after initial resuscitation, but the causes usually are multiple and difficult to distinguish. Under such circumstances, the trauma surgeon should evaluate patients carefully and decide whether nonsurgical management of the splenic injury is appropriate. Currently, the authors do not have a clear sense of the circumstances in which SAE may be performed for hemodynamically unstable patients. According to their current policy, all patients with unstable hemodynamics are treated in the operating room because their safety is of utmost importance. Although intraoperative angiography and embolization seem promising, this approach still requires further evaluation. At this writing, the authors have no experience with SAE for grade 5 splenic injuries. Knudson and Maull[4] suggest operative exploration for patients with these injuries. In the opinion of the current authors, SAE should be used for high-grade splenic injury if stable hemodynamics of the patient can be maintained and the trauma surgeon supervises the procedure in person.

In summary, with this study, the authors establish a new protocol, which includes SAE as an adjunct for the management of blunt splenic injury. They prove that SAE is an effective tool for both hemorrhage control and preservation of splenic function in selected cases. The success of SAE is based on the teamwork between surgeons and radiologists, and a competent surgeon should supervise the procedure. In conclusion, judicious use of SAE for patients with blunt splenic injury avoids unnecessary surgery and expands the number of patients who can retain their spleen.

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EDITORIAL COMMENT

Nonoperative management has become widely accepted as the treatment of choice for hemodynamically stable patients with blunt splenic injury. The development of standardized organ injury scaling systems and the identification of clinical (e.g., age > 55 years, coagulopathy) and radiographic criteria (vascular blush, hemoperitoneum) associated with failure of nonoperative management have allowed trauma surgeons to develop highly successful nonoperative management algorithms.[1–5] More recently, transcatheter embolization of the splenic artery and/or its branches has been used as an adjunct to nonoperative management of the injured spleen.[5–8]

Implicit in the nonoperative management of blunt splenic injury is that mortality caused by hemorrhage from the injured spleen must be essentially zero. Additionally, immune and reticuloendothelial function should be preserved because they represent the medical rationale for salvage of the injured spleen. Ideally, adjunctive therapies for splenic salvage should not disproportionately increase transfusion requirements, cost of care, or disability.

Although angiographic embolization has become an accepted modality to control arterial bleeding in injured patients with severe hepatic and pelvic trauma, its role in the management of traumatic splenic injury remains controversial. The clinical and radiographic criteria that predict benefit from angioembolization in patients with blunt splenic injury remain incompletely defined. Sclafani et al. used angiography with proximal splenic artery embolization liberally in patients with blunt splenic injury.[6] However, 30% to 82% of patients with blunt splenic injury had no extravasation in this study, and the effects of embolization on splenic function were not examined.[6] Importantly, splenic angioembolization was not associated with increased transfusion requirements or mortality when compared with nonoperative therapy alone.[6]

Although this strategy appeared to identify patients with evidence of arterial bleeding, nontherapeutic angiography (with associated risks and costs) was performed in almost 70% of patients with blunt splenic injury using this algorithm.[6,7] When contrast-enhanced spiral computed tomographic scanning was used to identify candidates requiring splenic angioembolization, contrast extravasation was associated with 100% sensitivity.[7] However, the sensitivity of computed tomographic scanning was only 50% when intraparenchymal vascular lesions (pseudoaneurysms, arteriovenous malformations) were used as the criteria for splenic angiography.[8]

The current study by Liu et al. uses a combination of clinical and radiographic criteria (recurrent hypotension, significant hemoperitoneum/contrast extravasation, grade 4–5 injury, and the progressive need for blood transfusion) to identify candidates for splenic angioembolization. Although splenic angioembolization is clearly being used successfully as an adjunct to nonoperative management of traumatic splenic injury, the indications, failure rate, and effects on splenic function remain poorly defined. In addition, there does not appear to be a consensus in the literature regarding the optimal technique (nonselective proximal vs. selective embolization of the distal splenic artery) for splenic angioembolization in patients with splenic injury.

We believe the relative paucity of data regarding the use of splenic angioembolization represents an opportunity for study by the multi-institutional trials committee of either the Eastern Association for the Surgery of Trauma or the American Association for the Surgery of Trauma. On the basis of the current literature, only a small percentage of patients with splenic injury are likely to benefit from angioembolization. A multi-institutional trial could help to further define the population that benefits from angioembolization, characterize postembolization immune function, and possibly demonstrate that the results of splenic angioembolization from high-volume trauma centers can be achieved in other trauma centers as well. Thus, the questions regarding angioembolization for splenic injury remain: who, what, where, and when?

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