Nonoperative Management of Blunt Splenic Injury: A 5-Year Experience

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Objectives: **The purpose of this study was to examine the success rate of nonoperative management of blunt splenic injury in an institution using splenic embolization.**

Methods: **We conducted a retrospective review of all patients admitted to a Level I trauma center with blunt splenic injury. Data review included patient demographics, computed tomographic (CT) scan results, management technique, and patient outcomes.**

Results: **A total of 648 patients with blunt splenic injury were admitted, 280 of whom underwent immediate surgical management. Three hundred sixty-eight underwent planned nonoperative management, and 70 patients were treated with observation, serial abdominal examination, and follow-up abdominal CT scanning. All were hemodynamically stable, with a 100% salvage rate. One hundred sixty-six patients had a negative angiogram, with a nonoperative salvage rate of 94%, and 132 patients underwent embolization, with a nonoperative salvage rate of 90%. Overall salvage rates decreased with increasing injury grade; however, over 80% of grade 4 and 5 injuries were successfully managed nonoperatively. The salvage rate was similar for main coil embolization versus selective or combined embolization techniques. Admission abdominal CT scan correlated with splenic salvage rates. Significant hemoperitoneum, extravasation, and pseudoaneurysm had acceptable salvage rates, whereas arteriovenous fistula had a high failure rate, even after embolization.**

Conclusion: **Splenic embolization is a valuable adjunct to splenic salvage in our experience, allowing for the increased use of nonoperative management and higher salvage rates for American Association for the Surgery of Trauma splenic injury grades when compared with prior studies. Main coil embolization has a similar salvage rate when compared with other angiographic techniques. An arteriovenous fistula as a CT finding was predictive of a 40% nonoperative failure rate.**

Key Words: **Nonoperative management, Blunt, Splenic injury, Embolization, Arteriovenous fistula, Angiography.**

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Nonoperative management in hemodynamically stable patients with blunt splenic injury is the standard of care.[1–26] Several groups, including our own, use splenic angioembolization as a nonoperative adjunct.[1,6–13,15,22,26] The multi-institutional Eastern Association for the Surgery of Trauma (EAST) trial established that pure observational management can be used successfully for patients with blunt splenic injury who are hemodynamically stable.[2] The utility of adding angiography to these purely observational protocols is an area of controversy.

Retrospectively, data on the use of angioembolization and its efficacy in higher grade injuries have been described.[1,6–13,15,22,26] Large-scale prospective data are not yet available. On the basis of our early experience, we modified our protocol, and angioembolization is now reserved for higher grade splenic injuries and those patients with active bleeding on admission computed tomographic (CT) scan.[1] We have shown that equally good salvage rates can be obtained while restricting the use of angiography to those with the greatest level of injury. This is a review of our progression from the use of admission angiography for all patients to a more recent protocol in which a more selective use of admission angiography is used to improve salvage rates.[1,9] We analyzed all patients who underwent operative and nonoperative management at our institution over a 5-year period, reviewing outcomes in an effort to better delineate the role of angiography versus pure observational management.

PATIENTS AND METHODS

All patients admitted with the diagnosis of blunt splenic injury to the R Adams Cowley Shock Trauma Center between October 1997 and September 2002 were reviewed. This group was then subdivided into those undergoing immediate operative therapy versus those receiving planned nonoperative management. Those patients in the nonoperatively managed group were then subdivided into those who were observed with serial hematocrits, serial abdominal examinations, and follow-up CT scanning, and a second group undergoing admission splenic angiography.

During this time period, there were two distinct protocols used. From October until early June 2000, all patients underwent admission angiography, followed by serial abdominal

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Table 1 Demographics

Mean Age (yr)	Sex (male)	White Race	CHI	Unstable	ACT Grade	Average ISS
32	76%	80%	8%	8%	2.8	17

ACT, average AAST splenic injury grade; CHI, admission Glascow Coma Scale score <8; ISS, Injury Severity Score; Unstable, admission systolic blood pressure <90 mm Hg.

examinations and complete blood cell counts every 6 hours until two stable examinations and hematocrits were obtained, as well as a follow-up CT scan 48 to 72 hours after injury. These results have been previously described.[9]

Because of the poor therapeutic yield for splenic injury grades 1 and 2, our protocol was modified in June 2000 to encompass the use of angioembolization only in AAST splenic injury grades 3, 4, and 5 or any injury grade with evidence of active bleeding. Postembolization management was similar to that of the observation group, with serial abdominal examinations and complete blood cell counts every 6 hours, until two stable examinations were obtained. Liberalization of activity and oral diet began after two consecutive stable examinations. An abdominal CT scan was obtained 48 to 72 hours after embolization.

By study design, all patients had splenic injury documented on their admission abdominal CT scans. These scans were reviewed by staff trauma radiologists for evidence of vascular injury (contrast extravasation, pseudoaneurysm, arteriovenous fistula formation, or vessel truncation) as well as degree of hemoperitoneum. Significant hemoperitoneum was defined as intra-abdominal blood that was greater than a minimal amount of perisplenic fluid. Postprocedural abdominal CT scans were obtained and then reviewed for evidence of persistent vascular injury, new pseudoaneurysm formation, infarct size, and evidence of splenic infection.

Angiographic results were analyzed including embolization technique (superselective or distal embolization, proximal main coil splenic arterial embolization, or a combination of techniques) as well as embolization material. Outcome variables were then reviewed within the main treatment groups (i.e., strict observation vs. angiography without embolization vs. splenic embolization). Outcome related to abdominal CT grade and CT evidence of vascular injury were analyzed. Outpatient records were reviewed for evidence of delayed complications, such as infarction or splenic infection.

Failure of nonoperative management was defined as the need for abdominal exploration regardless of the indication. Splenic salvage was defined as patient discharge with spleen in situ. Significant splenic infarction was defined as devascularization of greater than 25% of the spleen on postprocedural abdominal CT scan. Additional complications consisted of arteriovenous injury at the angiographic catheter site as well as persistent pain. All results then underwent statistical analysis using χ^2 and Student's t test analysis as appropriate. A value $p \leq 0.05$ was deemed statistically significant.

RESULTS

During the study period, a total of 648 patients were admitted with blunt splenic injury. Of these, 280 patients underwent immediate surgical management: 226 patients during the first 2.5 years of the review (when admission angiography was performed on all hemodynamically stable patients as previously published) and 54 patients during the remainder of this study (when the protocol was modified to restrict angiography to higher grade splenic injuries and those with evidence of active bleeding).[9]

Hemodynamic instability was the primary reason for operative therapy. The definition of hemodynamic instability varied between individual practitioners. Under the modified protocol, hemodynamic instability was defined as a systolic blood pressure less then 100 mm Hg, need for ongoing resuscitation, or patients felt to have other associative injuries requiring operative management. Multiplicity of injuries did not appear to play a role in the attending surgeon's decision-making regarding operative management versus nonoperative management.

Three hundred sixty-eight patients underwent planned nonoperative management; 126 patients underwent admission angiography during the first 2.5 years, whereas the remaining patients underwent angiography only for evidence of splenic vascular injury or AAST splenic injury grade 3 to 5. The mean age of the total patient group was 32 years. Seventy-six percent were male and 80% were white (Table 1). Eight percent of patients suffered significant traumatic brain injury (Glasgow Coma Scale score < 8 at admission) and 8% were hemodynamically unstable at the time of admission. Mean AAST splenic injury grade was 2.8 and mean Injury Severity Score was 17 (Table 1). The predominant mechanisms of injury were motor vehicle collisions (84%), followed by assaults (6%). Four percent were injured by falls from a height and 2% were pedestrians struck (Table 2). The overall splenic salvage rate was 94%. Splenic salvage decreased with increasing splenic injury grade, but higher grade injuries (grades 4 and 5) still had a greater than 80% salvage rate (Table 3).

Table 2 Mechanism of Injury

MVC	MCC	Assault	Fall	Pedestrian Struck
84%	4%	6%	4%	2%

MVC, motor vehicle collision; MCC, motorcycle or bicycle crash.

Table 3 Splenic Injury and Embolization Technique Success Rates

Technique[a]	1	2	3	4	5
Main coil	0	100% (8)	92% (38)	93% (30)	100% (5)
Distal	100% (2)	100% (8)	87% (13)	86% (19)	0
Combined[b]	0	0	75% (4)	80% (5)	0

[a] Technique rows denote nonoperative success rate by % and (total no. of patients in group).
[b] Patients undergoing main coil combined with distal embolization.

Seventy patients underwent observation with serial abdominal examinations and complete blood cell counts. Examinations and blood draws were performed every 6 hours until two consecutive examinations and hematocrits were obtained. Patients were then converted to daily laboratory values and activity and diet were liberalized. These patients had an average splenic injury grade of 1.8 without evidence of vascular injury on admission abdominal CT. There was a 100% salvage rate, with no evidence of delayed vascular injury on follow-up abdominal CT scan. Overall length of stay was 2.3 days.

One hundred sixty-six patients had a negative admission splenic angiogram. These patients had an overall splenic injury grade of 2.9 and an overall nonoperative salvage rate of 94%. Five of these patients underwent repeat angiography for diminished hematocrit, of which three then underwent therapeutic embolization.

One hundred thirty-two patients underwent embolization (Table 3). The overall nonoperative salvage rate was 90%. The salvage rate decreased with increasing injury grade; however, over 80% of grade 4 and 5 injuries were successfully managed nonoperatively. Seven of these patients underwent repeat angiography for falling serial hematocrit, of which three underwent therapeutic reembolization. The overall salvage rate was higher for main coil embolization when compared with the combined embolization technique (Table 3). This was not statistically significance ($p = 0.08$).

Within this group, there were two patients who underwent surgery for missed diaphragmatic injuries, both of whom underwent splenectomy to facilitate the repair. There were no missed hollow viscus injuries noted during this time period and there were no cases of contrast-induced renal failure, iatrogenic vascular injuries, or intra-abdominal injuries attributed to the angiographic catheterization in either the negative angiography group or the embolization subgroup. Additional delayed complications in this group included three splenic abscesses requiring splenectomy and three coil migrations after main coil embolization, two of which were retrieved and one of which was left in situ in a polar artery after placement of a second main coil.

The admission abdominal CT scan of the 132 embolized patients were then examined for markers of nonoperative failure (Table 4). Significant hemoperitoneum was the most common finding, followed by contrast extravasation, pseudoaneurysm, and arteriovenous fistula formation. Twenty-three percent of embolized patients underwent angiography for AAST splenic injury grades 3 to 5 without signs of vascular injury. Embolization was performed on the basis of angiographic evidence of injury only. The salvage rate was highest in those patients with hemoperitoneum (90%), and was nearly equivalent in those patients with active extravasation (88%) and pseudoaneurysm (89%). Arteriovenous fistula formation had a significant failure rate, although the patient sample size was limited. Arteriovenous fistula formation accounted for only 4% of the study population; however, the failure rate was 40%. These results were compared with the EAST Multi-institutional Trial where patients were treated with observation only. These results are depicted in Table 5. There is a statistically significant improvement in the rate of splenic salvage in grades 3, 4, and 5 injuries when embolization was used.

Table 4 Failure Rate vs. Admission ACT Findings

ACT Finding	Heme	Extrav	PA	AVF
% Patients	59% (78)	40% (53)	40% (53)	4% (5)
Failure rate	10% (8)	12% (7)	11% (6)	40% (2)*

* $p \leq 0.05$.
Heme, large hemoperitoneum; extrav, active uncontained leak; PA, pseudoaneurysm; AVF, arteriovenous fistula.

Table 5 Salvage Rate vs. EAST

Initial ACT Grade	1	2	3	4	5
Embolization	0% (1)	92% (17)	92% (62)	83% (58)	83% (6)
EAST	95.2% (276)	90.5% (299)	80.4% (247)	66.7% (194)	25% (78)

* $p \leq 0.05$.

DISCUSSION

The optimal treatment for blunt splenic injury remains open to question. Certain basic principles are universally accepted. Patients who arrive hypotensive or are refractory to resuscitation require operative exploration and are not reasonable candidates for nonoperative management. Those patients who are hemodynamically stable are candidates for nonoperative management with inpatient observation and serial physical examination, frequent hematocrit determinations, and a variable period of bed rest and limited oral intake. Within this subgroup, there are good data indicating that those patients with evidence of active bleeding, pseudoaneurysm formation, or arteriovenous fistula on admission abdominal CT scan are at higher risk of nonoperative failure. There is much debate as to the ideal definitive treatment of this difficult subgroup of patients.[1,6–13,15]

In 1995, Sclafani et al. first described the use of embolization for blunt splenic injury.[10] In that series, there were 150 patients treated nonoperatively. All splenic injury grades had diagnostic angiography. Sixty patients underwent transcatheter embolization, and the overall splenic salvage rate was 98.5%, the highest salvage rate with or without embolization reported to date. Studies from the Memphis Group found that 80% of vascular injuries were actually identified on a delayed rather than admission CT scan.[6,8]

Our group reported rather extensively on the use of admission angiography for all splenic injuries, with results similar to the findings of Sclafani et al.[9] Unlike their study, however, we found only minimal utility in the use of angiography for lower grade injuries (i.e., AAST splenic injury grades 1 and 2).[9] Because of this, our protocol was modified to a more selective use in those with vascular injuries. However, unlike other groups, which use angiography for vascular injury only, we continue to use angioembolization in splenic injury grades 3, 4, and 5, as 23% of patients embolized had no signs of vascular injury on admission abdominal CT scan.

Only angiography demonstrated the vascular injury requiring embolization.[1] We attribute this increased salvage rate to angiography's greater diagnostic sensitivity for vascular injury.

The Memphis Group did describe delayed emergence of vascular injury on a repeat abdominal CT scan.[6] We feel that angiography is, in fact, detecting these "delayed" injuries earlier in grades 3, 4, and 5 injuries because of its increased sensitivity, leading to earlier therapeutic embolization. This is supported by our follow-up CT findings, which have a low incidence of vascular injury.

We did identify patients with splenic vascular injuries who underwent main coil embolization but had evidence of residual distal pseudoaneurysms detected on the follow-up CT scan. Two of these injuries were embolized and three were merely observed; all had successful splenic salvage. Splenic perfusion pressure is decreased by the main coil embolization preventing pseudoaneurysmal bleeding. Because few of these injuries were encountered, it is difficult to say whether a persistent pseudoaneurysm, occluded by main coil splenic embolization, is adequate treatment or whether a catheter should be advanced through the main coil for a subselective embolization of the pseudoaneurysm itself.

The mean AAST splenic injury grade within our series was 2.8. The observational group had a mean splenic injury grade of 1.8. Within the negative angiography group, the mean grade was 2.9, and the embolization group had a moderately higher mean grade of 3.3. The most frequent injury grade within our group was grade 3, followed very closely by grade 4 injuries. This is comparatively higher than previous series, such as the EAST Multi-institutional Trial, where over half the patients were only grades 1 or 2.

Our results were statistically significantly better than those seen with simple observation used in the EAST study for grades 3, 4, and 5 injuries. This is very impressive when one recognizes that the majority of patients had evidence of vascular injury and had significant hemoperitoneum, a previously described marker for nonoperative failure. Although this is statistically significant, we must bear in mind that these are very different patient groups. The EAST study used patients from multiple institutions, without a discrete protocol. It is difficult to determine the variability between the protocols or patient demographics; however, the number of patients included in the study suggests that there may be some benefit to angioembolization in improving salvage rates.

The presence of a large hemoperitoneum predicted nonoperative failure in the EAST study.[2] This does not seem to be the case in our patients, where the failure rate of embolization was only 10%, and neither active contrast extravasation nor pseudoaneurysm predicted failure. The only statistically significant marker of failure in our study was the presence of an arteriovenous fistula. We hypothesize that main coil embolization is insufficient for treating arteriovenous fistula, as it only decreases splenic perfusion pressure. As this is a high-pressure to low-pressure flow system, the fistula is not expected to close without directed therapies. Selective embolization of the fistula itself may be a better option.

Approximately 60% of our patients underwent main splenic coil embolization. The failure rate of main coil embolization demonstrated no statistical difference in outcomes when compared with the patients undergoing combined proximal and distal embolization techniques ($p = 0.08$).

There were no complications within the observation group. The only significant complications noted in the negative angiography group were the nonoperative failures and three patients requiring repeat angiography with therapeutic embolization. The complications noted within the embolization group were minor, consisting of three splenic abscesses and two symptomatic splenic infarcts, resulting in an overall nonoperative failure rate of 10%, including failure secondary to hemorrhage. There was no evidence of catheterization site complication, dye contrast allergy, or other angiograph-spe-

cific complications within the negative angiogram group or the embolization group.

There were three instances in which the main coil migrated. In two cases, the coil was retrieved from the polar artery wall and in one case it was left in place because of the inability to retrieve it with a second, more proximal main coil placed. All three of these patients did well with splenic salvage, without significant infarction. To date, we have not encountered a missed hollow viscus injury, and the previously described missed diaphragmatic injuries, although certainly significant and requiring treatment, did not appear to harm the patient.

This is the largest described series of patients undergoing nonoperative management of blunt splenic injury from a single institution and the largest using splenic embolization. Although this is a retrospective review, we feel that several management caveats can be extrapolated from these data. We found that nonoperative management can be successfully used in high-grade splenic injuries, as evidenced by the vastly decreased use of laparotomy with good outcome. The use of angioembolization to better define patients with vascular injury led to a clinically improved outcome. As improved outcomes were observed, staff physicians became more comfortable taking patients with multiple injuries, patients with neurologic injuries, and patients undergoing aggressive resuscitation to the angiography suite rather than to the operating room.

We compared our data to the EAST outcomes, and although we demonstrated a statistically significant improvement in salvage rate, we recognize that the patient cohorts may be different. Selection bias in the patients treated with angiography is also possible.

For lower grade splenic injuries, we have adopted the use of an observational protocol similar to that described in the EAST multicenter trial, with an equivalent or improved outcome. We have also diminished length of stay for isolated splenic injuries to approximately 3 days. This balances the cost of the increased resources needed to perform the angiography.[1] We are attempting to gain a consensus group of institutions to participate in a prospective study of the use of angioembolization, possibly in a randomized fashion.

Complication rates such as nonoperative failure (10% vs. 13%) and reembolization (2% vs. 5%) rates were lower within our group when compared with the Western Trauma Association's multicenter study.[14,27] This may be attributable to several factors. First, patients were not empirically embolized for massive hemoperitoneum, which in one case resulted in abscess formation during that the Western Trauma Association study.[14]

The outcome of any procedure is improved with the team's familiarity with the procedure and its indications. This may lead to a better patient selection as well as an improved angiographic technique. The increased use of main coil embolization may have decreased the incidence of splenic abscess and treatment failure. This suggests that decreasing the perfusion pressure of the spleen is a more useful therapeutic modality than directed embolization, except in the incidence of arteriovenous formation. The immunologic consequences of proximal coil embolization remain unclear and require further study.

DISCUSION

Dr. Tiffany K. Bee (Memphis, Tennessee): Dr. Meredith, Dr. Nagy, members, and guests, I would like to thank you for the opportunity to open up the discussion on this interesting study. Nonoperative management of splenic injury has, indeed, become the norm in most of the major trauma centers in this nation. Dr. Haan and colleagues have eloquently added to the armamentarium, proving that nonoperative management can be successfully performed in the majority of our patients.

The uniqueness of this study, however, is the liberal use and availability of angiography for many years at Maryland's Shock Trauma Center. With these specialized resources, they are achieving a less than 20% failure rate in grades 4 and 5 splenic injuries.

I would like to open the discussion with a few questions that occurred to me after reading the article. First, I am interested in the 8%, or 29 patients, who were actually admitted hemodynamically unstable and underwent nonoperative management, especially those who had ongoing resuscitation while they were in the angiography suite itself. What was the failure rate in this population, and does it warrant the risk of taking these unstable patients to what in most hospitals is the black box of angiography?

Second, I noticed that approximately 5% of the patients with grades 1 and 2 spleens underwent embolization. I expect that most of these were in the first group of their patients. However, now that they are not routinely performing angiography for all grades 1 and 2 splenic injuries, I would like to know whether any of their failures in grades 1 and 2 have been acknowledged.

Third, I would like you to comment on the need for routine follow-up CT scans, both for low-grade injuries, those grades 1 and 2 injuries, and for those patients who have received embolization. Should CT scanning be reserved for only those patients who show a worsening condition? Finally, the studies at my institution, as well as many others, have shown that patients who have splenic injury and who are older than age 50 often have a higher failure rate. Have you noticed any trends of this nature at your center?

In conclusion, I would like to congratulate the authors on a well-developed and well-presented article, and I look forward to some of the prospective studies being ongoing at Shock Trauma. I would like to thank the Association for the privilege of the floor.

Dr. Michael D. McGonigal (St. Paul, Minnesota): I enjoyed this study, and actually, we're big proponents of this, and this answered a few of the questions that I already had. However, I do have two that are kind of in the curiosity

category. First, in what way did the follow-up CT scans that you obtained change your management? I know that you did show something on one of your slides about collections that were drained, air in the spleen, and so forth.

However, specifically, is this a helpful technique, and how many actually yielded actionable findings? The second question is you are creating splenic imparts. What are your criteria for administering vaccines for prophylaxis?

Dr. Michael D. Pasquale (Allentown, Pennsylvania): I enjoyed the talk as well. One of my questions centers around the unstable patients going to angiography: Did you have a protocol for those patients. The second question is, Did you look at blood transfusion requirements in those populations?

Dr. Eric R. Frykberg (Woodbine, Georgia): Dr. Haan, I have one question. The EAST Multi-institutional Trial had an approximately 10% nonoperative failure rate at a time in this country when virtually nobody was performing embolization. You show the same nonoperative failure rate. Tell us exactly how you see angiography having had any affect whatsoever on the management of these patients.

Dr. Michael L. Nance (Philadelphia, Pennsylvania): My comments are biased, as I work at a pediatric center. So everything is a little bit different. I am sort of dumbfounded. I mean, this is a selective use of embolization, but there are 166 negative embolizations, which seems just extraordinarily high, and I was wondering whether selective use would be better used if the patients were actually evaluated and then embolization used for those that were deemed to need it, rather than, it seems, like based on their grade of injury. I also wonder, with the extraordinarily high rate of negative embolizations, whether you performed any cost analysis, because that seems to me an extraordinarily expensive modality to use for patients who, in many cases, need nothing but observation.

Dr. David G. Jacobs (Charlotte, North Carolina): I enjoyed the article, and I just have one question. You mentioned that some patients had more than one angiogram, and I'm wondering how you figure out whether patients who failed their initial angiography should be operated on or receive undergo angiography, or are these patients that had pseudoaneurysms on their follow-up CT scans? Thank you.

Dr. Ari K. Leppaniemi (Helsinki, Finland): I have a question on the availability of radiologists at night. Did they come from home, or were they in house, and were they specialists or radiologist residents?

Dr. James M. Haan (closing): Beginning with Dr. Bee's questions and to some degree tying into some of the other questions, when we say hemodynamically unstable, the majority of these patients were, in fact, responders or people who responded to 2 L to crystalloid. Early in the study, many of these patients did end up in the operating room, because there was a fair amount of trepidation with nonoperative management in the angiography protocols. As you can see, 2.5 years later people become comfortable with it. Thus, we had a far larger number of them actually undergoing nonoperative management.

For truly unstable patients, we would not recommend they be in the angiography suite for many the things we just talked about, the black box, the lack of monitoring, the difficulty in controlling temperature, and things of that nature. These patients were not subevaluated regarding transfusion requirements. That was the second question. That would be worthwhile for the article.

Regarding the grades 1 and 2 injuries, the majority were in the initial 2.5 years, although there were several patients who had evidence of vascular injury with grade 2 injuries, who were embolized later in the series. There were approximately three of those.

We did not specifically look at age greater than 55 for this study. However, we were a contributing member for the Western Trauma Association evaluation, and we found that there was a 90% success rate in those aged older than 55, with similar demographics and similar evidence of vascular injury on CT scan.

The money question is a real question, as is angiograph suite availability. That was part of our reasoning, not just the fact that we weren't being therapeutic in grades 1 and 2, but this is an expensive modality. Regarding costs, I recently brought that up with a change in protocol.

Patient charges were approximately $18,000 for these negative angiograms. If you looked at them with your embolization and added in the failure rates, and the patients went to a splenectomy, that was cut in half to less than $9,000 by using the selective protocol.

Thus, there was a cost evaluation made here, and that's why we have converted. Actual availability, the attending angiographers are out of house. However, they do come in within an hour and a half. That's one of the rules we have, which to some degree can limit the applicability of this to other centers, depending on how available and interested your angiographers are.

Regarding the difference between EAST and our series, probably the biggest, I agree, we have a 90% they had and a 90% success rate. You can look at the 100% and 94% for observation and negative angiographic groups, but they're being treated basically the same way as the EAST group.

We have a much higher CT injury rate or AAST rate. We have a much higher vascular injury rate as opposed to the EAST series as well. I think these and hemoperitoneum might play a better defining role than just saying everybody had a 90% salvage rate.

If you have a far more injured group, these are not equivalent, and in fact, you're having a somewhat better outcome. Again, our numbers are far smaller than the EAST Multi-institutional Trial.

As far as indications for reembolization, patients who had just a drop in their hematocrit and had evidence of vascular injury on their follow-up CT scan constitute a very

small group. In this case, we're talking about only two. They were underwent reembolization.

For the positive CT scans and their cost-effectiveness, obviously we're talking about two patients who really didn't have a clinical indication. We will look at our follow-up CT scans still at the moment as being more of an experimental component of this rather than being a true therapeutic component. I would like to thank the Association once again for the privilege of the podium.

REFERENCES

1. Haan JM, Obeid NI, Kramer M, Scalea TM. Protocol-driven non-operative management of patients with blunt splenic trauma and minimal associated injury decreases length of stay. *J Trauma*. 2003; 55:317–322.
2. Peitzman AB, Heil B, Rivera L, et al. Blunt splenic injury in adults: Multi-institutional Study of the Eastern Association for the Surgery of Trauma. *J Trauma*. 2000;49:177–189.
3. Bee TK, Croce MA, Miller PR, et al. Failures of splenic non-operative management: is the glass half empty or half full? *J Trauma*. 2001;50:230–236.
4. Nix J, Constanza M, Daley B, et al. Outcome of the current management of splenic injuries. *J Trauma*. 2001;50:835–842.
5. Brasel K, DeLisle C, Olson C, Borgstrom O. Splenic injury: trends in evaluation and management. *J Trauma*. 1998;44:283–285.
6. Schurr MJ, Fabian TC, Gavant M, et al. Management of blunt splenic trauma: computed tomographic contrast blush predicts failure of non-operative management. *J Trauma*. 1995;39:507–513.
7. Shanmuganathan S, Mirvis S, Boyd-Kranis R, et al. Nonsurgical management of blunt splenic injury: use of CT criteria to select patients for splenic arteriography and potential endovascular therapy. *Radiology*. 2000;217:75–82.
8. Davis KA, Fabian TC, Croce MA, et al. Improved success in non-operative management of blunt splenic injuries: embolization of splenic artery pseudoaneurysm. *J Trauma*. 1998;44:1008–1015.
9. Haan JM, Scott J, Boyd-Kranis RL, et al. Admission angiography for blunt splenic injury: advantages and pitfalls. *J Trauma*. 2001; 51:1161–1165.
10. Sclafani SJ, Shaftan GW, Scalea TM, et al. Non-operative salvage of computed tomography-diagnosed splenic injuries: utilization of angiography for triage and embolization for hemostasis. *J Trauma*. 1995;39:818–827.
11. Hagiwara A, Yukioka T, Ohta S, et al. Nonsurgical management of patients with blunt splenic injury: efficacy of transcatheter arterial embolization. *AJR Am J Roentgenol*. 1996;167:159–166.
12. Killeen KL, Shanmuganathan K, Boyd-Kranis R, Scalea TM, Mirvis SE. CT findings after embolization for blunt splenic trauma. *J Vasc Interv Radiol*. 2001;12:209–214.
13. Cocanour C, Moore F, Ware D, et al. Age should not be a consideration for nonoperative management of blunt splenic injury. *J Trauma*. 2000;48:606–612.
14. Haan J, Knudson MM, Davis K, Scalea TM. Splenic embolization: a multicenter review. *J Trauma*. 2003;54:207.
15. Pachter HL, Grau J. The current status of splenic preservation. *Adv Surg*. 2000;34:137–174.
16. Krause KR, Howells GA, Bair HA, et al. Nonoperative management of blunt splenic injury in adults 55 years and older: a twenty-year experience. *Am Surg*. 2000;66:636–640.
17. Sartorelli K, Frumiento C, Rogers F, Osler T. Nonoperative management of hepatic, splenic, and renal injuries in adults with multiple injuries. *J Trauma*. 2000;49:56–61.
18. Velmahos G, Toutouzas K, Radin R, et al. Nonoperative treatment of blunt injury to solid abdominal organs: a prospective study. *Arch Surg*. 2003;138:844–851.
19. Hartnett K, Winchell R, Clark D. Management of adult splenic injury: a 20-year perspective. *Am Surg*. 2003;69:608–611.
20. Wong Y, Wang L, Fang J, et al. Perisplenic extravasation of contrast medium on enhanced helical computed tomography: a reliable indicator for early surgical management in blunt splenic injuries. *Chang Gung Med J*. 2002;25:381–387.
21. Owens C, Alkadir A, Yaghmai B, et al. Massive intraperitoneal hemorrhage from traumatic intrasplenic pseudoaneurysm: treatment using superselective embolotherapy. *Int Surg*. 2001;86:201–205.
22. Carlin A, Tyburski J, Wilson R, Steffes C. Factors affecting the outcome of patients with splenic trauma. *Am Surg*. 2002;68:232–239.
23. Oschsner M. Factors of failure for nonoperative management of blunt liver and splenic injuries. *World J Surg*. 2001;25:1393–1396.
24. Yao DC, Jeffrey R, Mirvis S, et al. Using contrast-enhanced helical CT to visualize arterial extravasation after blunt abdominal trauma: incidence and organ distribution. *AJR Am J Roentgenol*. 2002; 178:17–20.
25. Omert L, Salyer D, Dunham C, et al. Implications of the "contrast blush" finding on computed tomographic scan of the spleen in trauma. *J Trauma*. 2001;51:277–278.
26. Van der Hul R, van Overhagen H, Dallinga R, de Graaf P. Splenic salvage by superselective embolization after blunt abdominal trauma. *Eur J Surg*. 2001;167:73–75.
27. Haan J, Biffl W, Knudson M, et al. Splenic embolization revisited: a multicenter review. *J Trauma*. 2004;56(3):542–7.