Prospective Trial of Angiography and Embolization for All Grade III to V Blunt Splenic Injuries: Nonoperative Management Success Rate Is Significantly Improved

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BACKGROUND: Nonoperative management (NOM) of blunt splenic injury is well accepted. Substantial failure rates in higher injury grades remain common, with one large study reporting rates of 19.6%, 33.3%, and 75% for grades III, IV, and V, respectively. Retrospective data show angiography and embolization can increase salvage rates in these severe injuries. We developed a protocol requiring referral of all blunt splenic injuries, grades III to V, without indication for immediate operation for angiography and embolization. We hypothesized that angiography and embolization of high-grade blunt splenic injury would reduce NOM failure rates in this population.

STUDY DESIGN: This was a prospective study at our Level I trauma center as part of a performance-improvement project. Demographics, injury characteristics, and outcomes were compared with historic controls. The protocol required all stable patients with grade III to V splenic injuries be referred for angiography and embolization. In historic controls, referral was based on surgeon preference.

RESULTS: From January 1, 2010 to December 31, 2012, there were 168 patients with grades III to V spleen injuries admitted; NOM was undertaken in 113 (67%) patients. The protocol was followed in 97 patients, with a failure rate of 5%. Failure rate in the 16 protocol deviations was 25% (p = 0.02). Historic controls from January 1, 2007 to December 31, 2009 were compared with the protocol group. One hundred and fifty-three patients with grade III to V injuries were admitted during this period, 80 (52%) patients underwent attempted NOM. Failure rate was significantly higher than for the protocol group (15%, p = 0.04).

CONCLUSIONS: Use of a protocol requiring angiography and embolization for all high-grade spleen injuries slated for NOM leads to a significantly decreased failure rate. We recommend angiography and embolization as an adjunct to NOM for all grade III to V splenic injuries. (J Am Coll Surg 2014;218:644–651. © 2014 by the American College of Surgeons)

Splenic injury is common in the face of blunt trauma, and optimal methods for management of these injuries have been developed and studied extensively during the past 25 years. Nonoperative management (NOM) of hemodynamically stable patients with blunt splenic injury is now accepted as standard treatment in the appropriate clinical setting. Appropriate selection of patients for whom NOM is safe has been carefully examined and indications continue to expand. Additionally, adjuncts to NOM that can improve success, such as angiography and embolization, have been well described. Outcomes with use of this concept were described in 1995 and an extensive literature has grown surrounding its technique and use. Despite the use of and research on splenic angiography and embolization in the intervening years, optimal application of this technique is still debated.

One area of controversy is defining which patients with splenic injury are best served by this procedure. Many centers use angiography in hemodynamically stable patients with contrast blush on admission abdominal CT, signifying vascular injury. This finding represents either extravasation of intravenous contrast into the peritoneal
cavity or pseudoaneurysm within the splenic parenchyma. Others have added higher-grade injury (ie, grades III to V) as indication for angiography and possible embolization.\textsuperscript{5,6} Data from both patient populations has indicated that use of embolization of the injured spleen improves the rate of successful NOM, and practices vary widely from center to center. After extensive review of the available literature, our group published a recent meta-analysis that supported the concept of improved NOM outcomes when angioembolization was used in patients with higher-grade injuries.\textsuperscript{7} For this reason, a process-improvement project was developed in concert with our department of radiology. Given the information contained in the meta-analysis, we instituted a protocol that required referral for angiography and possible embolization for all hemodynamically stable patients with blunt splenic injuries of grades III to V. Our hypothesis was that this protocol would lead to a substantial improvement in our successful NOM of these injuries.

**METHODS**

This is a prospective study with historic controls examining a 6-year period at Wake Forest University Baptist Medical Center in Winston Salem, NC. The institution is a Level I trauma center. Hemodynamically stable patients with blunt splenic injury are all considered for NOM, which is carried out or altered based on the attending surgeon’s overall judgment. Before 2010, angiography was performed on those patients with contrast blush identified on admission CT. Embolization was performed at the discretion of the angiographer and was done mostly because of pseudoaneurysm or other vascular injury seen during angiography. Beginning in 2010, we began a process-improvement project for the management of stable patients with blunt splenic injuries of grades III to V. Our hypothesis was that this protocol would lead to a substantial improvement in our successful NOM of these injuries.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Early (n = 153)</th>
<th>Late (n = 168)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male/female, n</td>
<td>113/40</td>
<td>112/56</td>
<td>0.20</td>
</tr>
<tr>
<td>Age, y, mean ± SD</td>
<td>38 ± 15</td>
<td>38 ± 18</td>
<td>0.68</td>
</tr>
<tr>
<td>Admission lactate, mmol/L, mean ± SD</td>
<td>2.8 ± 2.5</td>
<td>2.5 ± 2.2</td>
<td>0.38</td>
</tr>
<tr>
<td>Injury Severity Score, mean ± SD</td>
<td>29 ± 24</td>
<td>24 ± 10</td>
<td>0.0007</td>
</tr>
<tr>
<td>Splenic injury grade, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>74 (48)</td>
<td>94 (56)</td>
<td>0.21</td>
</tr>
<tr>
<td>IV</td>
<td>57 (37)</td>
<td>61 (36)</td>
<td>0.95</td>
</tr>
<tr>
<td>V</td>
<td>22 (14)</td>
<td>13 (8)</td>
<td>0.08</td>
</tr>
<tr>
<td>Mortality, n (%)</td>
<td>23 (15)</td>
<td>7 (4)</td>
<td>0.0009</td>
</tr>
<tr>
<td>Nonoperative management mortality, n (%)</td>
<td>5/80 (6)</td>
<td>2/113 (2)</td>
<td>0.13</td>
</tr>
</tbody>
</table>

**RESULTS**

From January 1, 2007 to December 31, 2012, there were 20,888 injured patients seen at our Level I trauma center, and 879 sustained blunt splenic injury of any grade. One hundred and fifty-three with grade III to V injuries were admitted from January 1, 2007 to December 31, 2009 (early) and 168 with similar injuries were admitted from January 1, 2010 to December 31, 2012 (late). These patients comprise the studied dataset and the lower grade I and II injuries are not included in any analysis. Demographics, injury characteristics, and outcomes are provided...
in Table 1. Distribution of splenic injury grade within the early and late groups was similar, as was mean age, proportions of male and female patients, and admission lactate. Overall Injury Severity Score and mortality were higher in the early group, but mortality within the NOM group was similar between the 2 periods. The NOM rates in these higher-grade injuries increased from 52% in the early group to 67% in the late group (p = 0.006).

Overall, use of angiography in NOM patients increased considerably between these 2 time periods, as expected. In the early group, 21 (26%) patients underwent angiography, compared with 106 (94%) patients in the late period (p < 0.0001). Eighteen patients in the early group underwent angiography due to contrast blush and 3 were selected for angiography due to physician discretion. Fifteen patients who received angiography in the early group also underwent embolization due to identified injuries on angiography. The remaining 6 did not have injuries seen at angiography. In the late group undergoing angiography, 53 (50%) had contrast blush on CT and the remaining 53 did not. No patient with blush identified on CT in the late group failed to receive angiography. Of the 106 angiography patients in the late group, 97 also underwent embolization, for an overall protocol compliance of 86% (97 of 113 total NOM patients). Nine patients in the late group underwent angiography without embolization, and these patients, along with the 7 slated for NOM who did not receive angiography, are considered protocol violations.

Increasing use of angiography and embolization in the late group led to a significantly lower failure rate of 5% in the group managed according to protocol (n = 5), compared with 15% (n = 12) failure rate in the early group (p = 0.04). A comparison of those in the late group managed according to protocol with those who were not managed according to protocol, showed a significant advantage, with a 5% failure rate in those managed per protocol vs a 31% failure rate in those for whom protocol was not followed (p = 0.02).

Success of NOM in the late group managed according to protocol compared with those undergoing NOM in the early group showed a similar pattern in each distinct injury grade. Seventy-four patients with grade III injuries were seen in the early period, with 56 (76%) undergoing NOM. Eight (14%) patients experienced NOM failure and required splenectomy. In the late period, 94 patients with grade III injuries were admitted, with 78 (83%) overall undergoing NOM, but only 65 patients were managed according to protocol. Failure rate in this protocol group was 3% compared with 14% in the early group (p = 0.04). Failure rate in the late group not managed according to protocol was 25% compared with only 3% in the late protocol group (p = 0.03). Fifty-seven grade IV injuries were seen in the early period and 61 were seen in the late period. Nonoperative management was followed in 23 (40%) and 32 (49%) patients, respectively. Twenty-nine of the 32 NOM patients in the late group were managed by protocol and the NOM failure rate in this group was 7% (n = 2) compared with 17% (n = 4) in the early group (p = 0.38). In the late group, 2 (7%) patients managed per protocol experienced NOM failure vs 1 (33%) patient in the nonprotocol group (p = 0.26). Although management on protocol in grade IV injuries appears to be associated with greater NOM success, this did not reach statistical significance in either comparison. Grade V injuries were less common as expected, with 22 in the early group and 13 in the late group. Only 4% (n = 1) and 23% (n = 3) of patients were slated for NOM in these groups, respectively. Of 2 in the late group managed per protocol, treatment failed in 1 and there were no treatment failures in the early group (0 of 1, p = 1.000). The 1 nonprotocol patient in the late group experienced NOM failure.

Failures of NOM in both the early and late groups occurred largely outside of the population of patients with blush identified on admission CT. Nonoperative management failures in the early group included 11 patients who had no contrast blush on CT and 1 patient who did. None of these patients underwent angiography. All other patients in the early group with blush seen on CT underwent angiography, as mentioned earlier. Of the 9 patients with NOM failures in the late group, 3 had contrast blush seen on CT and 2 underwent angioembolization. Six patients did not have a contrast blush and 5 of these underwent angioembolization.

In examining NOM failures in those undergoing angiography and embolization, no specific pattern emerged. No patient who failed in the early group underwent angiography. In the late group, only 4 of the 9 patients with NOM failure had both angiography and embolization; 2 underwent main splenic artery embolization only, 1 underwent distal selective embolization only, and 1 underwent both.

No episodes of contrast nephropathy or groin/retroperitoneal hematoma occurred in patients undergoing angiography. We saw no post-embolization splenic abscesses.

**DISCUSSION**

Splenic angioembolization plays an important role in selected patients in improving the chance of successful NOM of blunt splenic injury. Optimal application of this technique, however, remains controversial. Some centers have relied on evidence of vascular injury on CT as shown by contrast blush to prompt angiography.2-4 Others...
have published series with high rates of successful NOM when this technique is applied to all higher-grade injuries in addition to those with CT signs of contrast blush.\textsuperscript{5,6,8,9} These prospective data demonstrate that NOM success in higher-grade (ie, grades III to V) injuries can be as high as 95% when angioembolization is applied in a protocolized fashion to these patients. This NOM success rate is substantially higher than the historic cohort in which only patients with CT contrast blush underwent angiography.

Angiography in the presence of contrast blush is supported by multiple studies. Davis and colleagues showed improved NOM success rates when this technique was added to their NOM scheme and multiple authors have expanded on this concept.\textsuperscript{7} Although there is wide acceptance of this indication for angioembolization, a survey of trauma care givers by the Eastern Association for the Surgery of Trauma in 2005 found that 17% of respondents would not respond to this CT finding with any specific action, including angiography.\textsuperscript{10} This issue might be complicated by the fact that the term contrast blush can be used to describe varying clinical scenarios. The first is the finding of a blush within the splenic parenchyma. This is believed to represent a vascular injury leading to a pseudoaneurysm within the spleen.\textsuperscript{11} The natural history of this lesion appears to be eventual rupture and hemorrhage in many cases. Because this is a delayed process, it is theorized that splenic embolization can lower the perfusion pressure of this area, allowing it to thrombose rather than rupture. Another scenario that is described by some as a contrast blush is that in which there is active extravasation of contrast/blood into the peritoneal cavity in the area of the spleen. This has been shown to behave quite differently than the pseudoaneurysm. It is commonly associated with impending hemodynamic instability and has been shown to be marker of failure of NOM even with angioembolization.\textsuperscript{6,12,13} One type of blush might signify a lesion that will be helped by angiography, and another type likely represents a lesion more likely to fail the procedure. Both patient populations were included in the group classified with contrast blush in this work and no stable patient with extravasation into the peritoneum failed angioembolization. It is our clinical observation that the majority of these patients will have hemodynamic instability develop before angiography and are no longer candidates for NOM; this has been echoed by other investigators. Use of more specific and clear language by authors and those interpreting CT scans can help clarify this issue to practitioners and aid in the development of local protocols in the future.

Some authors have advocated the use of angioembolization in higher-grade injuries in addition to those in which vascular injury is seen on CT. The range of injuries has encompassed grades IV to V in some datasets and grades III to V in others.\textsuperscript{5,8,14} The Baltimore group has done a great deal of work in this area and has demonstrated considerably improvement in NOM success rates using these criteria.\textsuperscript{6} We recently published a meta-analysis of available data on NOM management of blunt splenic injuries, which also supports improved NOM outcomes if this approach is used.\textsuperscript{7} The current study certainly indicates that angioembolization in these higher-grade injuries leads to improved NOM success.

Another area of controversy is which patients should undergo embolization when angiography is performed. Anecdotally, we perceived an unusual number of NOM failures in past patients who had undergone angiography but not embolization because no vascular injury was seen. We developed a protocol that required embolization of all patients undergoing angiography. Although “required” by protocol, different angiographers are free to deviate from the protocol and perform no embolization based on their best clinical judgment. This difference in practice between our angiographers led to a group of patients in which no embolization was performed and this cohort made up more than half of our protocol-violation group, which had a significantly higher failure rate than the protocol group. Based on these data, our angiographers currently perform embolization in virtually all splenic angiograms. These results seem to echo those of Haan and colleagues, in which 10% of patients undergoing angiogram without embolization went on to require additional intervention in the form of repeat angiogram or operation.\textsuperscript{7} Although the reasons for this are not clear, it is possible that small vascular injuries or subtle findings, such as truncation of vessels or “beading” of vessels, can be easily missed on angiogram. In addition, it is clear that pseudoaneurysms not seen initially might be found on subsequent CT or splenic angiogram, possibly related to vascular spasm.

When patients are exposed to any new or additional therapy, potential complications must be considered. Potential problems with angioembolization include contrast nephropathy, groin hematoma or infection, and splenic infarction/abscess. With respect to nephropathy, we limited patients exposed to the additional contrast of angiography to those that were least likely to be at risk for renal damage. We saw no contrast nephropathy in this cohort, but it certainly remains a possibility. Had patients with diabetes mellitus or decreased renal function been routinely subjected to angiography, it is likely that the rate of contrast-induced renal dysfunction would have been higher. Potential risks of the procedure must be weighed against the potential benefits of this therapy in higher-risk patients. No groin complications were seen, but with continued use of angiography in this population
they are likely to be inevitable. A recent large meta-analysis of angiography complication found vascular complication reported in 0.6% of patients.15

No episodes of symptomatic splenic infarction were seen in this population. However, this appears to be a relatively common occurrence found when patients undergo follow-up CT scans. This was reported in 21% of patients in a multicenter Western Trauma Association study on splenic embolization for blunt splenic injury. Fortunately, most of these were asymptomatic. This does raise the question as to whether the immune function of the spleen is preserved after embolization because natural flow is disrupted and infarcts can occur. Assessment of splenic immune function is complex and multifactorial, but there are a wealth of available data examining different measures of splenic function after embolization that indicate that immune function is likely preserved in the majority of cases.16-21

CONCLUSIONS
These data support the concept that angiography and embolization in all grade III to V injuries is a helpful adjunct to NOM of blunt splenic injury and leads to a significantly improved splenic salvage rate. Angiography of patients with evidence of vascular injury on CT scan has been shown to improve successful NOM rates, but addition of angiembolization to all higher-grade injuries reduces failure rate. Angiography should be considered in all such patients.

Author Contributions
Study conception and design: Miller, Chang, Hoth, Mowery, Hildreth, Martin, Holmes, Meredith, Requarth

Acquisition of data: Miller, Chang, Hoth, Mowery, Hildreth, Martin, Holmes, Meredith, Requarth

Analysis and interpretation of data: Miller, Chang, Hoth, Meredith, Requarth

Drafting of manuscript: Miller, Chang, Hoth, Mowery, Hildreth, Martin, Holmes, Meredith, Requarth

Critical revision: Miller, Chang, Hoth, Mowery, Hildreth, Martin, Holmes, Meredith, Requarth

REFERENCES