PAPER

Less Is More

Management of Pediatric Splenic Injury

Justin Lee, MD; Kevin P. Moriarty, MD; David B. Tashjian, MD

Objective: To analyze national trends in the nonoperative management of pediatric splenic injury.

Design: Retrospective cohort analysis.

Patients: All children and adolescents 18 years or younger from 2 national databases who were hospitalized with pediatric splenic injury.

Setting: Data from 9 years of the National Inpatient Sample database (2000-2008) and 3 years of Kids' Inpatient Database (2000, 2003, and 2006).

Main Outcome Measures: We calculated and chronicled rates of splenectomy, angiography, and transfusion from 2000 to 2008.

Results: During the study period, the rate of splenectomy decreased from 18.25% to 10.86%. Changes in nonoperative management included more than a 2-fold increase in angiography, from 2.43% to 6.94%, and a significant increase in transfusion, from 7.71% to 11.49%. Operative management was associated with increased length of stay (9.15 vs 6.52 days) and higher mean total hospital charges ($74 981.26 vs $36 156.30). Cases occurring in rural locations were more likely to undergo operative management (odds ratio, 1.24 [95% CI, 1.18-1.31]; $P<.001$), but less likely to undergo angiography (0.82 [0.76-0.89]; $P<.001$).

Conclusions: Children with pediatric splenic injury are undergoing fewer splenectomies but more angiography. Rural location may be an independent risk factor for operative management. Further studies are needed to assess for disparity in access to and availability of aggressive nonoperative management.

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EVIDENCE-BASED PRACTICE guidelines recommend nonoperative management for blunt pediatric splenic injuries (PSIs) in hemodynamically stable patients.[1] The pediatric population especially benefits from nonoperative management with the potential avoidance of overwhelming postsplenectomy sepsis.[2] However, changes in management recommendations may not always translate into changes in practice. Recent study of national estimates for 2000 indicated that approximately 76% of PSIs are managed nonoperatively.[3] To our knowledge, no national trend analysis has been performed for PSI management since 2000. In the era of angiography, percutaneous interventions, and increased nonoperative management, we need to assess trends in practice. In addition, in times of limited resources, economic and outcome analyses are needed. The objectives of this study were (1) evaluation of recent national trends in the rates of splenectomy, transfusion, and angiography, (2) cost analysis of operative vs nonoperative management, and (3) identification of factors associated with variability in PSI management.

See Invited Critique at end of article

Author Affiliations: Baystate Pediatric Surgery, Baystate Children's Hospital, Tufts University School of Medicine, Springfield, Massachusetts (Drs Lee, Moriarty, and Tashjian); and Department of Surgery, St Elizabeth Medical Center, Tufts University School of Medicine, Boston, Massachusetts (Dr Lee).

METHODS

DATA SOURCES

We performed a retrospective analysis of the national administrative National Inpatient Sample (NIS) database and the Kids' Inpatient Database (KID). Both databases are produced as part of the Health Care and Utilization Project of the Agency for Healthcare Research and Quality.[4] The all-payer NIS database annually contains information for as many as 8 million inpatient discharges from approximately 1000 hospitals across the United States. Hospitals are chosen to represent a 20% stratified sample of all hospitals. The number of states for which data are available has increased from 28 states in 2000 to 42 states in 2008. The KID contains a sample of pediatric, adolescent, and young adult (aged ≤20 years) discharges from participating community, nonrehablilitation hospitals. The KID samples patient discharges, which are then weighted to

Table 1. *ICD-9* Codes for Splenic Injuries

ICD-9 Code	Description
865.00	Without mention of open wound into cavity: unspecified injury
865.01	Without mention of open wound into cavity: hematoma without rupture of capsule
865.02	Without mention of open wound into cavity: capsular tears, without major disruption of parenchyma
865.03	Without mention of open wound into cavity: laceration extending into parenchyma
865.04	Without mention of open wound into cavity: massive parenchymal disruption
865.09	Without mention of open wound into cavity: other
865.10	With open wound into cavity: unspecified
865.11	With open wound into cavity: hematoma without rupture of capsule
865.12	With open wound into cavity: capsular tears, without major disruption of parenchyma
865.13	With open wound into cavity: laceration extending into parenchyma
865.14	With open wound into cavity: massive parenchymal disruption
865.19	With open wound into cavity: other

Abbreviation: *ICD-9*, *International Classification of Diseases, Ninth Revision*.

Table 2. Patient Demographics[a]

Characteristic[b]	Total (n = 89 835)	Operative Management (n = 13 306)	Nonoperative Management (n = 76 529)
Age, mean (SEM), y	13.25 (0.02)	14.94 (0.03)	13.00 (0.02)
Sex			
Male	63 763 (71.60)	9773 (74.05)	53 990 (71.17)
Female	25 293 (28.40)	3425 (25.95)	21 868 (28.83)
Race			
White	48 640 (75.91)	7107 (74.41)	41 533 (76.18)
Black	4837 (7.55)	760 (7.96)	4077 (7.48)
Hispanic	7135 (11.14)	1131 (11.84)	6004 (11.01)
Payer			
Medicaid	17 861 (19.98)	2600 (19.66)	15 261 (20.04)
Private HMO	61 697 (69.01)	8972 (67.83)	52 725 (69.22)
Self-pay	5614 (6.28)	990 (7.48)	4624 (6.07)
Income, median (quartile), %[c]			
0-25	15 406 (17.63)	2170 (16.88)	13 236 (17.76)
26-50	22 245 (25.45)	3482 (27.09)	18 763 (25.17)
51-75	22 733 (26.01)	3480 (27.07)	19 253 (25.83)
76-100	27 010 (30.91)	3722 (29.00)	23 288 (31.24)

Abbreviation: HMO, health maintenance organization.
[a] Unless otherwise indicated, data are expressed as number (percentage) of patients. Percentages have been rounded and might not total 100. Specific numbers of missing data will be provided upon request.
[b] For all characteristics, the difference between the operative and nonoperative management groups was significant (all $P < .001$).
[c] Socioeconomic status was estimated by median income of patient home zip code into 4 quartiles.

obtain national estimates. The sampling algorithm involves systemic random sampling to select 10% of uncomplicated in-hospital births and 80% of complicated in-hospital births and other selected pediatric cases. The KID contains information from as many as 38 states. A data use agreement is held by the Agency for Healthcare Research and Quality.

PATIENT SELECTION

All children and adolescents 18 years or younger who were hospitalized with PSI were selected from 9 years of the NIS database (2000-2008) and 3 years of the KID (2000, 2003, and 2006) (N = 95 937). Hospitalizations with a diagnosis of splenic injury were selected using codes from the *International Classification of Diseases, Ninth Revision* (*ICD-9*) (**Table 1**). We used procedure codes to identify splenectomy, splenorrhaphy, transfusion, and angiography. For this study, we defined *operative management* as splenectomy or splenorrhaphy and compared operative vs nonoperative management. We considered a 2-sided $P < .05$ to be statistically significant. Categorical and continuous variables were analyzed using the χ^2 and the 2-sided *t* tests, respectively. We identified independent risk factors for operative management via a multivariable logistic regression analysis. All statistical analyses were performed using commercially available software (SPSS, version 19.0; licensed by IBM). Recommended discharge and hospital weights were incorporated to create national estimates for all analyses.

RESULTS

DEMOGRAPHICS

We identified a national estimate of almost 90 000 cases of PSI. Overall, the mean age was 13.25 years (SEM, 0.02), with a predominantly white (75.91%) and predominantly male (71.60%) population. We calculated relative frequencies of patient demographics and their relationships with operative vs nonoperative management (**Table 2**).

NATIONAL TRENDS

During the study period, the rate of splenectomy decreased from 18.25% to 10.86% ($P<.001$) and that of splenorrhaphy decreased from 1.44% to 0.39% ($P<.001$) (**Figure 1**). The rate of angiography increased from 2.43% to 6.94% ($P<.001$) and that of transfusion increased from 7.71% to 11.49% ($P<.001$) (**Figure 2**). Annual rates are shown in **Table 3**. Blunt trauma constituted 91.94% of PSI cases, whereas 8.06% were penetrating PSI cases. When we correlated the *ICD-9* codes with the Abbreviated Injury Score–1990 (**Table 4**),[5] the most notable decrease in operative management was in grade V blunt injury cases from 54.34% to 37.52% ($P<.001$) (**Figure 3**).

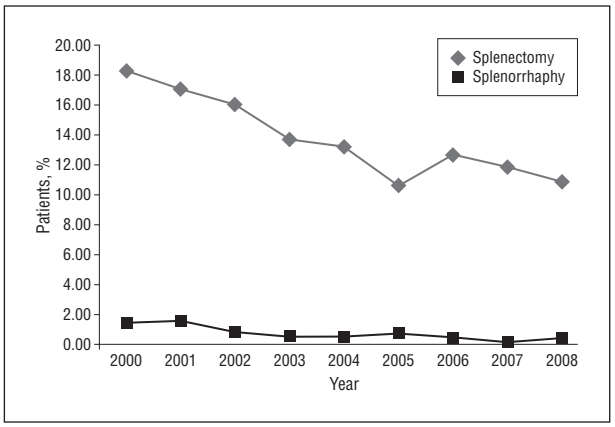

Figure 1. Annual rate of operative management of pediatric splenic injury.

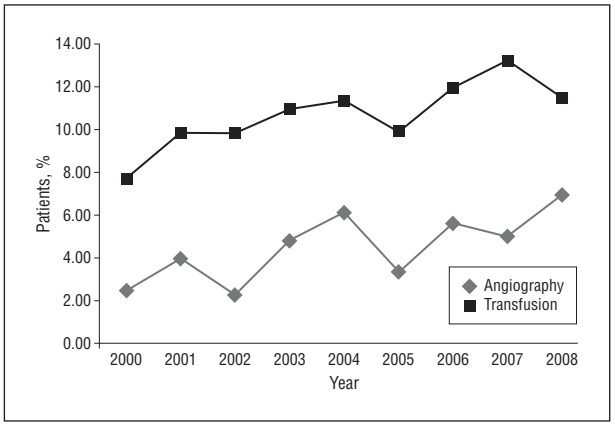

Figure 2. Annual rate of angiography and transfusion for the management of pediatric splenic injury.

OPERATIVE VS NONOPERATIVE MANAGEMENT

All-cause inpatient mortality was 3.56% in children with PSI (**Table 5**). Overall mean (SEM) length of stay was 6.52 (0.03) days, with mean (SEM) total hospital charges of $41 872.00 ($250.47). Mortality was substantially higher in the operative management group compared with the nonoperative management group (1575 of 13 281 cases [11.86%] vs 1625 of 76 489 [2.12%]; $P<.001$). The mean length of stay for the operative management group was significantly longer (9.15 vs 6.52 days; $P<.001$). Similarly, mean total hospital charges were significantly higher for the operative group ($74 981.26 vs $36 156.30; $P<.001$). Operative management was associated with increased disposition to short-term hospitals (4.69% vs 2.63%; $P<.001$) and skilled nursing facilities (9.80% vs 5.81%; $P<.001$).

MULTIVARIABLE LOGISTIC REGRESSION ANALYSIS

Multivariable logistic regression analysis identified increasing severity of splenic injury grades and rural location as independent risk factors for various management modalities (**Table 6**). Grade V injury cases were more likely to undergo operative management (odds ratio [OR], 7.87 [95% CI, 7.38-8.38]; $P<.001$), angiography (OR, 1.65 [95% CI, 1.47-1.84]; $P<.001$), and transfusion (OR, 2.12 [95% CI, 1.97-2.28]; $P<.001$). Cases occurring in a rural location were more likely to undergo operative management (OR, 1.24 [95% CI, 1.18-1.31]; $P<.001$) but less likely to undergo angiography (OR, 0.82 [95% CI, 0.76-0.89]; $P<.001$) and transfusion (OR, 0.96 [95% CI, 0.91-1.01]; $P=.12$).

COMMENT

The combination of improved pediatric intensive care unit care and technological developments has led to increases in the use of nonoperative treatment and

Table 3. Annual Rates of Procedures

Year	No. of PSIs	No. (%) of Patients			
		Splenectomy	Splenorrhaphy	Angiography	Transfusion
2000	14 978	2734 (18.25)	215 (1.44)	364 (2.43)	1155 (7.71)
2001	6981	1191 (17.06)	106 (1.52)	275 (3.94)	684 (9.80)
2002	7264	1163 (16.01)	57 (0.78)	165 (2.27)	715 (9.84)
2003	16 035	2196 (13.70)	78 (0.49)	769 (4.80)	1759 (10.97)
2004	8900	1175 (13.20)	48 (0.54)	543 (6.10)	1006 (11.30)
2005	8253	878 (10.64)	57 (0.69)	279 (3.38)	821 (9.95)
2006	15 017	1896 (12.63)	66 (0.44)	841 (5.60)	1801 (11.99)
2007	7030	832 (11.83)	9 (0.13)	351 (4.99)	931 (13.24)
2008	5377	584 (10.86)	21 (0.39)	373 (6.94)	618 (11.49)

Abbreviation: PSIs, pediatric splenic injuries.

interventional angiography to manage what had previously been considered operative injuries. Our study demonstrates how rapidly and significantly we have seen nationwide shifts in PSI management with decreasing operative management and increasing angiography and transfusion. One of the most interesting and rapid changes noted was in the case of grade V splenic injuries. These changes are beneficial in decreasing morbidity and mortality[6,7] in addition to short-term economic benefits, including decreased length of stay and total hospital charges, as shown in our study.

Although the overall operative volume of PSI management appears to be decreasing, our study identified significant variations and regionalization. We found rural location to be associated with an increase in operative management and a decrease in angiography. To our knowledge, this is the first study to document rural-urban differences in the management of PSI. Explanations for this difference in management may be multifactorial. Successful pediatric angiography and embolization require immediately available personnel and high levels of training to achieve technical skills. Rural hospitals may not have the luxury of 24-hour availability of this specialized intervention. Given hemodynamic instability or unavailable angiography, operative management is a safe choice. Pediatric surgeons, pediatric intensivists, and interventional radiologists are more likely to be found in urban hospitals and may have access to information and experience that favor nonoperative management. The database does not provide hospital resource factors, such as the presence of an intensive care unit or blood product availability, that may influence intervention modality and outcome. Advances in prehospital care, resuscitation, diagnostic imaging, critical care, splenorrhaphy techniques, and hemostatic agents are all factors that contribute to management decisions.[8] Additional studies are needed in assessing the resources and availability of these factors in small rural facilities to increase potential splenic preservation.

This study is subject to the limitations inherent to all retrospective studies using national administrative databases. Physiological and laboratory data, such as systolic blood pressure and hemoglobin levels, are lacking in the database. Some errors may be present in the data set because *ICD-9* codes assigned by coding staff were used to identify diagnoses and procedures. The precise timing of clinical diagnoses and procedures cannot be determined using the KID and NIS database. This issue limited our ability to fully characterize the hospital course. Given that our study used inpatient databases, we could not capture subsequent hospital visits or long-term patient outcomes. Certain

Table 4. Splenic Injury Grading Scale

Grade	Description	*ICD-9* Code	AIS-90
I	Capsular tear, parenchymal depth <1 cm	865.02, 865.12	2
II	Capsular tear that does not involve a trebecular vessel, depth 1-3 cm	865.02, 865.12	2
III	Laceration involving trebecular vessels, parenchymal depth >3 cm; ruptured subcapsular or parenchymal hematoma, intraparenchymal hematoma >5 cm or expanding	865.03, 865.13	3
IV	Laceration involving segmental or hilar vessels producing major devascularization, >25% of spleen		4
V	Shattered spleen or hilar vascular injury that devascularizes spleen	865.04, 865.14	5

Abbreviations: AIS-90, Abbreviated Injury Score–1990; *ICD-9*, *International Classification of Diseases, Ninth Revision*.

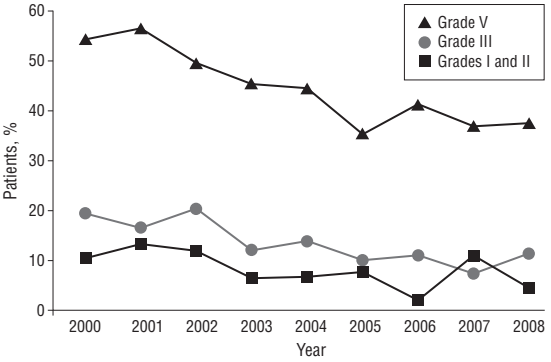

Figure 3. Annual rate of operative management of blunt pediatric splenic injury stratified by splenic injury grade.

Table 5. Hospital Outcomes[a]

Characteristic[b]	Total (n = 89 770)	Operative Management (n = 13 281)	Nonoperative Management (n = 76 489)
Mortality	3200 (3.56)	1575 (11.86)	1625 (2.12)
LOS, mean (SEM), d	6.52 (0.03)	9.15 (0.10)	6.52 (0.03)
THC, mean (SEM), $	41 872.00 (250.47)	74 981.26 (946.78)	36 156.30 (237.87)
Patient disposition			
Routine	75 199 (83.71)	9216 (69.39)	65 983 (86.27)
Short-term hospital	2634 (2.93)	623 (4.69)	2011 (2.63)
Skilled nursing facility or intermediate care	5746 (6.40)	1302 (9.80)	4444 (5.81)
Home health care	2747 (3.06)	518 (3.90)	2229 (2.91)

Abbreviations: LOS, length of stay; THC, total hospital charge.
[a] Unless otherwise indicated, data are expressed as number (percentage) of patients.
[b] For all characteristics, the difference between the operative and nonoperative management groups was significant (all $P < .001$).

Table 6. Multivariable Regression Analysis

	Odds Ratio (95% CI)	*P* Value
Operative management[a]		
Grades I and II	0.77 (0.70-0.86)	<.001
Grade III	1.30 (1.21-1.40)	<.001
Grade V	7.87 (7.38-8.38)	<.001
Rural location	1.24 (1.18-1.31)	<.001
Angiography[a]		
Grades I and II	1.19 (1.04-1.36)	.01
Grade III	1.72 (1.55-1.90)	<.001
Grade V	1.65 (1.47-1.84)	<.001
Rural location	0.82 (0.76-0.89)	<.001
Transfusion[a]		
Grades I and II	0.93 (0.84-1.02)	.13
Grade III	1.18 (1.09-1.27)	<.001
Grade V	2.12 (1.97-2.28)	<.001
Rural location	0.96 (0.91-1.01)	.12

[a]Grades are expressed as splenic injury grades.

fields in the databases, such as race, were missing significant data, which limited our ability to make definitive conclusions based on such characteristics.

Despite these limitations, our findings offer useful insight into national trends and outcomes in operative vs nonoperative management of PSI. Children and adolescents with PSI are undergoing fewer splenectomies but more angiography and transfusions. Rural location may be an independent risk factor for operative management. Significant nationwide variations in operative management that depend on patient location highlight potential disparity in access to changing guidelines and aggressive nonoperative management, including transfusion and angiography.

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Correspondence: Justin Lee, MD, Department of Surgery, St Elizabeth Medical Center, Tufts University School of Medicine, 24A Winship St, Boston, MA 02155 (Justin.Lee@tufts.edu).
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INVITED CRITIQUE

Management of Pediatric Splenic Injury

We Agree, More or Less

Forty years to the month after the success of planned nonoperative management of splenic injuries was first published,[1] Lee and colleagues[2] provide a snapshot of how widely accepted this approach is today. The rate of splenectomy in children is now only 11%, and the odds of successful nonoperative management are not much lower in a rural hospital than in a tertiary medical center in the city. Newer treatment modalities, in particular, angiographic embolization, have helped decrease the operative rate in adults (although they have found fewer proponents among physicians who treat the pediatric population[3]). Because these interventions require specialized equipment and skills, it is not surprising that they are more often used in an urban setting than in small rural facilities; after all, surgical exploration remains the safe default.

We can do better. Although the splenectomy trend continues to decrease, the authors[2] suggest an inevitable correlation with more aggressive nonoperative management, that is, blood transfusion and embolization. It is a stretch, however, to attribute increased splenic salvage rates to embolization procedures, which may be overused or unnecessary in this patient population. In our own experience with more than 200 pediatric splenic injuries during the same period, the splenectomy rate was only 3.5% (1% for isolated injuries), while only 2.5% of patients underwent angiography.[4] These figures are significantly lower than