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ORIGINAL ARTICLE

# Blunt splenic injury in children: haemodynamic status key to guiding management, a 5-year review of practice in a UK major trauma centre

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## Abstract

**Purpose** To review the management of children and adolescents (0–18 years), with blunt splenic injury treated at a single UK major trauma centre over a 5-year period, focusing upon efficacy of non-operative management and the use of haemodynamic stability as a guide to planning treatment strategy, rather than radiological injury grading. To produce a treatment pathway for management of blunt splenic injury in children.

**Methods** Retrospective, cross-sectional study of all paediatric patients admitted with radiologically proven blunt splenic injury between January 2011 and March 2016. Penetrating injuries were excluded. Follow up was for at least 30 days.

**Results** 30 Patients were included, mean age was 14.5 (SD 3.6), median injury severity score was 16 (IQR 10–31). 6 Patients (20%) had a splenectomy, whilst 22 patients (73%) were successfully treated non-operatively with 100% efficacy at index admission. 5/8 (63%) patients with radiological grade V injuries were managed non-operatively, injury grade was not associated with surgical intervention ($p = 1.57$). Haemodynamic instability was initially treated with fluid resuscitation leading to successful non-operative management in 5/11 (45%) patients. However, haemodynamic instability is a significant predictor of requirement for surgical intervention ($p = 0.03$), admission to critical care ($p = 0.017$), presence of additional injuries ($p = 0.015$) and increased length of stay ($p = 0.038$). No such relationships were found to be associated with increased radiological injury grade.

**Conclusions** Non-operative management should be first-line treatment in the haemodynamically stable child with a blunt splenic injury and may be carried out with a high degree of efficacy. It may also be successfully implemented in those initially showing signs of haemodynamic instability that respond to fluid resuscitation. Radiological injury grade does not predict definitive management, level of care, or length of stay; however, haemodynamic stability may be utilised to produce a treatment algorithm and is key to guiding management.

**Keywords** Spleen · Splenic · Injury · Trauma · Paediatric

## Introduction

Traumatic injury remains the leading cause of death in children and adolescents in the UK accounting for between 20 and 40% of all deaths [1], with blunt mechanism injuries accounting for more than 90% of paediatric trauma admissions worldwide. Although injury to the abdomen and pelvis accounts for only 10% of cases, they can be potentially life threatening [2]. Splenic injuries are seen in up to 45% of all patients sustaining blunt abdominal injury [3].

Over the last 3 decades there has been a radical shift from operative to non-operative management (NOM) of splenic injuries in the paediatric population. NOM is now a well-established practice with success rates of 97.5–99% reported [4]. NOM is preferred in children, as it eliminates the common risks and physical insult associated with major abdominal surgery and prevents the long-term risks of asplenism such as venous thrombosis and infection, which in its most severe form, can result in life-threatening postsplenectomy sepsis (OPSI). With a lifetime risk of 1–2% [5], OPSI is likely rarer than previously reported [6] and most cases will occur within the first 2 years; however, it retains a mortality rate of 50–80% [5, 7, 8]. Furthermore, children are at higher

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risk of developing the condition [8]; therefore, a long-term attraction of conservative management is the preservation of the immunological function of the spleen.

Despite the high success rate and acceptance of NOM, universal uptake has been inconsistent, with differences seen between specialist paediatric and generalist services [1, 9, 10], and between high and low volume centres [9, 11, 12]. The American Association for the Surgery of Trauma (AAST) radiological injury grading [13], rather than patient physiology, is still often used to determine the modality of definitive treatment, as high grade injuries have been shown to correlate with failure of NOM in adults [14, 15]. Admission length also varies with 1–9 days for low grade (I–II) and 3–10 days for higher (III–V) grade injuries [16] reported. A previous recommendation by the American Paediatric Surgery Association trauma committee suggested an admission length of radiological injury grade + 2 days [16]; however, this has been shown to be overly conservative [17], with further evidence supporting the notion that haemodynamic stability provides a more useful guide than radiological splenic injury grade [18–20]. There is also variation in admission to Intensive care [20], with current literature suggesting this should be offered in higher grade injuries due to risk of haemodynamic instability [16, 21]; however, other guidelines suggest all children with at least a grade II injury should be managed in a level 3 environment for a minimum of 24 h [19]. There is also debate over the time to resumption of both normal and sporting activities [11].

Despite the lack of clarity from the literature, treatment algorithms for traumatic splenic injury in children have previously been proposed and do exist internationally [18]; however, these have not been adopted into UK practice. In this retrospective study, we aim to evaluate the management and outcome of all patients aged 0–18 years with blunt splenic injury presenting over a 5-year period to the East Midlands Major Trauma Centre (EMMTC), Nottingham, UK, with the aim of assessing our practice, evaluating the role of haemodynamic stability and suggesting management approaches.

## Methods

This was a retrospective, cross-sectional study including all patients aged 18 years and under admitted to the EMMTC between January 2011 and March 2016 with a blunt traumatic splenic injury. Patients were identified by searching the EMMTC prospectively collected patient database, cross referenced with submissions to the Trauma Audit and Research Network. Penetrating injuries were excluded from the study. Patient's paper and electronic records were retrospectively scrutinised for data and follow up was for at least 30 days. Data collected included demographics, mechanism of injury, imaging results including AAST splenic injury grade [13], injury severity score [22], presence of other injuries, initial and subsequent management, length of stay, necessity of transfusion, monitoring environment and managing team.

All splenic injuries were diagnosed on an initial dual phase (arterial and portal venous) Computerised Tomography (CT) scan (Phillips Ingenuity 128 slice CT scanner, Phillips Healthcare, Cleveland, OH, USA) performed on presentation with the exception of one patient diagnosed on ultrasound. All CT scans were initially reported by the on-call radiology registrar and later verified by the consultant radiologist on-call. CT scanning, operating theatres and interventional radiological services are available 24 h a day, 7 days a week. Paediatric trauma calls at EMMTC are initially attended and led by both the Emergency Department and Major Trauma teams, with additional support from Paediatrics, Anaesthetics, Orthopaedics and Paediatric General Surgical teams. Admitted patients aged 16 and under are cared for on either a level 0 paediatric surgical ward under the joint care of paediatric surgery and major trauma with specialty input as required, or on paediatric intensivist-led level 2 and 3 critical care beds. For those aged 17–18 admission is under the major trauma team on our level 1 major trauma unit with input from the adult general surgical team or the intensivist-led level 2 and 3 beds as required. Over the study period, EMMTC had no official guidelines for the treatment of blunt splenic injury in children.

For the purposes of this paper, NOM is defined as conservative treatment with admission for observation. Operative procedures included both splenectomy and splenorrhaphy, angioembolisation was considered separately. Haemodynamic instability was defined by deranged weight and age adjusted physiological parameters with additional clinical review, leading to the use of resuscitative fluids or blood products. This was assessed from the time of presentation to the pre-hospital trauma team at the scene, up until instigation of definitive treatment at our major trauma centre. Other significant injuries were defined as other injuries requiring in-patient hospital treatment.

In total, 32 cases were identified and 30 were included in this study as notes were unavailable on two patients. Data were collected onto an electronic spreadsheet (Microsoft Excel 2015, Microsoft Corporation, released 2015) and statistical analysis was performed using SPSS statistics for Windows (Version 22, IBM corporation, released 2013). Categorical data were analysed using Fisher's exact and Mann–Whitney $U$ tests. A $p$ value of $< 0.05$ was considered statistically significant.

## Results

### Demographics

23 males and 7 females were admitted following a blunt traumatic splenic injury. Age ranged from 4 to 18 years (mean 14.5 years, SD 3.6). Median AAST injury grade was 4. ISS ranged from 1 to 75 (median 16, IQR 10–31). The total length of hospital stay ranged from 1 to 33 days (mean 7.6 days, SD 6.3).

### Mechanism of injury

Figure 1 shows the distribution of AAST injury grade by mechanism of injury. The majority of children ($n=17$) had road traffic accidents (RTA), followed by bicycle accidents ($n=8$). All grade V injuries occurred in these two patient groups.

### Definitive management

Figure 2 shows definitive management by AAST grade. Seven of the 30 patients underwent emergency surgery, with 6 patients (20%) receiving a splenectomy and 1 a splenorrhaphy. Of these 7 cases, 3 patients had grade V injuries with 2 being haemodynamically unstable. The remaining 4 patients all had grade III injuries, 3 with haemodynamic instability, 1 of which required splenectomy following an earlier attempt at arterial embolisation. Two patients underwent arterial embolisation.

Of the remaining 22 patients (73%) who received non-operative treatment, a 100% success rate was noted during the index admission. However, a 14-year-old male patient who had been haemodynamically stable throughout admission with a grade IV injury following a direct blow, was re-admitted 2 months later with a further splenic bleed requiring surgery, though it was unclear if this was simply a late re-bleed or if a further trauma had occurred.

13 patients (76%) with grade IV or V injuries were managed non-operatively, including 5 patients who demonstrated initial haemodynamic instability, but responded to fluid and blood product resuscitation and did not need any further invasive interventions. Two patients died from non-survivable head injuries, both were haemodynamically unstable, one with grade IV injury and active bleeding on CT, one with grade II injury.

### Haemodynamic stability

Eleven children were haemodynamically unstable (injury grades II–V). Of these, 4 patients underwent urgent surgery, 2 had embolisation followed by surgery in 1 case, and 5 (45%) were successfully treated non-operatively.

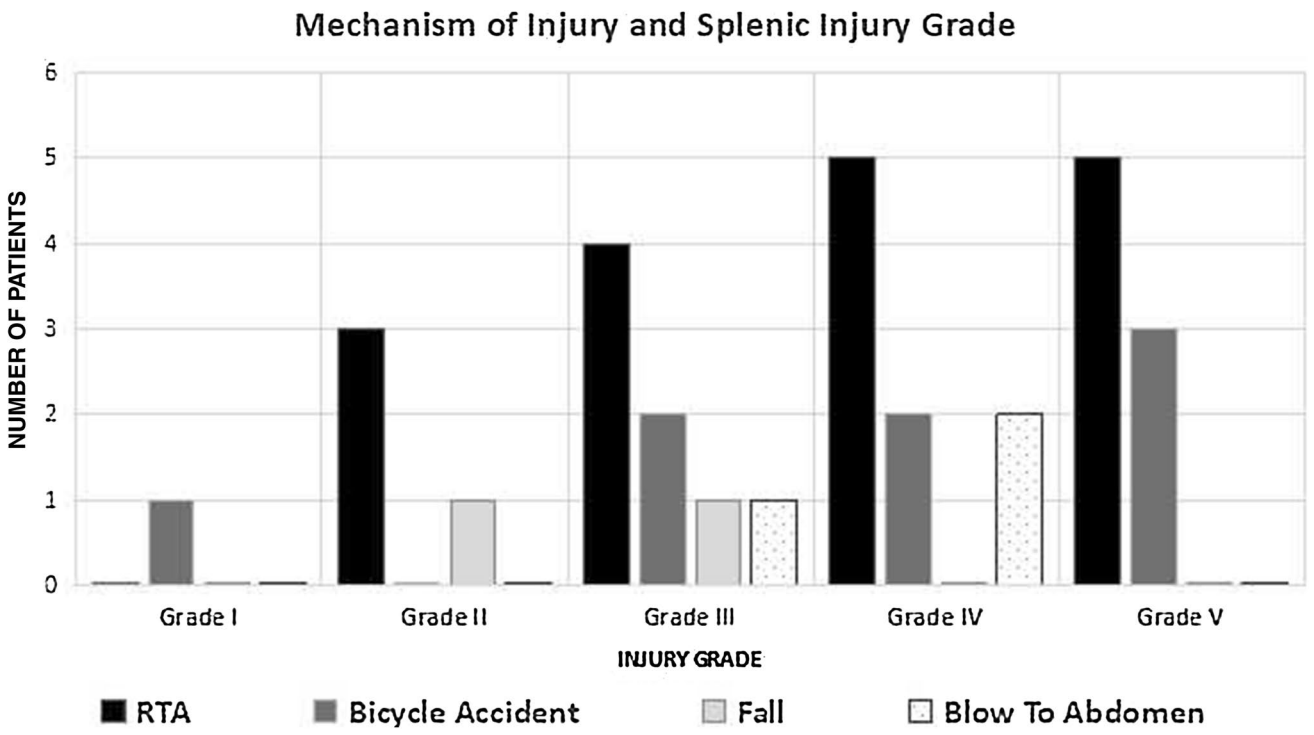


**Fig. 1** Distribution of AAST injury grade by mechanism of injury

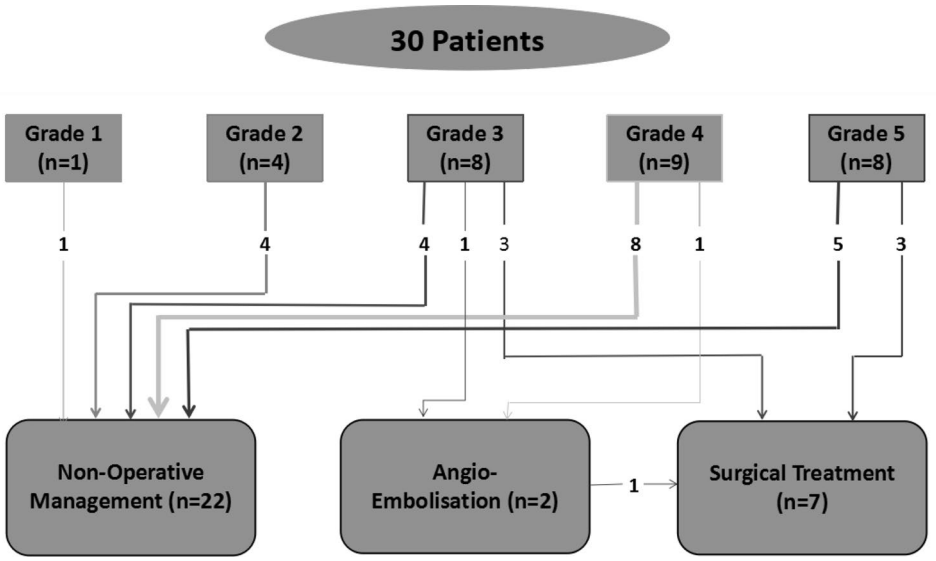


**Fig. 2** Definitive management by AAST injury grade

Although there was a trend towards greater instability and blood product requirement in higher injury grades, the relationship was not statistically significant. Operative management, however (Table 1), was significantly more likely in the unstable group of patients ($p = 0.03$, OR 8.5, confidence interval 1.2-57.93).

Unstable patients were also more likely to have other significant injuries ($p = 0.015$, OR 9.3, CI 1.6–53.2), be treated in a critical care setting $p = 0.017$ and have a longer length of stay (mean 11.3 days, SD 9.0) $p = 0.038$. Unstable patients treated non-operatively had a mean admission length of 6.6 days (SD 4.9). All unstable patients were monitored for at least 24 h in a level 1 or higher setting.

## AAST injury grade

All patients with Grade I and II injuries ($n = 6$) were managed conservatively, with two children discharged within 48 h. Non-operative management was also successfully carried out in a further 17 patients, 50% (4 of 8) with grade III injuries, 89% (8 of 9) with grade IV injuries and 63% (5 of 8) with grade V injuries. Although there was a trend for invasive procedures only to be carried out in higher grade injuries (III–V) this was not statistically significant.

In addition, there was no statistical difference in level of ward care required between low and high grade injuries ($p = 1.0$), for higher grade injuries to be associated with other significant injuries $p = 0.14$ (OR 0.167, CI 0.024–1.15), or for high grade injuries to be associated with longer length of stay $p = 0.175$ (mean 5.3, SD 5.0, grade I–II, mean 8.1,

**Table 1** Comparison of variables based upon haemodynamic stability, injury grade or managing team

| | Management[a] ($n = 29$) | | | Ward level ($n = 30$) | | | | Other injuries ($n = 30$) | | | Length of stay | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NOM | Surgery | $p$ | 0 | 1&2 | 3 | $p$ | No | Yes | $p$ | Mean (SD) | $p$ |
| Haemodynamic stability | | | | | | | | | | | | |
| Stable | 17 (89%) | 2 (11%) | **0.030** | 9 (47%) | 5 (26%) | 5 (26%) | **0.017** | 16 (84%) | 3 (16%) | **0.015** | 5.4 (2.4) | **0.038**** |
| Unstable | 5 (50%) | 5 (50%) | | 0 (0%) | 4 (36%) | 7 (64%) | | 4 (36%) | 7 (64%) | | 11.3 (9.0) | |
| Injury grade | | | | | | | | | | | | |
| 1–2 | 6 (100%) | 0 (0%) | 1.57 | 2 (33%) | 2 (33%) | 2 (33%) | 1.00 | 2 (33%) | 4 (67%) | 0.141 | 5.3 (5.0) | 0.175 |
| 3–5 | 16 (70%) | 7 (30%) | | 7 (29%) | 7 (29%) | 10 (42%) | | 18 (75%) | 6 (25%) | | 8.1 (6.6) | |
| Team | | | | | | | | | | | | |
| Adult | 7 (54%) | 6 (46%) | **0.026** | 1 (8%) | 7 (54%) | 5 (38%) | **0.016** | 6 (46%) | 7 (54%) | 0.056 | 8.4 (8.8) | 0.721 |
| Paediatrics | 15 (94%) | 1 (6%) | | 8 (47%) | 2 (12%) | 7 (41%) | | 14 (82%) | 3 (18%) | | 7.0 (3.6) | |

All tests performed using Fishers exact test unless stated otherwise

**Mann–Whitney *U* test

[a]Excludes 1 patient that had successful embolisation

SD 6.6, grades III–V), though all patients with higher grade injuries were observed for at least 48 h (mean 6.6 days, SD 3.0).

### Active bleeding on CT

Four patients had signs of active bleeding on imaging, defined as an arterial blush seen on CT scanning, there were no pseudoaneurysms reported. 2 patients had a grade III injury, one grade IV, one grade V. Three patients (75%) had associated haemodynamic instability. One patient died from a head injury. Of the remaining three patients with active radiological bleeding, all were ultimately managed surgically, one following an unsuccessful attempt at embolisation.

### Age of child and managing team

The majority of the children in our study were teenagers with only 4 children below the age of 12. Seventeen patients were managed by the paediatric surgical team (Fig. 3), of which 1 patient (5.9%) underwent surgery and 1 had successful embolisation. 3 children were haemodynamically unstable (18%) and received blood transfusions. Of the remaining 13 patients managed by the adult team, 6 underwent surgery (46%) including 1 patient following arterial embolisation. 8 patients were haemodynamically unstable (73%), 6 requiring blood products. There was no significant difference in injury grades ($p=0.36$) or length of stay ($p=0.72$) between the teams.

Patients treated by the adult team (Table 2) were significantly more likely to undergo operative treatment ($p=0.026$, OR 12.9, CI 1.3–128.1); however, they were also more likely to be haemodynamically unstable, ($p=0.023$, OR 7.47, CI 1.4–39.84), with results also approaching significance for presence of other significant injuries $p=0.056$ (OR 0.18, CI 0.04–0.96). Unfortunately, the patient numbers were too small for a logistic regression model with 83 patients required to accurately show an effect [23].

**Table 2** Comparison of adult vs paediatric patients in terms of haemodynamic status and injury grade

| | Team | | *p* |
|---|---|---|---|
| | Adult | Paeds | |
| Haemodynamic stability | | | |
| Stable | 5 (26%) | 14 (74%) | **0.023*** |
| Unstable | 8 (73%) | 3 (27%) | |
| Injury grade | | | |
| 1–2 | 4 (67%) | 2 (33%) | 0.360* |
| 3–5 | 9 (38%) | 15 (62%) | |

*Fisher's exact test

## Discussion

73% of our patients were successfully treated with non-operative management, supporting the modern approach that it should be considered first-line treatment in haemodynamically stable children and adolescents with splenic injuries [4, 21, 24], regardless of injury grade. One study reports that 97% of surgeons agree that conservative management should always be first-line treatment [25]; however, in the presence of haemodynamic instability, there is debate as to whether

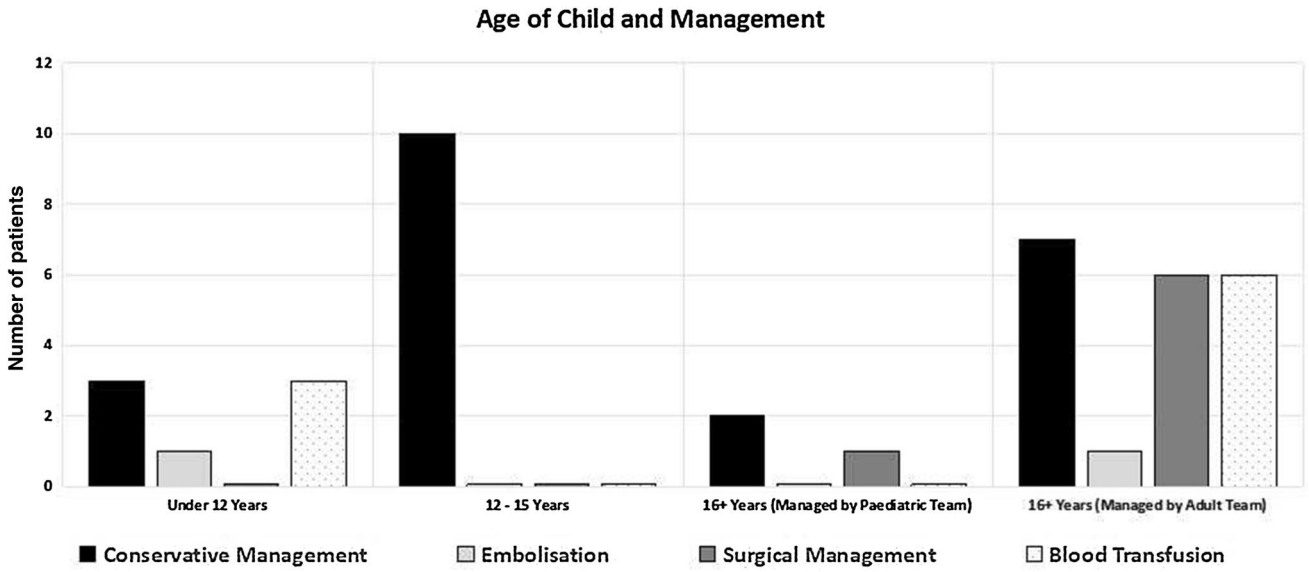


**Fig. 3** Management of patients by age

immediate surgery, or resuscitation with blood products with a trial of conservative management is most appropriate. In our series we managed to successfully treat 45% of haemodynamically unstable children non-operatively, and a further patient with angioembolisation, supporting the role of trial of conservative management as a first-line treatment. In addition, we found that haemodynamic stability was a more powerful indicator of requirement for critical care, presence of other significant injuries and length of stay than the traditional AAST injury grade. A limitation of the study was that we didn't look into other areas of management such as bed rest and return to activity in which there is still a lack of consensus among clinicians [11] and due to the relatively small number of cases we were unable to run regression models on multiple variables or have sufficient numbers to compare differing populations as no patients treated operatively were under the age of 16.

Eleven of our patients were haemodynamically unstable and significantly more likely to undergo surgery. Of these nearly half (5 of 11) had low-grade injuries and we found no link between AAST injury grade and either associated haemodynamic stability or need for surgical management. Interestingly of the 8 children with grade V injuries, for which splenectomy is often considered almost inevitable and previously reported to have an operative rate as high as 95% [26], five children (62.5%) were successfully managed conservatively. This contradicts previous AAST guidelines which suggest the higher the grade of injury the more likely the requirement for splenectomy [13, 27]. We did, however, find that haemodynamic instability was significantly linked ($p=0.03$) with operative management and 5 of the 6 patients undergoing splenectomy (83%) were unstable. We, therefore, suggest that haemodynamic stability is a better predictor of the need for intervention than injury grade. Several recent studies concur that it is one of the most accurate determinants of failure of conservative management in children [4, 24, 28–31]. In addition, age, sex, mechanism of injury and ISS have all been reported as not being linked to failure of conservative management [4, 24, 29, 30].

Thus we would propose a treatment algorithm based around haemodynamic stability and response to resuscitation, with conservative management trialled in all haemodynamically stable children, regardless of injury grade, and cautious observation of those initially unstable who respond to resuscitation. For active bleeding seen on CT scan, we would advocate the selective use of interventional radiology for a resuscitated child whom had shown signs of haemodynamic instability, with surgical intervention reserved for those who remain unstable despite resuscitation, and close observation for stable patients with a contrast blush. Indeed, utilisation of angioembolisation has been found to have an increasingly useful role [10], particularly in the adult population [27].

### Haemodynamic stability and length of stay

Regarding length of admission, again there is no consensus within the literature. One study has suggested that haemodynamically stable children with isolated splenic injuries can be treated safely with a 4-day hospital admission for high grade (III–V) and 72-h for low-grade injuries [19]; however, other published data suggest discharge should be on days 5–7 if haemodynamically stable, regardless of grading [20]. The difficulty with making any sort of recommendation is that there are always a small proportion of patients who rebleed late (after 10 days). In our series, all haemodynamically unstable patients or those with high grade (III–V) injuries were admitted for at least a minimum of 48 h. The two stable patients with low-grade injuries discharged after 24 h did not represent; therefore, this would seem an appropriate minimum period of observation in each case.

A mean length of stay of 7.6 days in our series may appear conservative; however, this does not account for other injuries sustained. Certainly, it was shown that haemodynamic instability significantly increased length of stay (mean 5.4 vs 11.3 days, $p=0.038$), but was also associated with other significant injuries that may have prolonged admission ($p=0.015$). However, higher injury grade did not significantly lengthen admission ($p=0.175$), nor was it associated with other injuries ($p=0.14$), thus supporting previous literature suggesting length of stay is unrelated to splenic injury grading [16–18], and that haemodynamic stability is a more useful indicator.

### Haemodynamic stability and intensive care

Unsurprisingly given that our study found haemodynamic instability to be associated with other injuries and a longer admission, it was also associated with a likelihood for requiring level 3 care ($p=0.017$); however, higher injury grade was not. Previous literature supports the concept of grade 4 and 5 injuries being managed in intensive care, with grade 3 and below being manageable on wards [11, 16, 21], due to lower transfusion and operation rates. However, our study found no difference in transfusion or operative rates based upon injury grade, and thus no difference in critical care admissions.

These findings are echoed in previous studies which suggest that critical care admission should be based upon haemodynamic instability and response to resuscitation rather than splenic injury grading [21, 32] with recommendations to standardise admission based upon haemodynamic criteria [33]. Our findings support this, with all haemodynamically unstable patients requiring at least level 1 care, and those selected for NOM observed in a level 2 or 3 environment initially.

## Adult vs paediatric team management

Studies have shown that children admitted to centres without paediatric trauma teams are statistically more likely to have a splenectomy [25, 31, 34–36]. In our study, patients admitted under the adult team were significantly more likely to have surgery ($p=0.026$); however, these patients were also significantly more likely to be haemodynamically unstable ($p=0.023$), and approaching significance for sustaining additional injuries ($p=0.056$). There was no significant difference in length of stay between teams.

Previous studies have suggested that age is not linked to failure of NOM [4, 24, 29]; however, in our study, all children who underwent surgery were 16 years or over. Therefore, is it possible that the younger child's physiology makes surgery or haemodynamic instability less likely, explaining the reported discrepancy in management between adult and paediatric teams? This may also explain why the NOM failure rate in children has been reported to be as low as 1–3% [4] yet has been shown to be much higher in adults [26] Further sufficiently powered study is needed to differentiate between child, adolescent and adult outcomes and between paediatric and adult team management.

## Management pathway

Figure 4 outlines a suggested management pathway based upon our findings, with an emphasis on utilising haemodynamic instability as an indicator for admission to critical care, a guide to minimum period of admission, and an indication for surgery. NOM is initially trialled in all cases. However, further studies in greater number are required to assess the impact of additional injuries, to more accurately predict length of stay, to more clearly define required levels of care and to assess for additional factors such as return to physical activity or contact sports; however, the algorithm serves as a guide to plan initial management, which may be expanded upon in the future with further research.

## Conclusion

Although it is now widely accepted practice to treat a haemodynamically stable child with a blunt splenic injury non-operatively as a first line, there remains a lack of a clear evidence base regarding several other aspects of management. In addition, there remains no evidence or consensus for treating those with haemodynamic instability either operatively, interventionally or with NOM. Radiological injury grading appears inaccurate in predicting outcome, however, is still widely used as a basis for management decisions.

Our retrospective study has shown that non-operative management can be safely carried out on all haemodynamically stable patients regardless of injury grade with a high degree of efficacy, and that even in the presence of haemodynamic instability, an initial attempt at resuscitation may prevent surgery in a number of patients. We have shown at our institution, that haemodynamic stability can guide length of admission, level of ward care and indication for surgery, and have suggested a basic management pathway to follow in cases of BSI in children up to the age of 18. However, more work needs to be done to provide a more definitive treatment algorithm for the management of paediatric splenic injuries in the UK. This should cover assessment of haemodynamic stability and concomitant injuries including clear criteria for admission to ICU, differences between age groups in terms of physiological response and injury severity, indications for surgical or radiological intervention and clearer guidance upon length

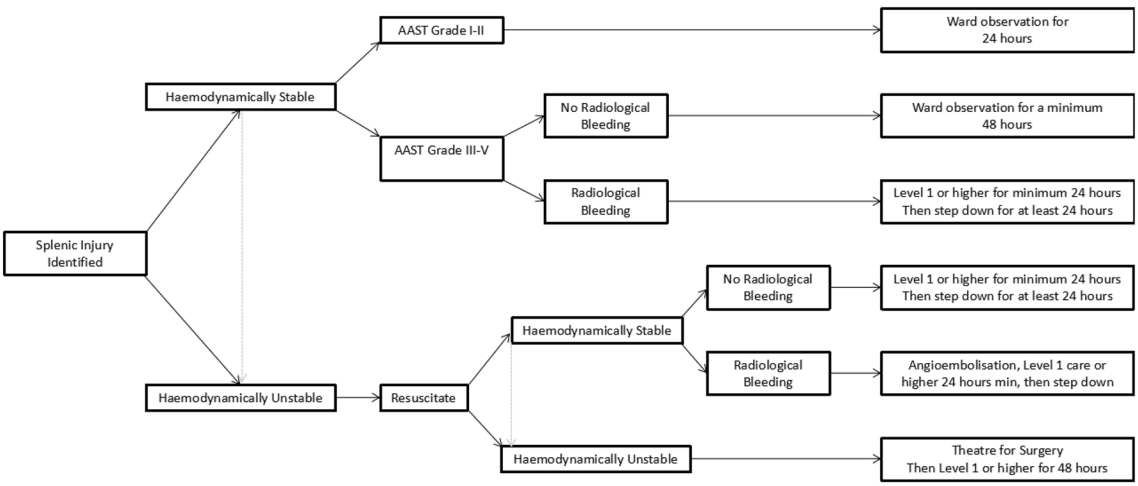


**Fig. 4** Suggested pathway for management of traumatic blunt splenic injury in children

of stay required for observation and resumption of activity. There should be an emphasis on conservative treatment as first line and use of physiological rather than radiological parameters. Finally, this should then be trialled throughout the UK trauma network. This would ensure that all children are managed optimally, in the most appropriate environment, for the adequate length of time.

## Compliance with ethical standards

**Conflict of interest** The author(s) declare that they have no competing interests.

**Human and animal rights** No research was conducted using human or animal participants

**Informed consent** None required.

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