

Original Article

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No need for surgery? Patterns and outcomes of blunt abdominal trauma

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Abstract

Introduction: The management of a patient suffering from blunt abdominal trauma (BAT) remains a challenge for the emergency physician. Within the last few years, the standard therapy for hemodynamically stable patients with BAT has transitioned to a non-operative approach. The purpose of this study is to evaluate the outcome of patients with BAT and to determine the reasons for failure of non-operative management (NOM).

Materials and methods: Analysis of 176 consecutive patients treated for BAT was conducted in a German level 1 trauma center from 2004 to 2011. Abdominal injuries were classified according to the American Association for the Surgery of Trauma (AAST). Patients included were demonstrated to have objective abdominal trauma with either free fluid on focused assessment with sonography for trauma (FAST) or computed tomography (CT), or proven organ injury.

Results: Patients, 142 of 176 (80.7%), with BAT were initially managed non-operatively, with a success rate of 90%. The

rates of NOM success were higher among those with less severe injuries; 100% with Abbreviated Injury Scale (AIS) of 1. In total, 125 patients (71.0%) were managed non-operatively, and 51 (29.0%) required surgical intervention. NOM failure occurred in 9.2% of the patients, the most common reason being initially undiagnosed intestinal perforation (46.2%). Positive correlation was identified ($r = 0.512$; $p < 0.001$) between the ISS (injury severity score) and the NACA (National Advisory Committee of Aeronautics) score. The delay in operation in NOM failure was 6 h in patients with underlying hepatic or splenic rupture and 34 h with intestinal perforation. The overall mortality of 5.1% was attributed especially to old age ($p = 0.016$), high severity of injury ($p < 0.001$), and greater need for blood transfusion ($p < 0.001$).

Conclusion: NOM was successful for the vast majority of blunt abdominal trauma patients, especially those with less severe injuries. NOM failure and operative delay were most commonly due to occult hollow viscus injury (HVI), the detection of which was achieved by close clinical observation and abdominal ultrasound in conjunction with monitoring for rising markers of infection and by multidetector computed tomography (MDCT) if additionally indicated. Based on this concept, the delay in operation in patients with NOM failure was short. This study underscores the feasibility and benefit of NOM in BAT.

Keywords: abdomen; blunt trauma; hepatic rupture; hollow viscus injury; NOM; NOM failure; splenic rupture.

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Introduction

Trauma is a leading cause of morbidity and mortality in the developed world, and by 2020, it will become a major reason for “years of productive life lost” worldwide [1, 2]. Abdominal trauma is associated with approximately 10% of all trauma cases, and the abdomen is recognized as the third most commonly injured region of the body [3]. In contrast to the USA where stab and gunshot wounds predominate, European trauma cases are mostly non-penetrating

in nature and are encountered in the setting of severe multiple trauma [4].

Over the past few decades, the standard treatment for hemodynamically stable patients with blunt abdominal trauma (BAT) evolved from operative to non-operative management (NOM). This transition was accompanied by a decrease in mortality due to continual improvement in NOM expertise and development of superior diagnostic and interventional radiology tools [5]. It was demonstrated that even patients with high-grade injuries (AIS grades IV and V) to solid abdominal organs can be successfully treated non-operatively if hemodynamically stable [6, 7]. Those presenting, however, with obvious BAT and hemodynamic instability or free fluid on focused assessment with sonography for trauma (FAST) and instability require immediate laparotomy without delay [5]. Multidetector computed tomography (MDCT) scanning can significantly increase the chance of survival for polytrauma patients by enabling definitive evaluation of abdominal and associated hollow viscus and musculoskeletal injuries [8]. By virtue of its distinct superiority over FAST scanning, it is recommended that MDCT be performed for hemodynamically stable patients with BAT [9].

Hollow viscus injuries (HVIs) occur in 3–5% of BAT cases. [10]. The complex and non-specific presentation of HVI makes the initial diagnosis difficult, and a repeat computed tomography (CT) scan may be necessary to detect occult laceration [11].

The purpose of this study is to evaluate the outcome of patients following BAT and to determine the reasons for failure of non-operative management.

Material and methods

Analysis of 176 consecutive patients treated for BAT was conducted in a level 1 trauma center at the University of Rostock, Rostock, Germany, from 2004 to 2011. Abdominal organ injuries were classified according to the American Association for the Surgery of Trauma (AAST) (Table 1). The Abbreviated Injury Scale (AIS) (Table 2) was used to define trauma severity. To specify the injury severity of the whole patient, the injury severity scale (ISS) was used. To calculate the ISS, the AIS of the three most injured regions (head, face, thorax, abdomen, extremities, and body surface) are squared and summed up, which leads to a range from 0 to 75. Every AIS of 6 leads automatically to an ISS of 75, and an ISS ≥ 16 is defined as a multiple trauma [14]. The National Advisory Committee of Aeronautics (NACA) score, which is determined by the emergency physician on scene, was used to classify the prehospital injury severity assumption (Table 3).

Patients included were those with either proven organ injury or free fluid on FAST or CT scanning. Initial identification of patients was by International Classification of Diseases and therapy classification

Table 1: AAST example for splenic injury scale (advance one grade for multiple injuries up to grade III) [12].

| Grade | Injury type | Description of injury | AIS |
|-------|-------------|--|-----|
| I | Hematoma | Subcapsular <10% surface area | 2 |
| | Laceration | Capsular tear <1 cm parenchymal depth | 2 |
| II | Hematoma | Subcapsular 10–50% surface area Intraparenchymal <5 cm in diameter | 2 |
| | Laceration | Capsular tear 1–3 cm parenchymal depth that does not involve a trabecular vessel | 2 |
| III | Hematoma | Subcapsular >50% surface area or expanding Ruptured subcapsular or parenchymal hematoma Intraparenchymal hematoma ≥ 5 cm or expanding | 3 |
| | Laceration | > 3 cm parenchymal depth or involving trabecular vessels | 3 |
| IV | Laceration | Laceration involving segmental or hilar vessels producing major devascularization (>25% of spleen) | 4 |
| V | Hematoma | Completely shattered spleen | 5 |
| | Laceration | Hilar vascular injury devascularizes spleen | 5 |

Table 2: AIS [13].

| Score | Injury |
|-------|---------------------------------|
| 1 | Minor |
| 2 | Moderate |
| 3 | Serious |
| 4 | Severe |
| 5 | Critical |
| 6 | Maximum (currently untreatable) |
| 9 | Not further specified |

codes (“German Procedure and Classification Code” Operationen- und Prozedurenschlüssel). Patient records, discharge letters, radiology results, and surgery reports were analyzed on the basis of gender, age, preclinical and clinical vital signs, time and date of hospitalization and discharge, laboratory values, and etiology and treatment of abdominal and other injuries. FAST was performed for all patients, the majority of whom also underwent CT scan.

Statistical analysis

Categorical data are reported in the form of frequencies and percentages. Continuous data are reported as medians and ranges alongside means and standard deviations. Normal distribution of the data was tested using the Kolmogorov-Smirnov test. In univariate analyses, parametric (t-test) or non-parametric (Mann-Whitney U test) were

Table 3: NACA score [15].

| NACA | ISS | SD | n | NACA description |
|------|------|------|----|--|
| 1 | | | 0 | No injury |
| 2 | 9.8 | 2.2 | 4 | Injuries without need for acute physicians' care |
| 3 | 19.0 | 11.0 | 21 | Injuries without acute threat to life but requiring hospital admission |
| 4 | 25.4 | 16.3 | 27 | Injuries where life-threatening condition cannot be excluded |
| 5 | 34.2 | 10.8 | 31 | Injuries with acute life-threatening |
| 6 | 44.0 | 25.5 | 3 | Injuries transported after successful resuscitation of vital signs |
| 7 | | | 0 | Lethal injuries |

adopted based on the characteristics of the distribution. Multivariate analysis was realized using a general linear model and Wilks' lambda as test statistic. The correlation among continuous parameters was calculated using the Pearson's correlation coefficient. All statistical analysis was performed using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA).

Results

One hundred and seventy-six patients were treated for BAT between 2004 and 2011, 62 of whom were female (35.2%) and 114 male (64.8%), with a median age of 31.5 years and a mean age of 36.7 years (± 20.7 years). The median duration of hospitalization was 17.0 days (mean 22.9 ± 22.0 days), including a median of 5.0 days (mean 12.0 ± 19.2 days) spent in the intensive care unit (ICU).

Road traffic accidents were the most common cause of trauma (108 cases; 61.4%) followed by falls (38 cases; 21.6%), assaults (10 cases; 5.7%), sports-related incidents (4 cases; 2.3%), and others (16 cases; 9.1%).

Ninety-five cases involved multiple trauma with an ISS ≥ 16 . A positive correlation was identified (correlation coefficient $r = 0.512$; $p < 0.001$) between the ISS and the NACA score, which is defined by the emergency physician at the site of accident (Table 3).

In total, 129 patients suffered 165 solid organ injuries due to BAT. The most commonly injured organ was the liver (40.6%; $n = 67$), followed by the spleen (37.0%; $n = 61$), kidney (18.2%; $n = 30$), and pancreas (4.2%; $n = 7$) (Table 4). Of those sustaining injuries to solid organs, 98

(76.0%) suffered single-organ injury, 26 (20.2%) experienced injury to two organs, and 5 (3.9%) endured triple-organ damage. The study also revealed 14 insults to hollow viscuses, 5 to the urethra, 2 to the diaphragm, and 2 to the urinary bladder.

Eighty-four (47.7%) out of 176 patients suffered from severe BAT corresponding with an AIS of 3 or higher. Forty-seven cases (26.7%) were classified with an AIS of 3, 27 (15.3%) an AIS of 4, 9 (5.1%) an AIS of 5, and 1 (0.6%) an AIS of 6.

One hundred and forty-two (80.7%) patients were initially treated non-operatively. Of these, 13 went on to require surgical intervention due to NOM failure and 4 due to a complication during hospitalization, yielding a success rate for non-operative treatment of 88% (Figure 2). In all, 51 patients (29.0%) required operative treatment. Sources of mortality included old age ($p = 0.016$), high severity of injury ($p < 0.001$), and greater need for blood transfusion (BT) ($p < 0.001$) (Table 5). Overall mortality rate was 5.1% ($n = 9$).

Of the 51 patients requiring surgical intervention, 29 (16.5%) underwent immediate emergency surgery due to hemodynamic instability and free abdominal fluid. Delay was experienced by 22 patients (12.5%) prior to being taken to the operating room, the causes of which included failure of NOM (13 cases; 7.4%), prolonged triage (4 cases; 2.3%), and complications during the hospital stay (4 cases; 2.3%). One patient received packing in an external hospital and was delayed in presentation. In all, 71.0% of the patients suffering from BAT were treated non-operatively. All patients who were treated with an immediate

Table 4: Pattern of solid organ injuries subdivided into severity regarding AAST.

| Organ | AAST 1 | AAST 2 | AAST 3 | AAST 4 | AAST 5 | n |
|----------|------------|------------|------------|-----------|----------|----|
| Liver | 15 (22.4%) | 30 (44.8%) | 12 (17.9%) | 9 (13.4%) | 1 (1.5%) | 67 |
| Spleen | 10 (16.4%) | 27 (44.3%) | 14 (23.0%) | 5 (8.2%) | 5 (8.2%) | 61 |
| Kidney | 11 (36.7%) | 6 (20.0%) | 6 (20.0%) | 5 (16.7%) | 2 (6.7%) | 30 |
| Pancreas | 5 (71.4%) | 1 (14.3%) | 1 (14.3%) | 0 | 0 | 7 |

Table 5: Comparison of died vs. survived patients regarding age, ISS, and BT^a in our studygroup compared to data of the German Trauma Registry Data (DGU) [16].

| | n | Median | Mean | SD | Univariate p-values | TR DGU | Multivariate p-value (Wilks' lambda) |
|----------|-----|--------|------|------|---------------------|--------|--------------------------------------|
| Age | | | | | | | |
| Died | 9 | 44.0 | 55.2 | 24.8 | 0.016 | | |
| Survived | 167 | 30.0 | 35.7 | 20.1 | | | |
| ISS | | | | | | | |
| Died | 9 | 43.0 | 44.8 | 19.1 | <0.001 | 35.7 | <0.001 |
| Survived | 154 | 17.5 | 20.5 | 14.7 | | 19.4 | |
| BT | | | | | | | |
| Died | 8 | 11.5 | 28.8 | 44.9 | <0.001 | | |
| Survived | 167 | 0.0 | 7.5 | 14.1 | | | |

^aBlood transfusion, e.g. red cell concentrate.

surgical intervention showed either a high-grade solid organ injury (AIS 4 or higher), an HVI, or an active bleeding with mass transfusion.

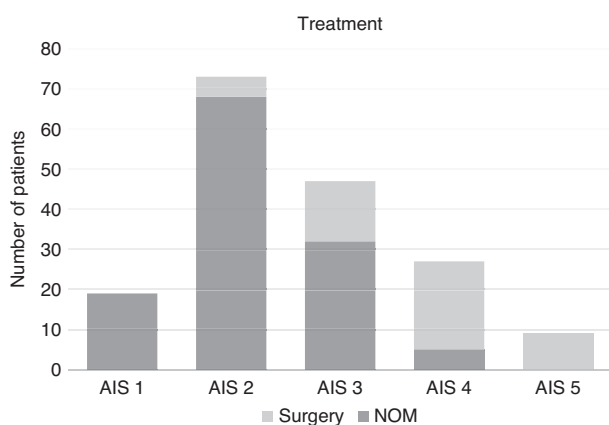
The success rates for non-operative treatment among the sub-groups were as follows: AIS of 1=100%; AIS of 2=93.2%, AIS of 3=68.1%, AIS of 4=18.5%, AIS of 5=0% (Figure 1). The one patient with an AIS of 6 passed away in the ER and could not undergo surgery.

Thirteen of the 142 patients (9.2%) who were initially treated non-operatively eventually went on to require an operation due to NOM failure. The most common reason for NOM failure was an initially undetected intestinal perforation (six cases; 46.2%), cases of which included four small bowel injuries, one perforation of the colon, and one combination of colon, small bowel, and rectal laceration. The second most common reason (46.2%) was the inaccurate assessment of organ injury (n=6) (six cases; three spleen, two liver, one pancreas). One patient (7.7%) demonstrated delayed enterothorax due to an undiscovered diaphragmatic rupture (Figure 2). NOM failure was

recognized following hepatic or splenic injuries after approximately 6 h (median 339 min) as a consequence of hemodynamic instability. In contrast, patients with undiagnosed bowel injury were subjected to observation for a median of 34.4 h before being taken to the operating room, after failure of NOM revealed itself via escalating parameters of infection and peritonitis. Patients in whom NOM failure was observed required a significantly longer period of treatment in the ICU compared to all other groups (p<0.008).

Discussion

Within the last few decades, non-operative management for BAT has become the standard of care in many cases, especially for stable patients with injuries of the liver, spleen, or kidney [17–20]. It is, therefore, necessary for emergency room teams to contain or work closely with GI or general surgeons, so that accurate assessment of abdominal injuries may be conducted, and the need for emergency laparotomy or NOM delineated [21]. It is crucial for patients to undergo frequent observation and ultrasound studies for at least 48 to 72 h in an intensive care or intermediate care setting in order to monitor for hemodynamic instability or the occurrence of new peritoneal signs [20]. Our study reveals an initial non-operative treatment rate of 80% for patients suffering from blunt abdominal trauma, with an approximate success rate of 90%. These findings correspond favorably with similar results documented by Raza et al., whose review also describes an 80% initial rate of NOM, with a 90% success rate [20]. The following are the initial rates of NOM stratified according to AIS scoring: AIS of 1=100%; AIS of 2=93.2%, AIS of 3=68.1%, AIS of 4=18.5%, AIS 5=0%. We identified lower rates of initial NOM among patients

**Figure 1:** AIS and the probability of NOM.

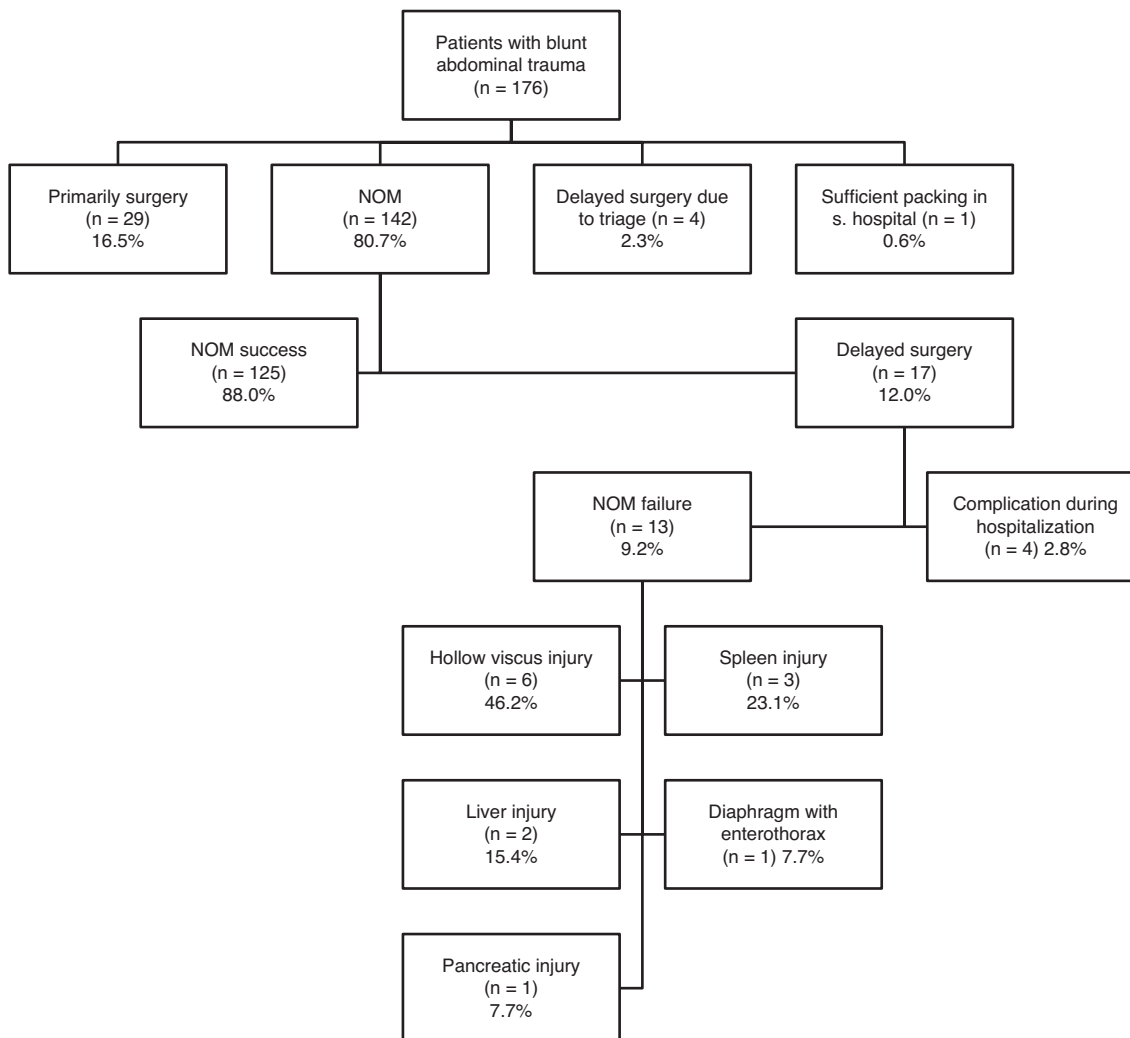


Figure 2: Tree diagram of treatment and NOM failure.

with higher-grade injuries, in whom the postponement of emergency surgery is often not realistic. High-grade trauma (AAST 4 or 5) necessitated immediate surgical intervention in 81.5–100%. It was demonstrated, however, by Van der Wilden et al. that high-grade injuries of the liver (AAST 4 and 5) are often amenable to non-operative treatment in hemodynamically stable patients with a success rate of 90% [22]. Nevertheless, high-grade injury (AAST 4 or 5) independent of hemodynamic status still engenders a much higher risk of NOM failure as illustrated via meta-analysis by Bhangu et al. [23]. This, in turn, impacts upon the need for resources and length of hospital stay, and must be considered during the decision-making process amid attempts to minimize morbidity and mortality. Furthermore, it has to be considered that we could not show a single case of a negative laparotomy in the cohort who underwent primarily operative treatment. In this study a

higher NOM rate would have led to a higher NOM failure rate.

Undetected perforation of the bowel was the most common reason for NOM failure in our study. Roughly half of unplanned laparotomies were as a result of intestinal lacerations (46.2%), which had not been discovered on initial assessment despite the use of ultrasound, CT, and in one case, contrast enema. MDCT was promoted as a more sensitive method by which HVI may be detected. Yet Ekeh et al. reported a detection failure rate for HVI of 19.3% even after the use of this much more detailed imaging modality [24]. A large study of 1082 patients by Stuhlfaut et al. regarding HVI detection by MDCT reported a sensitivity of 82% and specificity of 99% [25]. These values range throughout the literature from 55.3% to 88.3% and 99.2% to 99.4%, respectively [26–28]. It is important to recognize, as illustrated by Atri et al. that

operator experience, and the experience of the reporting physician remains intrinsic to the procurement of diagnostic results with sensitivity ranging from 87% to 95% and specificity from 48% to 84% [29]. The reliable recognition of HVI often requires regular ultrasound and clinical examinations, close monitoring for rising markers of infection, and occasionally repeat MDCT scanning [30]. Laparoscopy is an approach in cases of diagnostic doubt and was primarily advocated to lower the number of unnecessary laparotomies due to its diagnostic and therapeutic potential [31]. It is easy to implement and gives the surgeon an additional tool between imaging methods and laparotomy with the potential to decrease hospital stay and the number of laparotomies [32, 33]. In some institutions, laparoscopy is included in the NOM algorithm on a routine base to decrease NOM failure [34]. According to this concept, 129 patients would have been subjected to an unnecessary laparoscopy in our study. Therefore, we are in favor of a watchful waiting strategy after a negative MDCT. This conservative approach resulted in a delay in treatment of 34.4 h in the patients with HVI with no mortality. This time lag seems acceptable compared to a high number of negative laparoscopies if routinely applied, but can result in a longer ICU treatment period if the detection time of the occult HVI is too long. The seatbelt sign is the appearance of bruising and/or abrasions in the distribution of a seatbelt following a road traffic accident, the presence of which was identified by some authors to correlate with a higher likelihood of HVI [11, 35]. Miller et al. did reveal a relatively low rate of abdominal organ injury on MCDT (20%) among those exhibiting a seatbelt sign [9]. Nevertheless, it must be emphasized, therefore, that the importance of clinical examination cannot be overestimated, and occult HVI should always be suspected if any of the indirect signs of clinical deterioration are present. Bedside ultrasound, follow-up is often sufficient in cases of solid organ injuries, and repeat CT is usually not necessary unless an occult HVI is suspected. An analysis by Blackburne et al. showed that a significant improvement in ultrasound sensitivity for the diagnosis of blunt abdominal trauma (from 31.1% to 72.1%) can be achieved through the use of repeat scanning [36].

Velmahos et al. revealed a 28% rate of immediate surgical intervention among patients in their study with blunt abdominal trauma and a NOM failure rate of 22%. The authors were critical of the retrospective design of most studies and specified their preference that more prospective analyses be constructed [37]. Prospective models offer a clearer insight into the thought processes behind surgery vs. NOM decisions, with documentation of underlying assumptions and considerations more likely to be

available. In this way, we may improve comparability between studies and further illuminate the overarching explanations for NOM failure.

The overall injury severity in this study is comparable to the results of the German trauma register [16]. That underlines the transferability of our results to other hospitals. An injury severity classification index known as the NACA scoring system is used by emergency physicians at the scene of the accident as a simple method with which to predict mortality and identify emergency treatment requirements and respiratory therapy. NACA developed their system during the Vietnam War for patients receiving air transport, and scoring involves the collation of unmeasurable clinical parameters and is extremely subjective, depending upon the experience of the assessor [38]. Retrospective analysis by Knapp et al. highlighted the underestimation of injury severity by less experienced emergency physicians compared to expert colleagues [39]. Considering its absence of objectivity, Schlechtriemen et al. resolved to avoid the use of NACA scoring without further parameters for scientific work [40]. Other authors, however, demonstrated the potential benefit of pre-hospital evaluation using NACA scoring, with up to 84% of multiple trauma assessments correlating favorably with findings on in-hospital imaging [41]. Our study similarly demonstrated a significant correlation between NACA scoring and the more comprehensive in-hospital ISS. It, thus, appears evident that an experienced emergency physician can provide an accurate interpretation of on-the-scene traumatic injury severity, which by translation through established scoring algorithms, can lead to more effective and streamlined patient care. Still, further supplementation of the NACA score through the addition of measurable clinical parameters may increase even more the reliability and benefit of pre-hospital assessment. Nonetheless, it remains important to evaluate the transferability of this use to other settings, especially in countries where immediate emergency treatment is not delivered by physicians.

Conclusion

NOM is successful for the vast majority of BAT patients, especially those with less severe injuries. NOM failure occurs in 9.2% of patients. Hollow viscus perforation is the underlying pathology in 46% accounting for a delay in secondary surgery of 34 h due to the challenge of detection. There was no mortality due to occult HVI. In our study, we employed clinical monitoring, serial ultrasound, blood test for inflammatory parameters, and MDCT if

additionally indicated for the monitoring of NOM. Routine laparoscopy, as advocated by others, may facilitate the detection of occult injury but by definition includes many patients unnecessarily. In contrast, the delay in operation, if solid organ rupture is the cause of NOM failure, is only 6 h due to the overt sign of hemorrhage. On-the-scene NACA scoring can correlate favorably with in-hospital assessment, and allows for streamlined and more effective patient management. This study underscores the benefit of NOM in BAT.

Author Statement

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Author Contributions

Maximilian Goedecke analyzed and interpreted the data and drafted the manuscript. Florian Kühn assisted in data interpretation and revised the manuscript. Ioannis Stratos assisted in data interpretation and revised the manuscript. Robin Vasan assisted in data interpretation and revised the manuscript. Annette Pertschy provided substantial contributions to the study conception and design. Ernst Klar performed the critical revision for intellectual content. The article has been approved for publication by all authors.

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Supplementary Material: The article (<https://doi.org/10.1515/iss-2018-0004>) offers reviewer assessments as supplementary material.



Reviewer Assessment

Maximilian Goedecke, Florian Kühn, Ioannis Stratos, Robin Vasan, Annette Pertschy and Ernst Klar*

No need for surgery? Patterns and outcomes of blunt abdominal trauma

<https://doi.org/10.1515/iss-2018-0004>

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Reviewers' Comments to Original Submission

Reviewer 1: anonymous

Feb 04, 2018

| Reviewer Recommendation Term: | Revise with Major Modifications |
|---|---------------------------------|
| Overall Reviewer Manuscript Rating: | 60 |
| Is the subject area appropriate for you? | 5 - High/Yes |
| Does the title clearly reflect the paper's content? | 5 - High/Yes |
| Does the abstract clearly reflect the paper's content? | 4 |
| Do the keywords clearly reflect the paper's content? | 5 - High/Yes |
| Does the introduction present the problem clearly? | 4 |
| Are the results/conclusions justified? | 3 |
| How comprehensive and up-to-date is the subject matter presented? | 3 |
| How adequate is the data presentation? | 3 |
| Are units and terminology used correctly? | 5 - High/Yes |
| Is the number of cases adequate? | 5 - High/Yes |
| Are the experimental methods/clinical studies adequate? | 4 |
| Is the length appropriate in relation to the content? | 4 |
| Does the reader get new insights from the article? | 3 |
| Please rate the practical significance. | 3 |
| Please rate the accuracy of methods. | 4 |
| Please rate the statistical evaluation and quality control. | 3 |
| Please rate the appropriateness of the figures and tables. | 3 |
| Please rate the appropriateness of the references. | 4 |
| Please evaluate the writing style and use of language. | 5 - High/Yes |
| Please judge the overall scientific quality of the manuscript. | 3 |
| Are you willing to review the revision of this manuscript? | Yes |

Comments to Author:

This is a retrospective analysis of 176 blunt abdominal trauma patients in a single level one trauma center in a time period of 7 years (2004-2011). No reason is given why the analysis dates so far back, there is no long term follow up or any other reason. Since in recent years most trauma centres employed a more conservative approach towards blunt abdominal trauma including laparoscopy for unclear cases, newer data and the comparison between these two seven year periods (2004-2011 and 2011-2018) would be interesting.

This is in all, the data work up is adequate and nicely discussed. To justify the conclusion that „non-operative management is successful for the vast majority of blunt abdominal trauma...“ one certain subgroup of patients, however, has to be examined more closely: Patients with non-operative management failure (NOM failure). All diagnostic efforts are done to minimise this group of patients in whom delay of diagnosis of hollow organ injury or serious intraabdominal bleeding might lead to high morbidity or even mortality. It is mentioned that pts. with NOM failure required a significantly longer period of treatment in the ICU. How was the mortality in this group, and was there a similar outcome to the patients who were treated with early laparotomy in doubt? How was the rate of „negative“ (i.e. „unnecessary“) laparotomies in the cohort who underwent primarily operative treatment?

A delay of 35 hours in regard to hollow organ injury in 6/142 patients might justify an early laparoscopy in a high risk cohort. Can the authors predict which injury pattern/diagnostic findings could identify these patients who would benefit from operative management (other than the seatbelt sign taken from the literature). Laparoscopy obviously has no role in the algorithm of the presenting trauma center, has it? What was the rate of laparoscopies in the cohort who underwent operative treatment?

This retrospective analysis would certainly convey a more important message for the daily routine in other centres if characteristics for the patients that would benefit from early operation were developed by this analysis.

Minor points:

- table 1-3 need legends with the abbreviations explained.

- „source of mortality“ (= „old age...“): you mean contributing factors? was that a univariate analysis? a multivariate analysis would be necessary and interesting!

- table 1 does not describe the AIS sufficiently (various injured regions etc.) . Does the scoring in this study correlate to the predicted survival probabilities in the literature (NTDB, GIDAS etc.?)

- different scoring systems were used: AIS, ISS, NACA, AAST. Please clarify the relation between the scoring systems and report results (e.g. for NACA, preferably in a table) as you are referring to the results in the discussion

Reviewer 2: Tim Pohlemann

Jan 30, 2018

| Reviewer Recommendation Term: Overall Reviewer Manuscript Rating: | Accept N/A |
|--|---------------|
| Is the subject area appropriate for you? | 5 - High/Yes |
| Does the title clearly reflect the paper's content? | 5 - High/Yes |
| Does the abstract clearly reflect the paper's content? | 5 - High/Yes |
| Do the keywords clearly reflect the paper's content? | 5 - High/Yes |
| Does the introduction present the problem clearly? | 4 |
| Are the results/conclusions justified? | 5 - High/Yes |
| How comprehensive and up-to-date is the subject matter presented? | 5 - High/Yes |
| How adequate is the data presentation? | 5 - High/Yes |
| Are units and terminology used correctly? | 5 - High/Yes |
| Is the number of cases adequate? | 3 |
| Are the experimental methods/clinical studies adequate? | 4 |
| Is the length appropriate in relation to the content? | 5 - High/Yes |
| Does the reader get new insights from the article? | 5 - High/Yes |
| Please rate the practical significance. | 4 |
| Please rate the accuracy of methods. | 5 - High/Yes |
| Please rate the statistical evaluation and quality control. | 4 |
| Please rate the appropriateness of the figures and tables. | 5 - High/Yes |
| Please rate the appropriateness of the references. | 5 - High/Yes |
| Please evaluate the writing style and use of language. | 5 - High/Yes |
| Please judge the overall scientific quality of the manuscript. | 5 - High/Yes |
| Are you willing to review the revision of this manuscript? | Yes |

Comments to Author:

Accepting the limitations of a retrospective study in a highly variable Patient series of polytrauma and severely injured patients, this is a very valuable, exact Analysis about the value of NOM after blunt abdominal Trauma. Very helpful in justifying the Progress made in the Treatment of this life threatening injuries.

Authors' Response to Reviewer Comments

Mar 2, 2018

Dear Editors,

At first, we would like to thank the editorial board and the reviewers for the constructive criticism and for giving us the possibility to resubmit our manuscript. Thanks to the constructive reviews we are able to submit a clearly strengthened paper now.

Sincerely yours,

Maximilian Goedecke

-Pat. with NOM failure. How was the mortality in this group, and was there a similar outcome to the patients who were treated with early laparotomy in doubt?

-One Patient with NOM failure died (8%) which is higher than the average mortality (5%) but the case number is a little bit small for further statistical testing. Patients with HWI and initially NOM had a slightly lower outcome (Glasgow Outcome Scale) than Patients with early laparotomy (not significant). It is difficult to compare the cases because of the different injury severity. A patient who needed an immediate laparotomy was usually in worse condition than patients who were treated with NOM.

-How was there rate of "negative" (i.e. "unnecessary") laparotomies in the cohort who underwent primarily operative treatment?

-An injury was detected in every surgery and bleeding was treated, if that was necessary is difficult to tell from a retrospective standpoint. From our point of view a prospective study is needed to answer that question correctly

-Can the authors predict which injury pattern/diagnostic findings could identify these patients who would benefit from operative management (other than the seatbelt sign taken from the literature).

-Unfortunately we cannot. For example: In one patient the hollow viscus injury could not be detected by two CT-Scans, Ultrasound nor contrast enema. And was finally detected by laparoscopy

-Laparoscopy obviously has no role in the algorithm of the presenting trauma center, has it? What was the rate of laparoscopies in the cohort who underwent operative treatment?

-It does has. Especially in the diagnostic of HWI, but in this study they lead to a laparotomie for further treatment and were not further classified.

-table 1-3 need legends with the abbreviations explained.

-done

-"source of mortality" (= "old age..."): you mean contributing factors? was that a univariate analysis? a multivariate analysis would be necessary and interesting!

-done

-table 1 does not describe the AIS sufficiently (various injured regions etc.). Does the scoring in this study correlate to the predicted survival probabilities in the literature (NTDB, GIDAS etc.?)

-Table 1 describes the AIS regarding one injured region. The ISS covers various injured regions.

-different scoring systems were used: AIS, ISS, NACA, AAST. Please clarify the relation between the scoring systems and report results (e.g. for NACA, preferably in a table) as you are referring to the results in the discussion

-done

Reviewers' Comments to Revised Submission

Reviewer 1: anonymous

Mar 20, 2018

| Reviewer Recommendation Term: | Revise with Major Modifications |
|---|---------------------------------|
| Overall Reviewer Manuscript Rating: | 60 |
| Is the subject area appropriate for you? | 5 - High/Yes |
| Does the title clearly reflect the paper's content? | 4 |
| Does the abstract clearly reflect the paper's content? | 4 |
| Do the keywords clearly reflect the paper's content? | 4 |
| Does the introduction present the problem clearly? | 3 |
| Are the results/conclusions justified? | 3 |
| How comprehensive and up-to-date is the subject matter presented? | 3 |
| How adequate is the data presentation? | 3 |
| Are units and terminology used correctly? | 5 - High/Yes |

| | |
|--|-----|
| Is the number of cases adequate? | 4 |
| Are the experimental methods/clinical studies adequate? | 3 |
| Is the length appropriate in relation to the content? | 4 |
| Does the reader get new insights from the article? | 3 |
| Please rate the practical significance. | 3 |
| Please rate the accuracy of methods. | 3 |
| Please rate the statistical evaluation and quality control. | 2 |
| Please rate the appropriateness of the figures and tables. | 3 |
| Please rate the appropriateness of the references. | 4 |
| Please evaluate the writing style and use of language. | 4 |
| Please judge the overall scientific quality of the manuscript. | 3 |
| Are you willing to review the revision of this manuscript? | Yes |

Comments to Author:

Although the authors state in the response that all the suggestions of the reviewer were taken care of („done“), almost nothing was changed in the manuscript. I still think the manuscript could benefit from some of suggestions.

Authors' Response to Reviewer Comments

Apr 15, 2018

Dear Editors,

At first, we would like to thank the editorial board and the reviewers for the constructive criticism and for giving us the possibility to resubmit our manuscript. Thanks to the constructive reviews we are able to submit a clearly strengthened paper now.

Sincerely yours,

Maximilian Goedecke

-We performed a multivariate analysis and added them to results as well as in the Method area.

-The table legends explain the abbreviations now

-We explained the Scores more detailed in the Method section and also added to new tables the scores as mentioned. Due to the high quantity of the scores in the AAST, we just showed an example of the spleen scoring. Also a few more citations were used.

Reviewers' Comments to 2nd Revised Submission

Reviewer 1: .anonymous

May 07, 2019

| | |
|---|---------------|
| Reviewer Recommendation Term: | Reject |
| Overall Reviewer Manuscript Rating: | 50 |
| Is the subject area appropriate for you? | 5 - High/Yes |
| Does the title clearly reflect the paper's content? | 4 |
| Does the abstract clearly reflect the paper's content? | 4 |
| Do the keywords clearly reflect the paper's content? | 4 |
| Does the introduction present the problem clearly? | 3 |
| Are the results/conclusions justified? | 2 |
| How comprehensive and up-to-date is the subject matter presented? | 2 |
| How adequate is the data presentation? | 2 |
| Are units and terminology used correctly? | 4 |
| Is the number of cases adequate? | 4 |
| Are the experimental methods/clinical studies adequate? | 2 |
| Is the length appropriate in relation to the content? | 3 |

| | |
|--|-----|
| Does the reader get new insights from the article? | 3 |
| Please rate the practical significance. | 4 |
| Please rate the accuracy of methods. | 2 |
| Please rate the statistical evaluation and quality control. | 2 |
| Please rate the appropriateness of the figures and tables. | 3 |
| Please rate the appropriateness of the references. | 3 |
| Please evaluate the writing style and use of language. | 3 |
| Please judge the overall scientific quality of the manuscript. | 3 |
| Are you willing to review the revision of this manuscript? | Yes |

Comments to Author:

Dear Authors,

unfortunately you did not mark the changes you made in the revised manuscript.

However trying to compare the versions it seems that virtually the only sentence that was changed/added from R1 to R2 was : „included were those with either proven organ injury or free fluid on FAST or CT scanning. Initial identification of patients was by means of ICD- and therapy classification codes („German Procedure & Classification Code“ OPS). Patient records, discharge letters, radiology results and surgery reports were analyzed on the basis of gender, age, preclinical and clinical vital signs, time and date of hospitalization and discharge, laboratory values, and etiology and treatment of abdominal and other injuries. FAST was performed for all patients, the majority of whom also underwent CT scan.“

In the methods section you state: „Multivariate Analysis was realized by using a general linear model and Wilks' Lambda as test statistic. „ However, neither in R1 nor in R2 I have found the results of the multivariate model in the results section, nor in the tables, nor are they discussed. The same applies to all the other hints the reviewer brought up and that could have been utilized to improve the discussion for example.

If you dont think that the multivariate analysis or any other idea suggested by the reviewer is useful, tell the reviewer. A review's purpose is to improve the manuscript in a dialogue with the reviewer. Despite agreeing in your ,reply to the reviewer' with several of the criticisms of the reviewer („done“), you did virtually no changes to the manuscript itself from the first version to R1. From R1 to R2, one single paragraph was changed and three or so references were added. I have devoted considerable time and efforts trying to understand your manuscript and your intentions of the study and suggesting ways to improve it. If it is ignored in such a way, there is no need for review at all...

Authors' Response to Reviewer Comments

Mar 31, 2019

Revision

1) Pat. with NOM failure. How was the mortality in this group, and was there a similar outcome to the patients who were treated with early laparotomy in doubt?

One Patient with NOM failure died (8%) which is higher than the average mortality (5%) but the case number is a little bit small for further statistical testing. Patients with HWI and initially NOM had a slightly lower outcome (Glasgow Outcome Scale) than Patients with early laparotomy (not significant). It is difficult to compare the cases because of the different injury severity. A patient who needed an immediate laparotomy was usually in worse condition than patients who were treated with NOM.

2) How was the rate of “negative” (i.e. “unnecessary”) laparotomies in the cohort who underwent primarily operative treatment?

Due to your comment we reviewed all cases which were immediately treated surgically or supposed to be surgically treated immediately. (29 patients which were directly transported to the OR and 4 with delay due to triage). The abdominal AIS of those 33 patients were: AIS 2: 1; AIS 3: 9; AIS 4: 14 and AIS 5: 9 patients. We analyzed the 10 patients with an AIS from 2 to 3. The patient with the AIS 2 injury had an AAST II spleen injury which required massive blood transfusion and surgical treatment. From the remaining 9 patients with an abdominal AIS 3, four showed an intestinal injury. Two patients from the remaining 5 required a splenectomy because of the trauma. Blood transfusion was necessary in all 3 of the remaining patients: 2 needed two blood bags and the other one eight (6 of those in the first 24 hours due to a spleen(AIS3), liver (AIS2) and kidney (AIS3) injury). Both patients with an AIS 3 and the transfusion of 2 blood bags had an active bleeding in the CT scan and both received surgical haemostasis. Overall we think a high-grade trauma such as AIS 4-5 cannot be classified as “unnecessary” from the retrospective point of view. We could not show any “negative” laparotomies and added this to the paper. We think that a prospective study is needed to answer this question correctly.

3) Can the authors predict which injury pattern/diagnostic findings could identify these patients who would benefit from operative management (other than the seatbelt sign taken from the literature).

Unfortunately we cannot. For example: In one patient the hollow viscus injury could not be detected by two CT-Scans, Ultrasound nor contrast enema. And was finally detected by laparoscopy

4) Laparoscopy obviously has no role in the algorithm of the presenting trauma center, has it? What was the rate of laparoscopies in the cohort who underwent operative treatment?

It does have a role. Especially in the diagnostic of HWI, but in this study all laparoscopies lead to a laparotomy for further treatment and were not further classified. Patients which were treated with an immediate surgical intervention underwent a laparotomy because of the critical conditions.

5) Table 1-3 need legends with the abbreviations explained.

To the Tables 1-3 (page 15-16) legends were added and the abbreviations explained.

6) “source of mortality” (= “old age...”): you mean contributing factors? was that a univariate analysis? a multivariate analysis would be necessary and interesting!

Initially there was no multivariate analysis used in our study. Due to your comment a Multivariate Analysis was realized by using a general linear model and Wilks’ Lambda as test statistic. The result is shown in table 5 and highlights the correlation between the ISS and the probability of death caused by the trauma

7) table 1 does not describe the AIS sufficiently (various injured regions etc.). Does the scoring in this study correlate to the predicted survival probabilities in the literature (NTDB, GIDAS etc.?)

a. Table 1 describes the AIS regarding one injured region as an example for the score (spleen). We think that the description of all possible injured organs would maybe be overwhelming.

b. If we compare our data to the “TraumaRegister DGU – Jahresbericht 2011”: The mean ISS in our data is 21.8 compared to 21.5 (DGU), split into death and survival the DGU shows a ISS mean of 35.7 (died) / 19.4 (survived) which is comparable to our data with an ISS median of 43.0 (died) / 17.5 (survived) // mean of 44.8 (died) / 20.5 (survived). We now included this in the manuscript.

8) different scoring systems were used: AIS, ISS, NACA, AAST. Please clarify the relation between the scoring systems and report results (e.g. for NACA, preferably in a table) as you are referring to the results in the discussion

The relation between the different scoring systems is clarified (Material and Methods page 5) and the calculation explained. Furthermore the Tables 1&3 were added to report the results

Reviewers’ Comments to 3rd Revised Submission

Reviewer 1: anonymous

May 07, 2019

| Reviewer Recommendation Term: Overall Reviewer Manuscript Rating: | Accept with Minor Revision N/A |
|--|-----------------------------------|
| Is the subject area appropriate for you? | 5 - High/Yes |
| Does the title clearly reflect the paper’s content? | 5 - High/Yes |
| Does the abstract clearly reflect the paper’s content? | 5 - High/Yes |
| Do the keywords clearly reflect the paper’s content? | 5 - High/Yes |
| Does the introduction present the problem clearly? | 4 |
| Are the results/conclusions justified? | 4 |
| How comprehensive and up-to-date is the subject matter presented? | 2 |
| How adequate is the data presentation? | 3 |
| Are units and terminology used correctly? | 5 - High/Yes |
| Is the number of cases adequate? | 3 |
| Are the experimental methods/clinical studies adequate? | 5 - High/Yes |
| Is the length appropriate in relation to the content? | 5 - High/Yes |
| Does the reader get new insights from the article? | 3 |
| Please rate the practical significance. | 3 |
| Please rate the accuracy of methods. | 3 |
| Please rate the statistical evaluation and quality control. | 3 |
| Please rate the appropriateness of the figures and tables. | 3 |
| Please rate the appropriateness of the references. | 3 |
| Please evaluate the writing style and use of language. | 4 |
| Please judge the overall scientific quality of the manuscript. | 3 |
| Are you willing to review the revision of this manuscript? | Yes |

Comments to Author:

Thank you very much for the re-submission with reference to my previous suggestions. Since all of them have been addressed, I have no further critique. There is only one aspect, that I consider very important: If -according to the results of the paper- more patients will be treated with NOM after blunt abdominal trauma, there will be quite a number (10% according to your data) in which NOM fails and especially patients with hollow organ injury and undiagnosed intestinal perforation (46% according to your data) will have a considerable worse outcome due to prolonged peritonitis etc.

Since intestinal perforation is sometimes very hard to detect in CT scans, FAST etc., we have routinely adopted laparoscopy for all patients with high velocity trauma, free fluid and suspicious injury pattern (seat belt sign etc.) in our center. We thereby were able to diagnose intestinal perforations in a number of cases early enough to avoid open abdomen, diverting stoma etc. Explorative laparoscopy in an intubated polytrauma patient is straightforward, easy to implement and should be regarded as diagnostic modality and not as “failure of non-operative treatment”.

You are shortly discussing this topic (laparoscopy) on p9. Please give this discussion a bit more room, perhaps you are even able to tell from your data by which injury pattern or from which ISS / NACA Score patients could profit and be selected for explorative laparoscopy. It even could be helpful to add this to the conclusion and the abstract (which is the only thing most readers will read anyway), e.g.

“NOM failure and operative delay is most commonly due to occult hollow viscus injury, the detection of which may be improved through **diagnostic laparoscopy, or at least** the employment of frequent observation and ultrasound scanning, close monitoring for rising markers of infection and occasionally Multidetector Computed Tomography (MDCT).“

Authors' Response to Reviewer Comments

Aug 20, 2019

Dear reviewer,

thank you very much for your revision. The discussion of the topic laparoscopy is given more room and is also added to the conclusion. We hope that concurs the tenor of your review even though it is representing a more conservative approach. Unfortunately we could not find a significant ISS/NACA for a selection for an explorative laparoscopy. We hope that your comments are implemented as you wanted. If there is an additional adaption necessary we are more than happy to do so. Kind regards.

Reviewers' Comments to Re-Submitted Manuscript

Reviewer 1: anonymous

May 07, 2019

| Reviewer Recommendation Term: | Accept with Minor Revision |
|---|----------------------------|
| Overall Reviewer Manuscript Rating: | N/A |
| Is the subject area appropriate for you? | 5 - High/Yes |
| Does the title clearly reflect the paper's content? | 5 - High/Yes |
| Does the abstract clearly reflect the paper's content? | 4 |
| Do the keywords clearly reflect the paper's content? | 4 |
| Does the introduction present the problem clearly? | 4 |
| Are the results/conclusions justified? | 4 |
| How comprehensive and up-to-date is the subject matter presented? | 3 |
| How adequate is the data presentation? | 3 |
| Are units and terminology used correctly? | 5 - High/Yes |
| Is the number of cases adequate? | 4 |
| Are the experimental methods/clinical studies adequate? | 4 |
| Is the length appropriate in relation to the content? | 4 |
| Does the reader get new insights from the article? | 4 |
| Please rate the practical significance. | 4 |
| Please rate the accuracy of methods. | 4 |
| Please rate the statistical evaluation and quality control. | 4 |
| Please rate the appropriateness of the figures and tables. | 5 - High/Yes |
| Please rate the appropriateness of the references. | 5 - High/Yes |

| | |
|--|-----|
| Please evaluate the writing style and use of language. | 4 |
| Please judge the overall scientific quality of the manuscript. | 4 |
| Are you willing to review the revision of this manuscript? | Yes |

Comments to Author:

Dear authors,

thank you very much for your newest revision and for giving the concept of routine / selective laparoscopy more room in the discussion section. I think it has definitely rendered a bit more balance to the discussion. You obviously do not share my opinion to rather do a fast laparoscopy in a polytraumatized patient with certain injury features than to miss a hollow viscus injury, even if it means ,unnecessary' laparoscopy for several other patients. (And a delay of 34 hours for missed HVI seems very relevant in my opinion.) But I understand that routine use of laparoscopy for certain trauma patterns depends a lot on the routine use of laparoscopy for liver and splenic surgery as well as colorectal surgery in a department (and the familiarity of the entire team with it) and minimally invasive surgery was definitely not as advanced in your study period between 2004-2011. In addition, recommending laparoscopy would somewhat contradict the tenor of your paper to advocate non-operative management for blunt abdominal trauma.

So be it- there is space for different opinions in surgery and even data can be interpreted supporting both sides. Thank you again for using my hints to develop your manuscript, I will now recommend the manuscript for acceptance.
